Executive Summary
PK-16 Advisory Committee on Science

The PK-16 Advisory Committee on Science was assembled to provide guidance for the Steering Committee of the PK-16 Council. Science and technology drive many aspects of today’s society and is especially important in creating new businesses and guiding health care. Consequently, citizens need to have a solid education in science so that they can make informed decisions in their lives. Moreover, students who choose to pursue a career in science or engineering require a strong background in science, mathematics, and critical thinking skills. All of these aspects are important for work force development in Rhode Island and economic competitiveness in the global economy.

The PK-16 Advisory Committee on Science considered three topics in preparing its recommendations. First, what are the expectations regarding science preparation for college bound students? The discussion considered the needs of students who might major in science or engineering and those who major in other areas. Second, the committee examined the Grade Span Expectations, particularly on how they meet the needs of college bound students. Finally, the committee considered issues surrounding teacher preparation and continuing professional development in the sciences.

Education is an integrated activity of which science is a vital component. Based on the Committee discussions, its review of educational research literature, and national standards, five broad recommendations, listed below, are put forward. Their general themes are that content, skill sets, and thinking processes are all critical features in educating students in science. In particular, the skill sets required for success in science include reading, oral and written communication, and mathematics. However, the consensus of the Committee also emphasizes the unique aspect of science education, laboratory and field work. Thus, investigative experiences are an essential portion of any science curriculum. The expectations expressed for students must also be present in teacher preparation, for elementary, middle school, and high school teachers.

The five recommendations of the Committee are:

1. **Students must demonstrate the skills used in the process of science.**

   All scientists, regardless of discipline, use a common set of skills, including abilities in communication, formulating questions, critical thinking, problem solving, and investigative and informational research. Students must learn to gather data (i.e. make measurements), summarize their results, and draw meaningful conclusions. A strong background in mathematics is essential in all areas of science, including algebra, geometry, statistics, and three-dimensional spatial awareness.
2. All high school students must have 3 years of science with investigative experience.

Contemporary science is highly interdisciplinary so students need a broad background in the traditional science disciplines. Included in the three high school science courses must be investigative experiences that comprise a minimum of 40% of the instructional time spent in each class. Of the three science courses required, college bound students must have a minimum of one-year preparation in two of the foundational subjects of biology, chemistry, and physics. It is also important that students have the opportunity to learn earth and space sciences. Students planning to major in science or engineering in college should take courses in all three foundational areas and mathematics through introductory calculus.

3. Students must have authentic investigative experiences.

Investigative (or research) experiences are critical to teaching science effectively and for motivating students to develop skills beyond rote memorization. Laboratory and research activities aid students to attain mastery of the subject matter, acquire practical skills, demonstrate the ambiguity and complexity of the real world, and develop teamwork abilities.

4. Professional development and pre-service training for science teachers must emphasize instruction in pedagogy, content, and experimental investigation.

All science teachers must be able to help students meet the proficiency requirements for graduation, prepare students to study science after high school graduation, and provide an understanding of science and technology as it impacts individuals and society. The institutions of higher education in Rhode Island must assess and revise their programs to ensure that appropriate, sufficient, and rigorous math and science content is included in the teacher preparation curriculum. Further, the colleges and universities should schedule advanced courses and professional development opportunities at times when teachers are available.

5. The certification process for teachers needs to be revisited.

Currently, Rhode Island has science certifications in the areas of general science, biology, chemistry, and physics. The Committee recommends that a new certification in earth and space science be created because of recent changes in state and national standards. For high school teachers, it is recommended that the initial certification process be restructured such that the general science certificate be allowed only after successful attainment of a core certificate (biology, chemistry, physics, or earth/space science). For middle school teachers, a new middle school science certification should be added, analogous to the current general science certificate. Unlike any other disciplinary area, science teachers face the potential of needing multiple certifications (general science, biology, chemistry, or physics). So as not to penalize science teachers, the multiple fee structure for teachers holding multiple science certificates should be eliminated.
PK-16 Advisory Committee on Science  
Report and Recommendations

Introduction

The PK-16 Advisory Committee on Science was assembled to provide guidance for the Steering committee of the PK-16 Council. Rhode Island is moving to a standards-based education throughout the curriculum, from elementary through college. The role of science in the curriculum is critical. Today’s society is technologically driven. Thus, all citizens need a solid background in science to make informed decisions. Further, many new businesses are initiated based on cutting edge research, which requires that students be prepared for careers in science and engineering. Reform in science education is a nationally important topic (Adelman, 2006; Mervis, 2006). Now is the time for Rhode Island to join the rest of the country in systemic science education improvement.

At the February 28, 2006 kick-off meeting, the Commissioner of Higher Education, Jack Warner, and the Commissioner of Elementary and Secondary Education, Peter McWalters, gave the Committee several charges. The Commissioners broke these charges into two categories: College-Ready Expectations and the Alignment of the College-Ready Expectations with the new Rhode Island K-12 Grade Span Expectations in Science.

In the area of College-Ready Expectations, the Committee was charged with discussing the proficiencies and types of thinking that students need to achieve to be successful in college level science classes. This discussion was to include the needs of college bound students whether or not they major in science. In addition, for those students who plan to major in science in college, what additional skills in mathematics and science are required (Tai, 2006)? Perhaps most importantly, what types of thinking and habits of thought are developed by science courses (Costa, 2004)?

The Committee was also charged with determining if the Grade Span Expectations (GSEs) align with the College-Ready Expectations. In this area, the Committee was asked to consider the courses required for admission to the Community College of Rhode Island (CCRI), Rhode Island College (RIC), and the University of Rhode Island (URI). How many science courses should be included in the college-preparation curriculum for high school students? What courses should this curriculum include? How will these courses prepare students for general science education at the college level and how will these courses prepare students who wish to major in science at CCRI, RIC, or URI?

During the Committee’s deliberations, an additional charge was assumed. The area of teacher preparation was discussed and recommendations are put forward in this report. The Committee expressed strong sentiment that teacher preparation and continuing education (through certification) are essential parts of the process of educating students in science.

The general themes in this report are that content, skill sets, and thinking processes are all critical features in educating students in science. In particular, the skill sets required for success in science include reading, writing, speaking, and mathematics. That is, education is an integrated activity of which science is one piece. However, the sentiment of the Committee also emphasizes the unique aspect of science education, the laboratory. Thus, investigative experiences are an essential portion of any science curriculum. The expectations for students
must also be present in teacher preparation and professional development for elementary, middle school, and high school teachers.

Methodology

The PK-16 Advisory Committee on Science is composed of education professionals from across the state. The participants are listed in Appendix A. The Committee has representation from each of the state supported institutions of higher education (CCRI, RIC, & URI) and high school teachers from both urban and suburban districts. The Committee members spanned the diverse content areas of science including biology, chemistry, earth & space science, and physics as well as science education.

The Committee met eleven times between January 18, 2006 and July 25, 2006. The initial meeting included only the members from the higher education community. The purpose of this limited meeting was to introduce this subset of the Committee to the science GSEs, which were already familiar to the secondary education members. The kick-off meeting of the full Committee was held on February 28, 2006. At this meeting, the Commissioners gave the Committee its charges and an initial discussion was held that set the tone for the following work.

The next meeting was held on March 30, 2006 where the initial brainstorming took place. The Committee broke into two groups, partitioned by secondary school teachers and post-secondary representatives. Each group discussed the charges laid out by the Commissioners. Then each group reported the ideas generated. These ideas laid the groundwork for the subsequent activities of the Committee.

At the April 11, 2006 meeting the Committee split into three subgroups to generate ideas in three areas: student skills; teacher preparation; and secondary school science courses. The members of each working subgroup are listed in Appendix A. Each group reported the highlights of their discussions, which were used as topics to pursue in subsequent meetings. One observation that was striking as the outcome of this exercise was the substantial amount of overlap that arose from each group.

The May 4, 2006 meeting was used to review the findings of the previous meeting and to integrate those findings with the GSEs. This conversation heavily revolved around the standards for teacher preparation, which all felt were critical as part of the implementation of the recommendations in this report.

On May 18, 2006 the three co-chairs met to draft the Committee recommendations based on the discussion from the Committee. Five broad recommendations were agreed upon, which will be elaborated upon later in this report. For each recommendation, text to explain and support each recommendation was drafted.

During the final Committee meetings (May 25, June 6, June 12, July 10, and July 25, 2006) the Committee reviewed the language of the draft recommendations. Each recommendation was examined in detail until consensus was achieved.
Recommendations

The Committee reached five major recommendations, which are listed below. Each recommendation is followed by several paragraphs of support, elaboration, and substantiation. The recurring themes in the recommendations are that students learning science must have communication, problem-solving, and critical thinking skills. A strong mathematics background is essential. Laboratory, experiential, and research activities are required in any science and must be included in students’ education. Appropriate and safe facilities are mandatory in schools for meaningful study of science. Teacher preparation and ongoing certification processes must match the changes associated with student expectations.

1. Students must demonstrate the skills used in the process of science

Science is a dynamic process. The goal of science education is to have students think and act like scientists. All scientists, regardless of discipline, use a common set of skills (Dunbar, 2000). These include abilities in communication, critical thinking, problem solving, and experimental, investigative and informational research. Specific areas that students need to master are discussed in the following paragraphs.

Oral and written communication is a key to success in science. Students need to be able to read well enough to follow directions accurately. They must comprehend readings sufficiently to acquire (find and use) information, summarize it, draw conclusions pertaining to the material, and develop the skill of interpreting the relevance of science to society. Students also must be able to write effectively. They should write in a variety of styles, including persuasive, expository, procedural, and technical writing. Finally, students must be able to communicate orally. Oral communication includes both peer-to-peer and peer-to-mentor discussions as well as formal presentations.

A strong background in mathematics is essential in all areas of science. This must include a robust foundation in algebra. Given the importance of three-dimensional spatial thinking in many fields of science, the mathematics preparation should include geometry and trigonometry. Students need to have an understanding of probability and statistics, especially as these apply to scientific uncertainty and error. Students must also understand orders of magnitude and the concept of scale. The underlying mathematical fundamentals of graphing are essential for all students. Potential science and engineering majors should take calculus in high school or be ready to start calculus upon entry to college (Sadler, 2001).

Proficiency in science requires the manipulation of laboratory equipment and the ability to make accurate measurements. Consequently, students must be able to take measurements using rulers, balances, volumetric glassware, and other simple equipment. Students should understand how to extract data of the maximum precision and accuracy from any device that uses rule markings. Students must recognize that establishing the magnitude of the error is part of a measurement. Documentation of the results is critical in science. Students must be taught proper methods in maintaining and using a science notebook. Students must demonstrate proficiencies in all safety procedures associated with laboratory and field work. Safety must be a habit, not an afterthought.
Modern science also relies heavily on the use of technology, and all students should have opportunities to use important tools such as electronic probes and instruments for the collection of data and calculators and computers for analysis, statistics, and graphing. Students must have ready access to these tools and learn to use them to obtain meaningful experimental results. Students should also be introduced to the many other uses of computers in science today. These include, but are not limited to, molecular modeling in chemistry and biology, access to experimental data in the earth and space sciences (e.g. records of temperature or water quality indicators, topographical maps, satellite and other remote sensing images, astronomical data, etc.), and computer display of specimens viewed with a microscope. Students also need to learn how to gather reliable information from the myriad of literature sources available through the internet.

Associated with making measurements is understanding effective presentation and use of data. Students should be able to analyze data and be able to determine the best way to present data. Students must be able to construct appropriate graphs, charts, and tables both by hand and with computer tools. Students also should be able to extract and interpret data by reading graphs, charts, and tables.

Science is becoming increasingly interdisciplinary and collaborative. This means that students must be able to work in teams with people of varying skills and backgrounds. Working collaboratively, students can share strengths through various roles, check each others’ work, brainstorm solutions, and evaluate their work. All science courses must provide the opportunity for students to work in groups of three or four as well as individually.

Problem solving is the hallmark of science. Students must be able to identify a problem, then formulate and test a possible solution. Students should recognize that problem solving is an iterative process where trial and error is a key component. Students should be able to decide if the solution is reasonable within the given constraints of the problem. Problem solving extends to the laboratory and in the field. Students must be able to formulate an experimental problem and then design, conduct, and troubleshoot the experiment. Students should then be able to use the data collected from the investigation to draw appropriate conclusions, both qualitative and quantitative.

Critical thinking skills acquired from any science class are invaluable for any career path. Students must be able to enlist inquiry skills to formulate and address questions. Students also must be able to evaluate sources of information in terms of validity and potential bias. These sources of information should be used to produce evidence that supports warranted and responsible assertions. Students must demonstrate that they can use evidence connected to their assertions to draw reasonable conclusions.

The Rhode Island PK-16 Science Advisory Committee recommends the following:

- Integrate the identified skill sets into the learning opportunities for all Rhode Island students, consistent with the Applied Learning Skills of the Rhode Island High School Diploma System (Appendix C)
- Require that the assessment components of the science GSEs include a demonstration of proficiency in these skills
2. All high school students must have 3 years of science with investigative experience

Most high schools were designed more than fifty years ago to meet the needs of another age. Many groups such as Achieve, Inc., The Education Trust, the Thomas B. Fordham Foundation, the Business Roundtable, the United States Chamber of Commerce, and the Rhode Island Governor’s Blue Ribbon Panel on Mathematics and Science Education have reported the concern that American High School students are not sufficiently knowledgeable about science and math in general. As a result, too few students have the necessary preparation and desire to enter into engineering and science careers. To meet the needs of the 21st century, Rhode Island must raise the rigor of high school science standards. Evaluation of science programs is vital to bring about the change necessary for today’s students to be prepared with the essential skills for higher education and/or the workplace. Science, mathematics, and technology courses cannot be considered as being purely elective in nature. Today’s global society places enormous dependence on its citizenry to be literate in matters of science and mathematics, and this literacy must be reflected in the expectations for graduation in Rhode Island high schools.

Of particular concern, as reform in high schools moves forward, is the present perception of parents and students surrounding the areas of math and science. In their 2006 publication, Reality Check 2006: Are Parents and Students Ready For More Math and Science? (Johnson, 2006), the research group Public Agenda presented the following findings:

- Corporate CEOs and education experts feel that today’s schools aren’t as challenging as they need to be. Parents, however, feel that their children will be well-prepared for college or work, attend better schools than their parents did, and are dealing with much harder material.
- Most parents feel that the amount of science and math their own child is learning now is “right”.
- Nearly 4 in 10 students surveyed said they would be quite unhappy if they ended up in a career with a math or science focus.

The challenge is to demonstrate the urgent need for students to take more science and mathematics courses and to persuade the public of the imminent need of such reform.

In order to be effective, the course work required to fulfill science graduation requirements needs to be rigorous, experiential, and inquiry-based. Between 1982 and 2000, most states increased the number of science courses that all students need to take in order to graduate. In 1982, high school graduates earned an average of 2.2 science credits (1 credit equals 1 year of a course that meets daily). By 1998, the number grew to 3.2 credits. This expansion in the number of science courses taken included all racial/ethnic groups and both male and female students (National Center for Educational Statistics, 2004, page 119). The result of this action was an increase in the number of students who completed science beyond general biology (National Center for Education Statistics, 2004). Despite this increase, however, high school student scores on the science portion of the National Assessment of Educational Progress (NAEP) remained stagnant. Additionally, a substantial percentage of students entering almost any community college are in need of remediation in at least one course (McCabe & Day, 1998). This is consistent with observations at CCRI, where ~60% of students require
developmental education in mathematics. An explanation for this trend revolves around inconsistent academic preparation in the student’s high school courses (Roueche & Roueche, 1999).

In 2004 there were 13 states that specifically required students to complete laboratory science courses in order to graduate. Five of these states (Florida, Indiana, New York, South Dakota, and Virginia) required more than one laboratory science course. In addition to these 13 states, 3 states (Arkansas, Kentucky, and Rhode Island) required labs only for an optional college preparatory curriculum or advanced diploma (National Research Council, 2006).

According to the 2005 Rhode Island High School Diploma System Technical Assistance Bulletin (beginning with the class of 2008), science courses in Rhode Island schools are defined in the following manner:

All science courses in high school must have a regular laboratory component that embeds science safety procedures. By making science experiential, students will have the opportunity to master the process of science, as well as its content. Every graduating student must have engaged in at least one long-term (several weeks’ duration) science investigation. Students must have regular practice in writing technical reports and research papers, making presentations about science and examining the role of science and society. The multiple assessments required for proficiency-based graduation must include components that capture a student’s skill with science investigation and communication (Rhode Island Department of Education, 2005, page 29).

Recent research by Philip M. Sadler from the Harvard Smithsonian Center for Astrophysics and Robert H. Tai of the University of Virginia concludes “that the best predictors of success in college science courses are high school courses that foster mathematical fluency, value depth over breadth, and feature certain types of laboratory work (NSTA Reports, 2006).” Sadler and Tai conducted surveys of over 18,000 college students enrolled in science classes in 63 randomly selected colleges and universities. Their research indicates that:

- Mathematical fluency is the single best predictor of college performance in biology, chemistry, and physics, giving strong advantage to students whose high school science courses integrate mathematics.
- Students whose high school coursework emphasizes depth over breadth perform better in college courses.
- Laboratory experience as part of high school courses can be beneficial, but primarily when only minimal preparation is needed beforehand, the outcome of experiments is unknown in advance, and lab reports are written afterward (NSTA Reports, 2006).

Achieve, Inc., in its publication *Closing the Expectations Gap*, includes recommendations for State Policy Leaders (Achieve, Inc., 2006). Among these are three that speak directly to the recommendations of this Committee concerning increasing the rigor and level of science courses:

- Align academic standards in high school with the knowledge and skills required for college and workplace success
- Pay attention to content – not just course titles
- Encourage students to go beyond the core
All Rhode Island High Schools need to ensure that all students successfully complete high-quality curricula in mathematics and science. Students should be exposed to science content that is rooted in investigative experiences that are designed to increase their understanding and interest. A core curriculum surrounding the subjects of biology, chemistry, and physics, each with strong mathematics integration is essential to provide students with the skills to pursue science, technology, engineering and mathematics (STEM) related careers.

The Rhode Island PK-16 Science Advisory Committee recommends the following:

- Mandate that all students in Rhode Island High Schools be required to successfully complete three one-year courses in science that devote at least 40% of instructional time to authentic investigative experiences.
- Establish a pre-requisite for all students entering URI and RIC to have, among their three science courses, a minimum of one-year preparation in each of at least two different foundational subjects of biology, chemistry, and physics.
- Integrate mathematics into all science courses with sufficient rigor and relation to the subject matter.
- Clearly define the expectations of the investigative laboratory and field experience (involving observing, forming hypotheses, testing hypotheses through experimentation and/or further observation, and forming objective conclusions) and include hands-on scientific activities that are directly related to and support the other class work, and that involve inquiry, observation, analysis, and write-up.

3. Students must have authentic investigative experiences

Learning science is experiential, not passive. It is absolutely clear that graduates from Rhode Island high schools need to be scientifically literate citizens. Learning science involves particular ways of observing, thinking, questioning, experimenting, communicating, and validating. To be proficient in science, a student must apply science content knowledge, processes and skills to solving problems related to the natural world. In order for students to have the opportunities to develop as scientific thinkers, they must have genuine investigative experiences to fully embrace the processes of science and its content.

The National Research Council (NRC) publication *America’s Lab Report* (Singer, 2006, p. 3) defines the term laboratory experience as:

Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science.

“Laboratory experiences” are not restricted to specific rooms in which students use special equipment to carry out well-defined procedures. As is stated in the NRC definition, authentic investigative experiences can occur in a variety of locations within the lab, classroom, in the
field, or wherever “students interact directly with the material world.” Studies have shown (National Research Council 2004, 2006; Banilower, 2004) that students’ understanding of the processes of science is strengthened greatly when investigative experiences provide opportunities to:

- Pose a research question
- Use laboratory tools and procedures
- Make observations, gather, and analyze data
- Verify, test or evaluate explanatory models (including verifying known scientific theories and laws)
- Formulate alternative suggestions
- Build or revise explanatory models

Several studies have identified 7 learning goals of laboratory experiences (Millar, 2004; Anderson, 1976; Hofstein and Lunetta, 1982, 2004). The research shows that investigative experiences enhance the mastery of scientific facts and concepts, promote the development of scientific reasoning, increase the understanding of the complexity and ambiguity of natural phenomena, foster the development of practical skills, increase understanding of the nature of science, cultivate interest in science and science learning, and improve teamwork abilities. The research cautions, however, that these goals will be more effectively met if the investigative experiences are designed with clearly defined learning goals in mind, are integrated into the classroom instruction, aligned with content and process, and allow for student reflection and discussion of the experience (Roth, 1993).

To foster this investigative experience, the science GSEs are organized around six unifying themes of science. It is these unifying themes that provide students with multiple opportunities to relate the content they study to the skills, organizational structures, and processes inherent to the subject. The unifying themes are:

- **Systems and Energy** (cycles, energy transfer, equilibrium, interaction, interdependence, order and organization)
- **Form and Function** (Natural world, Designed world)
- **Models and Scale** (Evidence provided through..., Explanations provided through...Relative distance, Relative sizes)
- **Patterns of Change** (Constancy and change, Cycles, Evolutionary change)
- **Nature of Science** (Accumulation of science knowledge, Attitudes and dispositions of science, History of science, Science/Tech/Society, Scientific theories)
- **Scientific Inquiry** (Collect data, Communicate understanding & ideas, Design, conduct, & critique investigations, Represent, analyze, & interpret data, Experimental design, Observe, Predict, Question and hypothesize, Use evidence to draw conclusions, Use tools and techniques)

Though all of these unifying themes are essential, it is scientific inquiry that drives the investigative experience. This experience reposes within the learner as s/he moves on past high school and into the workforce or on to more advanced study. Additionally, the design of the upcoming Tri-State Science Assessment devotes one-third of the assessment to inquiry at grades 4, 8, and 11. This assessment will encourage the development and implementation of
more effective investigative teaching across all grade levels and provide a measurement of student attainment of science process skills.

Research emphasizes the critical nature of authentic investigative experience. National surveys show that only 61% of high school teachers indicated that they engaged students in hands-on or laboratory science activities once or twice a week, and nearly the same fraction of teachers (59%) indicated that students followed specific instruction in an activity or investigation once or twice per week (Banilower et al., 2004). Going further, the amount of time that students spend on investigative activities show a wide gap when compared by ethnicity and socio-economic indicators. To be proficient in science, all students need to have consistent, rigorous, and inquiry-based investigative experiences that integrate learning the processes of science with science content. These experiences need to be authentic in nature whether conducted in a formal laboratory setting, outside the confines of the classroom, through computer simulations, or in the field.

It is strongly recommended that the amount of time devoted to authentic, inquiry-based investigation in the science classroom be clearly defined. Currently few states have policies regarding the amount of time devoted to scientific investigation. This situation is further complicated by several factors that affect schools such as the organization of the school, structure of the school day, lack of adequate facilities, and lack of teacher understanding of inquiry-based teaching. The fact remains, however, that effective science instruction requires the student to become engaged in the processes of science. A clear, well-defined expectation of the amount of time a student is involved in inquiry-based activities is essential. The National Science Teachers Association’s Position Statement on Laboratory Science (National Science Teachers Association, 1990) recommends that:

A minimum of 40 percent of the science instruction time should be spent on laboratory-related activities. This time includes pre-lab instruction in concepts relevant to the laboratory, hands-on activities by the students, and a post-lab period involving communication and analysis. Computer simulations and teacher demonstrations are valuable but should not be substitutions for laboratory activities.

Similarly, the Texas Administrative Code (Chapter 74 Curriculum Requirements Subchapter A Required Curriculum (b) Secondary Grades 9-12, 2004) cites that:

Science courses shall include at least 40% hands-on laboratory investigations and fieldwork using appropriate scientific inquiry.

It should be noted that for grades K-8 these documents recommend even more time devoted to inquiry-based activities during science instruction. Time-on-task is only one part of the solution. The rigor and authenticity of the experience needs to directly relate to the content that is being taught. “Cookbook” type labs, worksheets, or activities where the outcome is obvious and predictable do little to enhance the processes and skills of science. Computer simulations of scientific phenomena, though useful for enrichment of content, cannot be substituted for investigative experiences.

Lastly, the efficacy of investigation relies upon the facilities, equipment, and the level of safety inherent to the activity. Fully appointed, well-designed facilities and equipment require significant funding on the part of the school districts. Research shows that schools with the highest concentrations of non-Asian minorities were more likely to have inadequate facilities
(Banilower, 2004). Access to adequate supplies promotes laboratory work. As with the condition of facilities, easy access and distribution of supplies necessary for scientific investigation is not equally distributed to all high schools and high school students. On a national level, the median of yearly expenditures per pupil for consumable science supplies was a mere $3 in 2000 (National Research Council, 2006). This is grossly inadequate to fund a quality science program to meet national and state science standards.

The issue of safety is a growing concern in PK-16 science. Facilities often lack regular safety inspections or have inadequate safety equipment. Class sizes for science courses frequently exceed NSTA recommended standards of 24 students per class (National Science Teachers Association, 1990). This places an undue burden of responsibility upon the teacher and limits the scope and nature of activities that can be conducted. On-going professional development in science safety is essential not only for teachers, but also for administrators at the building and school district levels in order to fully understand the instructional, supervisory, and maintenance levels of responsibility and liability.

The Rhode Island PK-16 Science Advisory Committee recommends the following:

- Mandate that all science courses devote at least 40% of science classroom instruction time to hands-on, investigative experience using appropriate scientific inquiry.
- Increase opportunities for high–quality, sustained professional development in the areas of scientific inquiry, laboratory skills, and laboratory safety for educators and administrators.
- Convene a panel composed of business, education, and community representatives to investigate the state of science facilities at all Rhode Island public schools and to explore creative solutions for funding to ensure adequate and equitable access.

4. Professional development and pre-service training for science teachers must emphasize instruction in pedagogy, content, and experimental investigation

The Report of the 2020 Commission on Science and Technology at the University of Virginia begins with the following:

Unprecedented advances in science, technology and engineering offer new opportunities to lengthen life, spur economic growth, revolutionize manufacturing and business, shape democratic processes, protect the environment, strengthen national defense and generally improve our daily existence.

This knowledge explosion and its impact on society and culture pose challenges and opportunities for every college and university. Progress in mathematics, natural sciences, engineering, and medicine originates – directly or indirectly – in the scholarship of universities where most fundamental long-term research occurs.

This progress depends strongly on the education of our future scientists and engineers. It also requires sound scientific and technological literacy. All citizens, legislators, jurors and voters
will need to judiciously evaluate how society will use these many advances. (University of Virginia, 2001)

This rapidly evolving state of the world, as described, has profound implications for the entire PK-16 educational system. Teachers of science today, more than ever before, must provide learning opportunities for all students to acquire both the vital science concepts and the habits of mind that will allow them to become successful citizens. Achieving the goal of science literacy for all in Rhode Island requires systemic examination and revision of science teacher preparation and professional development. The challenge for Rhode Island is to fully resource those efforts that will identify, implement and evaluate systemic changes within teacher preparation and professional development needed to improve student achievement. Moreover, recent federal and state education regulations and the recommendations of the Rhode Island Governor’s Blue Ribbon Panel on Mathematics and Science Education require an examination of how teachers are trained at Rhode Island’s public institutions. (See Appendix B, excerpts from the Executive Summary of the No Child Left Behind act, Appendix C, excerpts from the RI Diploma System, and Appendix D, excerpts from the Governor’s Blue Ribbon Panel on Science and Mathematics Education Report.)

Pre-Service Teacher Preparation

High quality science education is dependent upon teachers who have deep knowledge of content, understanding and experience in the process of science, and skill in the pedagogy of science instruction. In its 2006 report, “America’s Pressing Challenge–Building a Stronger Foundation, A Companion to Science and Engineering Indicators – 2006,” the National Science Board writes, “Research shows that a child who has teachers with the knowledge and skills needed to teach mathematics and science effectively in pre-college grades is more likely to be able to close the achievement gaps that he or she experiences and be prepared as an individual for success in work and life.” They note the need for more middle and high school teachers who have had rigorous preparation in the sciences they teach and express concern that many “elementary teachers do not feel qualified teaching science.” (National Science Foundation, America’s Pressing Challenge…, 2006).

The Standards for Science Teacher Preparation published by the National Science Teachers Association (NSTA) in 2003 serve as a national benchmark for preparing science teachers. (Appendix E) These guidelines were developed from the National Research Council (NRC) 1996 National Science Education Standards (NSES), coupled with recommendations by the American Association of Physics Teachers, the American Chemical Society, the National Association of Biology Teachers, and the National Earth Science Teachers Association. The NSTA standards are presented as “competencies rather than courses, and are intended to guide institutions and states in their selection of their subject matter requirements and assessment.” (National Science Teachers’ Association, 2003). This approach recognizes that there are many different ways in which curricula and courses can be designed to effectively incorporate these standards. The standards also emphasize the importance of content and pedagogy, both in preparing effective teachers and in the retention of new teachers.

The NSTA standards serve as the basis for accreditation of teacher education programs by the National Council for Accreditation of Teacher Education (NCATE), a coalition of 35 different organizations whose purpose is to establish and implement standards for the accreditation of teacher preparation programs in U.S. colleges and universities. The standards are presented in
table form as part of the NCATE program review. These tables provide a convenient summary of the NSTA standards (Appendix F). NCATE accredited institutions in Rhode Island are the University of Rhode Island and Rhode Island College. NCATE also recognizes specific programs within accredited institutions. Biology, Chemistry, Physics, General Science, and Elementary Education are among the programs at Rhode Island College that are listed as NCATE-recognized; the corresponding programs at URI are not listed (National Council for the Accreditation of Teacher Education, 2006).

The teacher preparation programs of URI, Rhode Island College, and the state’s private colleges and universities are summarized in Appendix G. The details, in some cases the actual text, are taken from the respective catalogs and web-based program materials. Each of these teacher preparation programs in Rhode Island requires a standard series of education courses. Most include a science-specific methods course, usually with a practical component that precedes student teaching. The content and emphasis of those courses vary with the instructor as well as by institution. Additionally, most science teacher preparation programs do not sufficiently address the nature of science, inquiry, experimental investigation, integration and use of technology, laboratory preparation and procedures, and laboratory and field safety.

For secondary teachers, URI and Rhode Island College list specific versions of the science content majors, whereas the other schools pair an education sequence with the standard Liberal Arts science major. Thus, in all the institutions, those preparing to be secondary science teachers have content preparation comparable to that of other science majors. They must have an undergraduate science major in the elected certification area (biology, chemistry, physics, or general science). However, there is considerable latitude in the science and mathematics requirements outside the certification concentration.

In general, each of the programs provides a reasonable foundation in the core scientific discipline. The addition of what NCATE terms supporting competencies varies, ranging from lists of specific science and math courses designed to meet the NCATE standards at Rhode Island College and a mixture of required and recommended courses at URI to the absence of any specific requirements or recommendations at some of the other institutions.

Preparation of elementary teachers is significantly weaker. The typical science content is two courses that also meet the school’s general education requirements. At Rhode Island College, these two courses, in biology and physical science, are tailored to elementary education students. PC also requires that one course be in biology and one in the physical/earth sciences.URI students fulfill the College of Arts and Sciences Basic Liberal Studies requirement in the sciences, which calls for two courses in different disciplines; but not all of these courses include laboratory. Salve Regina requires two science courses with no limits on discipline, no lab required.

Preparing a sufficient number of well-qualified teachers is an important part of the larger project of improving science learning and college readiness for all Rhode Island students. The public and private colleges and universities in the state all play a role, but the principal focus needs to be upon the state’s own programs at Rhode Island College and the University of Rhode Island. At the secondary level, Rhode Island College and URI offer programs with substantially the same goals. NCATE/NSTA approved programs in biology, chemistry, general science and physics at Rhode Island College have substantial content in the primary
teaching discipline as well as supplemental content in the remaining three areas of biology, chemistry, earth science and physics. Methods of teaching are learned and practiced in an inquiry-based course before candidates begin student teaching.

At the University, the content requirements are less specific and less rigorous. Without good advising students could miss some disciplines entirely. Implementation of new NCATE assessment standards will ensure that students have the content knowledge and pedagogical skills to be successful science teachers. Both state institutions should meet and maintain NSTA standards for teacher preparation with the intent to attain/retain NCATE certification. In addition to the undergraduate degree programs, there are post-baccalaureate programs including second undergraduate degrees, MAT programs, and the non-degree RITE program at Rhode Island College.

On the elementary level, while Rhode Island College has courses that are designed for elementary students, including a physical science course that is laboratory-driven and highlights inquiry methods, none of the institutions offer prospective elementary teachers the background and tools they need to be effective in meeting the instructional challenge of the new GSEs and the accompanying testing. In particular, the lack of earth and space science must be addressed.

**The Rhode Island PK-16 Science Advisory Committee recommends the following:**

- Act to unify and improve the science, mathematics, and science methods courses at the two state institutions
- Maintain NSTA standards and work towards attaining NCATE certification at both state institutions

**Professional Development**

Once individuals have secured positions in Rhode Island’s elementary and secondary schools, it is essential that their professional development in content and pedagogy be regular and required. Professional development is a system of continuous growth and learning that builds the capacity of the education community to respond to the needs of all learners. Recently, with the No Child Left Behind Act (Appendix B), the Federal Government has defined High Quality Professional Development. The Rhode Island Department of Education has established the *Rhode Island Quality Standards for Professional Development (RIQSPD)* in relation to the Federal Definition and to the National Staff Standards. *The RIQSPD will serve as a cornerstone as Rhode Island moves forward toward success for every child (Rhode Island Department of Elementary and Secondary Education, 2006).*

Science teachers must not only be informed of the latest advances in science, but also have opportunities through professional development programs to work collaboratively to share best practice. All teachers of science must learn how to design, implement and assess lessons that help students achieve:

- The science proficiency required for high school graduation under the Rhode Island Diploma System
• The academic preparation and the applied learning skills, including the appropriate use of diverse technologies, to pursue the study of science after high school graduation.
• An understanding of science and technology as it impacts individuals and society
• An awareness of careers and opportunities in science fields

Science education in the 21st century must be inquiry and skills-based. The ever-growing accumulation of scientific knowledge prohibits students from acquiring deep content in all areas through classroom lessons. Teachers must abandon over-dependence on traditional lecture, in favor of more inquiry and experiential learning (Singer, 2006). Effective instruction uses a variety of strategies, including direct teacher presentation, cooperative learning, project/problem-based learning, technology, and investigation. A varied instructional model will allow students to build the critical thinking, problem-solving, communication, technology, research, teamwork and self-management skills that they can apply to accessing and learning content. Since this approach differs from how many practitioners were trained, it is imperative that on-going professional development offerings from Rhode Island’s public universities and colleges, the Rhode Island Department of Elementary and Secondary Education, and approved providers present rigorous science content with instructional methodology. In its report on “Lessons on a Decade of Mathematics and Science Reform” Horizon Research states, that to better address teachers’ content needs, projects might consider devoting a more equitable share of professional development time to content, and/or creating more content-specific sessions to meet teachers’ wide-ranging needs in this area (Banilower, 2005).

Efforts are also needed to ensure that the content of these professional development opportunities are delivered via research-based instructional techniques, i.e. they model effective instructional methods. Furthermore, professional development programs must provide opportunities for teachers to acquire expertise in constructing science lessons that engage students who are traditionally underserved (Lee, 2006).

One area of concern is the general unavailability of content-rich courses at times when teachers are available. Upper level and graduate science courses are often scheduled during the morning or early afternoon hours, when PK-12 teachers are in class. Another issue is that courses designed specifically for teachers have a heavy focus on pedagogy, but are devoid of science content. Conversely, upper level science content courses are often not relevant for K-12 educators. Research on quality professional development indicates that content and pedagogy must be married throughout. The National Science Education Standards states:

“In this vision, people responsible for professional development work together with each other and with teachers as they integrate their knowledge and experiences. For example, higher education science and education faculty must learn to work together: An instructor in a university science course might invite a member of the science education faculty to participate in regular discussion time designed to help students reflect on how they came to learn science concepts. Not only must the departments in higher education institutions work together, but also schools and higher education institutions must enter into true collaboration. And science-rich centers, industry, and other organizations must participate in professional development activities with teachers.” (National Research Council, 1996)
The Rhode Island PK-16 Science Advisory Committee recommends the following:

- Require annual professional development of teachers of science.
- Make available advanced courses in science scheduled at times when classroom teachers can enroll.
- Mandate that all professional development offerings follow federal and state guidance and standards.
- Offer professional development that focuses on pedagogy and integrates rigorous content, as indicated by research studies on effective professional development.
- Encourage on-going collaboration between Rhode Island post-secondary institution departments of science and education to construct meaningful integrated professional development programming. (For example, provide incentives to higher education science instructors to design professional development for educators, involve graduate students, enable joint faculty appointments between departments in the sciences and education.)

5. The certification process for teachers needs to be revisited

Teachers of science in Rhode Island can hold various certifications issued by the Rhode Island Department of Elementary and Secondary Education (RIDE). For the most part, elementary teachers hold a certificate in elementary education, the coursework requirements of which allow them to teach multiple subjects, including science. Middle school science teachers may be specially endorsed elementary certified teachers or secondary science certified teachers. To qualify for a middle school science endorsement a candidate must have a valid Rhode Island certificate in elementary, secondary, special subjects, elementary/middle special education, or middle/secondary special education. In addition to professional education courses pertaining to middle school education, candidates must have a college major, minor, or 21 semester hours in science. (RIDE, Educator Quality…, 2006)

Secondary science teachers must be certified in the specific content areas of biology, chemistry or physics or in general science. Regulations require that all Rhode Island public high school biology, chemistry or physics courses be taught by a teacher holding a certificate in that area. Teachers with general science certificates can teach any middle school or high school science course not falling under a biology, chemistry or physics designation. This includes, but is not limited to, Physical Science, Earth Science, Environmental Science, Forensic Science, Meteorology, Astronomy, and Integrated Science.

In light of both the science and teacher quality mandates of the No Child Left Behind Act (NCLB, 2001) and the new structure of the National Assessment of Educational Progress (NAEP, 2009), Rhode Island’s requirements for gaining an initial secondary certificate in a science area are insufficient. NCLB specifies that each state have science standards in place by 2005-06 and a large-scale science assessment aligned with state standards once each in Grades 3-5, 4-8 and 9-12. In compliance, Rhode Island has developed the draft Rhode Island K-12 Grade Span Expectations (GSEs) Science and is working with New Hampshire and
Vermont on a common state science assessment. This work organizes science in three broad domains – Life Science, Physical Science and Earth and Space Science. (RIDE, Standards…., 2006) The 2009 NAEP Assessment Framework does likewise. The equal emphasis on the domains of life, physical and earth and space science are not represented in the science certification categories in Rhode Island. Additionally, the lack of a specific middle school science certificate allows teachers trained for other levels to transition to the middle school, perhaps without the necessary content and pedagogy to be effective.

Rhode Island’s certification in biology must indicate that a teacher is prepared to address the Life Science domain. Chemistry- and physics-certified teachers must be able to instruct relevant content in the Physical Science domain. In Rhode Island, specific preparation for the Earth and Space Science domain is severely deficient. Earth and Space Science may be taught by anyone certified in general science. Currently, the general science certificate does not require any coursework in either earth or space science. The outcome is that districts and schools are unable to guarantee that teachers are adequately prepared to teach content that falls under the Earth and Space Science domain, which constitutes one third of all the science content of the GSEs and the large scale science assessment. The Council of Chief State School Officers in its State Indicators of Science and Mathematics Education 2005 reports that 39% of main assignment earth science teachers are certified in the subject and 18% hold a broad-field certification. Of the 31 state departments of education that reported (excepting Guam, the Virgin Island and Georgia), 28 have a certification in earth science (CCSSO, 2005).

The time has come to restructure the certification requirements for science teachers in Rhode Island to reflect the science education priorities of the 21st century. RIDE has not reviewed the course requirements or the scope of study for certification in biology, chemistry, physics or general science for over two decades. While RIDE’s Office of Educator Quality and Certification has established a new system for recertification, the I-Plan, and has eliminated lifetime certification, the requirements for initial certification in the science content areas have not been updated to ensure coursework alignment with the state’s science content standards (RIDE, Educator Quality…., 2006). (Appendix H, Certification Requirements)

While the requirements and structure of all current Rhode Island science certifications must undergo review, the greatest priorities are the establishment of a secondary science certificate in earth and space science by the state and pathways to achieve it. The teacher preparation programs at Rhode Island College and the University of Rhode Island must develop programs to prepare new teachers in earth & space science, and offer professional development opportunities to existing teachers seeking earth and space science certification. Since these practicing teachers already have expertise in underlying science principles, any program for extending certification to include earth & space science should be specifically designed and convey the core content and current excitement of these areas. Traditional undergraduate courses in earth and space science may be inappropriate for experienced science teachers.

Furthermore, RIDE must implement restrictions to the attainment and employment of the general science certificate. To ensure that high school science teachers have the rigorous content knowledge required of them, the general science certificate must not be their primary certificate. All high school teachers must hold a content-specific (biology, chemistry, earth and space science and physics) certificate first, and then hold the general science certificate as supplementary. Currently, most middle school science teachers are general science certified.
Upon review, the certification in general science may be best reconfigured as a requirement for all middle school science teachers.

Recent changes in the administrative aspects of the Rhode Island teacher certification process include a fee for each area in which certification is sought. (RIDE, Educator Quality…, 2006). Unlike secondary certification in English or mathematics, where one fee is sufficient for all the different courses an individual high school teacher may instruct, science teachers are penalized for having expertise in multiple areas. Schools and districts look to hire science teachers with more than one certification to allow for flexibility in scheduling. This fee structure places an unfair financial burden on those who hold multiple science certifications. (Appendix I – Fee Structure)

The Rhode Island PK-16 Science Advisory Committee recommends the following:

- Revisit, evaluate and restructure the requirements for initial certification in secondary science
- Explore, with the state’s teacher preparation programs, the addition of a secondary certification in earth & space science
- Explore with the state’s teacher preparation programs, the addition of a middle school science certification or changing the requirements for the middle school endorsement
- Restrict the issuance of a general science certificate so that it is allowed only after the successful attainment of a core secondary science certification in biology, chemistry, physics, or earth and space science
- Eliminate the multiple fees for those who hold more than one science certificate
Conclusions

The Committee has brought forward five broad recommendations that can be used to improve science education in the state of Rhode Island. These recommendations cover the three areas of student skills, course work, and teacher training. First, the content that students need to be successful in science was addressed. The Grade Span Expectations meet the science content, but the Committee’s recommendations include the skill sets in the critical areas of oral and written communication and, especially, mathematics. The second broad area addressed in the recommendations is about programs that should be offered by high schools. The Committee emphasizes that all students should take a minimum of three science courses in high school and that all of these courses should have significant time committed to investigative experiences, be it in the laboratory or in the field. The hands-on aspect of science is a crucial and unique aspect of this educational topic. Finally, the Committee addressed the area of teacher preparation. Teachers of science must be prepared to instruct the content specific to the subject matter. Thus, it is incumbent upon the institutions of higher education to design programs that adequately prepare teachers for all aspects of teaching science, including content, pedagogy, and laboratory management. Further, teachers must have adequate opportunity for professional development to keep up with the ever changing landscape of science and education.

Science is as much about a thinking process as it is about content. Thus, whether students study biology, chemistry, earth & space science, or physics, all need similar critical thinking skills. Any program that expects to produce scientifically literate students must incorporate the content of science and, equally important, the process of science. All students must learn to make valid measurements, understand the error associated with the measurement, draw conclusions from data, put the conclusions in context, and be able to present those conclusions orally and in writing. Students who learn these skills will be able to succeed in our rapidly changing technology-driven world. For students who plan to pursue careers in science or engineering, these skills and a sound content foundation are critical for their success.

Finally, it is critical to note that the recommendations brought forward by the Committee are systemic and cannot be viewed independently. Science education, with its essential investigative experiences, must be supported by program content and teacher preparation. The specific scientific content and skills delineated in the science GSEs are not exclusive to science classes. Additionally, the broader skills in mathematics and communications important to science permeate all courses in primary and secondary education. The burden for science education is across the entire PK-16 spectrum: primary and secondary schools must follow the GSEs but the higher education institutions must prepare pre-service teachers successfully and offer appropriate opportunities for in-service teachers to enhance and update their training. Given the role of science and technology in new business development, emerging health care issues, and Rhode Island’s place in the global economy, progress towards systemic reform of science education is essential.
References


Johnson, J.; Arumi, A. M.; Ott, A.; and Remaler, M. H.; *Reality Check 2006 – Are parents and students ready for more math and science?* 2006. Available at: http://www.publicagenda.org/research/research_reports_details.cfm?list=96


Rhode Island Department of Elementary and Secondary Education (RIDE), *Standards, Instruction and Student Assessment, Grade Level Expectations and Grade Span Expectation, 2006*. Available at http://www.ride.ri.gov/standards/gle/default.htm


Appendix A

Composition of the Committee
(only participants who attended more than one meeting are listed)

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Bailey-Gates, Tracy</td>
<td>North Smithfield High School</td>
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<td>de Oliveira, Glenisson</td>
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<td>DiModica, Kathleen</td>
<td>Cumberland High School</td>
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<td>Euler, William (Chair)</td>
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<td>Jzyk, Linda A. (co-Chair)</td>
<td>Rhode Island Department of Education</td>
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<td>Knowlton, Christopher</td>
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<td>Krous, Steven</td>
<td>Cranston West High School</td>
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<td>Laliberte, Kimberly</td>
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<td>Magyar, Elaine</td>
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<td>Magyar, James</td>
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<td>McGovern, Lynn</td>
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<td>Miele, Janet</td>
<td>Woonsocket High School</td>
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<td>Pino, Josephine</td>
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<td>Pockalny, Robert</td>
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<td>Poirier, Ron</td>
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<td>Quan, Sarah</td>
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<td>Schoonover, Jeffrey</td>
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<td>Sullivan-Watts, Barbara</td>
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<td>Utley, Mary Jane</td>
<td>Westerly High School</td>
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<tr>
<td>Yordy, Denise</td>
<td>Community College of Rhode Island</td>
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<tr>
<td>Zoglio, David</td>
<td>Classical High School</td>
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Subcommittees for the three topic areas:

**Student Skills**
- Christopher Knowlton
- Judy McGowan
- Janet Miele
- Josephine Pino
- Ron Poirier
- Barbara Sullivan-Watts
- Mary Jane Utley

**Teacher Preparation**
- Glenisson de Oliveira
- Kimberly Laliberte
- James Magyar
- John Owens
- Robert Pockalny
- Sarah Quan
- Gail Scowcroft

**Secondary Science Courses**
- Tracy Bailey-Gates
- Kathleen DiModica
- Elaine Magyar
- Lynn McGovern
- Denise Yordy
- David Zoglio
Appendix B

THE NO CHILD LEFT BEHIND ACT OF 2001

These reforms express my deep belief in our public schools and their mission to build the mind and character of every child, from every background, in every part of America.

President George W. Bush
January 2001

Three days after taking office in January 2001 as the 43rd President of the United States, George W. Bush announced No Child Left Behind, his framework for bipartisan education reform that he described as “the cornerstone of my Administration.” President Bush emphasized his deep belief in our public schools, but an even greater concern that “too many of our neediest children are being left behind,” despite the nearly $200 billion in Federal spending since the passage of the Elementary and Secondary Education Act of 1965 (ESEA). The President called for bipartisan solutions based on accountability, choice, and flexibility in Federal education programs.

Less than a year later, despite the unprecedented challenges of engineering an economic recovery while leading the Nation in the war on terrorism following the events of September 11, President Bush secured passage of the landmark No Child Left Behind Act of 2001 (NCLB Act). The new law reflects a remarkable consensus—first articulated in the President’s No Child Left Behind framework—on how to improve the performance of America’s elementary and secondary schools while at the same time ensuring that no child is trapped in a failing school.

The NCLB Act, which reauthorizes the ESEA, incorporates the principles and strategies proposed by President Bush. These include increased accountability for States, school districts, and schools; greater choice for parents and students, particularly those attending low performing schools; more flexibility for States and local educational agencies (LEAs) in the use of Federal education dollars; and a stronger emphasis on reading, especially for our youngest children.

*Increased Accountability*

The NCLB Act will strengthen Title I accountability by requiring States to implement statewide accountability systems covering all public schools and students. These systems must be based on challenging State standards in reading and mathematics, annual testing for all students in grades 3-8, and annual statewide progress objectives ensuring that all groups of students reach proficiency within 12 years. Assessment results and State progress objectives must be broken out by poverty, race, ethnicity, disability, and limited English proficiency to ensure that no group is left behind. School districts and schools that fail to make adequate yearly progress (AYP) toward statewide proficiency goals will, over time, be subject to improvement, corrective action, and restructuring measures aimed at getting them back on course to meet State standards. Schools that meet or exceed AYP objectives or close achievement gaps will be eligible for State Academic Achievement Awards.

*More Choices for Parents and Students*

The NCLB Act significantly increases the choices available to the parents of students attending Title I schools that fail to meet State standards, including immediate relief—beginning with the 2002-03 school year—for students in schools that were previously identified for improvement or corrective action under the 1994 ESEA reauthorization.

LEAs must give students attending schools identified for improvement, corrective action, or restructuring the opportunity to attend a better public school, which may include a public charter school, within the school district. The district must provide transportation to the new school, and must use at least 5 percent of its Title I funds for this purpose, if needed.
For students attending persistently failing schools (those that have failed to meet State standards for at least 3 of the 4 preceding years), LEAs must permit low-income students to use Title I funds to obtain supplemental educational services from the public- or private-sector provider selected by the students and their parents. Providers must meet State standards and offer services tailored to help participating students meet challenging State academic standards.

To help ensure that LEAs offer meaningful choices, the new law requires school districts to spend up to 20 percent of their Title I allocations to provide school choice and supplemental educational services to eligible students.

In addition to helping ensure that no child loses the opportunity for a quality education because he or she is trapped in a failing school, the choice and supplemental service requirements provide a substantial incentive for low-performing schools to improve. Schools that want to avoid losing students—along with the portion of their annual budgets typically associated with those students—will have to improve or, if they fail to make AYP for 5 years, run the risk of reconstitution under a restructuring plan.

**Greater Flexibility for States, School Districts, and Schools**

One important goal of No Child Left Behind was to breathe new life into the “flexibility for accountability” bargain with States first struck by President George H.W. Bush during his historic 1989 education summit with the Nation’s Governors at Charlottesville, Virginia. Prior flexibility efforts have focused on the waiver of program requirements; the NCLB Act moves beyond this limited approach to give States and school districts unprecedented flexibility in the use of Federal education funds in exchange for strong accountability for results.

New flexibility provisions in the NCLB Act include authority for States and LEAs to transfer up to 50 percent of the funding they receive under 4 major State grant programs to any one of the programs, or to Title I. The covered programs include Teacher Quality State Grants, Educational Technology, Innovative Programs, and Safe and Drug-Free Schools.

The new law also includes a competitive State Flexibility Demonstration Program that permits up to 7 States to consolidate the State share of nearly all Federal State grant programs—including Title I, Part A Grants to Local Educational Agencies—while providing additional flexibility in their use of Title V Innovation funds. Participating States must enter into 5-year performance agreements with the Secretary covering the use of the consolidated funds, which may be used for any educational purpose authorized under the ESEA. As part of their plans, States also must enter into up to 10 local performance agreements with LEAs, which will enjoy the same level of flexibility granted under the separate Local Flexibility Demonstration Program.

The new competitive Local Flexibility Demonstration Program would allow up to 80 LEAs, in addition to the 70 LEAs under the State Flexibility Demonstration Program, to consolidate funds received under Teacher Quality State Grants, Educational Technology State Grants, Innovative Programs, and Safe and Drug-Free Schools programs. Participating LEAs would enter into performance agreements with the Secretary of Education, and would be able to use the consolidated funds for any ESEA-authorized purpose.

**Putting Reading First**

No Child Left Behind stated President Bush’s unequivocal commitment to ensuring that every child can read by the end of third grade. To accomplish this goal, the new Reading First initiative would significantly increase the Federal investment in scientifically based reading instruction programs in the early grades. One major benefit of this approach would be reduced identification of children for special education services due to a lack of appropriate reading instruction in their early years.
The NCLB Act fully implements the President’s Reading First initiative. The new Reading First State Grant program will make 6-year grants to States, which will make competitive subgrants to local communities. Local recipients will administer screening and diagnostic assessments to determine which students in grades K-3 are at risk of reading failure, and provide professional development for K-3 teachers in the essential components of reading instruction.

The new Early Reading First program will make competitive 6-year awards to LEAs to support early language, literacy, and pre-reading development of preschool-age children, particularly those from low-income families. Recipients will use instructional strategies and professional development drawn from scientifically based reading research to help young children to attain the fundamental knowledge and skills they will need for optimal reading development in kindergarten and beyond.

**Other Major Program Changes**

The No Child Left Behind Act of 2001 also put the principles of accountability, choice, and flexibility to work in its reauthorization of other major ESEA programs. For example, the new law combines the Eisenhower Professional Development and Class Size Reduction programs into a new Improving Teacher Quality State Grants program that focuses on using practices grounded in scientifically based research to prepare, train, and recruit high-quality teachers. The new program gives States and LEAs flexibility to select the strategies that best meet their particular needs for improved teaching that will help them raise student achievement in the core academic subjects. In return for this flexibility, LEAs are required to demonstrate annual progress in ensuring that all teachers teaching in core academic subjects within the State are highly qualified.

The NCLB Act also simplified Federal support for English language instruction by combining categorical bilingual and immigrant education grants that benefited a small percentage of limited English proficient students in relatively few schools into a State formula program. The new formula program will facilitate the comprehensive planning by States and school districts needed to ensure implementation of programs that benefit all limited English proficient students by helping them learn English and meet the same high academic standards as other students.

Other changes will support State and local efforts to keep our schools safe and drug-free, while at the same time ensuring that students—particularly those who have been victims of violent crimes on school grounds—are not trapped in persistently dangerous schools. As proposed in *No Child Left Behind*, States must allow students who attend a persistently dangerous school, or who are victims of violent crime at school, to transfer to a safe school. States also must report school safety statistics to the public on a school-by-school basis, and LEAs must use Federal Safe and Drug-Free Schools and Communities funding to implement drug and violence prevention programs of demonstrated effectiveness.
Appendix C
Excerpts from the Rhode Island Diploma System

June 2005

Dear Fellow Rhode Islanders:

The new Rhode Island Diploma System evolved directly from the Board of Regents’ High-School Regulations of 2003. The Board of Regents believes that all Rhode Island high-school graduates should be able to demonstrate that they are proficient in standards-based content as well as applied-learning skills.

We on the Board of Regents have been working closely with our counterparts on the Board of Governors for Higher Education to develop what we call the “PK-16 Initiative.” The goal is to help all our high-school graduates become college ready regardless of when, or even if, they choose to go to college. The graduation requirements of all high schools in Rhode Island are being aligned with the admissions requirements for our public institutions of higher education.

Ultimately, we aim to achieve a seamless system, from preschool through college graduation, so that at each step in the education process our students are being prepared for success. The Regents’ mission is to ensure that all our students achieve at the high levels needed to lead fulfilling and productive lives, to compete in academic and employment settings, and to contribute to society.

Sincerely,

James A. DiPrete
Chairman, RI Board of Regents for Elementary and Secondary Education

Donald L. Carcieri, Governor, State of Rhode Island and Providence Plantations
THE RHODE ISLAND BOARD OF REGENTS FOR THE ELEMENTARY AND SECONDARY EDUCATION
James A. DiPrete, Chairman
Patrick A. Guida, Esq., Vice-Chair
Colleen A. Callahan, Secretary
Amy Beretta
Robert Camara
Frank Caprio, Esq.
Karin Forbes
Gary E. Grove
Maurice Paradis
THE RHODE ISLAND HIGH-SCHOOL DIPLOMA SYSTEM

The Rationale

Schools must be sure that all students successfully complete a rigorous diploma program that gives them access to college or post-secondary training, whether immediately after high school or when and if they so choose.

In recent years, employers, higher education leaders and the general public have asked that diplomas guarantee more than that a student might have attended school and managed to pass a number of classes, sometimes with low grades. Employers and colleges want graduates who are competent in oral and written communication skills, strong foundational math, the ability to work in teams, and the critical thinking skills necessary to research and solve problems creatively and effectively.

Currently some 26 states require that all students pass high-stakes, standardized tests, administered by the state, as a condition of receiving a high-school diploma. But these states are finding that their make-it-or-break it system might spur on about 70% of the students. That approach can intimidate the remainder into dropping out of regular high school entirely.

To get more students over the testing hurdle to graduation, high-stakes states find themselves lowering the passing standard to an almost minimum competency, the very opposite of increasing academic rigor. Also, high-stakes tests give new English-language learners and certain students with disabilities no hope of proving any proficiencies and thus no hope of a regular high school diploma.

Furthermore, there is little evidence that suggests that even those who can pass the tests are necessarily able to apply their knowledge. In the real world, all students need to be able to perform a multi-step problem using critical thinking and a mastery of content. In RI, a student must be certified in both the content base as well as demonstrated abilities to apply knowledge and skills to complex problems. This two-dimensional model offers broad opportunities so that all students can achieve at high standards and apply their knowledge and skills in real-world situations.

Required:

Proficiency in Core-Content Knowledge

By 2008, every student must successfully complete at least 20 Carnegie units (courses), meeting requirements in six core areas.

- All students must complete four units – year-long courses – of both English language arts (ELA) and mathematics, though the fourth course in math might be math-related, such as computer programing, physics or accounting. Most high schools already require the three years of science that students will need to be successful on the state science assessment which comes online in 2008. All schools must align their existing courses in these three subject areas with the state’s Grade Span Expectations which have been completed for ELA and math and will be completed for science in 2006.

- Individual high schools will set their own local requirements for social studies, the arts and technology, based on national or state standards.

- At a minimum, all students will need to demonstrate proficiency in these six core areas. Existing course offerings must now give students frequent opportunities to practice applying their skills and knowledge, in order to prepare them for the more formal demonstrations of proficiencies necessary to earn a diploma. Naturally, high school courses will also continue to administer routine assessments such as tests, quizzes, papers, labs and so forth.

All students must participate in the state assessments for English Language Arts, mathematics and science.
Together, a tri-state partnership of Rhode Island, Vermont, and New Hampshire created the Grade Span Expectations, from which the partnership is developing a new set of standardized tests designed to measure students’ success in achieving thoseExpectations. Called the New England Common Assessment Program (NECAP), these tests will be administered across all three New England states. This partnership offers all three states a much larger pool from which to find examples of successful programs and strategies implemented by schools using identical tests. The ELA and math assessments will be ready as of Fall 2007. Science will follow in Spring 2008.

Each student's results from the NECAP tests will count toward graduation, but never enough to prevent a student from graduating. Students unsuccessful on the state assessments will have ample opportunities to demonstrate proficiency in all core subjects, using evidence-based proofs of proficiency, like course grades, projects, portfolios, and performances.

All schools will support each student’s creation of an Individual Learning Plan.

An Individual Learning Plan (ILP) is primarily authored by students themselves, with guidance from their school advisors, parents, and community contacts – such as a business or arts mentor, when applicable. Schools are creating structures and occasions – such as advisories – to revisit ILPs frequently and even rewrite them as the student chooses high school courses, documents his or her outside activities, prepares to meet graduation requirements, and generally plans for the future. The ILP helps students focus on goals and how to use the time in high school to accomplish their personal objectives, in conjunction with completing graduation requirements. If a student changes schools within RI, the student and new high school have the ILP to help avoid disruption in that student's progress towards graduation. ILPs offer an excellent opportunity to engage parents in their child’s learning.

Required:

Proficiency in applied learning skills
All students must demonstrate proficiency in applied learning skills in all six core content areas.

Applied learning skills are those which serve many aspects of a student’s life – critical thinking, problem solving, research, communication, decision making, interpreting information, analytic reasoning and personal or social responsibility.

RI’s Diploma System certifies mastery of content knowledge as well as the ability to apply that knowledge to real world projects and problems. For decades, employers and colleges complained that applied skills are sorely lacking in current high school graduates. Merely remembering facts is only a good first step toward a true subject mastery, which involves using facts and formulas to solve problems in widely different contexts. The mechanics of English are only valuable if a student can compose competent, effective business letters to a variety of clients, co-workers or potential employers, for example.

Demonstrations of applied learning skills will always involve some form of evidence or proof of mastery, whether from presentations – such as speeches, projects or performances – or from products – such as essays, collections of short stories or science journals. After high school, employers and higher education evaluate their workers or students primarily from evidence of mastery – such as completed and on-time tasks, written work, plans, designs, products, records and so forth. Except for occasional entrance and credentialing exams – the LSAT, state bar, or drivers license exams, for example – tests as such will fade from students’ lives, whereas demonstrations of proficiency by applying skills never will.

The new diploma system requires students to apply their learning to their own interests or passions, which motivates students to pursue their own learning.

Whether a student is interested in rock music, sports, cooking, car mechanics, or fashion design, most passions can reasonably become a subject for a demonstration of proficiency in content and applied skills. Music alone could suggest projects in the science of acoustics, the
math of tonality, the social studies of cultural tastes, the technology of instrument production and so forth. Indeed, one of the most compelling features of the new diploma system is that it harnesses students’ interests in the service of their own learning. Traditional education asked students to ‘park’ their passions at the door, which invited alienation among those students who find course work irrelevant to their real concerns. School advisors and content-area teachers will help students design exhibition and portfolio projects that satisfy their own natural thirst for information and skills. Outside interests and those content areas beyond the six core subjects – such as foreign language and technical education – can become integrated into everyday school life, making academics more interesting and relevant.

Each district is using two of three strategies for assessing applied learning – Digital Portfolio Exhibition or the Certificate of Initial Mastery (CIM)

✓ Using the state’s guidance, local districts and schools have developed their own criteria for successful demonstrations of applied learning skills. These criteria are on each school’s Website or otherwise easily accessible from the school so that students and parents know exactly what is expected. Equipped with protocols, small groups of teachers, parents, and community members will gather to view exhibitions, hear oral presentations, or examine portfolios to determine whether the student’s work has met the criteria for success.

The state monitors the rigor of all schools’ assessments through its Peer Support and Review process.

✓ Although proficiency assessments and scoring criteria are local, the state has the responsibility of ensuring that the demands to meet graduation standards are comparable no matter which school the child attends or in which community. The rigor, reliability, validity, and high standards of each local system must be consistently strong, from school to school. Local graduation systems will always need the perspective, reflections and quality review of an outside evaluator.

Required:

School support systems for all students

Enhanced Literacy Instruction begins in kindergarten and continues to support, ramp up or give special attention to any student not reading on grade level.

✓ Struggling readers are probably struggling with science, history and mathematics as well. Reading problems put any student at risk of failing courses and eventually dropping out of school. RI’s literacy initiative is designed to catch reading problems early and provide help quickly. All schools assess their students’ reading abilities at least once a year, and for any child reading below a certain grade level, teachers will develop a Personal Learning Plan (PLP). The plan outlines exactly what will be done to help the student become a strong reader. Schools must share these plans with the child’s parents, enlisting their help and support.

✓ Learning to read effectively is not confined to elementary school. Middle and high school students need to be taught how to read scientific documents and historical texts. All of RI’s secondary schools must implement an adolescent literacy program to accommodate their different students’ needs.

Universal Design for Access assumes that all students, including those with serious disabilities, are merely different kinds of learners on the same continuum.

✓ For some students, intensive literacy will be only one part of an even more comprehensive support plan. A diploma system for all students must have the flexibility to promote achievable success for all students, including those just learning English or children with disabilities. Using state guidance to assure rigor and true academic achievements, schools will create learning experiences and assessments that maximize the diverse learner’s ability to progress. ‘Universal’ does not imply one solution, but means high standards for all students, each of whose education is addressed with different and creative solutions.

Personalized education ensures that every student is known well by at least one adult in the school, who can offer guidance, help and on occasion, referrals.
The 2002 RI High School Regulations, where much of RI’s diploma system was first put in place, require that all schools eliminate anonymity and impersonal social climates by having the adults get to know the students better. Most commonly, schools begin ‘personalizing’ their educations with advisory systems, whereby every professional guides a small group of 12 to 15 students during the four years of their tenure. These advisors are essential to helping all students remove obstacles, handle adversity, stay focused, access outside help and in short, prepare for proficiency-based graduation. Other more specialized supports and professionals – social workers, psychologists, special educators – are available when students’ issues are beyond the expertise of a typical teacher. Mostly the adults get to know advisees and their families in order to monitor, guide, and cheer them on during high school. No longer can schools be sink-or-swim experiences, with a portion of acceptable casualties. Personalization is key to the success of every student and every school.

Nationally, Comprehensive School Counseling has been working to change the job and nature of the school guidance counselor to one who oversees and aids the school’s overall climate and its social-emotional issues – along with the more traditional work of supporting student academic and college success. Moving from the model of one-on-one counseling, the Comprehensive Guidance Counselor helps schools re-organize so students are more connected to the adults, to the resources they need, and to other students in positive ways. Guidance is a critical player in helping school professionals understand and carry out their new roles – as advisors, for example – to create a social and academic fabric without cracks through which students can fall. Comprehensive guidance makes sure that systems are in place such that all students are well prepared to leave school ready for a career, whether they immediately go on to college, further training, the military or directly into the workforce.
THE CHALLENGE

The last generation to pursue science, technology, engineering and mathematics (STEM) careers in significant numbers was the Baby Boom generation. They were inspired in part when the former Soviet Union launched Sputnik in 1957, and consequently, President John F. Kennedy challenged America to “put a man on the moon.” Our nation responded by educating significant numbers of young people to become scientists and engineers. It was an exciting and inspiring time. The breakthroughs and inventions that resulted went well beyond the space program. But that generation is reaching retirement. While our country faces many significant challenges today, thus far, we have failed to inspire a new generation of young Americans to pursue excellence in science, technology, engineering and mathematics. According to the National Science Foundation, half of America’s scientists and engineers are forty years or older and the average age is steadily rising. In recent years, our educational system has not been successful in training enough new scientists, technicians, engineers or mathematicians. Moreover, international and national studies show that students in the United States do not perform as well in math and science as students in many European and Asian countries. Students in Rhode Island also lag behind their peers in nearby New England states in math and science performance. Rhode Island high school students must compete with students from around the world to be accepted by math and science programs at colleges and universities. Our high school and college graduates also must compete with those same students for jobs that require math and science skills. High tech companies and other businesses in our state rely upon our educational system to produce graduates with basic math and science skills. Many local companies claim that they cannot hire enough Rhode Island graduates adequately educated in science, technology, engineering or mathematics to meet their manpower needs. As a result, Rhode Island employers are forced to recruit workers from outside our state or from other countries. The economic future of Rhode Island and the employment of our workforce depends upon the ability of our kindergarten, elementary, middle and high schools, as well as the institutions of higher learning who train our teachers, to improve the quality of math and science education in our state. We simply must do a better job!

Rhode Island Faces A Growing Shortage Of Fully Trained Math And Science Teachers

Progress is Being Made

Results of state mathematics assessments conducted by the R.I. Department of Elementary and Secondary Education showed a marked improvement in mathematics achievement from 1998 to 2004 in our elementary, middle and high schools. But we must accelerate our efforts and achieve even greater success to enable our students to be competitive with those in other states and around the world.

ENGAGING STAKEHOLDERS

Central to the work of the Governor’s Blue Ribbon Panel and Project Making the Grade was a multi-stakeholder engagement strategy that sought input from all those who affect or are affected by Rhode Island’s education system. Discrete dialog sessions were conducted with four key stakeholder groups: the higher education community, teachers and administrators from kindergarten through high school, business and industry leaders and high school students. Additional sessions were conducted with
mixed groups of educators, administrators, business leaders, community leaders and parents. All were
asked to share experiences, perceptions and perspectives to reach a common understanding of the
issues and to develop well-considered recommendations for change. Each session elicited frank
discussion about what is working and what is not in math and science education in Rhode Island.
Approximately 50 post secondary educators, 50 K-12 teachers, 35 parents, 40 business leaders and
80 students participated in the process. Concurrently, the project team conducted an extensive review
of student performance data and ongoing improvement initiatives affecting math and science
education. Both the dialog sessions and the research revealed that some existing initiatives have laid
the foundation for improving Rhode Island’s results, but much more still is needed to address the
challenge. The stakeholder engagement process created an opportunity for consensus building and
strengthened our capacity to turn ideas into action. To succeed, a collective commitment is needed.

DIALOGUE SESSION RECURRING THEMES

1. Our high school graduates are not adequately prepared in math and science when they enter a
college or university.
2. Current expectations of high school graduates are too low.
3. Our students do not understand how to “apply” math and science and have difficulty with “analytical
   thinking.”
4. More emphasis needs to be placed on teaching problem-solving skills.
5. Our society needs to do a better job of conveying why math and science are important and relevant
to other learning and to the careers of the future.
6. All stakeholders want standardized, rigorous, statewide curricula in math and science.
7. Too many good initiatives come and go. This initiative needs to address the issue of sustainability.
8. More cooperation, coordination, and alignment are required across the education system - Pre-K
   through 16 – so that there is a more integrated approach to education, particularly in math and
   science.
9. Equitable resources should be invested in high-performing students as well as under-performing
   students to meet No Child Left Behind regulations. Rhode Island needs to raise the performance of all
   students rather than just equalizing performance at lower than proficient levels.
10. Teacher contracts pose some unique challenges to math and science education improvements.
11. More money should be allocated to and spent on math and science education.
12. Many schools need more, better, and newer science and technology equipment.
13. Existing teacher preparation program curricula must be improved to produce well-qualified math
    and science teachers.

CREATING THE VISION

Building on the momentum of the dialog sessions, a statewide rally provided all stakeholders with the
opportunity to further inform the recommendations of the Governor’s Blue Ribbon Panel.

In the rally’s keynote address, Dr. Ioannis Miaoulis, President and Director of the Boston Museum of
Science, set the stage for action and provided a rich context for the need to change. His observations
clarified why our state’s math and science education improvement action plan must be set in a broader
framework that includes technology and engineering and emphasizes how important science,
technology, engineering and mathematics (STEM) are to everyday life and future employment. The
practical application of mathematics and science must become an integral part of the mathematics and
science curriculum that is taught in Rhode Island to our students. The Action Plan of the Governor’s
Blue Ribbon Panel on Math and Science Education that follows is a direct result of the active
participation and feedback received from students, parents, teachers, administrators, professors, and
business and community leaders across the Ocean State. Through Project Making the Grade, four
major issues emerged with specific strategies and performance measures for addressing the
challenge before us:

Governance and Culture:
Accountability for results in mathematics and science has been assigned to the Governor’s new Statewide PK-16 Council. Through this structure, responsibility for and commitment to action will be shared among our state’s educational and business leaders to ensure system improvement on each of the recommended strategies.

Teacher Recruitment:
Rhode Island administrators are concerned about the number of mathematics and science teachers that are retiring, or nearing retirement, and the scarcity of new candidates to fill those positions. The rise in the number of emergency certificates issued by the Rhode Island Department of Education for secondary math and science teachers reflects this reality. Creative strategies are needed to both encourage and retain quality teachers in these subjects.

Teacher Quality:
Rhode Island needs teachers who can design and carry out innovative, student-centered instructional approaches in STEM subjects that are directed toward high achievement and who bring a spirit of inquiry to classroom practice. They must be comfortable with using technology and teaming with people in their own school buildings and profession, as well as with a variety of people in business, at universities, and in the community. As such, change is needed in our teacher preparation programs and more opportunities for professional development must be provided, in particular for our elementary school teachers.

Improved Learning Opportunities for Students:
To empower students in mathematics and science, we must reform not only our curriculum, teaching methods, and delivery systems to emphasize inquiry-based, hands-on teaching and learning. We also must change our collective expectations, beliefs and values about the importance of STEM subjects and the ability of all our students to perform at a high level of achievement in these subjects. Our state has reached a time of decision. We are firmly resolved to move – step by step – from where we are to where we need to be to meet the challenge and improve our results in mathematics and science. Working together, our students, our schools, and our state will make the grade!

PK-16 Council
One of the key “champions” identified in the Project Making the Grade Action Plan is the PK-16 Council. On April 25, 2005, Governor Carcieri issued Executive Order 05-08 creating the Statewide PK – 16 (pre-kindergarten through college) Council. The Council, chaired by the Governor, is responsible for ensuring improved student achievement at all levels through more formalized and systemic communication and alignment between Rhode Island’s elementary, secondary, and post secondary education systems and workforce development programs. It is charged with supporting the recommendations of the Governor’s Blue Ribbon Panel on Math and Science and will track our state’s progress over time. Membership includes the:  
• Chair of the Board of Governors for Higher Education  
• Chair of the Board of Regents for Elementary and Secondary Education  
• Commissioner of Higher Education  
• Commissioner of Elementary and Secondary Education  
• Director of the Department of Labor and Training  
• Executive Director of the Rhode Island Economic Development Corporation  
• Chair of the Rhode Island Economic Policy Council  
• Chair of the Human Resources Investment Council

ACTION PLAN
Issue: Governance & Culture
Goal: Coordinate and sustain reforms in science, technology, engineering and mathematics (STEM) education across K-12 and higher education systems with employer involvement.

Strategy 1. Charge the PK-16 Council with driving STEM education reform to ensure implementation, sustainability, and success of this initiative.

Actions for consideration:
A. Appoint a project manager to coordinate implementation of the recommendations and ensure accountability.

B. Set performance targets on new student assessments as they are implemented.

Performance Measures:
1. PK-16 Council adopts Blue Ribbon Panel’s recommendations in fall of 2005.
2. PK-16 Council approves implementation and tracking strategies by spring of 2006 and reviews progress at six-month intervals.
3. All performance measures are met by specified target dates.

Strategy 2. Develop and execute a STEM education communication strategy and campaign to broaden public support for and recognition of the importance of STEM subjects to our state’s future economic vitality.

Actions for consideration:
A. Develop a core set of messages.
B. Conduct quarterly reviews and issue annual progress reports.
C. Sponsor events to publicize and recognize teacher/student achievements.
D. Establish a clearinghouse/web site to publicize STEM education improvement initiatives.

Performance Measures:
1. PK-16 Council adopts a STEM education communications strategy with implementation plan and budget by spring of 2006.
2. A STEM education improvement web site and clearinghouse is launched by fall of 2006.

Strategy 3. Develop statewide protocols to create community partnerships among business, non-profit organizations, community groups, schools, and colleges and universities in support of math and science education, including after school programs.

Performance Measures:
1. Protocols are developed and adopted by fall of 2006.
2. An increasing number of partnerships meeting the new protocols become actively engaged in STEM education improvement so that there are at least 10 such partnerships by 2007, 20 by 2008, and 30 by 2010.

Issue: Teacher Recruitment

Goal: Attract more individuals to teach STEM subjects in which teacher shortages exist.

Strategy 4. Develop and fund a system of financial incentives including scholarships, education loan forgiveness programs, hiring bonuses and pay scale differentials for pre- and in-service STEM educators.

Actions for consideration:
A. Require more extensive, precise and integrated data tracking to include the number of Rhode Island STEM teachers (certified, alternatively certified, emergency certified) and job placement trends of RI teacher prep program graduates with degrees in STEM.
B. Establish improvement targets for the increasing number of new graduates from Rhode Island teacher prep programs employed in RI as STEM teachers.

Performance Measures:
1. The requirement for emergency certified math teachers decreases at least 10% per year from 87 (2003-04 baseline), requiring that a minimum of 9 traditionally or alternatively certified math teachers are brought into the system each year as needed.

2. The requirement for emergency certified science teachers decreases 10% per year from 51 (2003-04 baseline) requiring that a minimum of 5 traditionally or alternatively certified science teachers are brought into the system each year as needed.

**Strategy 5. Facilitate and increase selective use of non-certified professionals (e.g., university professors, retired engineers, etc.) to partner with classroom teachers in STEM subjects.**

**Performance Measures:**

1. Regulations for increasing the selective use of non-certified professionals to partner with classroom teachers in STEM subjects are developed and adopted by 2007.

2. A minimum of 25% of Rhode Island school districts engage non-certified professionals to support teaching STEM subjects beginning in 2008.

**Strategy 6. Increase the number of STEM teachers by improving the alternative certification process.**

**Actions for consideration:**

A. Seed the development of summer course offerings on pedagogy.

B. Develop recommendations and adopt a more effective alternative certification process based on best practices of other states.

**Performance Measures:**

1. Recommendations are developed during 2006 and adopted early in 2007.

2. Summer course offerings in pedagogy for professionals seeking alternative certification as STEM subject teachers are available by 2006.

3. A minimum of 10 professionals become alternatively certified to teach math courses and 10 to teach science courses in 2007. In each subsequent year an additional 5 professionals in math and 5 in science are alternatively certified.

**Issue: Teacher Quality**

**Goal:** Improve mathematics and science teacher prep programs, especially for elementary school teachers.

**Strategy 7. Develop and implement a more rigorous teacher prep program that emphasizes a strong conceptual understanding and application of knowledge and skills for all Mathematics and Science teachers (K-12), but in particular for our elementary school teachers.**

**Actions for consideration:**

A. Strengthen requirements in math and science for certification of elementary school teachers.

B. Set more rigorous certification requirements that would include attaining a state-established cut-score on PRAXIS II Content Knowledge exams for middle and high school teachers.

**Performance Measures:**

1. RI teacher prep programs begin tracking secondary PRAXIS II Content Knowledge scores by 2006.

2. Math and science requirements for certification as an elementary school teacher in Rhode Island are strengthened by 2007.

3. RI teacher certification requirements include attaining a cut-score on PRAXIS II Content Knowledge exams for middle and high school teachers by 2008.
Goal: Provide relevant, quality, professional development for all mathematics and science teachers, including elementary school teachers.

Strategy 8. Develop a network of industry leaders and STEM professionals who will serve as mentors for mathematics and science teachers and work with local employers to increase school/industry partnerships.

Performance Measures:
1. A network of at least 35 industry leaders and STEM professionals is established in 2006 and grows by at least 25 members each year until the network is sustained at 250 – 260 members.
2. The number of Rhode Island mathematics and science subject teachers completing relevant externships increases annually against a 2005 baseline of 11 math and science teachers so that at least 50 teachers complete externships in 2008, and 100 in 2010.

Strategy 9. Require an annual prescribed amount of professional development for all math and science teachers, including our elementary school teachers.

Action for consideration:
A. Reallocate Article 31 dollars to incrementally increase the amount of funds targeted to mathematics and science professional development (currently, 2% of Article 31 funds professional development in math, 0% in science, and 5% in technology).

Performance Measures:
1. A minimum of 25% of all teachers complete approved math/science content-specific professional development each year.
2. 100% of in-service teachers have an I-plan (Individualized Professional Development Plan).

Issue: Learning Opportunities

Goal: Provide opportunities for all students to engage in rigorous STEM education.

Strategy 10. Develop and implement statewide mathematics and science curricula that align with Grade Span and Grade Level Expectations, and that integrate engineering and technology standards and a “hands-on/minds-on” instructional approach in accordance with identified, commonly accepted best practices.

Actions for consideration:
A. Require tracking of student course-taking data.
B. Set improvement targets for the number of students taking Algebra II and for the number of students completing STEM subject majors at RI post secondary schools.

Performance Measures:
1. Statewide curriculum in math is adopted in August 2006; legislation is passed to create statewide curriculum in science in spring of 2006 and science curriculum is adopted in 2008.
2. The percentage of RI 4th graders scoring at or above proficiency on NAEP math tests increases from 28% to at least 50% by the year 2015.
3. The percentage of RI 8th graders scoring at or above proficiency on NAEP math tests increases from 24% to at least 50% by the year 2015.
4. The percentage of 11th graders scoring at or above proficiency on the state’s math assessment (NSRE) increases from 44% to at least 55% proficient by 2007.
5. RI’s mean SAT math score increases annually against a baseline of 505 so that the mean score is at least 535 in 2008 and at least 565 in 2010.
6. The number of students scoring at college-level mastery on STEM subject AP exams increases annually from a baseline of 442 to at least 508 in 2008 and at least 584 in 2010.

7. The percentage of CCRI students requiring developmental math decreases annually from the 54% of students currently requiring such remediation, to 40% in 2008 and 25% in 2010.

**Strategy 11.** Establish statewide standards and a system that includes sufficient staffing to maintain up-to-date science and technology equipment in K-12 schools and institutions of higher education.

**Performance Measures:**
1. A statewide standard and process for equipment and technology modernization is adopted by 2007, and all schools have updated science and technology equipment by 2010.
2. All schools and institutions of higher education report sufficient staffing of technology management personnel by 2008.
3. All schools and institutions of higher education develop and begin implementing plans for continuous technology training for teachers and professors by 2008.
4. The ratio of students to computers improves from 4.9:1 to 2:1 by 2010.

**Strategy 12.** Develop a series of best practice guidelines that includes teacher training on the use of technology to increase both in-school and after-school access to innovative computer-based programs and opportunities for course sharing between schools.

**Performance Measures**
1. Guidelines are developed and adopted by 2007.
2. All mathematics and science teachers are integrating technology into instruction at least 50% of the time by 2010.
Appendix E

NSTA Science Teacher Preparation Standards

Introduction

Any project intending to write education standards for national dissemination and implementation is immediately confronted with the fact that education is a state function, and that the fifty states, plus Puerto Rico, each have their own ideas about what should be taught to their children. Education, unlike many professions, is a highly political act: parents and guardians are concerned about what their children are taught; and various stakeholders have their own ideas about what constitutes a good education. Whether or not they are directly engaged in setting standards, they want to know why a particular set of standards has been selected by those entrusted with their children. Similarly, regulatory agencies and educational institutions must understand why a particular set of standards has been chosen by the science education community to underlie the preparation of science teachers.

The National Science Teachers Association (NSTA) Standards for Science Teacher Preparation are based upon a review of the professional literature and on the goals and framework for science education set forth in the National Science Education Standards (NSES) (National Research Council [NRC], 1996). The NSES is a visionary framework for science teaching in precollege education, based upon the assumption that scientific literacy for citizenship should be a primary—if not exclusive—goal of science education at the precollege level.

In the broadest sense, scientifically literate citizens understand the subject matter of science, but also know and understand the evidence behind the major concepts of science, how such evidence was obtained and why it has been accepted. They are able, for example, to distinguish between science as a process of investigation and technology as a process of design.

Scientifically literate citizens know the difference between scientific and nonscientific knowledge; they understand that useful knowledge need not always be scientific, but that scientific knowledge is valued because it is productive in our interactions with the physical world. They use scientific approaches for analyzing and solving problems requiring investigation, basing their judgments upon evidence rather than presuppositions and bias. They understand how science affects their communities and their lives, and can distinguish productive from nonproductive science. They understand that science is not always intended to produce immediate tangible benefits.

The NSTA Standards for Science Teacher Preparation are consistent with this vision of the NSES. Teachers of science at all grade levels must demonstrate competencies consistent with the achievement of this vision. They should not only demonstrate that they have the necessary knowledge and planning skills to achieve these goals; but also that they are successful in engaging their students in studies of such topics as the relationship of science and technology, nature of science, inquiry in science and science-related issues.

These NSTA standards are intended as the foundation for a performance assessment system, through which teacher candidates must satisfactorily demonstrate their knowledge and abilities at stable assessment points—gateways—in the science teacher preparation program. The standards address the knowledge, skills and dispositions that are deemed important by the National Science Teachers Association for teachers in the field of science. They are fully aligned with the National Science Education Standards and consistent with the standards of the National Board for Professional Teaching Standards (NBPTS) and the Interstate New Teachers Assessment and Support Consortium (INTASC).
Changes from the 1998 Standards

These standards incorporate a number of changes from the 1998 version. These changes have come about to remedy weaknesses in the standards discovered in their use by the NSTA’s NCATE Program Review Board and to address concerns about the vagueness of some of the 1998 standards.

In NCATE institutional reviews, the review board quickly learned that the ten standards adopted in 1998 were too broad to be addressed effectively by institutions, who interpreted the standards in many—sometimes unintended—ways. As an interim measure, NSTA integrated more specific “dimensions,” into NCATE program review materials to help institutions understand the meaning of each standard. The dimensions thus became a de facto subset of standards to which programs seeking recognition were required to respond. In this revision, the task force has formally incorporated the dimensions into the standards, refining them in language and placement in order to define the knowledge, skills or dispositions sought for each of the original ten standards better. The standards themselves—especially standards two, three, four, seven and nine—have also been rewritten to focus and clarify their meanings.

The task force has also added a set of subject matter content recommendations to this version of the standards. In the 1998 standards, the content recommendations were similar to those found in the 1987 curriculum-based standards. In addition, the National Science Education Standards were not directly referred to in the 1998 standards; references were added later in NCATE documents. In this revision, content recommendations have been created by the task force based on the recommendations of the American Association of Physics Teachers, the American Chemical Society, the National Association of Biology Teachers and the National Earth Science Teachers Association, and review of the NSES. These recommendations are expressed in the form of competencies rather than courses, and are intended to guide institutions and states in their selection of their subject matter requirements and assessments.

The vision and recommendations of the NSES are given more prominence in this version of the standards than in the previous version. The unifying concepts, for example, have been given more attention, and their meanings have been delineated much more carefully.

In terms of the format of the standards, the revised standards are each followed by a “discussion” section—replacing the “rationale” in the 1998 standards—and an “application to programs” section—replacing the former “recommendations” section. Narratives in these new sections are tighter and more focused than in the previous document. The “indicators” sections in the 1998 version were dropped, since they proved more confusing than helpful in practice.

The revised standards have been subject to numerous reviews, and comments received from science teacher educators have been carefully examined for possible incorporation into the standards. This version of the standards has generally been positively received and the clarifications welcomed by institutional representatives who have responded to solicitations for input from the NSTA task force.

NSTA Standards for Science Teacher Preparation

Standard 1: Content

Teachers of science understand and can articulate the knowledge and practices of contemporary science. They can interrelate and interpret important concepts, ideas, and applications in their fields of licensure; and can conduct scientific investigations. To show that they are prepared in content, teachers of science must demonstrate that they:

a. Understand and can successfully convey to students the major concepts, principles, theories, laws, and interrelationships of their fields of licensure and supporting fields as recommended by the National Science Teachers Association.

b. Understand and can successfully convey to students the unifying concepts of science delineated by the National Science Education Standards.

c. Understand and can successfully convey to students important personal and technological applications of science in their fields of licensure.

d. Understand research and can successfully design, conduct, report and evaluate investigations in science.

e. Understand and can successfully use mathematics to process and report data, and solve problems, in their field(s) of licensure.

Discussion

The desirability of a strong content background for science teachers is widely recognized and generally accepted, even while it is generally recognized within the professional community that science content expertise alone is not sufficient to define a good teacher. In this standard, content is operationally defined to include the knowledge and skills that are learned, or should be learned, in the course of the teacher’s science curriculum. This includes important scientific concepts and relationships, applications of science in technological contexts, mathematical skills and applications, and methods and processes of conducting true scientific investigations. Other knowledge and skills such as those specifically identified in standards related to the nature of science, issues, and community might also be addressed in science content preparation, but are delineated into separate clusters for emphasis.

The National Science Education Standards and Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993) strongly emphasize all of the dimensions of preparation called for in this cluster of standards. The previous version of these standards did not contain specific recommendations on content, except those carried over from the curriculum standards that preceded them. This set of standards contains specific recommendations for content preparation.

They are based upon discipline-specific recommendations of the American Association of Physics Teachers, the American Chemical Society, the National Association of Biology Teachers and the National Earth Science Teachers Association. Their recommendations were integrated by the NSTA task force with those of the NSES as a basis for the recommendations in this document.

Because an increasing number of states and most members of the science education community have accepted the NSES as a framework document, the NSTA standards and recommendations for teacher preparation are intended as a framework for the preparation of teachers to work effectively in school systems with a science curriculum based on the NSES or professional standards with similar goals.

The rationales for three of the five content standards (subject matter, unifying concepts, and technology/applications [standards 1-3]) have been discussed at length in the NSES. Knowledge of research within the content discipline is required as the basis for conducting instruction through inquiry and engaging students in effective inquiry, as required by standards in the Inquiry cluster. Requirements for mathematics are based on the need for
candidates, as teachers, to lead students in the use of mathematics to solve problems and to process, present and interpret data.

The recommendations distinguish between the needs of elementary generalists, elementary-middle level general science teachers, and secondary science teachers in the four traditional disciplines. For the secondary level, core competencies are identified that should be required of any candidate licensed to teach in that discipline. Advanced competencies are identified for specialists in the discipline. Recommendations for multi-field licensure programs and composite teaching fields are also provided.

Applications in Programs

Until recently, the science content for many teachers consisted largely of lecture and validation labs (Boyer, 1987; Dunkin & Barnes, 1986; Smith & Anderson, 1984), with little attention given to undergraduate research experiences or applications of science in technological contexts. Consequently, teacher candidates with majors in the field frequently could not effectively interrelate concepts in their disciplines (Lederman, Gess-Newsome & Latz (1994); Mason, 1992). While these standards are intended as the framework for a performance-based teacher preparation program, there is a strong argument to be made that they, along with preparation standards under the nature of science, inquiry, and issues clusters, outline much of what should be known by any undergraduate science major.

Regardless of where preparation occurs, the science teacher education program has responsibility for demonstrating that candidates are prepared in relation to these standards and to the content recommendations. However, NSTA does not require gateway performance data for the recommendations as it does for each of the standards. The recommendations are presented as a basis for decision-making on course requirements and content in the program and to outline desired content-related competencies that graduates should demonstrate prior to licensure.

Graduate and Postbaccalaureate programs that do not control the content preparation of their candidates may need to prepare an admissions checklist and require deficiency work to ensure that candidates from other programs have the knowledge and skills required to meet these standards.

While standards must be addressed individually, the content recommendations may be addressed in clusters; for example, the unifying concepts may be dealt with together at one or two gateway assessment points. Related conceptual topics may be addressed in a particular course, from which a grade is used as an indicator of preparation. It is up to the program to demonstrate that it has accounted for all of the recommendations associated with this cluster of standards by showing where and how they are addressed.

As a practical matter, course grades may be used as performance indicators in relation to general subject matter preparation, which is the substance of standard one, or where a course specifically addresses the standard such that completing it successfully addresses the standard on its face; for example, a course in research design might meet standard four. The more specific standards (two through five) generally require more specifically targeted assessments. The number of assessments required for any given standard depends upon the alignment of the assessment tool with the standard, i.e., how valid it is as an indicator. GPA, for example, is a rough indicator and must be supported by other data such as test results and cooperating teacher observations. Results of state mandated tests of content knowledge MUST be reported to the NSTA.

Standards 1 - 3 also require evidence that candidates can effectively convey the content to students. A number of approaches may be used to ensure that this occurs, but it is imperative that student performance, i.e., the actual impact of candidate performance on student understanding or achievement, is taken into account when determining and reporting the effectiveness of the candidate in conveying knowledge. Other measures may be included to provide supporting data, such as candidate reflections on their videotaped performance, using an assessment rubric; student feedback ratings; case write-ups demonstrating where knowledge has been effectively conveyed; and cooperating teacher and supervisor observations using well-defined criteria.

Science Content Recommendations

A. Recommendations for Elementary Generalists

A.1. Elementary teachers without a science specialization should be prepared to teach science with a strong emphasis on observation and description of events, manipulation of objects and technological contexts. Consequently, teacher candidates with majors in the field frequently could not effectively interrelate concepts in their disciplines (Lederman, Gess-Newsome & Latz (1994); Mason, 1992).

As a practical matter, course grades may be used as performance indicators in relation to general subject matter preparation, which is the substance of standard one, or where a course specifically addresses the standard such that completing it successfully addresses the standard on its face; for example, a course in research design might meet standard four. The more specific standards (two through five) generally require more specifically targeted assessments. The number of assessments required for any given standard depends upon the alignment of the assessment tool with the standard, i.e., how valid it is as an indicator. GPA, for example, is a rough indicator and must be supported by other data such as test results and cooperating teacher observations. Results of state mandated tests of content knowledge MUST be reported to the NSTA.

Standards 1 - 3 also require evidence that candidates can effectively convey the content to students. A number of approaches may be used to ensure that this occurs, but it is imperative that student performance, i.e., the actual impact of candidate performance on student understanding or achievement, is taken into account when determining and reporting the effectiveness of the candidate in conveying knowledge. Other measures may be included to provide supporting data, such as candidate reflections on their videotaped performance, using an assessment rubric; student feedback ratings; case write-ups demonstrating where knowledge has been effectively conveyed; and cooperating teacher and supervisor observations using well-defined criteria.
14. Combinations of matter to form solutions, mixtures, and compounds with different properties.
15. Variations in the physical and chemical states of matter and changes among states.
16. Ordering and classification of matter and energy and their behaviors.
17. Factors affecting the position, motion and behavior of objects.
18. Properties of simple machines and tools, such as levers and screws.
20. Types of energy, energy sources, and simple transformations of energy.

A.4. In the Earth and space sciences, elementary generalists should be prepared to lead students to understand:
21. Natural objects in the sky and why they change in position and appearance.
22. Causes of the seasons and seasonal changes.
23. Changes in the atmosphere resulting in weather and climate.
25. Basic properties of rocks, minerals, water, air, and energy.
26. Differences between renewable and nonrenewable natural resources.

A.5. To create interdisciplinary perspectives and to help students understand why science is important to them, elementary generalists should be prepared to lead students to understand:
27. Differences between science, as investigation, and technology as design.
28. Impact of science and technology on themselves and their community, and on personal and community health.
29. How to use observation, experimentation, data collection, and inference to test ideas and construct concepts scientifically.
30. How to use metric measurement and mathematics for estimating and calculating, collecting and transforming data, modeling, and presenting results.

B. Recommendations for Elementary and Middle Level General Science Teachers

B.1. Elementary and middle level general science specialists should be prepared with a strong emphasis on collaborative inquiry in the laboratory and field. They should have a deeper understanding of the field than generalists, but should have the same thematic and interdisciplinary perspective on science. To achieve this, science specialists at this level should have all of the competencies described for the elementary generalist, but also should be prepared in biology to lead students to understand:
1. Factors governing the structures, functions, and behaviors of living systems.
2. Multiple systems of classification of organisms.
3. Cycles of matter, and flow of energy, through living and nonliving pathways.
4. Natural selection, adaptation, diversity, and speciation.
5. Structure, function, and reproduction of cells, including microorganisms.
6. Levels of organization from cells to biomes.
7. Reproduction and heredity, including human reproduction and contraception.
8. Behavior of living systems and the role of feedback in their regulation.
9. Hazards related to living things including allergies, poisons, disease, and aggression.

B.2. In relation to the physical sciences, science specialists at this level should have all of the competencies described for the elementary generalist, but also should be prepared in chemistry and physics to lead students to understand:
10. Properties and applications of sound, light, magnetism, and electricity.
11. Potential and kinetic energies and concepts of work.
12. Energy flow in physical and chemical systems, including simple machines
13. States of matter and bonding in relation to molecular behavior and energy.
15. Classifications of elements and compounds.
16. Solvents (especially water) and solutions.
17. Chemical nature of the earth and its living organisms.

B.3. In the Earth and space sciences, science specialists at this level should have all of the competencies described for the elementary generalist, but also should be prepared in the Earth and space sciences to lead students to understand:
20. Structures of objects and systems in space.
21. Earth’s structure, evolution, history, and place in the solar system.
22. Characteristics and importance of oceans, lakes, rivers, and the water cycle.
23. Characteristics of the atmosphere including weather and climate.
24. Changes in the Earth caused by chemical, physical, and biological forces.
25. Causes and occurrences of hazards such as tornados, hurricanes, and earthquakes.
26. Characteristics and importance of cycles of matter such as oxygen, carbon, and nitrogen.
27. Characteristics of renewable and nonrenewable natural resources and implications for their use.
28. Interactions among populations, resources, and environments.

B.4. To create interdisciplinary perspectives and to help students understand why science is important to them, elementary/middle level science specialists should have all of the competencies described for the elementary generalist, but also should be prepared to lead students to understand:

29. Interrelationships of pure and applied sciences, and technology.

30. Applications of science to local and regional problems and the relationship of science to one’s personal health, well-being, and safety.

31. Historical development and perspectives on science including contributions of underrepresented groups and the evolution of major ideas and theories.

32. Applications of science to the investigation of individual and community problems.

33. Use of technological tools in science, including calculators and computers.

34. Applications of basic statistics and statistical interpretation to the analysis of data.

C. Recommendations for Secondary Science Teachers

C.1. Recommendations for All Secondary Science Teachers

Secondary teachers are generally prepared with more depth in the content of a given field than are teachers of younger students. The major divisions of the natural sciences are biology, chemistry, the Earth and space sciences, and physics. All teachers licensed in a given discipline should know, understand, and teach with the breadth of understanding reflected in the core competencies for that discipline. Specialists in a discipline should also have achieved the advanced competencies for that discipline. All secondary teachers should also be prepared to lead students to understand the unifying concepts of science including:

1. Multiple ways we organize our perceptions of the world and how systems organize the studies and knowledge of science.

2. Nature of scientific evidence and the use of models for explanation.

3. Measurement as a way of knowing and organizing observations of constancy and change.

4. Evolution of natural systems and factors that result in evolution or equilibrium.

5. Interrelationships of form, function, and behaviors in living and nonliving systems.

C.2. Recommendations for Teachers of Biology

C.2.a. Core Competencies. All teachers of biology should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Life processes in living systems including organization of matter and energy.

2. Similarities and differences among animals, plants, fungi, microorganisms, and viruses.


4. Scientific theory and principles of biological evolution.

5. Ecological systems including the interrelationships and dependencies of organisms with each other and their environments.

6. Population dynamics and the impact of population on its environment.

7. General concepts of genetics and heredity.

8. Organization and functions of cells and multicellular systems.

9. Behavior of organisms and their relationships to social systems.

10. Regulation of biological systems including homeostatic mechanisms.

11. Fundamental processes of modeling and investigating in the biological sciences.

12. Applications of biology in environmental quality and in personal and community health.

C.2.b. Advanced Competencies. In addition to these core competencies, teachers of biology as a primary field should be prepared to effectively lead students to understand:


15. Molecular genetics and heredity and mechanisms of genetic modification.


17. Causes, characteristics and avoidance of viral, bacterial, and parasitic diseases.

18. Issues related to living systems such as genetic modification, uses of biotechnology, cloning, and pollution from farming.

19. Historical development and perspectives in biology including contributions of significant figures and underrepresented groups, and the evolution of theories in biology.

20. How to design, conduct, and report research in biology.


C.2.c. Supporting Competencies. All teachers of biology should also be prepared to effectively apply concepts from other sciences and mathematics to the teaching of biology including basic concepts of:

22. Chemistry, including general chemistry and biochemistry with basic laboratory techniques.

23. Physics including light, sound, optics, electricity, energy and order, magnetism, and thermodynamics.

24. Earth and space sciences including energy and geochemical cycles, climate, oceans,
weather, natural resources, and changes in the Earth.

25. Mathematics, including probability and statistics.

C.3. Recommendations for Teachers of Chemistry

C.3.a. Core Competencies. All teachers of chemistry should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Fundamental structures of atoms and molecules.
2. Basic principles of ionic, covalent, and metallic bonding.
3. Physical and chemical properties and classification of elements including periodicity.
5. Principles of electrochemistry.
7. Transition elements and coordination compounds.
10. Functional and polyfunctional group chemistry.
11. Environmental and atmospheric chemistry.
12. Fundamental processes of investigating in chemistry.
13. Applications of chemistry in personal and community health and environmental quality.

C.3.b. Advanced Competencies. In addition to the core competencies, teachers of chemistry as a primary field should also be prepared to effectively lead students to understand:

14. Molecular orbital theory, aromaticity, metallic and ionic structures, and correlation to properties of matter.
15. Superconductors and principles of metallurgy.
16. Advanced concepts of chemical kinetics, and thermodynamics.
17. Lewis adducts and coordination compounds.
18. Solutions, colloids, and colligative properties.
19. Major biological compounds and natural products.
20. Solvent system concepts including non-aqueous solvents.
21. Chemical reactivity and molecular structure including electronic and steric effects.
22. Organic synthesis and organic reaction mechanisms.
23. Energy flow through chemical systems.
24. Issues related to chemistry including ground water pollution, disposal of plastics, and development of alternative fuels.
25. Historical development and perspectives in chemistry including contributions of significant figures and underrepresented groups, and the evolution of theories in chemistry.
26. How to design, conduct, and report research in chemistry.
27. Applications of chemistry and chemical technology in society, business, industry, and health fields.

C.3.c. Supporting Competencies. All teachers of chemistry should be prepared to effectively apply concepts from other sciences and mathematics to the teaching of chemistry including:

28. Biology, including molecular biology, bioenergetics, and ecology.
29. Earth science, including geochemistry, cycles of matter, and energetics of Earth systems.
30. Physics, including energy, stellar evolution, properties and functions of waves, motions and forces, electricity, and magnetism.
31. Mathematical and statistical concepts and skills including statistics and the use of differential equations and calculus.

C.4. Recommendations for Teachers of the Earth and Space Sciences

C.4.a. Core Competencies. All teachers of the Earth and space sciences should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Characteristics of land, atmosphere, and ocean systems on Earth.
2. Properties, measurement, and classification of Earth materials.
3. Changes in the Earth including land formation and erosion.
4. Geochemical cycles including biotic and abiotic systems.
5. Energy flow and transformation in Earth systems.
6. Hydrological features of the Earth.
7. Patterns and changes in the atmosphere, weather, and climate.
10. Fundamental processes of investigating in the Earth and space sciences.
11. Sources and limits of natural resources.
12. Applications of Earth and space sciences to environmental quality and to personal and community health and welfare.
C.4.b. Advanced Competencies. In addition to the core competencies, teachers of the Earth and space sciences as a primary field should be prepared to effectively lead students to understand:

14. Oceans and their relationship to changes in atmosphere and climate.
15. Hydrological cycles and problems of distribution and use of water.
16. Dating of the Earth and other objects in the universe.
17. Structures and interactions of energy and matter in the universe.
18. Impact of changes in the Earth on the evolution and distribution of living things.
19. Issues related to changes in Earth systems such as global climate change, mine subsidence, and channeling of waterways.
20. Historical development and perspectives in the Earth and space sciences, including contributions of significant figures and underrepresented groups, and the evolution of theories in these fields.
21. How to design, conduct, and report research in the Earth and space sciences.
22. Applications of the Earth and space sciences and related technologies in society, business, industry, and health fields.

C.4.c. Supporting Competencies. All teachers of Earth and space sciences should be prepared to effectively apply concepts from other sciences and mathematics to the teaching of Earth and space sciences including concepts of:

23. Biology, including evolution, ecology, population dynamics, and the flow of energy and materials through Earth systems.
24. Chemistry, including broad concepts and basic laboratory techniques of inorganic and organic chemistry, physical chemistry, and biochemistry.
25. Physics, including electricity, forces and motion, energy, magnetism, thermodynamics, optics, and sound; as well as basic quantum theory.
26. Mathematics, including statistics and probability.

C.5. Recommendations for Teachers of Physics

C.5.a. Core Competencies. All teachers of physics should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Energy, work, and power.
2. Motion, major forces, and momentum.
3. Newtonian principles and laws including engineering applications.
4. Conservation of mass, momentum, energy, and charge.
5. Physical properties of matter.

6. Kinetic-molecular motion and atomic models.
7. Radioactivity, nuclear reactors, fission, and fusion.
8. Wave theory, sound, light, the electromagnetic spectrum and optics.
9. Electricity and magnetism
11. Applications of physics in environmental quality and to personal and community health.

C.5.b. Advanced Competencies. In addition to the core competencies, teachers of physics as a primary field should be prepared to effectively lead students to understand:

12. Thermodynamics and relationships between energy and matter.
13. Nuclear physics including matter-energy duality and reactivity.
14. Angular rotation and momentum, centripetal forces, and vector analysis.
15. Quantum mechanics, space-time relationships, and special relativity.
16. Models of nuclear and subatomic structures and behavior.
17. Light behavior, including wave-particle duality and models.
18. Electrical phenomena including electric fields, vector analysis, energy, potential, capacitance, and inductance.
19. Issues related to physics such as disposal of nuclear waste, light pollution, shielding communication systems and weapons development.
20. Historical development and cosmological perspectives in physics including contributions of significant figures and underrepresented groups, and evolution of theories in physics.
21. How to design, conduct, and report research in physics.
22. Applications of physics and engineering in society, business, industry, and health fields.

C.5.c. Supporting Competencies. All teachers of physics should be prepared to effectively apply concepts from other sciences and mathematics to the teaching of physics including concepts of:

23. Biology, including organization of life, bioenergetics, biomechanics, and cycles of matter.
24. Chemistry, including organization of matter and energy, electrochemistry, thermodynamics, and bonding.
25. Earth sciences or astronomy related to structure of the universe, energy, and interactions of matter.
26. Mathematical and statistical concepts and skills including statistics and the use of differential equations and calculus.
D. Recommended Program Requirements

When teachers are prepared to teach specific composite courses labeled physical science or general science, they should have at least core competencies in the primary disciplines comprising the composite course. Teachers in traditional disciplines (biology, chemistry, Earth and space sciences, or physics) are generally prepared in one of three ways:

1. Single field programs, which require specialization (often a major) in a primary discipline, with less preparation in a second discipline. In this case, the teacher should have advanced competencies in the primary discipline and at least core competencies in the second discipline, with supporting competencies in the remaining sciences.

2. Dual field programs, which require equal preparation in two disciplines, usually with less than a major in each. In this case, teachers should have advanced competencies in both disciplines, with supporting competencies in the remaining two disciplines.

3. Broad field programs, which require preparation in three or four disciplines at once, with licensure in each discipline. In this case, teachers should have advanced competencies in one discipline and core competencies in the remaining disciplines.

Preparation of middle school teachers as general science teachers (following National Middle School Association recommendations) should follow the specific middle school standards recommended in section 2, rather than the subject-specific secondary standards. Such programs are generally for middle level specifically, or are designed for elementary teachers who wish to be certified in middle level science.

Standard 2: Nature of Science

Teachers of science engage students effectively in studies of the history, philosophy, and practice of science. They enable students to distinguish science from non-science, understand the evolution and practice of science as a human endeavor, and critically analyze assertions made in the name of science. To show they are prepared to teach the nature of science, teachers of science must demonstrate that they:

a. Understand the historical and cultural development of science and the evolution of knowledge in their discipline.

b. Understand the philosophical tenets, assumptions, goals, and values that distinguish science from technology and from other ways of knowing the world.

c. Engage students successfully in studies of the nature of science including, when possible, the critical analysis of false or doubtful assertions made in the name of science.

Discussion

Understanding of the nature of science—the goals, values and assumptions inherent in the development and interpretation of scientific knowledge (Lederman, 1992) has been an objective of science instruction since at least the turn of the last century (Central Association of Science and Mathematics Teachers, 1907). It is regarded in contemporary documents as a fundamental attribute of science literacy (AAAS, 1993; NRC, 1996) and a defense against unquestioning acceptance of pseudoscience and of reported research (Park, 2000; Sagan, 1996). Knowledge of the nature of science can enable individuals to make more informed decisions with respect to scientifically based issues; promote students’ in-depth understandings of “traditional” science subject matter; and help them distinguish science from other ways of knowing (Lederman, personal communication).

An important purpose of pre-college science education is to educate individuals who can make valid judgments on the value of knowledge created by science and other ways of knowing, and to understand why the literature regards scientific knowledge not as absolute, but as tentative, empirically based, culturally embedded, and the product of some degree of assumption, subjectivity, creativity, and inference (Lederman & Niess, 1997).

Research clearly shows that students and teachers do not adequately understand the nature of science. For example, most teachers and students believe that all scientific investigations adhere to an identical set of steps known as the scientific method (McComas, 1996), and that theories are simply immature laws (Horner & Rubba, 1979). Even when teachers understand and support the need in the instruction, they do not always do so (Lederman, 1992). Instead they may rely upon the false assumption that doing inquiry leads to understanding of science (Abd-El-Khalick & Lederman, 2000).

Explicit instruction is needed both to prepare teachers (Abd-El-Khalick & Lederman, 2000) and to lead students to understand the nature of science (Khishe & Abd-El-Khalick, 2002). Helping teachers to focus on nature of science as an important instructional objective resulted in more explicit nature of science instruction (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001).

Applications in Programs

All students of science, whether teacher candidates or not, should have knowledge of the nature of science as defined in this standard, and should have the skills needed to engage students in the critical analysis of scientific and pseudoscientific claims in an appropriate way. This requires explicit attention to the nature of science, as defined in this standard, as a part of the preparation of science teachers. Candidates should have multiple opportunities to study and analyze literature related to the history and nature of science, such as The Demon Haunted World (Sagan, 1996); Great Feuds in Science (Hellman, 1998) Facts, Fraud and Fantasy (Goran, 1979) and The Structure of Scientific Revolutions (Kuhn, 1962). In addition, they should be required to analyze, discuss and debate topics and reports in the media related to the nature of science and scientific knowledge in courses and seminars throughout the program, not just in an educational context. Students should engage in active investigation and analysis of the conventions of science as reflected in papers and reports in science, across fields, in order to understand similarities and differences in methods and interpretations in science, and to identify strengths and weaknesses of findings.

Candidates are required to demonstrate that they are effective by successfully engaging students in the study of the nature of science. Assessments with regard to understanding may include such possibilities as completion of independent study courses, seminars or assignments; projects; papers; summative readings; or case study analyses. Assessments of effectiveness must include at least some demonstrably positive student outcomes in studies related to the nature of science as delineated by the standards in this cluster.
**Standard 3: Inquiry**

Teachers of science engage students both in studies of various methods of scientific inquiry and in active learning through scientific inquiry. They encourage students, individually and collaboratively, to observe, ask questions, design inquiries, and collect and interpret data in order to develop concepts and relationships from empirical experiences. To show that they are prepared to teach through inquiry, teachers of science must demonstrate that they:

- Understand the processes, tenets, and assumptions of multiple methods of inquiry leading to scientific knowledge.
- Engage students successfully in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner.

**Discussion**

Reviews of scientific literature demonstrate that scientific inquiry consists of more than a single series of steps called "the scientific method." Scientists may use multiple strategies and processes to solve different kinds of problems. One of the major goals of science education, according to the Benchmarks for Scientific Literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996) is to enable students to use inquiry to solve problems of interest to them. The ability to engage in effective inquiry using scientifically defensible methods is considered a hallmark of scientific literacy.

True inquiry requires the use of nonalgorithmic and complex higher-order thinking skills to address open-ended problems (Resnick, 1987). Multiple solutions may be possible, and the inquirer must use multiple, sometimes conflicting, criteria to evaluate his or her actions and findings. Inquiry is characterized by a degree of uncertainty about outcomes. True inquiry ends with an elaboration and judgment that depends upon the previous reasoning processes.

In science education, inquiry may take a number of forms: discovery learning, in which the teacher sets up the problem and processes but allows the students to make sense of the outcomes on their own, perhaps with assistance in the form of leading questions; guided inquiry, in which the teacher poses the problem and may assist the students in designing the inquiry and making sense of the outcome; and open inquiry, in which the teacher merely assess possible actions and outcomes based upon their goals and values. To show that they are prepared to engage students in studies of issues related to science, teachers of science must understand socially important issues related to science and technology in their field of licensure, as well as processes used to analyze and make decisions on such issues.

Students who learn through inquiry gain a deeper understanding of the resulting concepts than when the same concepts are presented through lecture or readings. This has led to the principle that less is more: Teaching fewer concepts with greater depth will result in better long-term understanding than covering many concepts superficially. In addition, students will gain the skills of inquiry and scientific attitudes desired by the standards, and gain greater knowledge of how scientific research is actually conducted.

**Applications in Programs**

Candidates in a science teacher preparation program should be provided with multiple opportunities to solve open-ended problems using appropriate scientific methods. These opportunities should be present in their science content courses, but also should be fundamental in their science methods preparation. Many candidates enter teaching because they want to impart knowledge: It is not easy for them to lead students by listening and questioning, and to allow students to infer proposed solutions to problems. Practice is essential.

The preparation of teachers for the elementary level, especially generalists, should require inquiry-based university science courses. Stalheim-Smith and Scharmann (1996) and Stoddart, Connell, Stofflett and Peck (1993) found that the use of constructivist teaching methodologies and learning cycles, methods that are generally inquiry-based, improved the learning of science by candidates in elementary education. Such courses also may increase the confidence level of generalists, who are often not confident in their ability to do science.

Secondary programs should also strongly emphasize inquiry and pay close attention to preparing teachers to effectively lead students in such activities. All programs should provide explicit instruction in the nature of inquiry as well as its applications. Like the nature of science, inquiry is not learned well simply through practice. In general, the term “scientific method” (for the hypothetico-deductive method) should be avoided, since it may lead students to believe there is only one way to conduct scientific inquiries. Inductive studies have played a valuable role in science, as have mathematical and computer modeling. Hypotheses are not used formally by scientists in all research, nor are experiments per se the substance of all research. Candidates should study cases from which different approaches to inquiry are used in science, and should endeavor to communicate such differences to their students.

The role of the teacher is not just to engage students in inquiry in order to develop their conceptual knowledge and process skills, but also to increase their understanding of how scientific inquiries are conducted, and how decisions are made in science. In this regard, the inquiry standards overlap and support the nature of science standards.

Inquiry demands skill in the analysis of data and assessment of results to reach reasonable and valid conclusions. Candidates must be able to demonstrate not only that they know and understand common and different modes of scientific inquiry, but also that they can and do effectively engage students in inquiries. They should be able to demonstrate their effectiveness through student data profiles or similar means that they are effective in conducting such activities.

**Standard 4: Issues**

Teachers of science recognize that informed citizens must be prepared to make decisions and take action on contemporary science- and technology-related issues of interest to the general society. They require students to conduct inquiries into the factual basis of such issues and to assess possible actions and outcomes based upon their goals and values. To show that they are prepared to engage students in studies of issues related to science, teachers of science must demonstrate that they:

- Understand socially important issues related to science and technology in their field of licensure, as well as processes used to analyze and make decisions on such
b. Engage students successfully in the analysis of problems, including considerations of risks, costs, and benefits of alternative solutions; relating these to the knowledge, goals and values of the students.

Discussion

An important basic function of science teacher education is to prepare teachers to relate science and technology meaningfully to the local community, to the daily lives of students, and to broader societal issues (AAAS, 1993; NRC, 1996).

Nearly fifty years ago Ralph Tyler argued that subject matter specialists should seek to answer the question: "What can your subject contribute to the education of young people who are not going to be specialists in your field; what can your subject contribute to the layman, the garden variety of citizen?" (Tyler, 1949, p. 26). The response of the science education community today is to identify elements of science instruction that contribute to the science literacy of individuals as citizens.

The abilities of students, as citizens, to make justified decisions on values and issues related to science and technology, to understand that there may be many sides to an issue, and that there are always cost-benefit tradeoffs in decision-making, are fundamental components not only of science literacy, but also of citizenship in a democratic society.

Many issues today are related to science and technology. Making a meaningful decision on these issues requires knowledge of related science content, the nature of science and technology, and the ways science relates to oneself and to others in society. Intelligent decision-making on issues requires data and context, or decisions become mere opinions. Science teachers must be prepared to lead students in structured explorations of issues of concern, not just soliciting opinions or conducting debates with little substantive backing.

To that end, programs must provide explicit tools for decision-making and cost-benefit analysis and ensure that candidates are prepared and capable of using these tools in their teaching.

Applications in Programs

Science teacher preparation programs should give explicit attention to the study of socially important issues related to science and technology such as species preservation, land use, chemical pollution, weapons development, and cloning, to name but a few. Such issues may be introduced in science courses, but seldom do science courses provide for structured cost-benefit analyses or decision-making on these issues that considers all perspectives. Programs must ensure that candidates are prepared to lead students in learning how to dissect and analyze issues using data and information as resources.

The question of how to consider an issue is just as important as the issues considered. To that end, candidates will themselves need to learn how to explore issues with an open mind. Once this is accomplished, they will need to learn how to lead students to explore these issues with the goal of making an informed and justified decision.

To meet this standard, candidates must demonstrate that they are aware of important issues and are knowledgeable of approaches to analyzing these issues. Candidates should access common sources of information (newspapers, magazines, televised reports) to relate their science instruction to contemporary issues and events. They must then demonstrate through student achievement that they are able to effectively lead them in the study of an important issue.

Standard 5: General Skills of Teaching

Teachers of science create a community of diverse learners who construct meaning from their science experiences and possess a disposition for further exploration and learning. They use, and can justify, a variety of classroom arrangements, groupings, actions, strategies, and methodologies. To show that they are prepared to create a community of diverse learners, teachers of science must demonstrate that they:

a. Vary their teaching actions, strategies, and methods to promote the development of multiple student skills and levels of understanding.

b. Successfully promote the learning of science by students with different abilities, needs, interests, and backgrounds.

c. Successfully organize and engage students in collaborative learning using different student group learning strategies.

d. Successfully use technological tools, including but not limited to computer technology, to access resources, collect and process data, and facilitate the learning of science.

e. Understand and build effectively upon the prior beliefs, knowledge, experiences, and interests of students.

f. Create and maintain a psychologically and socially safe and supportive learning environment.

Discussion

Science teachers and specialists must provide all students with motivation and opportunities to learn from instruction and make sense of science. A basic assumption of the science standards is that science instruction must address the needs of all students, and that all students can learn science (AAAS, 1989; NRC, 1996). Teachers must be creative decision-makers who adapt and create meaningful activities (Biological Sciences Curriculum Study [BSCS], 1995; Orlich, Harder, Callahan, & Gibson, 1998) with a responsibility to change their practices if necessary in order to help students learn more effectively.

Many factors shape a person's knowledge and perceptions, including life experiences; social, emotional, and cognitive developmental stages (APA, 1992); inherent intelligences (Gardner, 1983); learning styles (Curry, 1990); race and gender; ethnicity and culture (Banks, 1993); and demographic setting (Orlich, et al., 1998). Teachers must consider the influence of these factors, real or potential, on student learning.

Science related instruction should be presented in many ways including, but not limited to, cooperative learning, concept mapping, diagramming, model building, role playing, game-playing, simulating, studying cases, questioning, discussing, solving problems, inquiring, field trips, projects, electronic media, written reporting of investigative techniques and data, and reading.
In general, learning a particular concept should involve multiple interactions with various features of the concept. In turn, concepts must be integrated into a coherent network of concepts from which one can make cogent decisions. Teachers must provide learning opportunities requiring multiple interactions with a concept in different contexts.

Learning occurs within a social context. Science educators must teach students the social processes of consensus building and engage them in the social construction of meaning (Zeidler, 1997). In other words, science education, like education in all fields, should encourage students to think about thinking, facilitate creativity and critical judgment, and favor development of self-awareness (APA, 1992; Zeidler, Lederman & Taylor, 1992).

Candidates should know how to use appropriate technology including, but not limited to, computers and computer peripherals, both to enhance learning and to relate the use of technology to science. The ability of students to use technological tools is becoming increasingly important for collecting and processing data; and for presenting and disseminating the results. In addition to using technology in the science classroom, teachers should also ensure that students understand the role technology plays in professional science.

Teachers of science should be able to determine and use presently held student knowledge to frame and develop new concepts to be learned. Much of what we know about how people learn has been encapsulated in the epistemology of constructivism, which holds that “...learners are actively involved in the knowledge construction process by using their existing knowledge to make sense of new experiences” (Marion, Hewson, Tabachnick, & Blomker, 1999, p. 249). Pre-existing knowledge influences the way new knowledge is added to the individual’s conceptual model, modifying its subsequent meaning (Stahl, 1991). To be effective, teachers must learn how to listen and to probe for various conceptualizations, and then use this knowledge to frame the way the concepts to be learned are taught.

Applications in Programs

The standards under the general teaching cluster are largely skills based and must be demonstrated by data from the classroom. Not all of the standards require demonstrations of student achievement or performance, but where effectiveness must be demonstrated, data from students should be used.

Programs should provide candidates with ample opportunities to work with students using well-defined indicators of effective pedagogy. Candidates must go beyond demonstrating that they can create varied plans for instruction (as in a methods course) and actually implement a unit that has appropriate variety.

Not all schools have diversity in terms of racial or ethnic makeup, but almost all have variations in socio-economic status, gender and learning styles. Candidates should be able to show how they have considered such differences in their planning and teaching. These considerations may be directed at a group or at individuals. For example, demonstrating the ability to make appropriate provisions for a student who does not speak English well, or who has a defined disability might be acceptable evidence of adapting instruction.

The ability to use structured collaborative learning effectively is an important part of Standard 15. This includes, but goes beyond, setting up effective lab groups. Strategies such as Teams-Games-Tournament (TGT) and Student Teams, Achievement Division (STAD) are examples of alternative ways to organize instruction, where students teach each other (Slavin, 1996).

Technology use is the emphasis of standard 16, as opposed to teaching about technology in contrast with science. The availability of technology in schools may limit the ability of some candidates to demonstrate their performance with students. If a teacher preparation program is situated in an area where computer technology is not common in the schools, it may be necessary to purchase laptops and lab ware for use in the schools.

Pretesting and preconceptions surveys are excellent ways for candidates to determine the prior conceptual knowledge of their students. Candidates should also be able to show how they used prior conceptions and variations in the knowledge of their students to plan instruction in relation to the target concept.

The cooperating teacher, using a rubric designed by the program, may assess classroom atmosphere. The candidate may also collect student feedback using an instrument of his or her own design.

Standard 6: Curriculum

Teachers of science plan and implement an active, coherent, and effective curriculum that is consistent with the goals and recommendations of the National Science Education Standards. They begin with the end in mind and effectively incorporate contemporary practices and resources into their planning and teaching. To show that they are prepared to plan and implement an effective science curriculum, teachers of science must demonstrate that they:

a. Understand the curricular recommendations of the National Science Education Standards, and can identify, access, and/or create resources and activities for science education that are consistent with the standards.

b. Plan and implement internally consistent units of study that address the diverse goals of the National Science Education Standards and the needs and abilities of students.

Discussion

The National Science Education Standards defines curriculum as “the way content is delivered . . . the structure, organization, balance, and presentation of the content in the classroom.” (NRC, 1996, p. 2). The Third International Study of Mathematics and Science identifies three major dimensions: the intended curriculum (goals and plans), the implemented curriculum (practices, activities, and institutional arrangements) and the attained curriculum (what students actually achieve through their educational experiences) (Schmidt, et al., 1999, p. 16).

For purposes of this standard, curriculum encompasses the intended and implemented curriculum, well-prepared science teachers can plan, implement and evaluate a high quality, standards-based science curriculum that includes long-term expectations, learning goals and objectives, plans, activities, materials, and assessments. To do this effectively, a teacher must be familiar with professionally developed national, state, and local standards for science education. They must be able to find and use, adapt, or create materials that are consistent with these standards. Candidates should know how to effectively use various resources such as news media, libraries, resource centers and the Internet.

Units of study, from lesson plans to topical units, to yearlong plans, should be internally consistent and well structured, based upon stated goals achievable through well-articulated activities. They should also be consistent with the ages, interests, and abilities of the students to be taught. The aims of such units should be demonstrably aligned with the National Science Education Standards as well as any other set of standards required of the candidate, and should be shown as well to meet the needs and consider the abilities of students.
Applications in Programs

Teacher candidates should engage in planning and implementing lessons and units of instruction early and often, and should be held responsible for demonstrating such planning throughout the program. With little experience in teaching, candidates may find such planning difficult and time-consuming. There is a tendency among novices to fall back upon activities for their own sake, rather than to deliberately plan a lesson or a unit with concern for how it might be made more effective. Practice in implementing units that have been designed to portray the National Science Education Standards and that have been field-tested may offer an opportunity to practice inquiry based teaching in a supportive context with a high probability of success.

Resource units or collections of related materials are one way candidates can be shown to be familiar with a wide variety of materials in relation to a particular topic. Lesson plans and unit plans are generally required in most programs and can be used as data to verify that the program addresses the standards.

Candidates can be asked to formally assess the internal consistency of their plans using program criteria and may create a reflective narrative to explain that assessment. This assessment may then be returned as part of a portfolio or as an independent assessment and may be used by the program to verify candidate skills in relation to standard 20.

Standards 7: Science in the Community

Teachers of science relate their discipline to their local and regional communities, involving stakeholders and using the individual, institutional, and natural resources of the community in their teaching. They actively engage students in science-related studies or activities related to locally important issues. To show that they are prepared to relate science to the community, teachers of science must demonstrate that they:

a. Identify ways to relate science to the community, involve stakeholders, and use community resources to promote the learning of science.

b. Involve students successfully in activities that relate science to resources and stakeholders in the community or to the resolution of issues important to the community.

Discussion

Community resources can be used to facilitate teaching and help students learn science. It is the teacher's responsibility to identify resources and use them effectively to help students learn. However, teachers often do not know much about the families and communities of their students (Ford, 1993; Nieto, 1992; Patthey-Chavez, 1993; Rivera & Poplin, 1995). They may not reside in the same neighborhoods as their students and so may not know of resources that could help them teach science more effectively. Students may be important contacts for identifying these resources.

The National Science Education Standards call for teachers of science to "identify and use resources outside the school" (NRC, 1996, p.3). Local resources are most important for several reasons, not the least of which is that they are available and relevant. Global resources and issues may seem distant and unrelated to the lives of many students; on the other hand, local resources and issues have a reality in their immediate lives.

Examples of activities may include the involvement of family members in science-related activities or field trips, guest speakers, field trips, service learning, issues surveys, and research or study projects on a local problem such as plant or animal inventories or pollution studies. Involvement of students in informal educational opportunities could also be relevant to this standard. If the community has significant cultural diversity, a study of science in different cultural contexts could be undertaken.

Culturally relevant teaching (Atwater, Crockett & Kilpatrick, 1996; Ladson-Billings, 1995) helps science come alive for many students, especially those who have traditionally been uninvolved in science. Examples and investigations based on students' personal experiences and on cultural contexts promote curiosity and help students build a personally meaningful framework for science (Atwater, 1994).

Values of the community, often religious values, may directly conflict with tenets of science. Teachers must study the composition of the community carefully and understand the beliefs that are commonly held by its members. Teachers of science should not feel forced to compromise the values and ethics of what they teach. Instead, they must find ways, through study and analysis, to accommodate these deeply held beliefs; for example, by discussing beliefs at a different level, i.e., by examining the role of belief in all human thought. By understanding that students are a product of the community, teachers may often find better ways to ensure that science is meaningful to them.

Applications in Programs

To meet this standard, candidates must know the community in which they teach. Programs should provide candidates with the background and tools they need to learn about the community. This could include a community survey or visits to a community website that provides demographic and resource information about the community. Candidates should also know how to obtain information from their students that might help them to understand their needs, and might lead to guest speakers from the students' families.

A good resource for finding out about the community is the local newspaper. News media may report on issues relevant to science and technology, which then may be used as the focus of discussion and cost-benefit analysis. It may be desirable for candidates to create and maintain a resource list for topics in their field and arrange to either take students to the field or have guest speakers come in. The Internet can also be a useful tool for finding resources in some communities.

It is not always necessary for candidates to arrange for guest speakers or a field trip in order to make use of community resources. Students, alone or in small study groups, may be asked to investigate questions, collect data, visit sites, attend presentations, or interview people after school or on weekends.

Standards 8: Assessment

Teachers of science construct and use effective assessment strategies to determine the backgrounds and achievements of learners and facilitate their intellectual, social, and personal development. They assess students fairly and equitably, and require that students engage in ongoing self-assessment. To show that they are prepared to use assessment effectively, teachers of science must demonstrate that they:

a. Use multiple assessment tools and strategies to achieve important goals for instruction that are aligned with methods of instruction and the needs of students.
b. Use the results of multiple assessments to guide and modify instruction, the classroom environment, or the assessment process.

c. Use the results of assessments as vehicles for students to analyze their own learning, engaging students in reflective self-analysis of their own work.

Discussion

The National Science Education Standards (NRC, 1995) give the topic of assessment considerable attention, an emphasis that highlights the importance of assessment to science teachers, who are called upon to evaluate diverse skills. Contemporary teachers must feel confident in using authentic assessment to measure achievement of science standards and benchmarks (AAAS, 1997).

Assessment is not a punitive action; rather it should be a process of learning by teacher and student. Good assessment strategies help students learn about their strengths and weaknesses. Poor assessments result only in a sense of failure or incompetence for sincere students. Reflective teachers help their students identify and celebrate their achievements.

Central to the process of assessment is the concept of alignment: the consistency between goals, actions and assessments. New teachers must learn how to design instruction and assessments that are consistent with multiple goals, not just those aimed at content acquisition. In a climate of positive assessment, learners and their teachers look for evidence to document growth. Diagnostic, formative and summative assessment strategies are woven throughout instruction as a natural part of the classroom activities. Portfolios are often used to collect evidence of growth and change.

Multiple assessment methods including videotapes, demonstrations, practicum observations, discussions, reports, simulations, exhibitions and many other outcomes are useful alternatives to the traditional written test. Peer assessment in cooperative learning groups is especially useful for demonstrating skills using laboratory equipment, and for evaluating process skills such as the creation and interpretation of graphs. Computer-based testing can help students diagnose their own abilities while placing fewer demands on teacher time.

Authentic assessment has also become an important part of educational reform. It is "assessment that mirrors and measures students’ performances in 'real-life' tasks and situations" (Hart, 1994, p. 106). It is expected that candidates should provide evidence of the ability to develop and use both authentic and traditional assessment strategies. This includes preparation on how to design and use valid and reliable rubrics.

Professional teachers accept responsibility for judging the relative success of activities they design (National Board for Professional Teaching Standards [NBPTS], 1996). They monitor the successes and failures of both individuals and classes. Such teachers use information about how students are doing "on average" to analyze the success of their instructional strategies. They know how to align instructional practices and materials with outcomes as measured on carefully selected assessment instruments (Webb, 1997).

Applications in Programs

An important tenet of education is that the mode of assessment often drives methods of instruction rather than the other way around. The very nature of a performance based teacher preparation program requires candidates to pay far more attention to determining the results of instruction than has been necessary in the past.

Multiple assessment tools should be aligned with the multiple purposes of instruction. Candidates should be called upon to justify their selection of assessment tools in relation to the purposes of the instruction. For example, it is clearly inconsistent to use a multiple-choice quiz to assess the result of an open inquiry. Variety of assessments does not just include different kinds of traditional and nontraditional assessments, but also assessments to measure different dimensions of learning—cognitive, affective and psychomotor knowledge and skills—and dispositions of students.

It would be expected that candidates should show at least some disposition to use assessments to guide and change instruction. These assessments may be formal or informal, formative or summative. A supervisor may note this occurring and assist the candidate in reflecting upon this change. Alternatively, candidates may use pretests or may collect data formatively to determine whether further instruction on a concept or in a skill is needed. Some teachers have found it effective to ask students at the end of each class period to write something they have learned that day; they have then used the student response to guide their work the next day and clear up misconceptions or misunderstandings.

It is also important that teachers be able to involve students in self-analysis. Too often assessment is something done to students. It takes little effort for candidates to include items that require student reflection on tests, projects, or activities they have completed. Conferencing with students using data from their assessments may also be a way of involving students in self assessment as long as the students themselves are doing the assessing: such conferences would not meet standard 25 if it is just another form of teacher assessment.

Standard 9: Safety and Welfare

Teachers of science organize safe and effective learning environments that promote the success of students and the welfare of all living things. They require and promote knowledge and respect for safety, and oversee the welfare of all living things used in the classroom or found in the field. To show that they are prepared, teachers of science must demonstrate that they:

a. Understand the legal and ethical responsibilities of science teachers for the welfare of their students, the proper treatment of animals, and the maintenance and disposal of materials.

b. Know and practice safe and proper techniques for the preparation, storage, dispensing, supervision, and disposal of all materials used in science instruction.

c. Know and follow emergency procedures, maintain safety equipment, and ensure safety procedures appropriate for the activities and the abilities of students.

d. Treat all living organisms used in the classroom or found in the field in a safe, humane, and ethical manner and respect legal restrictions on their collection, keeping, and use.

Discussion

The National Standards for Science Education (NRC, 1996) identify the dimensions of the learning environment as providing (a) time for extended investigations; (b) a flexible and supportive setting for inquiry; (c) a safe working environment; (d) sufficient resources, including tools, materials, media and technological resources; (e) resources outside school; and
(f) engagement of students. Some of these factors have been dealt with in other standards and will not be repeated here.

Safety and liability are especially of concern to science teachers, given the variety of environments in which they may teach and the materials they may use. Nagel (1982) recommended that safety education should be a condition of certification. Flinn Scientific Inc. (1992) has developed a generic chemical hygiene plan for high school laboratories covering many procedural issues. Guidelines and recommendations are also available from the American Chemical Society for chemistry laboratories (American Chemical Society, 1995). Yohe and Dunklebeeger (1992) have suggested an insurance format for teaching safety that is applicable to all teachers of science. In the same vein, teachers should also be aware of the legal issues related to liability for their actions. Purvis, Leonard and Boulter (1982) have delineated the conditions of negligence and liability and related them to school science in the important areas of lab security, appropriate facilities, proper instruction and protective gear. Because science teachers are particularly likely to encounter injuries among their students, they should thoroughly understand the criteria for liability and negligence, and defenses against negligence. By being aware of their responsibilities, they can act to ensure the well-being of the students under their care.

Weld (1990) discusses the need to provide an accessible and safe environment for all science students, including those with special needs. Teachers must demonstrate awareness of the impact of special needs on potentially difficult activities such as field trips. They should also be aware of steps they can potentially take to meet the needs of all learners, from customizing equipment to adapting lessons to using cooperative learning approaches.

Teachers should be aware of issues related to the keeping of animals in the classroom. The U.S. Humane Society recommends stringent controls on the keeping and handling of animals in the classroom (Carin, 1997). The National Association of Biology Teachers does not recommend such restrictions, but does recommend careful attention to the humane care and use of animals, awareness of dangers, and the use of alternatives to dissection when they are available (National Association of Biology Teachers, 1990). Plants may also be hazardous, both in and outside of the classroom (Riechard, 1993).

Applications in Programs

Teacher preparation programs must ensure that candidates possess the knowledge needed to maintain a safe environment for all students. This includes knowledge of how to avoid or control hazardous materials or organisms, how to prepare and/or store materials properly, and how to clean up spills and dispose of chemicals safely.

Candidates must know how to check and use safety equipment properly and the hazards of improperly shielded equipment, and must be able to avoid risks from fire hazards and biological contaminants.

It is also important that candidates actually behave in a safe manner, model ethical and safe behavior, and ensure that students behave safely at all times. They must give proper safety instruction and cautions, and must label materials and equipment in such a way as to maintain safety.

In addition to safety concerns, candidates who may keep or use animals in the classroom or field should be knowledgeable of their care. They should know and comply with laws and professional standards for classroom treatment of animals and should be aware of regulations controlling the use of sentient, usually vertebrate, animals. They should be able to properly maintain the environment of the animals and dispose of wastes, respond to the illness of the animals and ensure that they have the food, water, space, shelter and care needed for their well-being.

Where candidates may use viruses, microorganisms, or other living things potentially harmful to students, candidates should know how to clean up the classroom and dispose of materials in order to maintain safety for students and anyone who may encounter such materials. Chemical hazards or biohazards must be dealt with according to rules and regulations that apply to all laboratories.

Candidates should know and respect restrictions on collecting and using plants and animals, or parts of plants and animals, from the wild. They should be aware of the potential hazards of common plants as well as animals.

Finally, they should know the common emergency precautions, responses, and reporting procedures that they are to follow in the event problems arise.

Both knowledge and behaviors are essential components in demonstrating that this standard is met. Safety readings, tests, artifacts, projects, classroom safety evaluations, and so forth may be used to demonstrate knowledge and attention to safety matters. Reviews of regulations related to the collection and use of living things and general guidelines for safety and use of living things may also contribute to evidence of preparation. Actual performance in the classroom might be demonstrated by completion of a safety and ethical behaviors rubric or checklist by cooperating teachers.

Standard 10: Professional Growth

Teachers of science strive continuously to grow and change, personally and professionally, to meet the diverse needs of their students, school, community, and profession. They have a desire and disposition for growth and betterment. To show their disposition for growth, teachers of science must demonstrate that they:

a. Engage actively and continuously in opportunities for professional learning and leadership that reach beyond minimum job requirements.

b. Reflect constantly upon their teaching and identify ways and means through which they may grow professionally.

c. Use information from students, supervisors, colleagues and others to improve their teaching and facilitate their professional growth.

d. Interact effectively with colleagues, parents, and students; mentor new colleagues; and foster positive relationships with the community.

Discussion

Teaching becomes a profession when teachers practice with a common knowledge base and apply their knowledge to effective practice (Wise & Leibbrand, 1993). Professional teachers must be capable of profound reflection on practice, competent to enter into dialogue of the practice they know and the theory or literature they read; able to engage in . . . interpretation and critique with colleagues and with children; and able to observe, document, and analyze their own practice and experience, and take that analysis into the white-hot cauldron of public forums and public accountability” (Socketed, 1996, p.26).

To be truly professional, technical competencies must be linked to a set of professional virtues (Sergiovanni, 1992) among which is a commitment to growth and
improvement characterized by efforts to move toward exemplary practice. Such commitment may be demonstrated through efforts to stay abreast of the latest research in practice, examination of one’s own teaching, experimentation with new approaches, and the sharing insights with other teachers. This in turn requires numerous opportunities to develop the skills of reflection in the context of real life experiences. (Roychoudhury, Roth & Ebbing, 1993).

A commitment to excellence based on the needs of others as well as one’s self is crucial. At the heart of this commitment is a willingness to trust others, behave ethically and collegially, and share with a community of learners. Mann (1995) found that teachers can be their own best resource for improvement when their ideas are trusted and supported.

Intrinsic, as opposed to extrinsic rewards are powerful motivators (Lortie, 1975) thus programs must takes steps to help candidates reflect upon their teaching and find ways they can grow professionally that will add value to their sense of self. Many studies affirm the central role of intrinsic motivation in facilitating professional development (Bookhart & Freeman, 1992; Espinet, Simmons & Atwater, 1992; Green & Weaver, 1992; Rogers, Bond, & Nottingham, 1997; Serow, 1994).

Applications in Programs

Programs must help candidates enter the professional community as science educators. Science teaching is a composite profession requiring knowledge and skills in both science and education. Ideally, these skills come together in the preparation program. Associations and activities related to science teaching are abundant. Participation in such activities at the local, state and national levels should be encouraged, some being required. They are a resource for improving one’s teaching, but also they provide the opportunity for constructive interaction with others in the same field. Teacher preparation programs should keep records of such activity so that they may then try to increase the activity of their candidates year by year.

The best teachers tend to be goal-focused, but flexible and reflective. These characteristics allow them to relate to students and to modify and improve their practices. Candidates in teacher preparation programs must demonstrate the ability to reflect, but also to respond positively to constructive feedback from others. Few teacher educators are unfamiliar with candidates who enter their programs with preset ideas that they refuse to change, even when students do not respond well to them. It is imperative that such individuals not be allowed to continue on into teaching.

The ability to get along with others is crucial in education, certainly with students, but also with other stakeholders such as teachers, administrators, support staff and parents. Dispositional factors can be assessed through the behaviors of candidates; candidates should be held accountable for behaviors that are contrary to the expectations of the profession as determined by the faculty and reflected in these standards. Carefully constructed criteria are needed and may be used as a source of data for candidate preparation and practice by the program.

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## Appendix F

### Tables Used For NCATE Program Review

#### Content Analysis for Secondary Science

Instructions for Preparing for Your Review

Tables provided below include, in the left column, the 2003 NSTA subject matter for each science discipline. With licensure requirements varying from state to state, the requirements for each discipline were delineated and placed in separate tables, to include:

- Competency requirements for all secondary teachers;
- Core competencies required of all teachers in a discipline (biology, chemistry, etc.);
- Advanced competencies required of specialists in a given discipline; and
- Supporting competencies for each discipline in the other sciences and mathematics.

Include the tables relevant to your licensure area. Use this table to decide on that mix.

<table>
<thead>
<tr>
<th>If the preparation program:</th>
<th>Then the candidates must demonstrate:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepares a teacher to teach composite courses such as physical science or general science at or above the middle school/junior high level</td>
<td>✓ Competency Requirements for All Science Teachers, and&lt;br&gt; ✓ Core competencies in the disciplines comprising the composite course (Table A in Bio, Chem, Phys, E/Sp), and&lt;br&gt; ✓ Composite of the supporting competencies in the disciplines (Table C in Bio, Chem, Phys, E/Sp).</td>
</tr>
<tr>
<td>Prepares a teacher in a single field (often a major) with or without a supporting second teaching field (a teaching minor). This is a single field program.</td>
<td>✓ Competency Requirements for All Science Teachers, and&lt;br&gt; ✓ Core (Table A in Bio, Chem, Phys, or E/Sp)) and advanced competencies (Table B in Bio, Chem, Phys, E/Sp) in the primary discipline, and&lt;br&gt; ✓ Core competencies in the second discipline (Table A in Bio, Chem, Phys, or E/Sp), and&lt;br&gt; ✓ Supporting competencies in the specific discipline (Table C in Bio, Chem, Phys, or E/Sp).</td>
</tr>
<tr>
<td>Prepares a teacher about equally in two teaching disciplines, usually with less than a major in each. This is a dual field program.</td>
<td>✓ Competency Requirements for All Science Teachers, and&lt;br&gt; ✓ Core (two from Table A in Bio, Chem, Phys, E/Sp) and advanced competencies (two from Table B Bio, Chem, Phys, E/Sp) in both primary disciplines, and&lt;br&gt; ✓ Supporting competencies in both disciplines (two from Bio, Chem, Phys, E/Sp).</td>
</tr>
<tr>
<td>Prepares a teacher at once to teach in three or four disciplines with licensure in each individual discipline. This is a broad field program.</td>
<td>✓ Competency Requirements for All Science Teachers and&lt;br&gt; ✓ Advanced competencies (Table A in Bio, Chem, Phys, E/Sp) in one discipline and&lt;br&gt; ✓ Core competencies (Table B Bio, Chem, Phys, E/Sp) in all disciplines and&lt;br&gt; ✓ Supporting competencies in the all disciplines (Table C Bio, Chem, Phys, and E/Sp).</td>
</tr>
</tbody>
</table>
For each program, the program level, licensure track, and the nature of preparation are at the top of the page. For example, “Masters secondary single field program in biology with possible minors in chemistry, physics, or earth/space science.” Report your requirements in the most efficient way. For example, if all of the teaching minors are the same regardless of the major they are paired with, report them only once.

Your program does not have to be aligned completely with the standards, at least initially. A 90% alignment between the NSTA content standards and program coursework is expected within teach content table.

Instructions for Completing the Forms
For each program, complete the curriculum evaluation as follows:

- If your institution prescribes the coursework in science for each teaching major and minor, as is the case in most undergraduate programs, enter in column B the numbers and titles of the required courses that address the subject matter identified in column A. Include outlines of your course requirements in the appendix as well (i.e., advising sheets).
- If you accept candidates with science coursework taken elsewhere, enter in Column C and state the advising requirement that ensures that candidates have studied the subject matter content in column A. Include your advising sheets in the appendix.
- If most of the science content is covered by advising, but some content (such as unifying concepts) is covered by specific courses taught in the program, enter the number and title of the course(s) where it is taught in column C.
- If you have candidates in both preparation categories, use both of the columns, B and C.
- DO NOT provide syllabi. Include brief content descriptions for courses ONLY when the course titles are not reasonably descriptive of the content. (“Ecology” is reasonably descriptive, while “Introduction to Biology” is not descriptive). Be sure to refer reviewers to the descriptor.
- Note that the same courses or advising requirements may appear multiple times in these tables.
- If you do not have a requirement that covers a particular topic, simply enter “not covered.” Do not leave the space blank unless you are not using one or the other of the columns. Don’t enter anything into a space in a column not being used. To be safe, if it may be wise to enter a tag like “Not Relevant to Our Program” in the first box of an unused column.

NOTE: Science content may be in science courses or in education courses

Special instructions:
Secondary Physical Science is usually a composite of two disciplines (chemistry and physics) but sometimes also includes earth/space sciences. General science usually includes all four traditional subject area disciplines.

Preparation of elementary science specialists or middle school teachers science teachers (following National Middle School Association recommendations) should follow the specific recommendations outlined on the Elementary/Middle Level Science Content Analysis Form available from the NSTA website.

Secondary Physical Science is usually a composite of two disciplines (chemistry and physics) but sometimes also includes earth/space sciences. General science usually includes all four traditional subject area disciplines.
### Competency Requirements for All Science Teachers

**Table I: Unifying Concepts**

<table>
<thead>
<tr>
<th>A: Competency (numbers 1-5)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple ways we organize our perceptions of the world and how systems organize the studies and knowledge of science.</td>
<td></td>
</tr>
<tr>
<td>2. Nature of scientific evidence and the use of models for explanation.</td>
<td></td>
</tr>
<tr>
<td>3. Measurement as a way of knowing and organizing observations of constancy and change.</td>
<td></td>
</tr>
<tr>
<td>4. Evolution of natural systems and factors that result in evolution or equilibrium.</td>
<td></td>
</tr>
<tr>
<td>5. Interrelationships of form, function, and behaviors in living and nonliving systems.</td>
<td></td>
</tr>
</tbody>
</table>

### Science Content Requirement Analysis Tables A, B, and C for Biology

**Table A: Biology**

<table>
<thead>
<tr>
<th>A. Core Competencies (numbers 1-12)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Life processes in living systems including organization of matter and energy.</td>
<td></td>
</tr>
<tr>
<td>2. Similarities and differences among animals, plants, fungi, microorganisms, and viruses.</td>
<td></td>
</tr>
<tr>
<td>3. Principles and practices of biological classification</td>
<td></td>
</tr>
<tr>
<td>4. Theory and principles of biological evolution</td>
<td></td>
</tr>
<tr>
<td>5. Ecological systems including the interrelationships and dependencies of organisms with each other and their environments.</td>
<td></td>
</tr>
<tr>
<td>6. Population dynamics and the impact of population on its environment.</td>
<td></td>
</tr>
<tr>
<td>7. General concepts of genetics and heredity</td>
<td></td>
</tr>
<tr>
<td>8. Organizations and functions of cells and multi-cellular systems.</td>
<td></td>
</tr>
<tr>
<td>9. Behavior of organisms and their relationships to social systems.</td>
<td></td>
</tr>
<tr>
<td>10. Regulation of biological systems including homeostatic mechanisms</td>
<td></td>
</tr>
<tr>
<td>11. Fundamental processes of modeling and investigating in the biological sciences</td>
<td></td>
</tr>
<tr>
<td>12. Applications of biology in environmental quality and in personal and community health</td>
<td></td>
</tr>
</tbody>
</table>

**Table B: Biology**

<table>
<thead>
<tr>
<th>B. Advanced Competencies (numbers 13-21)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Bioenergetics including major biochemical pathways</td>
<td></td>
</tr>
<tr>
<td>14. Biochemical interactions of organisms and their environments</td>
<td></td>
</tr>
<tr>
<td>15. Molecular genetics and heredity and mechanisms of genetic modification</td>
<td></td>
</tr>
<tr>
<td>16. Molecular basis for evolutionary theory and classification</td>
<td></td>
</tr>
<tr>
<td>17. Causes, characteristics, and avoidance of viral, bacterial,</td>
<td></td>
</tr>
</tbody>
</table>
and parasitic diseases

18. Issues related to living systems such as genetic modification, uses of biotechnology, cloning, and pollution from farming.

19. Historical development and perspectives in biology including contributions of significant figures and underrepresented groups, and the evolution of theories in biology.

20. How to design, conduct, and report research in biology.


### Table C: Biology

**C. Supporting Competencies (numbers 22-25)**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.</td>
<td>Chemistry, including general chemistry and biochemistry with basic laboratory techniques.</td>
</tr>
<tr>
<td>23.</td>
<td>Physics including light, sound, optics, electricity, energy and order, magnetism, and thermodynamics.</td>
</tr>
<tr>
<td>24.</td>
<td>Earth and space sciences including energy and geochemical cycles, climate, oceans, weather, natural resources, and changes in the Earth.</td>
</tr>
<tr>
<td>25.</td>
<td>Mathematics, including probability and statistics</td>
</tr>
</tbody>
</table>

### Science Content Requirement Analysis Tables A, B, and C for Chemistry

#### Table A: Chemistry

**A. Core Competencies (numbers 1-13)**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fundamental structures of atoms and molecules</td>
</tr>
<tr>
<td>2.</td>
<td>Basic principles of ionic, covalent, and metallic bonding</td>
</tr>
<tr>
<td>3.</td>
<td>Physical and chemical properties and classification of elements including periodicity</td>
</tr>
<tr>
<td>4.</td>
<td>Chemical kinetics and thermodynamics</td>
</tr>
<tr>
<td>5.</td>
<td>Principles of electrochemistry</td>
</tr>
<tr>
<td>6.</td>
<td>Mole concept, stoichiometry, and laws of composition</td>
</tr>
<tr>
<td>7.</td>
<td>Transition elements and coordination compounds</td>
</tr>
<tr>
<td>8.</td>
<td>Acids and bases, oxidation-reduction chemistry, and solutions</td>
</tr>
<tr>
<td>9.</td>
<td>Fundamental biochemistry</td>
</tr>
<tr>
<td>10.</td>
<td>Functional and polyfunctional group chemistry</td>
</tr>
<tr>
<td>11.</td>
<td>Environmental and atmospheric chemistry</td>
</tr>
<tr>
<td>12.</td>
<td>Fundamental processes of investigating in chemistry</td>
</tr>
<tr>
<td>13.</td>
<td>Applications of chemistry in personal and community health and environmental quality</td>
</tr>
</tbody>
</table>

#### Table B: Chemistry

**B. Advanced Competencies (numbers 14-27)**

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Molecular orbital theory, aromaticity, metallic and ionic structures, and correlation to properties of matter</td>
</tr>
<tr>
<td>15.</td>
<td>Superconductors and principles of metallurgy</td>
</tr>
<tr>
<td>16.</td>
<td>Advanced concepts of chemical kinetics, and thermodynamics</td>
</tr>
<tr>
<td>17.</td>
<td>Lewis adducts and coordination compounds</td>
</tr>
<tr>
<td>18. Solutions, colloids, and colligative properties</td>
<td></td>
</tr>
<tr>
<td>19. Major biological compounds and natural products</td>
<td></td>
</tr>
<tr>
<td>20. Solvent system concepts including non-aqueous solvents</td>
<td></td>
</tr>
<tr>
<td>21. Chemical reactivity and molecular structure including electronic and steric effects</td>
<td></td>
</tr>
<tr>
<td>22. Organic synthesis and organic reaction mechanisms</td>
<td></td>
</tr>
<tr>
<td>23. Energy flow through chemical systems</td>
<td></td>
</tr>
<tr>
<td>24. Issues related to chemistry including ground water pollution, disposal of plastics, and development of alternative fuels.</td>
<td></td>
</tr>
<tr>
<td>25. Historical development and perspectives in chemistry including contributions of significant figures and underrepresented groups, and the evolution of theories in chemistry</td>
<td></td>
</tr>
<tr>
<td>26. How to design, conduct, and report research in chemistry</td>
<td></td>
</tr>
<tr>
<td>27. Applications of chemistry and chemical technology in society, business, industry, and health fields</td>
<td></td>
</tr>
</tbody>
</table>

### Table C: Chemistry

| C. Supporting Competencies (numbers 28-31) | B: Required Courses or advising requirements |
| 28. Biology, including molecular biology, bioenergetics, and ecology |
| 29. Earth science, including geochemistry, cycles of matter, and energetics of Earth systems |
| 30. Physics including energy, stellar evolution, properties and function of waves, motions and forces, electricity, and magnetism |
| 31. Mathematical and statistical concepts and skills including statistics and the use of differential equations and calculus |

### Science Content Requirement Analysis Tables A, B, and C for the Earth/Space Sciences

#### Table A: Earth/Space science

| A. Core Competencies (numbers 1-12) | B: Required Courses |
| 1. Characteristics of land, atmosphere, and ocean systems on Earth |
| 2. Properties, measurement, and classification of Earth materials |
| 3. Changes in the Earth including land formation and erosion |
| 4. Geochemical cycles including biotic and abiotic systems |
| 5. Energy flow and transformation in Earth systems |
| 6. Hydrological features of the Earth |
| 7. Patterns and changes in the atmosphere, weather, and climate |
| 8. Origin, evolution, and planetary behaviors of Earth |
| 9. Origin, evolution, and properties of the universe |
| 10. Fundamental processes of investigating in the Earth and space sciences |
| 11. Sources and limits of natural resources |
| 12. Applications of Earth and space sciences to environmental quality and to personal and community health and welfare. |

#### Table B: Earth/Space Science

<p>| B. Advanced Competencies (numbers 13-22) | B: Required Courses or |
|  |  |</p>
<table>
<thead>
<tr>
<th></th>
<th>advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.</td>
<td>Gradual and catastrophic changes in the Earth</td>
</tr>
<tr>
<td>14.</td>
<td>Oceans and their relationship to changes in atmosphere and climate.</td>
</tr>
<tr>
<td>15.</td>
<td>Hydrological cycles and problems of distribution and use of water</td>
</tr>
<tr>
<td>16.</td>
<td>Dating of the Earth and other objects in the universe</td>
</tr>
<tr>
<td>17.</td>
<td>Structures and interactions of energy and matter in the universe.</td>
</tr>
<tr>
<td>18.</td>
<td>Impact of changes in the Earth on the evolution and distribution of living things.</td>
</tr>
<tr>
<td>19.</td>
<td>Issues related to changes in Earth Systems such as global climate change, mine subsidence, and channeling of waterways.</td>
</tr>
<tr>
<td>20.</td>
<td>Historical development and perspectives, including contributions of significant figures and underrepresented groups, and the evolution of theories in the Earth and space sciences.</td>
</tr>
<tr>
<td>21.</td>
<td>How to design, conduct, and report research in the Earth and space sciences</td>
</tr>
<tr>
<td>22.</td>
<td>Applications of the Earth and space sciences and related technologies in society, business, industry, and health fields.</td>
</tr>
</tbody>
</table>

### Table C: Earth/Space Science

#### C. Supporting Competencies (numbers 23-26)

<table>
<thead>
<tr>
<th></th>
<th>B: Required Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.</td>
<td>Biology including evolution, ecology, population dynamics, and flow of energy and materials through Earth systems</td>
</tr>
<tr>
<td>24.</td>
<td>Chemistry, including broad concepts and basic laboratory techniques of inorganic and organic chemistry, physical chemistry, and biochemistry</td>
</tr>
<tr>
<td>25.</td>
<td>Physics including electricity, forces and motion, energy, magnetism, thermodynamics, optics, and sound; as well as basic quantum theory</td>
</tr>
<tr>
<td>26.</td>
<td>Mathematics, including statistics and probability</td>
</tr>
</tbody>
</table>

### Science Content Requirement Analysis Tables A, B, and C for Physics

#### Table A: Physics

<table>
<thead>
<tr>
<th>A. Core Competencies (numbers 1-11)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Energy, work, and power</td>
</tr>
<tr>
<td>2.</td>
<td>Motion, major forces, and momentum</td>
</tr>
<tr>
<td>3.</td>
<td>Newtonian physics w/engineering applications</td>
</tr>
<tr>
<td>4.</td>
<td>Conservation mass, momentum, energy, and charge</td>
</tr>
<tr>
<td>5.</td>
<td>Physical properties of matter</td>
</tr>
<tr>
<td>6.</td>
<td>Kinetic-molecular motion and atomic models</td>
</tr>
<tr>
<td>7.</td>
<td>Radioactivity, nuclear reactors, fission, and fusion</td>
</tr>
<tr>
<td>8.</td>
<td>Wave theory, sound, light, the electromagnetic spectrum and optics</td>
</tr>
<tr>
<td>9.</td>
<td>Electricity and magnetism</td>
</tr>
<tr>
<td>10.</td>
<td>Fundamental processes of investigating in physics</td>
</tr>
<tr>
<td>11.</td>
<td>Applications of physics in environmental quality and to personal and community health</td>
</tr>
</tbody>
</table>
### Table B: Physics

#### B. Advanced Competencies (numbers 12-22) 

<table>
<thead>
<tr>
<th>Number</th>
<th>Course Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.</td>
<td>Thermodynamics and energy-matter relationships</td>
</tr>
<tr>
<td>13.</td>
<td>Nuclear physics including matter-energy duality and reactivity</td>
</tr>
<tr>
<td>14.</td>
<td>Angular rotation and momentum, centripetal forces, and vector analysis</td>
</tr>
<tr>
<td>15.</td>
<td>Quantum mechanics, space-time relationships, and special relativity</td>
</tr>
<tr>
<td>16.</td>
<td>Models of nuclear and subatomic structures and behavior</td>
</tr>
<tr>
<td>17.</td>
<td>Light behavior, including wave-particle duality and models</td>
</tr>
<tr>
<td>18.</td>
<td>Electrical phenomena including electric fields, vector analysis, energy, potential, capacitance, and inductance</td>
</tr>
<tr>
<td>19.</td>
<td>Issues related to physics such as disposal of nuclear waste, light pollution, shielding communication systems and weapons development</td>
</tr>
<tr>
<td>20.</td>
<td>Historical development and cosmological perspectives in physics including contributions of significant figures and underrepresented groups, and evolution of theories in physics</td>
</tr>
<tr>
<td>21.</td>
<td>How to design, conduct, and report research in physics</td>
</tr>
<tr>
<td>22.</td>
<td>Applications of physics and engineering in society, business, industry, and health fields</td>
</tr>
</tbody>
</table>

#### B. Required Courses

<table>
<thead>
<tr>
<th>Number</th>
<th>Course Description</th>
</tr>
</thead>
</table>

### Table C: Physics

#### C. Supporting Competencies (numbers 23-26) 

<table>
<thead>
<tr>
<th>Number</th>
<th>Course Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.</td>
<td>Biology, including organization of life, bioenergetics, biomechanics, and cycles of matter</td>
</tr>
<tr>
<td>24.</td>
<td>Chemistry, including organization of matter and energy, electrochemistry, thermodynamics, and bonding</td>
</tr>
<tr>
<td>25.</td>
<td>Earth sciences or astronomy related to structure of the universe, energy, and interactions of matter</td>
</tr>
<tr>
<td>26.</td>
<td>Mathematical and statistical concepts and skills including statistics and the use of differential equations and calculus</td>
</tr>
</tbody>
</table>

#### B. Required Courses or advising requirements

<table>
<thead>
<tr>
<th>Number</th>
<th>Course Description</th>
</tr>
</thead>
</table>
Science Content Analysis Tables for Elementary Generalists, Elementary Science Specialists, or Middle School Science Teachers

Instructions
Tables provided below include, in the left column, the 2003 NSTA subject matter for the Elementary Generalists, Elementary Science Specialist or Middle School Science Teacher.

Include the tables relevant to your licensure area to be reviewed by NSTA. Use this table to decide on that mix

<table>
<thead>
<tr>
<th>If the preparation program:</th>
<th>Then the candidates must demonstrate:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepares a teacher to teach elementary level (up to middle level).</td>
<td>✓ Competency Requirements for All Teachers (A Tables in Life, Physical, Earth/Space, Interdisciplinary).</td>
</tr>
<tr>
<td>Prepares a teacher as a Science Specialist in the elementary level (up to the middle level).</td>
<td>✓ Competency Requirements for All Teachers (A Tables in Life, Physical, Earth/Space, Interdisciplinary), and ✓ Competency Requirements for Elementary Science Specialists and Middle Level Science Teachers (B Tables in Life, Physical, Earth/Space, Interdisciplinary)</td>
</tr>
<tr>
<td>Prepares a teacher to teach science in the middle level.</td>
<td>✓ Competency Requirements for All Teachers (A Tables in Life, Physical, Earth/Space, Interdisciplinary), and ✓ Competency Requirements for Elementary Science Specialists and Middle Level Science Teachers (B Tables in Life, Physical, Earth/Space, Interdisciplinary)</td>
</tr>
</tbody>
</table>

Use this table to report the alignment of course or advising requirements for elementary and middle level general science specialists. A 90% alignment between the NSTA content standards and program coursework is expected within each content table.

Report alignments for secondary science teachers on the Secondary Science Content Analysis forms available from the NSTA website.

Name of program:____________________________________________________________
(e.g.: "undergraduate middle level science ")

Instructions for Completing the Forms
For each program, complete the curriculum evaluation as follows:

• If your institution prescribes the coursework in science, enter in column B the numbers and titles of the required courses that address the subject matter identified in column A. Include advising sheets of your course requirements in the appendix as well.
• If you accept candidates with science coursework taken elsewhere, enter in Column C and state the advising requirement that ensures candidates have studied the subject matter content in column A. Include your advising sheets in the appendix.
• If most of the science content is covered by advising, but some content (such as unifying concepts) is covered by specific courses taught in the program, enter the number and title of the course(s) where it is taught in column C.
• If you have candidates in both preparation categories, use both of the columns, B and C.
• DO NOT provide syllabi. Include brief content descriptions for courses ONLY when the course titles are not reasonably descriptive of the content. ("Ecology" is reasonably descriptive, while “Middle school science” is not descriptive). Be sure to refer reviewers to the descriptor.
• Note that the same courses or advising requirements may appear multiple times in these tables.
• If you do not have a requirement that covers a particular topic, simply enter “not covered.” Do not leave the space blank unless you are not using one or the other of the columns. Don’t enter anything into a space in a column not being used. To be safe, if it may be wise to enter a tag like “Not Relevant to Our Program” in the first box of an unused column.

NOTE: Science content may be in science courses or in education courses
Table A: Competency Requirements for All Teachers: Unifying Concepts

<table>
<thead>
<tr>
<th>A: Competency (numbers 1-5)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple ways we organize our perceptions of the world and how systems organize the studies and knowledge of science.</td>
<td></td>
</tr>
<tr>
<td>2. Nature of scientific evidence and the use of models for explanation.</td>
<td></td>
</tr>
<tr>
<td>3. Measurement as a way of knowing and organizing observations of constancy and change.</td>
<td></td>
</tr>
<tr>
<td>4. Evolution of natural systems and factors that result in evolution or equilibrium.</td>
<td></td>
</tr>
<tr>
<td>5. Interrelationships of form, function, and behaviors in living and nonliving systems.</td>
<td></td>
</tr>
</tbody>
</table>

Table A: Life Science Competency Requirements for All Teachers

<table>
<thead>
<tr>
<th>A: Competency (numbers 1-8)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Life Science standards for all areas on form</td>
<td></td>
</tr>
<tr>
<td>2. Features distinguishing living from nonliving systems.</td>
<td></td>
</tr>
<tr>
<td>3. Characteristics distinguishing plants, animals, and other living things.</td>
<td></td>
</tr>
<tr>
<td>4. Multiple ways to order and classify living things.</td>
<td></td>
</tr>
<tr>
<td>5. Ways organisms function and depend on their environments</td>
<td></td>
</tr>
<tr>
<td>6. Ways organisms are interdependent.</td>
<td></td>
</tr>
<tr>
<td>7. Reproductive patterns and life cycles of common organisms.</td>
<td></td>
</tr>
<tr>
<td>8. Growth, change, and interactions of populations to form communities.</td>
<td></td>
</tr>
</tbody>
</table>

Table B: Life Science Competency Requirements for Elementary Science Specialists and Middle Level Science Teachers

<table>
<thead>
<tr>
<th>A: Competency (numbers 9-17)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Factors governing the structures, functions, and behaviors of living systems.</td>
<td></td>
</tr>
<tr>
<td>10. Multiple systems of classification of organisms.</td>
<td></td>
</tr>
<tr>
<td>11. Cycles of matter, and flow of energy, through living and nonliving pathways.</td>
<td></td>
</tr>
<tr>
<td>12. Natural selection, adaptation, diversity, and speciation.</td>
<td></td>
</tr>
<tr>
<td>13. Structure, function, and reproduction of cells, including microorganisms.</td>
<td></td>
</tr>
<tr>
<td>14. Levels of organization from cells to biomes.</td>
<td></td>
</tr>
<tr>
<td>15. Reproduction and heredity, including human reproduction and contraception.</td>
<td></td>
</tr>
<tr>
<td>16. Behavior of living systems and the role of feedback in their regulation.</td>
<td></td>
</tr>
<tr>
<td>17. Hazards related to living things including allergies, poisons, disease, and aggression.</td>
<td></td>
</tr>
</tbody>
</table>

Table A: Physical Sciences Competency Requirements for All Teachers

<table>
<thead>
<tr>
<th>A: Competency (numbers 1-8)</th>
<th>B: Required Courses or advising requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Properties of matter such as mass, solubility, and density.</td>
<td></td>
</tr>
</tbody>
</table>
2. Combinations of matter to form solutions, mixtures, and compounds with different properties.

3. Variations in the physical and chemical states of matter and changes among states.

4. Ordering and classification of matter and energy and their behaviors.

5. Factors affecting the position, motion and behavior of objects.

6. Properties of simple machines and tools, such as levers and screws.


8. Types of energy, energy sources, and simple transformations of energy.

<table>
<thead>
<tr>
<th>Table B: Physical Sciences Competency Requirements for Elementary Science Specialists and Middle Level Science Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: Competency (numbers 9-18)</strong></td>
</tr>
<tr>
<td>9. Properties and applications of sound, light, magnetism, and electricity.</td>
</tr>
<tr>
<td>10. Potential and kinetic energies and concepts of work.</td>
</tr>
<tr>
<td>11. Energy flow in physical and chemical systems, including simple machines</td>
</tr>
<tr>
<td>12. States of matter and bonding in relation to molecular behavior and energy.</td>
</tr>
<tr>
<td>14. Classifications of elements and compounds.</td>
</tr>
<tr>
<td>15. Solvents (especially water) and solutions.</td>
</tr>
<tr>
<td>18. Chemical, electrical and radiation hazards.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table A: Earth and Space Sciences Competency Requirements for All Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: Competency (numbers 1-6)</strong></td>
</tr>
<tr>
<td>1. Natural objects in the sky and why they change in position and appearance.</td>
</tr>
<tr>
<td>2. Causes of the seasons and seasonal changes.</td>
</tr>
<tr>
<td>3. Changes in the atmosphere resulting in weather and climate.</td>
</tr>
<tr>
<td>5. Basic properties of rocks, minerals, water, air, and energy.</td>
</tr>
<tr>
<td>6. Differences between renewable and nonrenewable natural resources.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table B: Earth and Space Sciences Competency Requirements for Elementary Science Specialists and Middle Level Science Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: Competency (numbers 7-15)</strong></td>
</tr>
<tr>
<td>7. Structures of objects and systems in space.</td>
</tr>
<tr>
<td>8. Earth’s structure, evolution, history, and place in the solar system.</td>
</tr>
</tbody>
</table>
10. Characteristics of the atmosphere including weather and climate.

11. Changes in the Earth caused by chemical, physical, and biological forces.

12. Causes and occurrences of hazards such as tornados, hurricanes, and earthquakes.

13. Characteristics and importance of cycles of matter such as oxygen, carbon, and nitrogen.

14. Characteristics of renewable and nonrenewable natural resources and implications for their use.

15. Interactions among populations, resources, and environments.

<table>
<thead>
<tr>
<th>Table A: Interdisciplinary Perspectives Competency Requirements for All Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Competency (numbers 1-4)</td>
</tr>
<tr>
<td>B: Required Courses or advising requirements</td>
</tr>
<tr>
<td>1. Differences between science, as investigation, and technology as design.</td>
</tr>
<tr>
<td>2. Impact of science and technology on themselves and their community, and on personal and community health.</td>
</tr>
<tr>
<td>3. How to use observation, experimentation, data collection, and inference to test ideas and construct concepts scientifically.</td>
</tr>
<tr>
<td>4. How to use metric measurement and mathematics for estimating and calculating, collecting and transforming data, modeling, and presenting results.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table B: Interdisciplinary Perspectives Competency Requirements for Elementary Science Specialists and Middle Level Science Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Competency (numbers 5-10)</td>
</tr>
<tr>
<td>B: Required Courses or advising requirements</td>
</tr>
<tr>
<td>5. Interrelationships of pure and applied sciences, and technology.</td>
</tr>
<tr>
<td>6. Applications of science to local and regional problems and the relationship of science to one’s personal health, well-being, and safety.</td>
</tr>
<tr>
<td>7. Historical development and perspectives on science including contributions of underrepresented groups and the evolution of major ideas and theories.</td>
</tr>
<tr>
<td>8. Applications of science to the investigation of individual and community problems.</td>
</tr>
<tr>
<td>9. Use of technological tools in science, including calculators and computers.</td>
</tr>
<tr>
<td>10. Applications of basic statistics and statistical interpretation to the analysis of data.</td>
</tr>
</tbody>
</table>
## Appendix G

### Summary of Science Content in Secondary Teacher Preparation Programs

1. **Biology**

**University of Rhode Island**

- Introductory Biology: BIO 101-102
- Microbiology: MIC 211
- Ecology: BIO 262
- Genetics: BIO 352
- Human, plant or animal physiology or cell biology
- Botany: one course
- Anatomy: one course (or other choices)
- General Chemistry: one year
- Organic Chemistry: one semester
- Physics or earth science: one semester
- Math: one semester
- History/philosophy of science: Recommended
- Science and society: Recommended
- Computer course: Recommended

**Rhode Island College**

- Introductory Biology: BIO 111-112
- Microbiology: BIO 348
- Ecology: BIO 318
- Genetics: BIO 221
- Human Physiology: BIO 335
- Advanced Biology (choice of Botany, Anatomy, Invertebrate Zoology, Developmental): BIO 353, BIO 354, BIO 329, BIO321, BIO 300
- Cell and molecular biology: BIO 320
- Problems in Biology (Research): BIO 491
- Senior Seminar in Biology
- General chemistry: Chem 103-104 (2 semesters, with lab)
- Organic chemistry: Chem 205-206 (2 semesters, with lab)
- Physics: Physics 101 (1 semester, with lab)
- Math: Pre-calculus and statistics
- Earth Science: PSCI 212
- History/philosophy of science: PSCI 357
- Science and society: PSCI 357
Brown University

[The student] must have taken eight (8) biology courses, which should include work in botany, zoology, physiology, genetics, and ecology. *(From Brown University Catalog)*

Roger Williams University

Undergraduates participating in the teacher education program must complete the requirements for a specific academic major, the University Core Curriculum, and either the Elementary or Secondary Education course sequence. After Education students have applied and been accepted to the teacher education program, they may choose any Core Concentration. Students currently earning an undergraduate degree may enroll in the program as an Education major, but must choose another major from the Roger Williams University Program of Studies. The double major requirement is for undergraduates in both the Elementary and Secondary teacher education programs. Elementary undergraduates earn teacher certification in grades 1-6. Secondary undergraduates may enroll and earn teacher certification in grades 7-12 in one or more of the following areas: English, History, Social Studies, Mathematics, Biology, General Science, Foreign Languages or Chemistry. *(From Roger Williams University Catalog)*

Salve Regina University

Eligibility for Rhode Island Secondary Teaching Certification is dependent upon three criteria: the successful completion of an academic major in one of the approved areas below; the successful completion of the secondary education curriculum; and the completion of required state testing. This certification is valid for teaching in grades 7-12. The Secondary Education Program is approved by the Rhode Island Department of Education in the following academic areas: Biology, English, French, History, Mathematics, Spanish, Theatre Arts, and Music. By virtue of the Interstate Certification Contract, students who are eligible for Rhode Island initial certification are also eligible for initial certification in some forty-five states, the District of Columbia, and Guam. Some states require additional testing. Students who seek initial certification in states other than Rhode Island should consult those State Departments of Education for their specific certification requirements. *(From Salve Regina University Catalog)*

Providence College

Students preparing for the teaching profession must complete a subject area major in addition to the teacher preparation program.

2. Physics

University of Rhode Island

<table>
<thead>
<tr>
<th>Course</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary Physics I and lab</td>
<td>PHY 203/273</td>
</tr>
<tr>
<td>Elementary Physics II and lab</td>
<td>PHY 204/274</td>
</tr>
<tr>
<td>Elementary Physics III and lab</td>
<td>PHY 205/275</td>
</tr>
<tr>
<td>Modern Physics</td>
<td>PHY 306</td>
</tr>
<tr>
<td>Mechanics</td>
<td>PHY 322</td>
</tr>
<tr>
<td>Electricity and magnetism</td>
<td>PHY 331</td>
</tr>
<tr>
<td>Optics</td>
<td>PHY 334</td>
</tr>
<tr>
<td>Advanced Lab (6 Cr)</td>
<td>PHY 381/382</td>
</tr>
<tr>
<td>Seminar in Physics</td>
<td>PHY 401</td>
</tr>
<tr>
<td>Introduction to Quantum Mechanics</td>
<td>PHY 451</td>
</tr>
<tr>
<td>Math</td>
<td>calculus through differential equations</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1 semester required; 1 year recommended</td>
</tr>
</tbody>
</table>
Earth Science/ Biology/ Astronomy
History/philosophy of science
Science and society
Computer course
one course
recommended
recommended
recommended

Rhode Island College

Mechanics with lab
Electricity and Magnetism with lab
Thermodynamics, Waves and Optics with lab
Atomic and Nuclear Physics with lab
Intermediate Mechanics
Advanced Electricity and Magnetism
Senior Lab (3 Cr)
Research in Physics
Quantum Mechanics
Calculus 1, 2, 3
Differential Equations
General Chemistry with Lab
Introduction to Geology with Lab
Introductory Biology with Lab
Historical & Contemporary Contexts of Science
PHYS 200
PHYS 201
PHYS 202
PHY 303
PHY 403
PHY 401
PHY 413
PHY 491
PHY 407
MATH 212, 313, 314
MATH 416
CHEM 103-104
PSCI 212
BIOL 111
PSCI 467

3. Chemistry

University of Rhode Island

General Chemistry I and lab
General Chemistry II and lab
Quantitative Analysis
Organic Chemistry I, II and lab
Physical Chemistry and lab
Physical Chemistry II
Introductory Biochemistry
Elective
Intermediate Calculus with Analytic Geometry
Elementary Physics I and Lab
Elementary Physics II and Lab
Elementary Physics III and Lab
Forensic Chemistry Seminar
BCH 311 or CHM 441
CHM 300 +
MTH 142
PHY 203, 273
PHY 204, 274
PHY 205, 275 +
CHM 391
Additional Science (16 Hrs) including 2 of Biology, Physics, or Earth Science

Rhode Island College

General Chemistry I and II, with lab
Analytical Chemistry with lab
CHEM 103 and 104
CHEM 404
Organic Chemistry with lab (2 semesters)  CHEM 205-206
Physical Chemistry I with lab  CHEM 405, 407
Physical Chemistry II with lab  CHEM 406, 408
Biochemistry  CHEM 410
Research in Chemistry  CHEM 491
Calculus I-3  MATH 212, 313, 314
Mechanics with lab  PHYS 200
Electricity & Magnetism with lab  PHYS 201
Introductory Biology with lab  BIOL 111
Introduction to Geology with lab  PSCI 212
Historical & Contemporary Contexts of Science  PHY 467

Providence College

See above.

4. General Science

University of Rhode Island

Principles of Biology I  BIO 101
Principles of Biology II  BIO 102
General Chemistry and Lab  CHM 101, 102
General Chemistry II and Lab  CHM 112, 114
General Physics and Lab  PHY 111-185
General Physics II and Lab  PHY 112-186
Two of:
  Introductory Astronomy  AST 108
  Environmental Geology  GEO 100
  Physical Geology and Lab  GEO 103,106
  General Oceanography  OCG 401
Two additional science courses numbered over 300
Mathematics – one course is required, two are recommended
History/philosophy of science  recommended
Science and society  recommended
Computer course  recommended

Rhode Island College

General Chemistry I with lab  CHEM 103
General Chemistry II with lab  CHEM 104
Introductory Biology I with lab  BIOL 111
Introductory Biology II with lab  BIOL 112
General Physics I with lab  PHYS 101

73
General Physics II with lab
Geology with lab
Oceanography with lab
Historical & Contemporary Contexts of Science
Research (1 Credit)

PHYS 102
PSCI 212
PSCI 217
PSCI 357
CHEM, BIOL, PHYS or PSCI 491

3 Courses at the 300- to 400-level or above, two in same discipline as research

Precalculus
Calculus I
Statistical Methods I

MATH 209
MATH 212
MATH 240
Summary of Science Content in Elementary Teacher Preparation Programs

Elementary Science Generalists Each of the institutions has requirements for science and science methods in all elementary teacher preparation programs. The requirements are listed below.

Elementary Science Specialists Most institutions require a content major as well as the elementary education major or program. These majors can come from among the sciences.

University of Rhode Island
Two science courses in different disciplines, on of which must be a lab science
EDC 457 – Science Methods
Elementary Education students must select a major in the College of Arts and Sciences in addition to the major in Elementary Education and must fulfill the Basic Liberal Studies requirements of the College of Arts and Sciences.

Rhode Island College
PSCI 103 – Physical Science with Lab
BIOL 109 – Fundamental Concepts of Biology with Lab
ELED 437 – Teaching Elementary School Science
Specialists: In addition to the Arts and Sciences majors in biology, chemistry, or physics, students may elect a specific elementary education general science content major that is described below:

Introductory Biology
General, Organic, and Biochemistry I
Introduction to Geology
Historical & Contemporary Contexts of Science
General Physics I
Research

One course from
Introductory Biology II
General, Organic, and Biochemistry II
Astronomy
Meteorology
Oceanography
General Physics II

Two Courses from
BIOL 318, 321, 324, 329, 353, 354
CHEM 404
PSCI 340

(Students electing this content major do not take BIOL 109 and PSCI 103)

Roger Williams University
Science and Mathematics Core requirement – 4 credits
EDU 341 Science and Technology in the Elementary School

Salve Regina University
General Education Science requirement – 6 credits
EDC323: Teaching Mathematics and Science in the Elementary School (6 credits)

Providence College
EDU 270 Teaching Science and Mathematics in Elementary School
EDU 270L Teaching Science and Mathematics – Field Experience
NSC (2) Natural Science Requirements (2 courses) Students in elementary/special education are required to take at least one semester of a biological science and one semester of an earth/physical science.
Appendix H

RHODE ISLAND

REQUIREMENTS FOR THE SECONDARY TEACHING CERTIFICATE

The Secondary Teaching Certificate is valid for teaching a special content area in grades seven through twelve in a junior/senior high school.

I. Certificate of Eligibility for Employment (CEE) – valid for three (3) years

The initial certificate in Rhode Island for all areas of certification is a CEE. The CEE is used to seek regular employment in the schools of Rhode Island for the field identified on the CEE. The CEE is also valid for service as a substitute teacher. If regular employment is not secured in the three (3) year period, the CEE can be renewed every three (3) years (SEE NOTE ONE) until regular employment is secured. To be issued a CEE in secondary education an individual needs to satisfy all of the following:

- Bachelor’s Degree from an accredited or an approved institution of higher education as defined in these regulations
- Graduate of an approved program for the preparation of secondary education school teachers within the previous five (5) years from the date of application. Applicants who have not completed an approved program can be certified by transcript analysis by presenting evidence of six (6) semester hours of student teaching (SEE NOTE TWO) in the secondary grades and not less than eighteen (18) semester hours of course work to include work in each of the following areas: Adolescent Psychology, Secondary Methods, Measurements and Evaluation, Identification of and Service to Special Needs Students, Teaching of Reading in the Content Area, and Foundations of Education.
- Applicants who have not previously been certified in the State of Rhode Island must achieve a score of at least 167 on the Principles of Learning and Teaching Test, 7-12 prior to being certified.

II. ACADEMIC REQUIREMENTS: 1 SEMESTER HOURS

<table>
<thead>
<tr>
<th>Course</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>36</td>
</tr>
<tr>
<td>Business Education</td>
<td></td>
</tr>
<tr>
<td>Secretarial Business</td>
<td>36</td>
</tr>
<tr>
<td>Social Business</td>
<td>36</td>
</tr>
<tr>
<td>English</td>
<td>30</td>
</tr>
<tr>
<td>History</td>
<td>30*</td>
</tr>
<tr>
<td>Mathematics</td>
<td>30</td>
</tr>
<tr>
<td>Science</td>
<td>30*</td>
</tr>
<tr>
<td>a. General Science</td>
<td>30</td>
</tr>
<tr>
<td>b. Biology</td>
<td>30</td>
</tr>
<tr>
<td>c. Chemistry</td>
<td>30</td>
</tr>
<tr>
<td>Science (Must include at least 6 semester hours each)</td>
<td>30</td>
</tr>
<tr>
<td>Biology (as otherwise prescribed by law)</td>
<td>30</td>
</tr>
<tr>
<td>Chemistry</td>
<td>30</td>
</tr>
</tbody>
</table>
d. Physics........................................... 30
*Certified science teachers, having earned initial certification with 30 credits, are entitled to additional science certification with 24 semester hours in an area of science.

8. Social Studies............................................................ 36*
*The issuance of a social studies certificate requires 24 semester hours in history as required for a history certificate. The social studies certificate is valid for the teaching of history and will be endorsed to teach any academic area in which an individual has completed six semester hours. Academic areas include anthropology, economics, geography, political science, and sociology.

9. Academic Areas not listed above............................... 18*
*A teaching certificate will be issued in any academic area not listed above provided the candidate has met all requirements listed under parts A and C of Section I and has 18 semester hours of credit in the academic area for which certification is sought.

II. PROFESSIONAL CERTIFICATE: valid for five (5) years.

• The professional certificate is issued to individuals who secure regular employment in the schools of Rhode Island. Upon securing regular employment in Rhode Island, the CEE is used to request a five (5) year professional certificate. When applying for a five (5) year professional certificate the applicant must submit the CEE along with documentation from the employing authority that regular employment has been secured in the certification area of the CEE. Upon securing regular employment, the educator must write and get approved a five (5) year Individual Professional Development Plan (I-Plan).

• The professional certificate may be renewed every five (5) years upon the successful completion of an (I-Plan) that has been approved by the I-Plan Review Panel. Individuals who have not served as a secondary education teacher in Rhode Island for the five (5) year period are entitled to an extension to the professional certificate (SEE NOTE THREE) at the end of each five (5) year period without the completion of an I-Plan.

NOTE ONE (1): Individuals who do not renew their CEE or Professional Certificate within six (6) months from the date of expiration may be required to complete additional requirements under new regulations to re-instate the expired certificate.

NOTE TWO (2): The student teaching requirement may be waived for an applicant who has had two or more documented years of successful teaching experience in an approved secondary setting. Certified teachers who have had two or more years of teaching experience and who seek Secondary certification may fulfill the student teaching requirement by completing a one-year supervised internship at the secondary level. After completing the necessary course work for the secondary certificate, and arranging through the local community for a one-year internship, the Superintendent of Schools may request the issuance of a one-year professional certificate. The Department of Education must approve the internship in advance and the supervisor must have at least 3 years of teaching experience. Upon successful completion of the internship, the individual will be issued a five (5) year professional certificate.

NOTE THREE (3): The five (5) year professional certificate requires the successful completion of an I-Plan every five years for renewal for individuals who have been in regular employment for the five-year term of the certificate. To be entitled to an extension of the professional certificate without the completion of an I-Plan, educators must document their employment history during the previous five (5) years. Educators holding regular employment who serve for less than 135 days during any school year are entitled to a one (1) year extension of the professional certificate for each year of service less than 135 days to complete their I-Plan. Educators who leave regular employment during the term of the professional certificate are also entitled to an extension of the professional certificate for the number of years not engaged in regular employment. Educators who return to regular employment must modify, if appropriate, the I-Plan on record and complete the five (5) year I-Plan during the remaining term of the extended certificate.

Individuals who desire to secure certification in secondary education by means of transcript evaluation will be required to submit evidence that they have completed appropriate academic course work (see Preamble for required course work in each academic area). The Certification Office will publish an updated list annually of academic content areas required for each secondary area of certification. This list of courses will take into consideration the desired distribution and appropriate level of academic course work which must be completed by individuals desiring to teach in the secondary grades.
AGRICULTURE
Within the 36 credits for Agriculture certification, the candidate must have course work in Plant Science, Animal Science, Related Mechanics and Related Economics.

SOCIAL BUSINESS
Within the 36 credits for Social Business certification, the candidate must have course work in Accounting, Marketing, Management, Business Law, Introduction to Computer Science, Word (Document) Processing, and two courses in Typewriting/Keyboarding.

SECRETARIAL BUSINESS
Within the 36 credits for Secretarial Business certification, the candidate must have course work in Accounting, Marketing, Management, Business Law, Introduction to Computer Science, Word (Document) Processing, Abbreviated Writing and Transcription, and two courses in Typewriting/Keyboarding.

ENGLISH
Within the 30 credits for English certification, the candidate must have course work in Composition, American Literature, and English Literature.

HISTORY
Within the 30 credits for History certification, the candidate must have course work in History of Western Civilization, United States History, European History, and a non-western history. Six semester hours may be included in the Social Studies areas (see Social Studies).

FOREIGN AND CLASSICAL LANGUAGES
Within the 30 credits for a Foreign Language certification, the candidate must have course work in Elementary, Intermediate and Advanced Grammar and Conversation, Literature, Culture and Civilization.

MATHEMATICS
Within the 30 credits for Mathematics certification, the candidate must have course work in the basic math areas of Algebra, Geometry, Trigonometry, and Math course work in Number Theory, History of Math, Statistics, and two courses in calculus. Course work in basic math areas may not be required for individuals who have completed 30 semester hours in Math with a sequence of higher level course work.

GENERAL SCIENCE
Within the 30 credits for General Science certification, the candidate must have course work in: Biology, Chemistry, and Physics unless otherwise qualified by law.

BIOLOGY
Within the 30 credits for Biology certification, the candidate must have course work in Botany, Zoology, Physiology, Genetics, and Ecology.

CHEMISTRY
Within the 30 credits for Chemistry certification, the candidate must have course work in General Chemistry, Inorganic Chemistry, and Organic Chemistry.

PHYSICS
Within the 30 credits for Physics certification, the candidate must have course work in General Physics and Modern Physics.

SOCIAL STUDIES
Within the 36 credits for Social Studies certification, the candidate must have 24 credits in History, as outlined previously under History. The Social Studies certificate may be endorsed to teach other areas of Social Studies by completing six (6) credits in any of the following content areas: Anthropology, Economics, Geography, Political Science, and Sociology.

Effective January 1, 2005
Appendix I

Rhode Island Certification Fee Structure
(Effective January 1, 2005)

<table>
<thead>
<tr>
<th>Service</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issuance of Certificate of Eligibility for Employment (CEE)</td>
<td>$25.00 non-refundable per certificate area</td>
</tr>
<tr>
<td>Renewal of CEE</td>
<td>$25.00 non-refundable per CEE</td>
</tr>
<tr>
<td>Issuance/Renewal of Five-Year Professional</td>
<td>$100.00 non-refundable per certificate area</td>
</tr>
<tr>
<td>Extension of Professional Certificate</td>
<td>$20.00 non-refundable per year/per certificate area</td>
</tr>
<tr>
<td>Evaluations</td>
<td>$25.00 non-refundable per certificate area</td>
</tr>
<tr>
<td>Duplicate Certificate</td>
<td>$25.00 non-refundable</td>
</tr>
<tr>
<td>Reinstatement of Five-Year Professional</td>
<td>$100.00 non-refundable per certificate area</td>
</tr>
<tr>
<td>Reinstatement of CEE (formerly Provisional or Extended Provisional)</td>
<td>$25.00 non-refundable per CEE</td>
</tr>
<tr>
<td>Substitute Permit</td>
<td>$25.00 non-refundable per permit</td>
</tr>
<tr>
<td>Special 2-Year Professional Certificate</td>
<td>$300.00 non-refundable per certificate area</td>
</tr>
<tr>
<td>Athletic Coach</td>
<td>$25.00 non-refundable per certificate</td>
</tr>
</tbody>
</table>