The Status of Science Education Doctoral Programs in the United States: The Need for Core Knowledge and Skills.

by

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Abstract

The last study of science education doctoral programs in the United States was completed over two decades ago. Since then there have been major standards, curriculum and school change initiatives that should have had an impact on framing the structure of these doctoral programs. This article synthesizes and analyzes the data from two surveys regarding science education doctoral programs. The first survey elicited data from 64 science education doctoral program heads about the status of their programs. The second elicited data from deans and heads of schools and departments of education about the need for and qualities expected of science education doctoral graduates. The findings, although encompassing the broad scope of content and skills of doctoral programs, have a particular focus on the need for enrichment in the areas of urban science teaching, the nature of science, and effective school change strategies in science education.

• Introduction

During the past two decades since the last nationwide report on science education doctoral programs in the United States (Yager, 1980) there have been major advances in cognitive research about how students learn science (Gabel, 1993). Additionally, there have been corresponding advances in our understandings of organizational structures and effective change strategies that would translate these theoretical understandings into classroom practice (Fullan, 1998; Loucks-Horsley, Hewson, Love & Stiles, 1998). Simultaneous with these research-based advances, there have been three large government-initiated projects that have had pervasive effects upon the science education community.

The first of these projects was the development and publication of the two sets of science education standards, the pioneering *Benchmarks* from Project 2061 (AAAS, 1993), and the subsequent document that not only addressed student learning outcomes, but also expectations for teacher preparation, *the National Science Education Standards* (National Research Council, 1996). The decade long enterprise that engaged hundreds of science educators, scientists, and classroom teachers in writing, reviewing, and revising these documents, has had a galvanizing effect upon a substantial part of the science education community. At least theoretically (Rodriguez, 1997), there should not be a time in the past century when there has been such a chance for universal agreement upon the goals of science education.

Occurring simultaneously with the creation of these standards was the design and publication over the past 12 years of the second major wave of National Science Foundation supported science curriculum materials and the consequent effects upon the ways in which science education is approached in our schools (National Science Research Center, 1996; NSRC, 1998). Unlike the curricula of the 60s and early 70s whose purpose was to create the elite scientists for our Cold War technology race, these curricula were designed to promote scientific literacy for all Americans. Much of the cognitive, social, and educational research findings including conceptual change strategies (Klahr, 2000), STS contextualization (Yager, 1996), alternative assessment strategies

(National Research Council, 1999), effective cooperative learning modalities (Slavin, 1990), and the infusion of new technologies (King, 2001), is incorporated into the structure of these materials. In addition, these NSF supported curricula are much more "teacher friendly" than their predecessors.

To assure that these curricular expenditures were broadly utilized by school districts across the nation, the National Science Foundation began the funding of large-scale systemic change. Unlike the previous two decades where most of their teacher enhancement monies were spread out thinly supporting hundreds of small projects, the focus now was on finding effective strategies to affect the way all students in school systems were taught science (Bybee, 1993; Friel & Bright, 1997). These focused either on large school districts or coalitions of smaller districts, especially those with under-represented minorities in urban areas. After ten years of funding such endeavors, a coherent set of effective, yet complex, change strategies has emerged (Loucks-Horsley, et al., 1998).

The last strand in this effort to raise student achievement in science for all Americans was the funding of projects that redesigned the science teaching preparation programs for both secondary science teachers and elementary teachers. These change projects have not only focused, as in previous decades, on the science methods courses and student teaching experiences of the students, but also on the science faculty who teach them their science content (Jablon, 1995; Shroyer &Wright, 1994). There was a focus on getting these faculty members to incorporate inquiry-based approaches, with a consequent shift to process skill outcomes in addition to conceptual understandings and application.

Each of the projects in the four endeavors listed above requires skilled and informed leadership. Historically in this country, this leadership has fallen to those with doctorates in science education. Indeed, in order for a materials development, systemic change, or teacher preparation grant to be funded by the NSF, a university science educator must either be the director or play a major role in the project leadership. One would, therefore, expect that there would have been a simultaneous metamorphosis of science education doctoral programs that would prepare the graduates to have the requisite skills needed to lead these reforms.

• The Impetus for the Study

In a proposal that the author submitted to the National Science Foundation (NSF) seeking to encourage the systemic change leaders from NSF-funded projects around the country with enrollment in specialized science education doctoral programs, the statement was made that there were few science education doctoral programs in major metropolitan areas. Hence there were few graduates with experience in either urban school teaching or change strategies to service the large bureaucracies in urban school systems. The program officers at NSF noted the possible significance of this claim when they were shown two examples of major metropolitan areas where there were no doctoral graduates with urban teaching experience, yet nine science education positions went unfilled in urban colleges for lack of qualified candidates. However, neither NSF nor any identifiable agency or researcher had any comprehensive statistics about science education doctoral programs that would allow these examples to be generalized to the whole country. It is significant that NSF could not only tell you how many students graduated with Ph.D. degrees in physics each year, but could also tell you their ethnicity and gender. Conversely, they could not even identify which universities had doctoral programs in science education, no less the number and type of graduates. Although NSF expects to be served by the graduates of science education doctoral programs, it assumes little responsibility for collecting data that would assure that the appropriate funding is maintained to create the number and quality of graduates necessary to support their own efforts in science education.

After a number of postings on the Association for Educators of Teachers of Science (AETS) and the National Association for Research in Science Teaching (NARST) listserves, direct inquiries to leaders in the science education community, and announcements at general sessions at national science education conferences, it became clear that no one knew of any studies of science education doctoral programs since the Yager report in 1980. Likewise, although AETS had just completed a position statement on professional knowledge standards for science teacher educators (Lederman, Ramey-Gassert, Kuerbis, Loving, Roychoudhuray & Spector, 1997), there were no organization-sponsored position papers about the actual structure of science education doctoral programs since the AETS committee report chaired by Jim Rutherford in 1966. If the grant proposal to NSF was ever to be resubmitted, it became clear that a survey of doctoral programs would need to be done. Hence, a comprehensive questionnaire was designed that would serve the science education community as a tool for collecting the necessary data.

In addition to the survey instrument that was to be sent to science education doctoral program heads, another survey instrument was created to determine if there was a dearth of qualified science educators with doctorates applying for science education positions in the elementary or secondary education departments of colleges in the United States. This second survey was sent to every dean or head of schools or departments of education in colleges across the nation, with special note being taken of the geographic location of the colleges.

• Objectives of the Study

The survey instrument sent to the science education doctoral program heads was designed to accumulate a large amount of relevant data in a brief period of time. The recipients of the survey needed to be able to complete the survey in less than 15 minutes. There was no impetus for science education doctoral program heads to expend a great effort other than their desire to assist in the study, as it lacked the prestige of a government-sponsored study. Drafts of the survey document were sent to a sample of heads of science education doctoral programs for suggestions and modifications. The final survey document that was utilized sought to focus on the following areas:

1. The identity of institutions with science education doctoral programs.

2. The type of degrees (Ph.D. or Ed.D.) offered, and the context of these programs (pure science education degrees compared to Curriculum and Instruction (C&I) degrees with a specialty in science education, biology education, etc.).

3. An analysis to determine whether there are differences between the content of C and I programs compared to pure Science Education programs.

4. The type of community in which programs are located (rural, suburban, urban, urban inner city) and whether programs in these categories have different foci, needs, and designs.

5. The number of graduates each year over the past three years, and the demographics of these graduates by gender, race, ethnicity, and school teaching experience.

6. A comparison of the number of full-time faculty in the program over the past 30 years.

7. The content themes of the required and elective courses in each program.

8. The various roles [careers] (e.g., college science education professor, public school supervisors, science teaching researcher) that they believe their graduates are qualified to pursue.

9. The amount of doctoral student participation in school change projects, student teacher supervision, and methods course teaching.

10. The amount of correlation between the experiences and courses doctoral students are exposed to and the skills and knowledge they need to fill the roles they will undertake.

11. The amount of teaching and science content knowledge required for entrance into the program.

12. A perception about the adequacy of numbers of students enrolled in programs and the adequacy of numbers of faculty to meet department responsibilities.

As mentioned in the previous section, a second survey instrument was created to collect data about the need for science educators with doctorates in colleges in the United States. This instrument (*Survey of Need for Qualified Science Educators*) was also brief and allowed for anonymity. It contained mainly fill-in-the-blanks, check off items, and Likert Scale items with only one or two open-ended items. This survey instrument sought to focus on the following perceptions of department heads of elementary and secondary education programs:

1. The type of community in which their programs are located (rural, suburban, urban, urban inner city) and whether programs in these categories have different needs.

2. The qualifications that were sought for science educators in their departments including:

- doctorate,
- teaching experience at secondary or elementary level,
- ability to teach methods courses,
- ability to supervise student teachers,
- expertise in science subject matter,
- ability to teach inservice courses,
- ability to coordinate major science school reform projects in local school districts,
- ability to work with science department faculty in creating effective college level science courses.

3. The importance of hiring science educators who had school teaching experience in schools with similar demographics to the community in which the college is located.

4. The college's attempts to hire a science educator in the past ten years and if so, their ability to get the qualifications they desired.

5. The college's ability to have enough science education faculty to meet their institution's needs.

6. The college's experience with having an advertised science education position left unfilled for more than a year.

• Identifying which Universities have Doctoral Programs

As mentioned earlier, NSF does not gather statistics about science education doctoral programs, nor do any of the organizations representing universities or university education programs have comprehensive lists of universities that confer science education doctorates. (Note: This is still true as this article goes into publication.) Likewise, commercial sorted-by-degree-and-program mailing lists from publishers such as Peterson's Guides are woefully incomplete. None of the major science education organizations categorize their member's institutions by degree programs that they offer.

The search to identify current doctoral programs in science education was an arduous task. It entailed first writing letters, making phone calls, sending e-mails, reading through college guides, going to web sites, placing announcements on science education listserves, and making announcements at national conventions. This was followed by the more time consuming task of sending follow-up e-mail, letters and phone calls to most everyone that you first contacted. Responses were received from 64 of the 69 institutions identified. There were five identified programs, despite constant reminders, who did not return surveys Perhaps of equal significance, is the question of the currently unidentified institutions that have science education doctoral programs. There is no way to know at present, despite the time placed into this study and the likelihood that the 64 identified represent the vast majority, how many additional programs exist.

• Identifying which Colleges have Elementary and Secondary Education Programs

Unlike the difficult search for science education doctoral programs, it was relatively easy to acquire a rather complete list of both graduate and undergraduate elementary and secondary education programs in colleges in the United States. After some research, the most complete and updated available mailing list was purchased from Peterson's Guides. It contained 882 programs, their department heads or deans, and their addresses. The *Survey of Need for Qualified Science Educators* was mailed with a cover letter and a return envelope in January of 1999. These over-burdened deans and department heads responded by completing and returning 242 surveys. This return rate of 28% despite no follow-up calls is testament to the concern that these college education leaders have about the need for qualified science education doctoral graduates.

• The Types of Degrees Offered and an Analysis of Uniformity

In order to gather some baseline understandings about science education doctoral programs to be used to craft the survey questions, a brief questionnaire was given to about 35 science education professors from around the country at two different workshops at national conferences in 1997 and 1998. One set of findings from these surveys indicated that their general belief was that degrees in science education, as opposed to degrees in Curriculum and Instruction with a specialty in science education, would be more focused and, therefore, have more required science education coursework and field experiences. The results of this report support a modified version of that belief. An initial perusal of the data show that there are great variations in the content offered among the various institutions within any category of degree program. However, there are also some trends that are revealing when the categories of programs are compared. Probably most upsetting is the minimal course requirements of a majority of the programs in any category. Although it is true that the quality of a program cannot be described solely by the number of science education courses in which students are required to enroll, some level of structured engagement is necessary to analyze and synthesize the sizable amount of ideas and research concerned with teaching and learning science.

It might be expected by those institutions seeking candidates for positions that require a doctorate in Science Education that there would be a baseline set of understandings and skills that they could expect of these applicants. Similar expectations of baseline knowledge, despite specialization, are applied to medical doctors and lawyers. Similar curricular expectations might be applied to doctoral degrees in science education, but the results of this survey demonstrate that it is not even close to reality at the present time.

Types of Degrees

There are almost two thirds the number of pure science education doctoral degree programs than there are science education specializations within a C & I doctoral program. Hybrid science education doctoral degrees (e.g., biology education, science and math education account for less than 19% of the degrees.

Of the 64 institutions represented in the sample, 21 award pure science education degrees. Of these, ten offer Ph.D. degrees, four offer Ed.D. degrees and seven offer both. Thirty one institutions offer Curriculum and Instruction degrees with a specialization in science education. Of these, eleven offer Ph.D. degrees, six offer Ed.D. degrees and fourteen offer both. Two institutions offer both a pure Science Education degree and a Curriculum and Instruction degree with a specialization in science education. Both of these programs offer both a Ph.D. and an Ed.D. Twelve institutions offer the hybrid science education degrees. Environmental education, biology education, and science and math education are some examples of these hybrid degrees. Of these, three offer Ph.D. degrees, two offer Ed.D. degrees, and two offer both (See Table 1).

Table 1

Types of Programs and Degrees Offered

	Total number of Programs	**Ph.D. offered**	**Ed.D. offered**	**Both offered**
Science Education	21	10	4	7
Curriculum and Instruction	31	11	6	14
Both Sci. Ed. and C &I	2 Data also integrated above	0	0	2
Hybrid	12	5	3	4

Comparing Course Requirements of C&I, Science Education, and Hybrid Programs

The survey was designed to determine how much course time was spent on each of the fifteen key topics (see Table 3). These topics were identified as important both by reviewing the AETS Position Statement on *Professional Knowledge Standards for Science Teacher Educators* (Lederman, et al., 1997) and the feedback received during the piloting of the survey instrument (See table 3). From the responses it is possible to determine how many of these complex topics were given adequate time to be considered, i.e., a full semester of a required course (called *required whole science education course* in this report). Most programs that did not have these key topics covered as whole required courses either had them as part of required courses, part of electives, or no courses were available at all. Only a few had these key topics covered as whole course electives.

Of the programs offering pure science education degrees (n=21), the number of required whole science education courses ranged from a high of nine to a low of zero, however, the mean was five courses and the median was six courses. (See *Table 2* below for the complete results**.)** In contrast, of the programs offering a degree in C&I with a specialization in science education (n=31), the number of required whole science education courses ranged from a high of five to a low of zero, with a mean of 2.5 and a median of two. As noted earlier, this simply means that in pure science education doctoral programs a graduate is likely to have been exposed to six essential or key areas of science education with the time for an in-depth analysis. C&I doctoral graduates are likely to have had an in-depth study of two key areas, and will have the possibility of some exposure to the rest. For the students in the seven hybrid programs the number of required whole science education courses ranged from a high of seven to a low of one, with a mean of three and a median of three. A more complete analysis of which areas are being studied through course work in any of the degree programs is presented in the next section (see Table 3).

The number of topics that are part of a required course also infers that graduates are assured of some exposure to these complex topics. The median number of topics covered in required courses was twelve, for the pure science education programs compared to seven in the C&I programs, and eight in the hybrid programs. In the case of both measures, whole required courses and topics covered in required courses, the pure science education doctoral programs appear to assure a more concentrated look at a variety of essential science education topics for their graduates.

However, program titles can be deceiving and one must be cautious of over-generalizing from the data. As can be seen from Table 2 below, there were some C&I and hybrid doctoral programs that far exceeded the course requirements of a majority of the pure science education doctoral programs. Likewise, there is no way of determining the relative quality of any of these courses, nor of determining if there are any other mechanisms in place other than courses through which students could gain these understandings and skills. Yet when a doctoral program focusing on science education has only one or two required science education courses, there is great reliance on the advisement of an ever-changing and overburdened faculty to ensure the quality of its graduates. Likewise, as seen in the next section, when institutions do not offer any courses through which a student could be engaged in one or more of the key topics in science education, then any homogeneity of a set of basic understandings and skills from doctoral candidates across institutions cannot be assured.

Table 2

The Number of Required Whole Courses by Program Type that Cover Only One Specific Key Science Education Topic

	9	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Science Education	1	1	3	6	2	3	1	3	0	1
Curriculum and Instruction	0	0	0	0	4	7	3	10	3	4
Hybrid	0	0	1	0	1	2	4	2	2	0

What Areas of Expertise in Science Education can we Expect Doctoral Graduates to Have?

Also significant are the specific courses that students are not required to take in each of the programs, or are not even available to students in the programs, hence the lack of core understandings and skills that can be expected from a science education doctoral candidate.

An anecdote included in one of the surveys adds a rich context for reviewing the data from the next section. At a 1996 meeting of the Collaborative for Excellence in Science Teacher Preparation in New York City science education faculty members from four institutions were having a side discussion about the quality, or lack of it, of the finalists in their institutions' search for additional science education faculty. The consensus was that almost none of the finalists interviewed could tell you the difference between *FOSS* and *ChemCom*, almost none could lay out a plan for systemic change in science teaching in a school district, almost none could suggest the format for teaching assessment in science to a set of elementary school preservice teachers, and none had any urban school experience. All but the last item are symptomatic of a lack of understandings that could have been ameliorated by an effective science education doctoral program. The question left unanswered at the time was, "then what did these applicants study as part of their science education doctoral programs?" This survey supplies some insight into the answer to that question. However, the data collected was not comprehensive enough to paint a truly accurate picture of the general nature of all these programs. Hopefully, further funding can be supplied in the future from a funding source such as the National Science Foundation that will allow for in-depth interviews with a sample of the programs represented here. This would supply additional insight into the nature of the programs beyond their course offerings, and into the dilemmas faculty face in order to meet the missions of their programs. Some of this qualitative richness was uncovered in the three essay questions at the end of the survey and the following statistics must be read knowing that each program is not structured with a traditional set of required courses for all enrolled. There are even two major nationally recognized doctoral programs where every student's program is individually tailored. In cases such as these, program heads were asked to list courses that almost every student must take as "required".

Table 3

Science Education Course Topics Offered by Various Types of Degree Programs

	All Programs = 64					Science Educ. = 21					Curr. & Instr. = 31					Hybrid = 12				
	WR	WE	PR	PE	0	WR	WE	PR	PE	0	WR	WE	PR	PE	0	WR	WE	PR	PE	0
Nature of Science	12	4	34	8	5	6	0	11	2	2	6	3	14	5	2	0	1	9	1	1
Sci Ed Curric. Materials	25	6	25	3	2	11	1	6	1	2	12	2	15	1	0	4	3	4	1	0
Science and Human Values	6	6	35	7	9	3	2	12	2	2	2	3	17	3	5	1	1	6	2	2
History of Science	4	13	22	8	16	2	7	1	2	9	2	6	13	5	4	0	0	8	1	3
Reasoning and Prob. Solving	18	5	24	6	10	8	2	2	2	7	7	1	15	4	3	3	2	7	0	0
Constructivist Perspectives	13	3	38	8	1	5	1	12	3	0	5	2	18	4	1	3	0	8	1	0
Meth of School Change in Sci.	7	2	28	9	17	1	1	12	3	4	4	1	11	4	10	2	0	5	2	3
Intro. Seminar in Sci Ed	34	6	6	1	20	12	3	0	0	6	12	3	4	1	10	6	0	2	0	4
Research Meth. and Design	55	3	4	0	1	20	1	0	0	0	24	2	3	0	1	11	0	1	0	0
Sci Educ Dissert. Sem	22	6	9	3	24	13	0	1	0	7	4	5	7	2	12	5	1	1	0	5
Moral and Ethical Issues	3	5	31	9	15	0	2	12	4	3	3	3	12	4	8	0	0	7	1	4
Sci. Ed. Assessment	11	5	32	9	6	6	2	9	3	1	4	0	18	4	4	1	3	5	2	1
Public Underst. of Science	2	3	27	7	24	1	1	10	3	6	1	2	13	3	11	0	0	4	1	7
Use of Tech in Science Educ.	9	14	25	8	7	4	4	7	4	2	3	6	14	3	4	2	4	4	1	1
Indep Study in Sci. Ed.	20	25	6	4	6	5	11	3	0	2	11	9	3	3	4	6	5	0	1	0

Key

WR = Required Whole Course WE = Elective Whole Course PR = Part of Required Course

PE = Part of Elective Course 0 = No Course Offered that Includes Topic

In 1980 the average number of credit hours devoted to the history, philosophy, and sociology of science in doctoral programs was 4.5 out of 60 (Yager, 1980). The trend does not seem to have changed much over the 2 decades since then. Despite the recommendations of both the 1966 AETS Rutherford report and the 1977 AETS Yearbook chapter on science education doctoral programs (Butts, 1977) for a substantial amount of the history, philosophy, and sociology of science to be included in a doctoral program, less than half of the programs in 1999 have even a part of a course devoted to the history of science. Only 6% require a whole course. Twenty four percent of the programs have *no* opportunity for students to take even part of a course on the history of science. Eight percent of the programs had no way for students to study the nature of science, while only 20% had a full course required about the nature of science. All this despite a growing trend that demonstrates the effectiveness of including some history and nature of science in curriculum and instruction

(McComas, 1998). In contrast, 81% of the programs require at least part of a course be devoted to the study of constructivism, which should include a good deal of epistemological and ontological discourse.

Although most programs require whole or parts of courses devoted to the study of science curriculum, only 53% require even part of a course that looks at ethical and moral issues in science. Twenty four percent of the programs have no opportunity for students to engage in this discourse as part of a course. This is true despite the need for a deep understanding of these issues and how best to present them in order to effectively engage in Science-Technology-Science teaching.

Although a full course in research methods is still the mainstay of the programs (94%), as we move into the next millennium only 53% of the programs require their students to take even a part of a course in the use of technology in teaching science. A full 24% have *no* option to learn this skill and conceptual framework as part of their doctoral studies. How can we be assured that those preparing science teachers will have acquired technical computer skills, a deep knowledge of effective science education software instructional design, and a knowledge of the currently available effective science education software?

The opportunity to understand the complexities of school and district change strategies is denied to students in 27% of the programs, and only 11% are required to give it the in-depth understanding necessary to lead reform projects. Finally, a chance to gain insight into the public's understanding of science is likewise denied to students in 38% of the programs. The issue of the preparedness of doctoral graduates to lead science reform in schools and districts will be addressed extensively later in this report

• Some Demographics about Science Education Doctoral Candidates

Number of Graduates

There is concern among science educators that there are not enough appropriately prepared graduates with a doctoral degree to fill the available science education faculty lines in colleges and universities throughout the country. The same is said to be true of available positions for district or statewide leaders in science education. Before the number of graduates who have certain qualifications can be addressed, it is necessary to look at the total number of graduates. From these 64 universities there were a total of 174 graduates in 1999. This number was a marked increase from 1997 (131) and 1998 (141), however, since the 1999 number could only be an estimate, it might be modestly inflated. The largest graduating class was 15 and the smallest zero. The median number of graduates per institution was two.

Compared to institutions identified in the Yager report of 1980, there are less total graduates. In 1969 there were 171, in 1974 there was 220, and in 1979 there were 244 graduates. There were 59, 66, and 67 programs respectively. The number of programs surveyed are comparable to the 64 programs identified in this report, yet the numbers of graduates in the 1970s was substantially higher. If we compare this with general enrollment figures for education doctoral programs from 1986 to 1996 (Syverson & Welch, 1996) we see that the general education doctoral student population has remained stable with only a 1% increase, while the science education population has decreased about 29% or more.

This is particularly an area of concern for two reasons. The late 1970s was a time of small appropriation of funds to science education. This meant very little chance of NSF-funded graduate assistantships as part of grants, and yet there were more graduates than now. Secondly, there are now substantially more colleges throughout the nation, and therefore more need for qualified science educators with doctorates, yet there are fewer applicants graduating from doctoral.

Extended responses from doctoral program heads sheds some light onto this situation. Almost all felt that the number of high caliber applicants has become less over the past 15 years. The number of applicants from high school science teachers has decreased most sharply. The number of science faculty from science departments in four and two year colleges has risen most rapidly. Although it is beneficial to have trained science educators teaching in college science departments, improving the quality of science courses at the post secondary level, these graduates will not move on to schools and departments of education at universities and colleges. Nor will they become school district science coordinators.

It was suggested that it is simply a matter of economics. Almost everyone cited the lack of high paying scholarships and assistantships, either from NSF or from their home institutions. Either there are no stipends or they are too low to attract, more experienced, higher paid public school teachers. Without these there certainly cannot be full-time students, and many middle-age teachers with children in school cannot even afford to pay university tuition for part-time study. Sixty credits at a public institution costs at the least $15,000 and at the most costly private institution nearly $42,000 (1999 figures). Most school district-based staff upon receiving a doctorate would not only have this graduate school debt to pay back, but for those who had taught for more than 10 years would need to take a substantial pay cut to go to a university as an assistant professor. Unlike medical schools and law schools, universities don't pay beginning assistant professors in education substantially more because of their successful pre-college teaching.

Although a few assistantships become available if some faculty in a doctoral program have a multi-million dollar grant, these are limited and sporadic. There is not an ongoing community of research supported in science education by the National Science Foundation as there is in Physics, Biology, Chemistry, Geology and Engineering. These ongoing research communities are funded not only for the faculty member's research, but also for a substantial number of full-time doctoral students to assist in the research. It is ironic that there are probably more jobs presently available for qualified science education doctoral graduates than in the other fields, yet there is substantially less money being spent on supporting doctoral students in science education. It is even more ironic that some fields such as engineering and physics are seeking more undergraduate majors, yet the science teacher educators who could create better elementary and secondary science teachers, and subsequently more college science and engineering majors, are not supported in their doctoral studies. There was a general belief among program heads that responded in the extended response sections that NSF doesn't have respect for the science education research community and that until there are more science educators in charge of policy decisions at NSF this inequity in funding for research and assistantships will not change.

This being said, a number of program heads thought that it was incumbent upon each institution and the science education research community to be more proactive both in doctoral student recruiting efforts and in publicizing the positive effects of research findings and their subsequent applications in curriculum and instruction on the improvement of science education in our schools. Of course, this is a vicious cycle. As there are now far fewer full-time doctoral students, the graduates' research capabilities and potential for input into an effective research effort are likely less substantial. Hence, there will be likely less to show from recent graduates.

Type of School Teaching Experience

Of 174 graduates in 1999, 44 % had experience teaching in suburban schools, 21 % had experience teaching in rural schools, 28 % had experience teaching in small urban areas, and 7 % had experience teaching in large urban inner city areas (as defined by NSF as eligible cities for the Urban Systemic Initiatives grant monies).

Ten percent of the students had experience teaching at the elementary level, 15 percent at the middle school level, 43 percent at the high school level, 28.5 percent at the college level, 3.5 percent at informal science institutions and 13% did not have any teaching experience whatsoever. The preceding totals to more than one hundred percent because some students had taught at more than one level. Some programs had as many as 65% of the doctoral candidates having their teaching experience at the elementary level, while 44% of programs had no candidates that fit that description. Given the need for science methods professors who have elementary teaching experience to lead elementary school change projects and to teach elementary methods type courses, some information needs to be gathered and disseminated about how certain institutions attract and maintain this elementary teacher population in their science education doctoral programs.

Gender and Ethnicity

In contrast to past trends, the gender balance amongst doctoral graduates in science education has shifted. In a generally male dominated profession, 39.8% of the doctoral candidates were male and 61.2% were female. The number of females might even be higher if programs could attract more elementary level candidates.

Five percent of the science education doctoral students are Latino, 8.5% are Afro-American, .06% (one graduate every three years in the country) are Native American, .14% (1 every four years) are Pacific Islanders, 5% are Asian, and 81% are Caucasian.

• Some Demographics About the Doctoral Programs and their Universities.

Geographic Location of Science Education Doctoral Programs

The majority of programs are located in rural and small urban areas, while half this number of programs are located in suburban areas and large metropolitan area cities with inner city populations (as defined by the NSF in their Urban Systemic Change guidelines). There are 25 programs located in small urban areas, 17 programs in rural areas, 13 programs in urban inner city areas, and 9 programs in suburban locations. Given that students, especially part-time students, generally enroll in programs located geographically adjacent to their teaching jobs, these variations in numbers of programs by location will have an effect upon the qualifications of graduates of the programs. This will be discussed later in this article.

Number of Faculty

In order to have the ability to offer comprehensive doctoral programs in science education, each university must have adequate faculty to teach courses, supervise student research, and do advisement in addition to other responsibilities required of these science education faculty by their universities, their own research and the surrounding communities that they serve. The survey requested information about the number of program faculty over the past 20 years and also the respondent's perspective on the adequacy of this number of faculty to fulfill all these responsibilities.

As mentioned in the introduction to this report, the attention paid to science education in the past decade is virtually unparalleled in American history. The amount of NSF grant money available for teacher enhancement, undergraduate programs, and other forms of science education research is much higher than the lean years of the late 1970s. Yet the number of faculty that have been added to university programs since 1978, one of the leanest times in the past 40 years for both financial and public support of science education, is surprisingly sparse. The effects of this lack of growth of faculty is discussed in detail below, but first a quick perusal of Table 4 will elucidate the changes in science education doctoral faculty numbers over the past 20 years.

As can be seen from Table 4, for about half of the programs the number of faculty remained constant from 1978 to the present. About 15 % of the programs had an increase of between two and four faculty and about 15% had a decrease of between one and five faculty. The major shift was an increase of one faculty member in about 19% of the programs.

The discussion from respondents about the adequacy of faculty numbers was a rich one. One program just received three endowed professorships in science education and felt they had sufficient faculty, another counted the need for five additional faculty to get back to a program that provided for the needs of all their

Table 4

Amount of Change in the Number of Science Education Program Faculty from 1978 to 1998

Change in Number of Faculty	Number of Universities
down 5	1
down 2	3
down 1	6
remained the same	32
up 1	12
up 2	6
up 3	3
up 4	1

constituencies. Most respondents identified with the latter. Virtually all those responding felt their faculty were torn between doing adequate graduate and undergraduate advisement, dissertation advisement, graduate and undergraduate course preparation, inservice work in local schools, major school change grants, and their own science education research. Only in a few institutions did they feel that they had enough faculty so that one or more of these areas didn't suffer greatly. The areas most likely to suffer were personal research projects, grant funded reform projects in school districts, and student advisement. A quote from one of the surveys is a good summary of the overall sentiment. "We have some very large undergraduate and masters degree program enrollments. Faculty are spread too thin in their advisement, teaching, research, and social change responsibilities to do all the work at the level one expects at a doctoral granting institution. Although faculty collaborate in some efforts, systematic work across all domains has been difficult to achieve."

Although most programs report that there are sufficient doctoral students for the number of faculty available, they also report that there are not enough faculty available and consequently see the need for more doctoral students. There is almost total agreement, with about 7 exceptions, that there are not enough full-time doctoral students. Although some of the larger programs have 20-25 full time students, most have between zero and five. Usually about one third are full-time and two thirds are part-time, but some programs have no full time students. Whether full or part-time the desired ratio is to have no more than two graduates per faculty member per year. However, this is considered overwhelming when factored in with all the other departmental responsibilities. The institutions that reported that they are satisfied with the faculty per doctoral student ratio had a one to one faculty per graduate rate per year or less.

Considered both a strength and weakness, a number of programs considered their "science education doctoral faculty" to be housed in a number of departments. For some this means science educators housed in various science departments. This usually causes difficulties in coherence of program and in focus on the doctoral program because faculty are generally rewarded through traditional departmental tracks. Other programs consider science faculty, engineering faculty, general curriculum researchers, sociologists, philosophers and other faculty as integral parts of their science education program as these faculty meet regularly (in one case, weekly) with the doctoral students as part of research teams and supply a broad spectrum of expertise. Despite these more broadening perspectives on what doctoral faculty members need to be, almost all reported the need for more science educators on faculty to meet the larger institutional needs.

It would be expected that in urban areas, especially in urban inner city areas where faculty most need to be engaged in school change projects, there would be the most number of faculty. Although it is true that the number of program faculty in universities in urban areas are skewed slightly higher (see Table 5 below), the need for assistance from the surrounding school systems in these inner city areas is so great that the extra faculty member sometimes available does not match the tremendous need for additional personnel. An example given was New York City where there are 38 school districts, each with at least 15 schools. Although 5 school districts hold NSF-funded change grants, there are at least 6 other districts that are seeking college faculty to be Co-PI's on grants that they are writing, however, the available college faculty are already over-extended with grant projects and college partners cannot be found. One school district in New York City submitted a Systemic Change grant with a university in Indiana as their partner. Needless to say it wasn't funded. This problem in metropolitan area inner city institutions is exacerbated by the number of programs with only one science faculty member who is responsible for running the graduate and undergraduate programs and assisting in these highly needed school change projects. Thirty percent of the urban inner city institutions had only one faculty member, compared to zero percent in smaller urban areas, 11% in suburban areas, and 12% in rural areas.

Table 5

Number of Program Faculty by Type of Geographic Location

Type of Geographic Location	Mean Number of Faculty	Median Number of Faculty
Urban Inner City	3.5	3
Urban	3.8	3
Suburban	2.7	2
Rural	2.6	2

In a similar, but not as pressing manner, a majority of programs in rural universities felt they did not have adequate faculty to meet their responsibilities. Although the populations in close proximity to the universities are small, rural universities service a much larger geographic area than urban or suburban universities and both the number and geographic distance of the school districts they work with adds to the enormity of their task.

• Are the Graduates Prepared to be Leaders in the New Millennium?

This question is unanswerable to any degree of certainty. Although we know what current "best practice" is, and the requisite set of skills and knowledge a graduate would need to participate in leading initiatives to support the proliferation of this practice, we don't know what the next few decades portend. The limited scope of the survey further limits the potential to define what each program does in the preparation of these graduates.

However, some generalizations can be drawn from the data that are present about the level of skill and knowledge preparation of doctoral graduates. These can then be compared to knowledge and skills necessary to engage in current university or school district leadership and teaching responsibilities. Although some programs seem to have a nice match between preparation and expectations of their graduates, the overall data does not support such a correlation for many of the programs. The following are some examples of this mismatch between program and expectations.

Systemic School Change

Whether graduates eventually take positions as science education faculty in a college or university, science education leaders in school districts, faculty in science departments in a university, or as administrators of informal science centers there is a likely chance that they will be called upon to either lead or collaborate in some large scale systemic change process at the K-12 or college level. Hence, a deep knowledge of multiple means of engaging faculty and administration in building new models of teaching and learning, peer support systems, and administrative materials and curriculum replenishment systems becomes a prerequisite for doctoral graduates.

A majority of the respondents to the survey were in agreement with this proposition. Eighty nine percent thought their graduates were prepared to lead million dollar K-12 science education reform projects, and seventy two percent considered them prepared to lead million dollar college science education reform projects.

Yet a dichotomy appears to exist between these expectations and the preparation sequence required in these programs. There is general agreement that the process of leading a large school change project is an incredibly complex undertaking (Hall & Hord, 1987). Furthermore, since elementary teachers are terrified of teaching science (Raizen & Michelsohn, 1994) and secondary and college science faculty are so mired in a strong culture of "the transmission model" (Tobin & Espinet, 1989; Yeany & Padilla, 1986), the change process is even more difficult in science than in most other curriculum areas. Hence, in order for a doctoral student to become familiar with the research findings about science school change, the effective structures for cooperative science change projects at each grade level, and then to integrate and synthesize these ideas into an effective system of day to day interpersonal interactions it is necessary to work on this for more than two or three class sessions. Most people who engage in this process on a regular basis find that it takes not only one complete focused course, but an apprenticeship to a mentor who is engaged in effectively leading a systemic reform project (Friel & Bright, 1997) to get the doctoral student even to a novice level of competence. One of the respondents expressed it this way. "Understanding how to lead science systemic change cannot be done in depth in a course.

Our people must have such experiences as part of paid employment under an assistantship or by becoming part of a collaborative research endeavor."

Overall, seventeen programs (27%) had no coursework in science school change. Nine programs (14%) offered only a few sessions of an elective in science school change. Two programs (3%) offered a whole elective in science school change. This means that 44% of the graduates will not be required to take any courses in science school change. Since twenty-eight programs (44%) only offer a few sessions of a required course as their instruction about science school change then 86% of the graduates only have an opportunity to have either nothing or a few class sessions as their instruction on how to engage in science school change. Only seven programs (11%) require a whole course in school change, and only one of these is located in an urban inner city area where the need is greatest for systemic change leaders.

Table 6

Programs with Course Work in Methods of School Change in Science

None available	17
Part of an elective course	9
Whole elective course	2
Part of a required course	28
Whole required course	7

If we add the other ingredient expected for the development of a change leader, the experience of having been apprenticed to someone who is effectively leading a systemic change project, the picture doesn't become too much brighter. Twenty four programs (37%) had no opportunity to participate, twenty four programs (37%) had an elective opportunity, and sixteen programs (26%) required their students to be part of a school change project. Since there was complete overlap between the programs that required participation in a school project and the seven programs who require whole courses, only about one quarter of the graduates are required to have adequate preparation to lead systemic school change projects. Yet, as mentioned earlier, virtually one hundred percent will be expected to do so in their positions after graduation. Of those programs with any school change requirement, only three are located in urban inner city locations. Since these three programs have a combined total of two graduates each year, the number of graduates available to fill all the leadership positions at university education and science departments, as well as local school districts and informal science institutions, in the twenty five urban inner cities is grossly inadequate. In the national needs survey of urban inner city elementary and secondary science teacher preparation programs, over one third of the colleges expected new faculty to be prepared to lead large scale school reform projects in science.

Urban School Experience and a Diverse Faculty

The data from the *Need for Qualified Science Educators* survey of colleges with secondary and elementary education programs (described in detail earlier in this report.) demonstrated that 75% of the faculty in programs located in urban inner cities desired that science education tenure track line positions be filled by candidates with inner city teaching experience. Experience has demonstrated that both the credibility and the knowledge and skills necessary to prepare urban teachers in methods courses, to conduct effective staff development through in-service workshops, and to lead systemic change projects in inner city areas could only be fully garnered by having taught successfully within the inner city school culture (Jablon, 1996).

Doctoral programs in the country are not responding to this need with graduates with the appropriate background. Of the twenty five urban inner cities identified by NSF, only eleven have any type of science education doctoral program. Each year these programs graduate a total of twenty one students, of which only eleven have any inner city science teaching experience.

Consequently, 54% of the inner city colleges with positions open during the last 10 years have left science education lines unfilled for at least one year for lack of qualified candidates, and 62% filled positions with candidates they still consider under-prepared for the responsibilities of a science education faculty in an inner city college. In 1996 in New York City, one of the 25 UIC cities, there were six tenure track science education college positions open, eleven district science coordinator positions, and two informal science institution science education director positions available. As mentioned earlier in this report, a majority of these positions were not filled, and any that were filled were filled with either temporary faculty or under-prepared faculty.

This picture becomes even more dreary when one takes into account the comments from many of the UIC deans and department heads on the *Needs* survey that in most of their institutions there is either one or no full-time science educator (they couldn't find one with qualifications) and that between 70 and 88% of their science education sections are being taught by adjunct faculty.

Most of these colleges are also trying to ethnically and racially diversify their science education faculties to better match the make-up of their student bodies, especially with those constituencies historically under-represented in science. Of the eleven graduates with inner city teaching experience, there was only one Latino and three Afro-Americans. How many school districts and colleges across the country are competing for those 4 individuals?

Teaching Methods Classes and Supervising Student Teaching

Over 96% of those responding to the *Need for Qualified Science Educators* survey expected a new faculty member with a doctorate in science education to be prepared to teach either an elementary or secondary science methods class and to supervise science teachers during their student teaching. Although not as complex as supervising reform projects, the ability to do exemplary teaching of a methods course (or inservice workshop) and then to give systematic, yet appropriate, feedback during student teaching is usually honed through apprenticeship. Even though 100% of the doctoral program heads expected their graduates to be able to both teach methods courses and supervise student teaching (96% expected proficiency at inservice workshops), only 34% required their graduates to be involved in a mentored teaching of a methods course, student teaching, or inservice workshops. Forty two percent said the students could do this as an elective and 24% said their graduates had no opportunity to be mentored in any of these skills. These statistics are even more disheartening when a vast majority of the graduates will have taught in secondary schools but will be expected to teach mainly elementary science methods courses. If they don't gain this experience in an apprenticeship during their doctoral program it is very unlikely they will teach an appropriate and effective elementary methods course in their first job, or in some cases, ever.

Some of the respondents to the doctoral programs survey likened this situation to a medical school giving medical students courses in Anatomy and Physiology and Neurology and then never letting them do any practice surgery as an intern or resident under the supervision of a mentor surgeon and then giving them a full-time job as a surgeon upon graduation.

One program connected this need to mentor doctoral students to their need for additional faculty to meet all their institutions' needs. "We would like to expand our preservice program to provide more sequential methods courses (perhaps 3 required). This would not only improve our preservice ed but allow us a training ground for our doctoral students. We would like to provide systematic education as teacher education rather than assuming that all teachers become teacher educators just by finishing a Ph.D." In order to co-teach in these classes, many of which are held during the day, doctoral students would need to be full-time on a "well paid" assistantship or do this during their residency. Although 90% of the programs still require a residency, this does not always translate into being available full-time during the day, but can translate into taking a certain number of credits or an expanded research relationship with a mentor professor. As for assistantships, most are not sufficient to support the families of the middle age doctoral candidates in many of the programs.

The deans and department chairs answering the *needs* survey also expected the science educators to have K-12 teaching experience. On the other hand, only 46% of the doctoral programs required any prerequisite teaching experience. A few of the other 54% that didn't require any said that it was informal policy to require it. None of this speaks to the quality of the teaching experience. Basically, those deans and department chairs seeking new science education faculty could only be assured that less than 50% of their faculty candidates with doctoral degrees in science education had any classroom teaching experience and the programs that granted them their degrees had little or no knowledge of the quality or approaches practiced in that teaching. It is unbelievable that programs that grant degrees to science teacher educators would not have as their primary criterion for admission that candidates be the "science teachers with the most exemplary practice available."

Other Needs Identified of Qualified Science Educators at a College

Presented here are some of the additional data from the *Survey of Need for Qualified Science Educators* that did not fit into any of the above categories.

• Eighty percent of the institutions expected their science educator to have a doctorate in science education. This sample was of an extensive cross-section of colleges and universities in the United States. This included many small private colleges with small faculties. Yet most of these institutions still required their science education faculty to hold doctoral degrees in science education. As can be seen from the last three sections they thought that this would bring with it a particular level of expertise.

• An implication of the *Professional Knowledge Standards* in the *AETS Position Statement* (Lederman, et al., 1997) was also an area of concern for these education deans and department heads. Over 79% of them expected new science education faculty to have the ability to effectively work with college science department faculty in creating appropriate college level science courses. Those few science educators who have engaged in this undertaking on their own campuses know what a daunting task this is for a senior science educator, no less a novice who has not had any experience in such an enterprise during their doctoral studies.

• As mentioned earlier in this report, a high percentage (72%) of those institutions located in UIC areas expected their science education faculty to have had school teaching experience in a school with similar demographics to the schools in the community in which their college is located. This "additional skills needed for local demographics" carries over into the urban-based colleges (60%), and is of less importance in rural (44%) and suburban (42%) based college settings.

• Given these additional needs for UIC college science educators (and the almost absence of graduates with such qualifications) it is not surprising that UIC-based colleges report that 39% of the science educators they hire do not meet their minimum qualifications compared to a 90% satisfaction rate for suburban, 70% for urban, and 67% for rural based colleges. Overall this is a fairly dismal satisfaction rate for science education doctoral program graduates. This confirms some of the assertions made in earlier sections of this report about the lack of skills and knowledge of some graduates of doctoral programs in this country and the lack of baseline consistency of programs.

• Although UIC-based colleges again had the largest number of advertised positions left unfilled for more than a year (54%), the other geographical areas are not far behind. Rural-based colleges had 50%, suburban based colleges had 42%, and urban-based colleges had 41% of their positions left open for more than a year. That means that almost half (46%) of the advertised positions for a science educator were not filled the first year they were advertised, and as seen previously, the satisfaction rate upon those eventually hired was less than satisfactory as well. This possibly speaks to a need for more and better qualified science education doctoral program graduates.

• Have Trends continued or Changed since the 1980 Yager Report?

1. The number of science education doctoral graduates was increasing during the 1960 to 1980 period and has since decreased into the 1990s with a slight increase within the last year, but not back to the 1980 level.

2. Course requirements have changed little over the past 20 years with the exception of a decrease in the amount of pure science courses required for both admission (26% an undergraduate bachelors degree, 49% a masters degree, and 19% have a masters for some and a bachelors for others) and graduation. Most degrees have moved away from half the credits in the doctorate being in pure science as it was in 1980.

3. The inability of faculty to keep up with their personal research agenda is still prevalent in 1999 despite the admonition of the Yager report to lessen the teaching and advising load of science education faculty to allow for more sustained research.

4. Faculty in major centers for science education research in 1999 appear not to be as homogeneous in their sex, age, academic preparation and professional teaching and inservice responsibilities, as were those of their counterparts in 1980. But additional data is (**NOUN-VERB AGREEMENT**) needed to affirm this. Certainly the number of women graduates of doctoral programs has increased radically. Unfortunately the number of under-represented minorities, teachers with elementary experience, and graduates with urban, and especially UIC, teaching experience has not increased noticeably.

5. The trend in the "Yager years" for science education programs to become part of a larger curriculum and instruction department has continued such that there are now more than twice as many of these "strands" within larger programs as there are separate science education programs.

6. The decrease in funding for both research and assistantships in science education that began in 1975 appears to have continued to the present.

7. Since 1978 there has been about a 16% increase in science education faculty at doctoral granting institutions. There had been a decline from 1979 to 1975 so this brings faculty levels close to 1970 levels despite the greater demands placed upon faculty by the national reform movement in science education.

It should be noted that many issues such as preparation of graduates to direct school change, work in an urban environment, or teach methods courses was not addressed in the earlier report. Likewise, the Yager study did not specifically report the number and nature of topics that were taught in which programs. Therefore, trends cannot be compared to the specifics offered in this report in those areas. There were also many areas that were addressed in the more comprehensive Yager report that are not studied as part of this survey.

• Some Recommendations Drawn from the Data in this Report.

1. The most obvious need is not only for a better funded and more comprehensive study, but an ongoing unit (of NSF, or funded by NSF) that would collect and analyze data about the quantity and quality of science education doctoral programs and their graduates and the subsequent need in the larger science educational community for these graduates.

2. There needs to be a well designed, timely, funding response from both government and private funding agencies that address some of the more urgent needs described in this report. For example:
• Support for UIC focused programs, and high-priced assistantships for exemplary UIC experienced teachers, that would give full-time experience-based preparation in school change, UIC based instruction, teaching of methods and preservice courses, etc.
• Special stipends for under-represented minorities with exemplary UIC experience for enrollment in these programs.

3. Likewise there needs to be a well designed funding response from both government and private funding agencies that addresses the need for an increase in both faculty research and well paid assistantships for all science education doctoral programs in order to attract more of the most highly qualified science education doctoral students into the programs.

4. There needs to be an ongoing set of focus groups, perhaps cosponsored by AETS, NARST, and NSF, that would bring together diverse groups of individuals that would better define the "baseline" set of experiences necessary to meet the standards already put forth in the AETS position paper. Doctoral programs could then voluntarily evaluate their programs against this set of guidelines that would evolve from these focus groups.

5. Last, but not least, is a request from the faculty in each of the doctoral programs that contributed to this study that they begin to evaluate their own program and the mechanisms it utilizes to have its graduates be proficient in each of the areas addressed. For as suggested above, it will take money to solve some of the problems we have in our programs, however, much of the initiative comes from within.

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