Ensuring Quality Science, Math, Engineering, and Technology Teachers to the United States' K-12 Classrooms

Rachel Dubbert
Kansas State University

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About the Author

Rachel Dubbert majoring in Industrial Engineering at Kansas State University. She will graduate in December 2000. This paper is the result of her research conducted through the Washington Internships for Students of Engineering (WISE) program in the summer of 1999.

WISE

The Washington Internships for Students of Engineering is a ten-week program for outstanding engineering students who have completed their junior year, displayed leadership abilities, and expressed an interest in public policy. The students spend the summer in Washington, DC, exploring how engineers contribute to the policy making process particularly on technological issues. Through meetings and discussions with government officials and other non-government organizations, the students expand their knowledge on a variety of public policy issues. Each student completes a paper that examines a specific engineering related public policy issue that is of interest to them and their sponsoring engineering society. For more information about the WISE program, contact WISE, Attn: Anne Hickox, 400 Commonwealth Dr., Waredale, PA 15096-0001.

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Executive Summary

K-12 students knowledgeable in science, math, engineering, and technology (SMET) are crucial to the continuing economic growth of the U.S. Not only is this instruction important to students going into careers in SMET, these skills are also necessary for all individuals, considering that technology increasingly affects their everyday lives. To ensure a technically literate society, emphasis needs to be put on where this knowledge begins: our **K-12 teachers**. Student achievement in SMET can be best improved if teachers are prepared and knowledgeable in these subjects. A growing concern is finding enough qualified teachers to assure the nations' K-12 students receive the SMET education they need for their futures. While quality teachers need to be found, a quantity of teachers is also needed. Because of increasing enrollment in K-12 classrooms, the increasing number of teachers reaching retirement age, and efforts to reduce class sizes, the nation is facing a high demand for new teachers. Efforts need to be made to improve teachers' pre-service training and professional development and to recruit and retain SMET teachers.

Emphasis has been put on improving math and science education from grades K-12 and higher since the launch of Sputnik. These past efforts have shown little or no improvement in student achievement. For example, the Third International Math and Science Study (TIMSS) revealed that U.S. students are still not performing as well as their international counterparts in math and science. TIMSS also studied teaching methods in 8th grade math classrooms in different countries. This study showed that U.S. teachers use different methods than other countries, whose students scored higher in TIMSS. Several players continue to make efforts to improve the quality of K-12 SMET teachers. Congress, the Department of Education (ED), the National Science Foundation (NSF), engineering and teacher societies, and universities all play a part in improving the pre-service training, professional development, recruitment, and retention of SMET K-12 teachers.

The issue of ensuring quality K-12 SMET teachers to the U.S.' classrooms has received much attention in the past and present but has not been resolved completely due to several reasons. Conflicts exist that may inhibit or stall progress, such as the distribution of power between the Federal government and states. Another conflict is the emphasis on teacher quality versus classroom size reduction. Many groups are making efforts toward the pre-service training and professional development of these teachers. Several concerns need to be addressed in order to make these efforts more effective. NSF and ED both provide funds to support professional development and pre-service training activities for teachers, but may lack communication on how their programs overlap and complement each other. Also, government agency programs may not be the most effective due to inadequate funding. Many universities need to overcome inner conflicts between their education and SMET faculties to properly train future K-12 SMET teachers, and the engineering societies could use their influences more effectively towards this issue.
Several policy alternatives that may aid in the improvement of K-12 SMET teachers

include:

1. The individual states need to develop programs and certification processes to ensure that there are quality SMET teachers in their K-12 classrooms.
2. The Federal Government needs to continue to make SMET K-12 teacher quality a priority by passing legislation that supports excellence in teacher pre-service training and professional development.
3. Funding for NSF programs that support and develop SMET K-12 Teacher pre-service training and professional development activities should be increased.
4. Faculty of Colleges of Education and Colleges of Engineering and/or Departments of Mathematics and Sciences should work together to develop effective SMET classes designed for K-12 education majors.
5. Engineering societies should form a coalition to support K-12 SMET teacher pre-service training and professional development.

Science, Math, Engineering and Technology K-12 teacher quality requires immediate attention from the engineering societies. In order to prepare for the engineers of the future, these societies should form a coalition to support actions and programs to strengthen the K-12 SMET teacher workforce. In addition, this issue demands attention from all players in Federal and State governments, engineering, science, and teacher societies, and universities. Efforts to improve K-12 SMET teachers should be a priority of all groups in order to ensure the quality development of US K-12 students' technical knowledge. Efforts also must be long-term. Drastic improvements in all teachers and increases in student achievement will not take place overnight: they will take time.

Issue Definition

This paper focuses on policy alternatives to help ensure there are quality teachers in the United States mathematics, sciences, engineering, and technology (SMET) K-12 classrooms. Students knowledgeable in SMET are crucial to the continuing economic growth of the U.S. Not only is this instruction important to students going into careers in math, science, engineering, or technology, these skills are also necessary for all individuals, considering that science and technology increasingly affect their everyday lives. To ensure a technically literate society, emphasis needs to be put on where this knowledge begins: our K-12 teachers. The performance of students in math and science is dependent on the quality of the instruction they receive. Student achievement in math and science can be best improved if teachers are prepared and knowledgeable in these subjects. Several issues involving the recruitment and retention of quality K-12 science, math, engineering, and technology teachers exist and are examined in this paper: the quality of teachers' preparation during undergraduate education, the poor public recognition teachers are given, and the lack of professional development for current teachers.

Some very disturbing facts exist regarding the U.S.' current K-12 science and math teacher workforce. Many teachers at this level lack confidence that they are knowledgeable enough to teach science and scientific concepts. This lack of confidence may be due to inadequate training. For example, about 28% of high school math teachers do not possess an undergraduate minor or major in the subject[1]. Also, teachers are not recognized or rewarded by the public for achievement as in other professions. During a recent House Committee on Science hearing, Howard Voss, a physics professor at Arizona State University who is very concerned with the recruitment, training, and retention of science teachers, stated that "the American culture no longer holds teaching and teachers in high regard"[2].

A growing concern is finding enough qualified teachers to assure the nations' K-12 students receive the SMET education they need for their futures[3]. While quality teachers need to be found, a quantity of teachers is also needed. Because of increasing enrollment in K-12 classrooms, the increasing number of teachers reaching retirement age, and efforts to reduce class sizes, the nation is facing a "demand for 2 million additional teachers over the next decade"[4]. Also, the shortage of math and science teachers is far greater than in other core subjects such as reading or English. Efforts to increase the number of teachers in math and science as well as the quality of these teachers may be the direct responsibility of higher education institutions. New teachers must be recruited into the profession as well as be suitably trained to teach their subjects during their undergraduate education.

The recruitment of new teachers and the retention of current teachers are directly related to the public's perception of the teaching profession. Starting salaries for K-12 teachers are considerably lower than other occupations such as engineering, mathematics, or sciences. This gap in salaries deters many individuals knowledgeable

in math, science, and engineering from teaching these subjects at the K-12 level. Also, a large turnover of teachers, especially in rural areas, exists because of public acceptance. Because every year many rural schools experience a 30% turnover in teachers, these areas' people are reluctant to accept, support, and bond with new teachers. This problem is difficult to solve, because the lack of acceptance causes young teachers to leave, which continues to increase public reluctance. Many of these teachers relocate to suburban schools where they receive more support and reassurance from parents and other teachers[5].

As teachers continue in their careers, they need adequate professional development programs to deliver quality math and science instruction. A professional development program should stimulate teachers to expand their knowledge of their subjects. Many professional development programs today are based on how to teach the subject instead of the concepts and content of the subject. Professional development programs also need to be long-term in order for teachers to develop and retain adequate skills in science and math[6].

Background

General History and Facts

After the USSR succeeded with the launching of Sputnik and shocked the U.S. in the competition for space, heavy emphasis was put on improving math and science education from grades K-12 and higher. These efforts showed little or no improvement in student achievement during the years following, particularly in math and science[7]. The focus for strengthening K-12 education began to shift in the 1980's from the military logic of the Cold War to ensuring the U.S.' economic and technological competitiveness.

In 1983, the National Commission on Excellence in Education issued a report to the Secretary of Education entitled "A Nation at Risk". The report called for a reform in the U.S.' school systems and to renew the National commitment to quality education. With the continued development of technology, the "risk" included the U. S. faltering as an economic power with technologically literate citizens. The report emphasized that every citizen needed "to reach common understandings on complex issues" in order for the country to function[8].

The concerns about our nation's K-12 students' science and math education were brought to attention again in 1996 and 1997 with the results of the Third International Math and Science Study (TIMSS) conducted by the International Association for the Evaluation of Educational Achievement. Although U. S. 4th graders scored above the international average in math and science, TIMSS reported some disturbing results. 12th grade students scored below the international average in math, physics, and math

and science literacy, and 8th grade students were below average in math but above average in science[9].

TIMSS also studied teaching methods in 8th grade math classrooms in three countries, Germany, Japan, and the U.S. Japanese teachers, whose students scored higher than U. S. students in math and science, taught thinking and understanding of the subject while U.S. and German teachers concentrated on teaching skills[10].

The findings of TIMSS showed progress towards national goals adopted in 1994 by the Goals 2000: Educate America Act. The goal that "by the year 2000, U.S. students will be first in the world in mathematics and science achievement" has not been accomplished, but progress continues to be made in student achievement. Another national goal stated in this Act relates to quality teachers. According to this goal, U.S. teachers "will have access to programs for the continued improvement of their professional skills and the opportunity to acquire the knowledge and skills needed to instruct and prepare all American students" by the year 2000[11]. Slowly, advancement is being made toward this goal. For example, many states have adopted standards and accountability measures relating to teachers' certification, subject assignment, and professional development requirements.

The House Committee on Science focused on the training, recruitment, and retention of qualified K-12 math and science teachers in its study, "Unlocking our Future: Toward a New National Science Policy." The report highlights that teachers at least should take college classes in the subject they teach if not have a minor, and that professional development during teachers' careers is also important. Of high school math teachers, about 28% do not have either a major or a minor in the subject[12]. Many elementary teachers lack the confidence to teach science, because they feel their knowledge and understanding of the subject is deficient.

The U. S. is also facing a shortage of K-12 teachers, which adds to the problem. An estimated 2.2 million new teachers will be needed by 2008 to compensate for increasing enrollment and to replace current teachers who will be retiring[13]. Within all K-12 academic subjects, math and science teachers are in the greatest demand. Of the nation's school districts, 96% report a demand for science teachers and 67% for mathematics teachers[14]. Since the demand for teachers exceeds the supply, many schools must hire underqualified teachers. Of newly hired teachers, 10.7% have no license to teach in their state and 16.3% possess an emergency or other provisional license. Some of these emergency licenses are granted under the expectation that the teacher will move toward full certification or are held by individuals seeking teaching as a career change by alternative certification routes[15].

Another point "Unlocking our Future" discusses is the need for increased salaries or other incentives to make the profession of teaching desirable to those qualified to teach math and science. The report emphasizes that "recruitment of qualified math and science teachers must be encouraged"[16]. College students majoring in science, math,

engineering, or technology fields would be ideal candidates to recruit into teaching. Most students are reluctant to explore K-12 teaching as a career because, they would be taking tremendous salary cuts. The average starting salaries for K-12 teachers are much lower than starting salaries for mathematicians, chemists, and engineers of all fields with bachelor's degrees, see Figure 1[17]. Teachers also have limited possibilities for large raises considering the average national salary for teachers is $37,900[18].

Average Starting Salaries in 1997	
K-12 Teachers	$25,462
Chemists	$38,418
Mathematicians	$31,800
All Engineering	$38,500
Aerospace Engineers	$37,957
Chemical Engineers	$42,817
Civil Engineers	$33,119
Electrical Engineers	$39,513
Industrial Engineers	$38,026
Mechanical Engineers	$38,113
Nuclear Engineers	$37,194

Figure 1: Comparison of average starting salaries in 1997 for teachers and other professions.

Lack of public recognition is another reason why students do not choose the field of teaching. Professional development activities and recognition through awards are not as common in the teaching profession as in others.

Recent Congressional Action

The 106th Congress is examining the issue of quality teachers as they consider the reauthorization of the Elementary and Secondary Education Act (ESEA) that among other programs authorizes the Eisenhower Professional Development program. This program supplies funds to state and local education agencies for the conducting of professional development programs. Eisenhower puts an emphasis on math and science by requiring states to spend a minimum of funds on these subjects[19].

The House Committee on Science is holding a series of hearings to explore the options to strengthen science and mathematics education. The role that the Federal government can have in these efforts such as oversight or funding allocation is being considered. The Committee has held a hearing in this series focusing directly on how to find, train, and keep quality math and science teachers[20].

The U.S. House of Representatives passed The Teacher Empowerment Act on July 20, 1999. This bill combines several education programs including the Eisenhower Professional Development Program to provide funding to the states and local education agencies for teacher professional development, classroom size reduction, and other education programs. This Act maintains emphasis on math and science professional development, but also grants the states the ability to decide how to utilize Federal funds and apply for waivers from spending requirements[21]. This Act amends Title II of the ESEA; the House is considering reauthorizing the ESEA's other Titles individually.

The Senate is expected to reauthorize the ESEA as a whole in late 1999 or early 2000. Currently, the Senate Committee on Health, Education, Labor, and Pensions is conducting hearings on the ESEA issues, and there are no significant bills in the Senate for ESEA consideration.

The Department of Education

The Department of Education (ED) administers the Eisenhower Professional Development Program, which provides grants to all 50 states to promote professional development among K-12 teachers[22]. States receiving grants of $250,000 or less must use the entire grant for professional development in math and science. To receive a Eisenhower grant, states submit an application to ED including a plan for utilizing these funds. Each plan includes an assessment of the state and local needs for teacher professional development, especially in math and science, and a description of how the plan addresses these needs. Part of the grants are allocated according to a formula based on K-12 population, the other funds are distributed on a competitive grant basis. Local school districts apply to their states to receive Eisenhower funds with a very similar procedure. However, local education agencies must set up performance indicators for improvement in teaching through professional development[23].

ED is presently studying the effectiveness of the Eisenhower Professional Development Program. Unfortunately, many local school districts do not receive enough money to support long-term professional development programs for their teachers. This is one reason that a goal of the program to provide extended learning opportunities at the district level has not been achieved. Other preliminary findings of the evaluation indicate that developing teachers' knowledge and skills in math and science has not been achieved as much as desired. Two-thirds of teachers responded that Eisenhower-sponsored activities deepened their knowledge and skills in instructional methods, but only 49 percent replied the same for math and science knowledge. The study has found that districts coordinating and co-funding Eisenhower activities with other Federal funded programs such as the National Science Foundation (NSF) systemic initiatives conduct more successful and quality professional development activities[24].

ED is scheduled to complete the evaluation of the Eisenhower program in 2000. Other efforts to improve the quality of America's teachers are indicated in ED's strategic goals. ED's goals support efforts to increase teacher effectiveness and pre-service training quality and to decrease the amount of teachers leaving the profession[25]. ED has also formed a commission to explore a strategy for improving math and science teaching nationwide. The National Commission on Mathematics and Science Teaching for the 21st Century, chaired by John Glenn, will report its findings and recommendations in the fall of 2000[26].

The National Science Foundation

The National Science Foundation (NSF) is another Federal agency that supports K-12 math and science teacher development. NSF's programs for this purpose include Teacher Enhancement, the Collaboratives for Excellence in Teacher Preparation, and their systemic initiative.

The Teacher Enhancement Program provides grants to school districts, colleges, universities, or other organizations to form and deliver professional development activities to expand and develop K-12 teachers' knowledge of math and science. These activities also improve teachers' abilities to give challenging instruction in SMET. Teacher Enhancement supports two types of projects: Local Systemic Change and Leadership. In Local Systemic Change projects, all teachers in the schools must participate in the sponsored activities that concentrate on using instructional materials and student centered learning. The Leadership projects are more voluntary. While involved in activities, teachers are put into teams to strengthen their content knowledge and instructional methods[27].

The Collaboratives for Excellence in Teacher Preparation addresses the national need to develop and retain large numbers of teachers qualified in math and science. Grants are made to partnerships between school districts, universities, 2 or 4-year colleges, and community organizations. Collaboratives work to develop competent math and science teachers during their pre-service training by, for example, developing new courses and curriculum for education majors, recruiting students including SMET majors into the teaching profession, and requiring education students complete majors in their academic subjects. In developing new courses and curriculum, faculties from Colleges of Education work with SMET faculties. Scholarships are used to recruit students into the programs, and after graduation these scholars are expected to continue participating in the Collaboratives by mentoring future graduates[28].

NSF sponsors three types of systemic initiative programs; Rural, Urban, and Statewide. The Rural and Urban Systemic Initiative programs concentrate on school districts in those areas which are defined to have a certain level of population and/or poverty. Statewide Systemic Initiatives involve a state's entire system of school districts. Systemic initiatives work to improve math and science education by reforming all elements in school systems, including standards based curriculum content and materials, administration participation and support, community participation, etc.[29]. Systemic initiatives require that projects align other resources to support the reform. This includes the use of Eisenhower funds for teacher development activities to support the initiatives[30].

All projects NSF awards grants to undergo a rigorous application process. In the application process, detailed plans of how the project will be implemented, administered, and evaluated must be developed and explained. This rigorous process alleviates the need for rigid monitoring by the NSF program managers. An annual report is required from each project on its progress and results. The program managers use these reports to make suggestions for project improvements. Projects involved with the Rural Systemic Initiatives and the Collaboratives for Excellence in

Teacher Preparation program are also visited by their program managers for direct observation. If a project is not performing well, efforts are under taken for improvement, but program managers have the option to discontinue grants and redirect the funds elsewhere.

Most of the NSF education programs require the alignment of other federal funds for the enhancement of the projects. The Teacher Enhancement projects use Eisenhower funds to more effectively develop teacher professional development activities. Eisenhower funds are also used for teacher development in the systemic initiatives.

Engineering Societies

Engineering societies also have taken positions on K-12 math and science teacher recruitment and retention. The Institutes of Electrical and Electronics Engineers (IEEE) has encouraged states and institutes of higher learning to develop programs to minimize the retraining time and financial resources needed for engineers to enter the teaching profession[31]. Decreasing the further training needed may attract these qualified, knowledgeable individuals to teaching. Also, IEEE has suggested that the engineering societies work in coalition on the issue of strengthening K-12 education[32]. Efforts to build a coalition have not been initiated presently. IEEE tries to lead the other societies by example with their education efforts in universities and local education agencies. The American Society of Mechanical Engineers (ASME) has supported the emphasis on math and science in the Eisenhower program and improvement in teacher professional development efforts nationwide[33]. ASME has made efforts to communicate with Congressmen and other pertinent players on advancing SMET instruction in classrooms[34] and continues to research and update its members on the issue. The American Association for the Advancement of Science (AAAS) recently conducted Project Alliance, a 4-year program that created partnerships between scientists, engineers, and schools. Teachers in these schools participated in professional development programs during the summer and school year and were supported by their outside partners. Many of these schools continued the partnerships even after funding was discontinued[35].

Many engineering societies have engineering education programs for K-12 students, but do not concentrate directly on strengthening teacher knowledge and skills that are needed for quality instruction. The American Society for Engineering Education (ASEE) concentrates mostly on engineering recruitment efforts in K-12 classrooms. ASEE's new President, John Weese, has established one priority for his term to improve physics education at the K-12 and community college levels, which may include teacher development[36]. The Society of Automotive Engineers (SAE) conducts a program called "A World in Motion" which brings engineers into the middle school level classroom to teach engineering concepts and teamwork. SAE and the American Institute of Chemical Engineers (AICHE) have expressed concern with K-12 teacher quality, but neither have programs or positions directly related to the issue[37].

Teacher Societies

The National Science Teachers Association (NSTA) and the National Council of Teachers of Mathematics (NCTM) are both concerned with the issue of quality K-12 teachers in their subjects. NSTA is active in following congressional action and making suggestions for legislation that effects this issue. They contributed suggestions during the writing of the Teacher Empowerment Act and supported this Act through the House because of its emphasis on science. As the ESEA is reconsidered in the Senate, NSTA continue to follow its progress[38].

NSTA also sponsors the "Building a Presence for Science" program which has created a network of science teacher colleagues in 13 states and the District of Columbia to develop standards based learning and instruction in science classrooms. Each state uses representatives from the communities or industry partners to develop science teachers' knowledge and methods in order to deliver standards based instruction[39].

NCTM also follows relevant legislation closely and informs its members on issues and actions in Congress. NCTM has also developed standards relating to the pre-service training of math teachers. NCTM's standards include detailed guidelines for courses that math education majors should take during college. These standards have been widely accepted within the math teaching community[40].

University Education Programs

Many university programs exist to train and recruit quality SMET K-12 teachers. Universities that currently have efforts for this purpose include Kansas State University, Montana State University, and Temple University.

Kansas State's College of Education requires future math, physics, chemistry, or general science high school teachers to complete 40-50 credit hours of course work in their areas of concentration, which is more than other area institutions. Elementary Education majors must take a minimum of 12 credits in science and 9 in mathematics. Kansas State has recently entered a NSF Collaborative for Excellence in Teacher Preparation with the University of Kansas and area community colleges[41].

Montana State University - Billings runs a teacher certification program for people possessing baccalaureate degrees equivalent to teaching majors and minors at Montana State including chemistry, mathematics, and physics. Interested candidates are eligible to obtain a Masters of Education degree and become certified to teach at the elementary or secondary level. Students in this program complete courses to develop teaching methods, strengthen their content knowledge, and become teachers[42].

Temple University is creating a model for urban teacher preparation through its Collaborative for Excellence in Teacher Preparation. During the project, Temple is working with Community Colleges of Philadelphia to revise existing courses and develop new courses to prepare future science and math teachers. These courses will expand the existing education curriculum to include more math and physics[43].

Key Conflicts and Concerns

The issue of ensuring quality K-12 SMET teachers to the U.S.' classrooms has received much attention in the past and present but has not been resolved completely due to several reasons. Conflicts exist that may inhibit or stall progress, such as the distribution of power between the Federal government and states. States possess most of the decision control of funds and resources to train teachers; the Federal government distributes funds and oversees state activities at a distance. Another conflict is the emphasis on teacher quality versus classroom size reduction. Many groups are making efforts toward the pre-service training and professional development of these teachers. Several concerns need to be addressed in order to make these efforts more effective. NSF and ED both provide funds to support professional development and pre-service training activities for teachers, but may lack communication on how their programs overlap and complement each other. Also, government agency programs may not be the most effective due to inadequate funding. Many universities need to overcome inner conflicts between their education and SMET faculties to properly train future K-12 SMET teachers, and the engineering societies could use their influences more effectively towards this issue.

Federal vs. State Control

The Federal government is limited in its control over K-12 education. Guidelines on how the state and local education agencies are to use the Eisenhower funds are outlined in ESEA. These outlines are about as far as the Federal government's control over the funds goes. Through Acts such as the ESEA, Congress and the Administration can only make recommendations to the states on how to make progress. Currently, the states and especially the local education districts report little to the Federal government on how these funds are spent after receiving funds from the initial applications. As the 106th Congress considers the reauthorization of the ESEA, one of the issues being debated is the accountability the states have to the Federal government. Increasing such accountability raises concerns over the Federal government's respect of the states' sovereignty. States' current power to make decisions on education allows them to prescribe their own needs in education. If states

are allowed to use Eisenhower funds for subjects other than math and science, the purpose of this program may be compromised.

As Congress considers the reauthorization of the ESEA, there is concern that the emphasis on using the Eisenhower Professional Development funds for math and science professional development activities may be decreased due to flexibility given to the states. The Teacher Empowerment Act, H.R. 1995, provides funding for teacher professional development in math and science, but allows State and Local Education Agencies the ability to receive a waiver from this requirement if professional development needs in math and science have been met[44]. On the other hand, the current ESEA sets a minimum amount of Eisenhower funding each State Education Agency must spend on math and science professional development activities. If a state receives less than $250,000 in funding, all must be spent on math and science activities[45].

Teacher Quality vs. Classroom Size Reduction

Teacher quality tends to suffer from recent initiatives to reduce America's classroom sizes. In order to reduce class sizes, State and Local Education Agencies may have to hire out-of-fields teachers or emergency certified teachers to teach math and science. Reducing class size may not increase student achievement as intended, without quality teachers in these classrooms. During debate in the House Committee on Education and the Workforce on the Teacher Empowerment Act, this issue was brought up frequently. The Republican bill provides funds for teacher professional development and for the reduction of classroom sizes. If the local education agency has met the requirements for classroom size or does not possess the resources to reduce classroom size further, a waiver to spend these funds toward increasing the quality of their teachers can easily be obtained. Democrats would like to make reducing classroom size a priority. They would require school districts to reduce classroom size by hiring only teachers that are certified in their field and not out-of-field teachers or emergency certified teachers[46]. This party does not directly address the need for an abundance of quality teachers.

Interagency Communication and Coordination

Two federal agencies, NSF and ED, currently distribute funds or grants for K-12 SMET teacher training and professional development. Some of NSF's programs, such as their Systemic Initiatives, require their projects to report what other federal funds, such as ED, they receive and to use these funds for enhancing the NSF program activities[47]. One concern is the lack of communication between ED and NSF on how their funds overlap and are utilized. For optimum use of these grants and funds, the coordination between them should be considered. Currently, the Director of NSF and the Secretary of Education give periodic overviews of their agencies' programs to each other instead

of the agencies' program directors communicating. These are the individuals that actually run the programs on an everyday basis and distribute the grants and funds.

Inadequate Funding for NSF Program Monitoring

Some of the NSF programs for pre-service training and professional development lack the ability to directly visit and make suggestions to the projects' local principle investigators and administrators. If funding were available, program directors would be able to make more on-site visits to projects. This would enable them to make better suggestions for improvement, monitor the progress of the projects, and understand the successes and failures of each project[48].

Cooperation between University Departments

Future SMET K-12 teachers start their careers at the U.S.' universities. These higher education institutions need to ensure that future teachers get a proper college education, so they will be qualified and knowledgeable when entering the workforce. Without backgrounds in SMET, teachers instructing children in math or science cannot deliver quality lessons to their students. Some programs exist, such as NSF's Collaboratives for Excellence in Teacher Education, which involve departments of engineering, math, or science in the education of future K-12 teachers. These programs have been successful, but have only been initiated because of NSF grants. Without money to encourage the development of programs similar to these, the cooperation between departments of science, math, or engineering with departments of education would be difficult to initiate. University administrators and SMET faculty are reluctant to use the time and resources required to sufficiently educate education majors in SMET. Most universities offer no incentives or rewards to SMET faculty for this kind of involvement.

Insufficient Effort by Engineering Societies

Many engineering societies have expressed concern for the lack of quality SMET K-12 teachers, but very few have made concrete efforts to solve the problem. Engineering societies have a good position to influence faculty of universities and their members, but most focus on post-secondary education issues and other concerns of their members, not K-12 teacher quality. Most engineering societies exist to serve their members and spend money and time on efforts that directly benefit their members. The future engineering workforce and engineering society members start their education in the K-12 classroom. Without quality instruction at this level, many potential engineers may not develop the skills they need to pursue or succeed in professional training.

Also, the engineering societies have not worked together on this issue as best as they could. Working as a whole, engineering societies have influence on government policy making. Quality K-12 SMET teachers is an ideal issue for the societies to work on as a coalition.

Policy Alternatives

Involvement by the States

The individual states need to develop programs and certification processes to ensure that there are quality SMET teachers in their K-12 classrooms. By increasing utilization of Eisenhower Professional Development funds and NSF program grants and modeling successful state programs, each state has the potential to train and retain quality teachers. States with successful programs must publicize their methods and benefits to provide examples for modeling by other states.

Effectiveness: As the educational system exists today, most efforts to improve teacher pre-service training and professional development will not be effective without individual state support. State educational agencies have the power to strengthen their certification processes in order to make them more rigorous. States also make the most direct decisions on how to utilize Federal monies and grants to improve teacher development.

Efficiency: By effecting the most directly influential group on this issue, the states, this alternative will efficiently affect the quality of SMET K-12 teachers. Revising state programs and certification processes will take time to accomplish and produce results in student improvement through better teachers. States may be reluctant to communicate their efforts to other states or take suggestions because of required time commitments, costs, and their education system structures. This communication may be initiated and conducted through the National Governors Association during their annual meetings or task force meetings.

Equity: The states will have to provide the funding or use their federally distributed funds to provide for these efforts. States without adequate funding may not be able to make as extensive efforts in improving their SMET teachers and classrooms as others with more funding might. A large gap exists in funding between several states. For example, in 1997, California was able to spend almost $34.5 billion on education where as Mississippi only spent $2.3 billion[49]. As a result of using more resources to improve teaching in SMET, other core academic classes may suffer such as reading, social studies, or foreign language.

Flexibility: Each state can make decisions that fit its educational situation making this alternative flexible in that respect. If states are to consider other existing programs

and model these, diversity among the state programs to support teacher training and development may be slim. States currently have some flexibility on how they use Eisenhower funds for subjects other than science and math, but this alternative would decrease or even erase that flexibility.

Implementability: This alternative would be implemented directly within the states which have the most power to make decisions on pre-service training and the professional development of teachers. Communication between the states to promote existing successful programs may be difficult and would rely on each state's willingness to discuss its programs and take suggestions. The National Governors Association would be the most immediate resource for communication on state education issues. Communication between the state boards of education would be ideal for direct communication of education issues.

Congress and the Federal Government Efforts

The Federal Government needs to continue to make SMET K-12 teacher quality a priority by passing legislation that supports excellence in teacher pre-service training and professional development. In the reauthorization of the ESEA, the Eisenhower Professional Development program must continue to emphasize and require professional development activities in math and science. Also, legislation should ensure that teacher quality does not suffer as a result of reducing classroom sizes. How an abundance of quality teachers is to be found and trained must be emphasized before concentration is put on hiring.

Effectiveness: With leadership from the federal government, the issue of providing quality SMET teachers to K-12 classrooms will continue to be a national effort. By continuing to write legislation that includes requirements on the amount of Eisenhower funds state educational agencies must spend on science and math activities, this would be an effective method to improve SMET K-12 teaching. Reduced classroom size is important, but first, qualified teachers should be in these classrooms or there may not be positive effects on student achievement. An example of legislation emphasizing that quality teachers need to be hired for classes as their sizes are reduced is H. R. 1995.

Efficiency: This alternative would efficiently put emphasis on SMET professional development, by requiring Eisenhower funds be spent on science and math activities. With federal funds being spent on teacher quality programs, more qualified teachers will be in the nation's classrooms. All emphasis should not be taken from reducing class sizes; even a highly qualified teacher needs a reasonable sized class to deliver instruction sufficiently. Federal support must continue in order to remain a long-term solution.

Equity: If flexibility to spend Eisenhower funds on subjects other than science and math is taken away, professional development in other core academic subjects may suffer. States should have the power to prescribe their own needs within core subjects. For example, if states need more assistance with reading programs, these may continue to suffer at the expense of math and science development. In order to ensure that quality teachers are employed before reducing classrooms, the Republican and Democratic parties in Congress must compromise on their priorities.

Flexibility: This alternative may be difficult to administer considering the Federal government would be decreasing the flexibility the states possess to spend professional development funds on other subjects. This would lessen the states power to make decisions on their education programs and needs.

Implementability: In order to be implemented, legislation must be passed to require Eisenhower funds are used for SMET and that quality teachers be developed and hired. To pass such legislation, a compromise must be made in Congress that will not decrease emphasis on science and math or teacher quality. ED would be the direct implementers of this legislation and would oversee the states use of Eisenhower and other funds. The states may be in opposition to these efforts considering flexibility in their decision making would be decreased or taken away.

NSF K-12 Teacher Programs' Funding

Funding for NSF programs that support and develop SMET K-12 Teacher pre-service training and professional development activities should be increased. This would provide for more on-site monitoring by the NSF program managers and assist in potentially making the programs more long term.

Effectiveness: NSF programs have been effective in improving teacher pre-service training and professional development within their projects. By increasing funding, these programs will be able to continue and expand. Increased funding will improve these programs by providing for more effective guidance through on-site visits by the program managers.

Efficiency: To increase funding of these programs the money must come from somewhere. Focusing more of the nation's financial resources on programs in the NSF will re-emphasize the Federal government's commitment to improving science and math in our nation's schools. NSF projects take time to develop and show results, so this solution would have to be long-term, probably 10 to 15 years, to sufficiently see results.

Equity: Schools and institutions of higher learning that receive NSF grants would benefit from this solution the most. Many schools may not know about the programs, apply for grants, or be accepted into the programs. These educational institutions that do not receive such funding would be left out of the benefits and programs and would

have to find other funding to improve and support their SMET teacher training and development. Participating schools may see more results in student achievement and instruction. Whereas, the teachers and students of schools not involved in NSF programs would also be excluded from the benefits.

Flexibility: NSF has many programs for teacher improvement that consider a wide range of social and economic groups such as rural, urban, and poverty areas. Funding this wide range of NSF programs would provide for activities in all areas of the nation and provide quality teachers to at-risk children and schools. Increased funding would provide for better administration of these programs and improve them with more oversight and assistance from program managers. If a project sponsored by NSF is not performing well, actions are taken to discontinue funding and direct it elsewhere.

Implementability: These NSF programs are already in place, so implementation would be very simple. The programs would be improved in the areas that their managers deem appropriate. The projects themselves would have to adapt to more oversight and on-site visits by their program managers. This adaptation may lead to more efforts for project improvements and outcomes.

Cooperation within Universities

Faculty of Colleges of Education and Colleges of Engineering and/or Departments of Mathematics and Sciences should work together to develop effective SMET classes designed for K-12 education majors. These faculties should also work to develop the curriculum for these students to utilize these classes and ensure that every SMET education graduate has an adequate background in these subjects. To provide incentive for SMET faculties' participation, universities need to develop rewards and benefits for these efforts such as tenure, awards, or salary increases.

Effectiveness: The best resources at universities for knowledge in SMET are the faculties that teach these courses. By developing classes for future teachers with education faculties, SMET faculties will make a significant contribution to developing qualified SMET K-12 teachers. Faculties can develop courses that will effectively meet the needs of their university's education students.

Efficiency: Faculties would have to use extensive time and resources to follow this alternative. Many faculties of SMET may not be willing to make such sacrifices considering this would benefit education students and not necessarily their own. Universities and Colleges of Education would have to provide funding for the development of new courses and curriculum unless an outside grant was provided. Just as any other change, this alternative would take time to develop and generate positive results.

Equity: Education students would directly receive the positive effects of this option with improved courses. While resources of SMET faculties are used for this alternative, SMET students may suffer. Efforts to improve education classes by SMET faculty may take away time and resources from classes in their own departments. Faculty seeking tenure would hesitate to participate unless these efforts were accepted for tenure tracks by universities.

Flexibility: Each university would be able to develop classes and curricula that fit its students and faculties, making this a flexible alternative for each institution. These changes may be very difficult to administer if the university's administration, faculty, and students do not provide support.

Implementability: This option could be very difficult to implement if opposition comes from the groups directly involved. SMET faculties may not be willing to cooperate with education faculties or use their time and resources for this purpose unless benefits are offered for these efforts. University administration may not be willing to support funding to adequately develop these classes or curricula unless outside sources, such as government agencies provide the money. Significant effort would be required by faculties and administration to provide high quality classes for future SMET K-12 teachers.

Increased Engineering Society Involvement

Engineering societies should form a coalition to support K-12 SMET teacher pre-service training and professional development. Because the future of engineering relies on the students in these grade levels, the engineering societies must be concerned with what affects these students directly, their teachers. The issue of ensuring quality SMET teachers to the K-12 classrooms pertains to all the engineering societies therefore all should make an effort to create programs to prepare and develop teachers.

Effectiveness: The engineering societies could be an extensive influence in the recruitment and training of teachers, especially if they work in collaboration. Engineering societies could encourage their members to support legislation that positively effects teacher quality and also encourage faculty members to get involved in the development of future SMET K-12 teachers.

Efficiency: Engineering societies would benefit from strengthening the K-12 teaching workforce, since these teachers are instructing students that are the future of the engineering profession. The costs for this benefit would be using resources to support these efforts.

Equity: Engineering societies may have to redirect some of their current efforts to provide enough time and funding to positively effect the quality of SMET K-12 teachers. This means that existing programs that benefit their professional members may suffer.

Societies with large memberships and more influence would be able to direct their efforts toward education more effectively than other societies with fewer resources.

Implementability: This alternative will not be easily implemented without leadership from within each society. IEEE has already suggested the building of a coalition, and may be a potential leader for this effort. The American Association of Engineering Societies AAES would an ideal consortium for joining the societies in efforts for development of quality K-12 SMET teachers. However, smaller societies should also be included in such a coalition. Many of these societies have education programs that could be expanded and strengthened. Programs and efforts from each society could be considered for modeling by the societies' coalition.

Recommendations

Science, Math, Engineering and Technology K-12 teacher quality requires immediate attention from the engineering societies. In order to prepare for the engineers of the future, I strongly suggest that these societies form a coalition to support actions and programs to strengthen the K-12 SMET teaching workforce. Such an alliance should consider the following:

1. Supporting legislation that provides funding to the states for SMET teacher professional development and continues the states' ability to utilize these funds for activities that most benefit their needs in science and math education.

2. Educating the states on successful K-12 teacher pre-service training and professional development programs assist the states in modeling, developing, and strengthening these programs. Also, encouraging state communication on K-12 SMET teacher improvement through the National Governors Association or state education agencies.

3. Supporting continued and increased funding for NSF and other successful federal agency programs that focus on the development and training of quality science and math K-12 teachers.

4. Developing engineering society sponsored programs within K-12 schools or institutes of higher education that concentrate on the development and strengthening of teachers' SMET knowledge.

An engineering society coalition should also explore and research the possibilities of supporting the following alternatives not developed in this paper:

1. Increased communication between program managers at NSF and ED for the coordination of funding use for pre-service training and professional development programs for teachers.

2. Expanding efforts by societies, universities, and other groups to recruit SMET students into K-12 teaching. Also, encouraging student members and professional members of the engineering societies to consider K-12 education as a career choice or switch.

3. Developing positive public recognition and acceptance of teachers by increasing salaries, providing more prestigious awards, such as the Presidential Awards for Excellence in Science and Mathematics Teaching, and developing the teaching profession.

When making efforts to improve the quality of SMET teachers in K-12 classrooms, every group involved must realize that change and progress will take time. Many solutions such as new courses in universities and engineering society programs will take time to develop and reveal positive results. Programs supported by Federal funds must have continued long-term support in order to make significant impacts. For every K-12 student to have a quality SMET teacher, action needs to be taken immediately and continuously supported.

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