Minnesota Department of Education

January 26, 2010

Legislative Reference Library
645 State Office Building
100 Constitution Avenue
St. Paul, Minnesota 55155

Re: In The Matter of the Proposed Rules of the State Department of Education Relating To Science Academic Standards, *Minnesota Rules*, 3501.0800-3501.0855; Governor's Tracking #AR 518

Dear Librarian:

The Minnesota Department of Education intends to adopt rules relating to science academic standards. We published a Dual Notice in the January 19, 2010, State Register.

The Department has prepared a Statement of Need and Reasonableness. As required by Minnesota Statutes, sections 14.131 and 14.23, the Department is sending the Library an electronic copy of the Statement of Need and Reasonableness.

If you have questions, please contact me at (651) 582-8583.

Yours very truly,

Kerstin Forsythe Hahn

Kerstin Forsythe Hahn
Rulemaking Coordinator

Enclosure: Statement of Need and Reasonableness

Minnesota Department of Education

STATEMENT OF NEED AND REASONABLENESS

Proposed Rules Governing Science Academic Standards, Minnesota Rules, 3501.0800-3501.0855.

INTRODUCTION

Importance of better science education for all students

> "Science is more essential for our prosperity, our security, our health, our environment and our quality of life that it has ever been. And if there was ever a day that reminded us of our shared stake in science and research, it's today."[1]

Today, the United States is experiencing a whirlwind of technological change. This is evident when we administer the latest vaccine to prevent disease, dream about spaceflight to Mars or use instant messaging or tweeting to socialize with others. Historically speaking, some amount of technological change has always been a reality in our society. In the late 1800s, for example, new inventions appeared at a rate comparable to those created in modern times. The key difference, however, between then and now is the pace of technological change and the pervasive manner in which these changes affect almost all parts of life. The National Academy of Engineering and the National Research Council report that the pace of change today, with its social, economic and other impacts, is "as significant and far reaching as at any other time in history."[2] The rapidly changing world in which we live offers challenges and opportunities on a global scale. Today, the majority of topics that make headline news, capture political attention and become the subject of dinner-table conversations involve emerging issues and problems of science and technology. The search for new sources of energy, solutions to reverse the effects of global climate change and the design of an efficient health care system are just a few examples of the types of science and technology issues that are capturing the concern—and imagination—of many.

The quality of the science and mathematics education that citizens of the United States receive as K-12 students increasingly plays a critical role in their ability to successfully address the technologically complex issues of our current world. Scientifically proficient students are informed citizens when making personal decisions in their day-to-day lives that involve science and technology. They intelligently discuss technological issues affecting society, and thus can participate more fully in civic life. Scientifically proficient

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1 President Barack Obama, Address at the National Academy of Sciences (Apr. 27, 2009). *Available at* http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-at-the-National-Academy-of-Sciences-Annual-Meeting/.

2 Committee on Technological Literacy, National Academy of Engineering, National Research Council, *Technically Speaking: Why All Americans Need to Know More About Technology*, p. 11 (Greg Pearson & A. Thomas Young eds., 2002).

students have almost unlimited opportunities to establish careers in an ever-expanding array of challenging and rewarding technical occupations. These students are key to the country's economic productivity. The Carnegie Corporation of New York-Institute for Advanced Study describes how mathematics and science education are critically linked to success for the individual and the country as a whole:

> "The nation's capacity to innovate for economic growth and the ability of American workers to thrive in the global economy depend on a broad foundation of math and science learning, as do our hopes for preserving a vibrant democracy and the promise of social mobility for young people that lie at the heart of the American dream."[3]

Given the fast pace and far-ranging extent of technological challenges that lie ahead, the Carnegie report warns that not only must the quality of mathematics and science education improve, but participation in math and science likewise must dramatically improve. In the past it was acceptable for only *some* students to be technologically proficient. The future depends upon *all* students being proficient in mathematics and science: "The U.S. must mobilize for excellence in science and math education so that all students—not just a select few, or those fortunate enough to attend certain schools—achieve much higher levels of math and science learning."[4]

In today's world, the goal in science education is for all students to be scientifically literate. Science literacy prepares students for further education, work and citizenship by enabling them to:

- Use scientific principles and processes in making personal decisions;[5]
- Participate in discussions of scientific issues that affect society;
- Strengthen skills that are used every day, like solving problems creatively, thinking critically, working cooperatively on teams, using technology effectively, and valuing lifelong learning;
- Acquire knowledge and skills that are tightly linked to the economic productivity of our society; and
- Experience the excitement and personal fulfillment that can come from understanding and learning about the natural world.

Scientific literacy is important for all Minnesota students. It is the key to opportunity for a productive life in our rapidly changing, increasingly complex world. Using these proposed science academic standards as the key reference point, school districts will adapt their curriculum, instruction and professional development plans so that the goal of science literacy is achieved for all students.

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3 Carnegie Corporation of New York-Institute for Advanced Study Commission on Mathematics and Science Education, *The Opportunity Equation: Transforming Mathematics and Science Education for Citizenship and the Global Economy* vii (2007). *Available at* www.OpportunityEquation.org.
4 *Id.* at vii.
5 The bullets are from the National Science Education Standards, National Academies Press (NAP), Washington D.C., p. ix (1996) [hereinafter NAP, *National Science Education Standards*]. *Available at* http://www.nap.edu/openbook.php?record_id=4962.

Role of standards in high quality science education for all students

The foundation of a quality science education is rigorous academic standards. States across the nation are developing, implementing, measuring and revising K-12 academic standards. They are building the foundation of a relatively new approach to educational improvement—an approach that focuses instruction on the most important knowledge and skills of the discipline. Once these learning targets are established and understood, educators can effectively plan instruction and other educational supports to help their students. A standards-based system has implications not only for instruction, but accountability, as well. It shifts the traditional accountability focus from education *inputs* such as number of school days or credit hours to student achievement of the standards. A system that is "standards-based," therefore, shines a spotlight on the results or *outcomes* of student learning.

The promise of standards-based education is improved student achievement. Minnesota's approach to standards-based education is to set clear expectations for students at the state level—the standards—while allowing local school districts the flexibility to determine the curriculum, instructional methods, assessment tools and learning environments that will best help their students achieve those standards. The first step, then, in a standards-based education system is the development of academic standards. Standards define the learning targets. The standards identify the most important knowledge and skills of the content area without specifying particular curriculum or instruction. Put another way, the standards identify *what* must be taught (at a minimum), rather than *how* it must be taught.[6]

More specifically, standards are broad statements of the knowledge and skills that students need to master in order to be considered proficient in a content area. The state's current science academic standards were established in 2004 after several years of standards-based reform initiatives at the state and federal levels. The proposed revisions refine the state's science academic standards to better target the most important knowledge and skills in science.

Need for revised standards in science

There are several important reasons to revise the state's current science standards, including:

1. Meeting state and federal mandates;
2. Defining statewide graduation requirements;
3. Providing guidance for curriculum improvement efforts; and
4. Encouraging best practices in science education.

At the federal level, the No Child Left Behind Act requires the development and assessment of "challenging academic content standards" in subjects "including at least mathematics, reading or language arts, and (beginning in the 2005-2006 school year)

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6 This is also in accordance with statute Minn. Stat. § 120B.02.

science, which shall include the same knowledge, skills, and levels of achievement expected of all children."[7] The statewide tests known as the Minnesota Comprehensive Assessments assess student achievement of the content standards. Since the standards provide the foundation for the state's educational accountability system,[8] it is important to revise them periodically to reflect the most important knowledge and skills. The commissioner is required to review and revise state standards according to a schedule set forth in state law.[9]

State law provides other reasons for revising the standards in science. They include aligning the standards and benchmarks with the knowledge and skills needed for college and work readiness,[10] and technology and information literacy.[11] Revised standards also must "include the contributions of Minnesota American Indian tribes and communities."[12]

In addition to meeting federal and state mandates, the standards need to be revised to serve other purposes. The standards define the state's expectations of what students should know and be able to do in science. As such, the standards have implications for graduation requirements and curriculum development. First, the standards define the expectations for statewide graduation requirements. All students must earn three course credits in science, one of which must be in biology. Minn. Stat. § 120B.024 (a)(3). The standards define the content that comprises, at a minimum, the remaining two credits. For the graduating class of 2014-2015, students must earn a chemistry or physics credit, in addition to the biology credit, as part of the three-credit requirement. Minn. Stat. § 120B.023, Subd. 2(d). The standards define the content that comprises, at a minimum, the remaining one credit.

Since the standards are the basic component around which schools plan K-12 curriculum and instruction, they must be reviewed and revised on a periodic basis to ensure that they reflect current best practice research. The standards need to reflect the kinds of science content tested in national and international assessments, such as the *Trends in International Math and Science Study* (TIMSS) and the *National Assessment of Educational Progress* (NAEP), as well as the national standards documents.

Consideration also should be paid to the attributes of high-quality standards as addressed in current research, the national and international assessments and model standards documents. For example, high-quality standards typically contain equivalent "chunks" of content; that is, they are a consistent "grain size" with no standard being too big or too small. Another example of high quality standards documents are those which have fewer, more focused standards. Finally, standards should be written to clearly communicate to educators and others exactly what students need to know and be able to do.

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7 Public Law 107-110-Jan. 8, 2002 (No Child Left Behind Act of 2001), 115 STAT. 1445.

8 Minn. Stat. § 120B.30, governing statewide testing and accountability.

9 Minn. Stat. § 120B.023, Subd. 2.

10 *Id.*

11 *Id.*

12 Minn. Stat. § 120B.021, Subd. 1.

Standards should address advancements in the field of science education. These include providing flexibility in the standards so that science can be delivered within the larger context of integrated STEM (Science, Technology, Engineering and Mathematics) education. Integrated STEM education can be described as "intentionally-designed, linked learning experiences for students to apply (and/or develop) science, technology, engineering, and mathematics concepts and processes. Integrated STEM education exemplifies standards-based, best practice instruction from each domain to explore relevant, real-world questions and problems and mathematics content."[13]

Another advancement that bears consideration is the increasingly widespread recognition of the need to add engineering learning to science curricula. An effective way to do this is to incorporate engineering into state science academic standards. The core activity of engineers is engineering design—an iterative, open-ended, problem-solving method that is easily integrated into life science, physical science, earth and space science and other content areas. Available evidence recently reviewed by the National Academy of Engineering and the National Research Council suggests that "under certain circumstances, engineering education can boost learning and achievement in science and mathematics. These effects may be more significant for certain populations, particularly underrepresented minority students."[14]

Engineering education also can foster awareness of the need for engineers and the value of engineering as a career. This is important because engineering is central to technology development, and technology influences the well-being of everyone. However, research has uncovered the fact that K-12 teachers and students generally have a poor understanding of what engineers do.[15] Many adults in our country believe that engineers, as compared with scientists, "are not as responsive to societal and community concerns and are not as important in saving lives."[16] Teens and adults strongly associate engineering with mathematics and science skills, but much more rarely with creativity, rewarding work, or a positive effect on the world.[17] These findings point to the importance of giving children and youth opportunities to learn about engineers and what they do. Participation in engineering education activities can provide those opportunities.[18]

Minnesota's history with standards-based initiatives and science legislation

Minnesota's history with standards-based initiatives spans more than a decade. Public schools implemented state academic standards for the first time in 1997 when they were required to implement the state-mandated Profile of Learning. The development of the

13 Description of Integrated STEM education adopted by MDE.
14 The National Academy of Engineering (NAE) and National Research Council, *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*, p. 55, The National Academies Press (2009) [hereinafter NAE, *Engineering in K-12 Education*].
15 *Id.* at 56.
16 *Id.*
17 *Id.*
18 *Id.*

Profile standards was spurred, in part, by the Elementary and Secondary Education Act (ESEA) re-authorization that occurred in 1994. The ESEA re-authorization required the establishment of statewide academic standards in core content areas.

In 2003, the Minnesota Legislature repealed and replaced the Profile of Learning with required state academic standards in mathematics, language arts, science and social studies; required state or locally developed academic standards in the arts; and locally developed standards in vocational and technical education and world languages.[19] The legislature required these new academic standards in order to maintain Minnesota's commitment to rigorous educational expectations for all students, as well as to comply with the re-authorization of the ESEA, now widely known as the No Child Left Behind Act of 2001.[20]

In 2004, the commissioner submitted proposed standards in science and social studies to the legislature as required by the previous year's "Profile repeal legislation."[21] The legislature approved the standards proposed by the commissioner in both subjects. Full implementation of the science and social studies standards in all schools was scheduled for the 2005-2006 school year. Schools have continued to implement the 2004 science standards since that time. In addition to approving the science and social studies standards, the 2004 legislature also passed a requirement for districts to develop local standards in health and physical education.[22]

Legislation passed in 2006 requires that Minnesota's academic standards be revised to reflect an increased level of rigor that prepares students with the knowledge and skills needed for success in college and the skilled workplace. This legislation also establishes a timetable and requirements for revising state academic standards in each subject and directs the Minnesota Department of Education to revise these state academic standards.[23]

Science standards were scheduled to be revised during the 2008-2009 school year, with all schools implementing and all students satisfactorily completing the revised standards by the 2011-2012 school year. Under the revised standards, students scheduled to graduate in the 2014-2015 school year or later must satisfactorily complete a chemistry or physics credit in addition to a biology credit as part of the three science credits required for graduation.[24]

The revised standards in each required subject area must include—

- Technology and information literacy standards, and
- College and work-readiness skills and knowledge.[25]

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19 2003 Minnesota Laws, chapter 129, article 1, section 3.
20 Pub. L. 107-110 (2001).
21 2003 Minnesota Laws, chapter 129, article 1, section 3.
22 2004 Minnesota Laws, chapter 294, article 2, section 2.
23 Minn. Stat. § 120B.023, Subd. 2.
24 *Id.*
25 *Id.*

In addition to these requirements, the review and revision of required academic standards must include the contributions of Minnesota American Indian tribes and communities as they relate to the standards.[26]

Process for revising the standards

The standards revision process began with the solicitation and formation of a Science Standards Revision committee (the committee), a group consisting of K-12 science teachers; postsecondary science and/or engineering instructors and teacher educators; business and community representatives with expertise in science and/or engineering; and parents. Applications for the committee were solicited and the commissioner selected 30 committee members from the pool of applicants. Three co-chairs were named. In addition to knowledge of science content and pedagogy spanning the K-12 grade levels, educators on the committee brought expertise that included teaching students with special needs, English Language Learners, low-income students and urban and rural students. Staff from the Minnesota Department of Education facilitated the committee.

The committee worked from March 2008 through February 2009. Several members of the Committee served on the Technical Writing Team, a sub-set of the Committee charged with writing initial drafts of the revised standards. The Committee met 12 times to review feedback and provide direction to the Technical Writing Team. The Technical Writing Team met between meetings of the full Committee and revised the draft according to direction provided by the Committee.

MDE invited the public to submit suggestions for revising the standards through an online process that was completed prior to the first meeting of the Committee. The feedback was collected, sorted into categories of like suggestions, and submitted to the Committee for consideration. MDE again sought public comment following the first and second drafts of the proposed standards. Overall, it received approximately 200 comments, which the Committee categorized, reviewed and used at several points in the drafting process to guide its work.

The Committee relied on significant research in science education throughout the standards revision process. National documents that are widely respected in the fields of science and science education were used as the foundation for revising the standards. The following documents significantly influenced the development of Minnesota's 2009 science academic standards:

- *National Science Education Standards*, National Academy of Science;[27]
- *Benchmarks for Science Literacy* and accompanying documents, American

26 Minn. Stat. § 120B.021, Subd. 1.
27 *See* NAP, *National Science Education Standards, supra* note 5.

Association for the Advancement of Science Project 2061;[28]

- *Science Framework for the 2009 National Assessment of Educational Progress (NAEP),* WestEd and the Council of Chief State School Officers;[29] and
- *Standards for Technological Literacy*, International Technology Education Association.[30]

Other important documents that the Committee reviewed included *GreenPrint for Minnesota*[31] and the *Environmental Literacy Scope and Sequence*[32] published by the Minnesota Pollution Control Agency, the *Minnesota Educational Media Organization (MEMO) Standards for Information and Technology Literacy,*[33] and the *Minnesota Academic Standards in Mathematics-2007.*[34]

In order to determine the kinds of knowledge and skills that reflect college and career readiness, the committee consulted the *Report of the Postsecondary and Workforce Science Readiness Working Group*[35] sponsored by the Minnesota P-16 Education Partnership. The P-16 Education Partnership analyzed reports and test results of international significance and "benchmarked" Minnesota's standards against those in high-performing countries.[36] The committee followed many of the Report's recommendations in order to ensure that the revised standards reflect the science skills and knowledge that students need to be successful in college freshman science courses or entry level career-track positions in the highly skilled workplace. The committee also referred to model standards documents from other states including Michigan and Virginia, and the 2006 *Massachusetts Science and Technology/Engineering Curriculum*

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28 American Association for the Advancement of Science (AAAS), Project 2061, *Benchmarks for Science Literacy,* Oxford Press (1993) [hereinafter AAAS, *Benchmarks for Science Literacy*]. *Available at* http://www.project2061.org/publications/bsl/online.

29 WestEd and the Council of Chief State School Officers, *Science Framework for the 2009 National Assessment of Educational Progress (NAEP)* (September, 2008) [hereinafter WestEd, *Science Framework*]. Available *online at* http://www.nagb.org/publications/frameworks/science-09.pdf.

30 International Technology Education Association (ITEA), *Standards for Technological Literacy* (2007) [hereinafter ITEA, *Standards*]. *Available at* http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf.

31 Kennedy, Michael J. & Stromme, Denise, *GreenPrint for Minnesota: State plan for environmental education,* 3rd. edition, Minnesota Pollution Control Agency (August, 2008) [hereinafter Kennedy, et. al, *GreenPrint*]. *Available at* http://www.seek.state.mn.us/publications/p-ee5-01.pdf.

32 Minnesota Office of Environmental Assistance (MOEA)/Minnesota Pollution Control Agency, *Environmental Literacy Scope and Sequence: Providing a Systems Approach to Environmental Education in Minnesota,*(March 2002) [hereinafter MOEA, *Environmental Literacy*]. *Available online at* http://www.seek.state.mn.us/eemn_c.cfm/.

33 Minnesota Educational Media Organization (MEMO*),Recommended Standards for Information and Technology Literacy* (October, 2004) [hereinafter MEMO, *Recommended Standards*]. *Available online at* http://www.memoweb.org/htmlfiles/linkslitstandards.html.

34 *Minnesota Academic Standards in Mathematics. Available at* http://education.state.mn.us/mde/Academic_Excellence/Academic_Standards/Mathematics/index.html. These standards were adopted into law in 2008 at can be found at the Revisor of Statutes website.

35 Report of the Postsecondary and Workforce Science Readiness Working Group, Minnesota P-16 Education Partnership (August 1, 2008) [hereinafter Postsecondary and Workforce Working Group]. Accessed online on 10.12.09 at http://www.mnp16.org/.

36 Specifically, academic standards from Canada and Finland.

Framework.[37] Members reviewed information about the performance of Minnesota students on large-scale standardized assessments including the Minnesota Comprehensive Assessments (MCAs), the Trends in International Math and Science Study (TIMSS) and the National Assessment of Educational Progress (NAEP).

To assist the committee in its charge to include engineering knowledge and skills in the standards, the department arranged for a presentation by Dr. Yvonne Spicer of the National Center for Technological Literacy at the Museum of Science in Boston, Massachusetts. Dr. Spicer discussed how she and her colleagues incorporated engineering into the *Massachusetts Curriculum Framework*—the first state in the country to adopt engineering knowledge and skills into its curriculum framework.

To determine whether the committee's preliminary revisions regarding technology, engineering and environmental education were "on target," the department facilitated discussions with focus groups on July 28, 2008. Representatives from the education and business communities with specific content expertise reviewed the suggested changes and provided feedback.

The committee also met with representatives of the Postsecondary and Workforce Science Readiness Working Group sponsored by the Minnesota P-16 Education Partnership. The working group was charged by the Partnership to examine and define postsecondary and workforce science readiness in Minnesota. Its membership consisted of university and college science faculty, high school science faculty and business representatives. The group based its analysis and subsequent recommendations on a review of international, national and state science standards, key reports that received national attention, and the experience of many of its members. Recommendations outlined in the group's August 1, 2008, report were shared with the Standards Committee. These included strategies for integrating college and career readiness skills into the science standards and suggestions for other improvements.[38]

The following lists specific activities conducted by the department to solicit feedback on the standards from the general public and expert reviewers.

- The public was invited to submit feedback on the existing standards for consideration in the standards revision process.
- Focus groups composed of representatives in the fields of technology and engineering, and environmental education provided feedback on preliminary changes to the standards.
- Representatives of Minnesota's American Indian community met with department staff and committee leaders to discuss strategies for addressing the contributions of Minnesota American Indian tribes and communities in the standards.

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37 Massachusetts Department of Education, *Massachusetts Science and Technology/Engineering Curriculum Framework* (October 2006). *Available at* http://www.doe.mass.edu/frameworks/scitech/1006.pdf.
38 *See* Postsecondary and Workforce Working Group, *supra* note 35.

- The public was invited to submit online feedback regarding the first draft of the revised standards.
- The public was invited to ask questions and submit written and oral comments on the first draft at regional town hall meetings hosted by MDE Assistant Commissioners Karen Klinzing or Morgan Brown, MDE Academic Standards and P-16 Initiatives Director Beth Aune, Science Standards Committee Co-chairs Laurie Peterman, John Olson and Tom Tommet, and other department staff and committee members. The meetings were held in September 2008 in Fergus Falls, Bemidji, Rochester, Duluth, Marshall and Roseville.
- National experts in science education were contracted to review and provide detailed feedback on the second draft. The reviewers were as follows:
    - ❖ **Roger Bybee**, Director Emeritus of Biological Sciences Curriculum Study (BSCS), former director of the National Research Center's Center for Science, Mathematics and Engineering Education.
    - ❖ **Audrey Champagne**, Professor Emerita, University of Albany, SUNY. Expert in assessment and all elementary science areas. Chaired 2009 NAEP Science Issues panel.
    - ❖ **Kenneth Welty**, Professor of Technology Teacher Education, School of Education, University of Wisconsin-Stout. Co-director of the National Center for Engineering and Technology Education.
- The commissioner's office hosted small meetings on March 31 and April 3 2009 with representatives of several stakeholder groups to hear their feedback on the proposed final draft.
- The department convened a team of special education professionals to review the draft standards for items that might be biased against students with special needs.

The committee released the first draft of the revised science standards after careful consideration of the online and focus group feedback; standards from other states; national frameworks documents and national reports; recommendations from the Minnesota P-16 Science Readiness Working Group, and much discussion on specific science and education issues. A public review and comment period followed the release of the first draft, and extended from September 12 through September 28, 2008. The committee considered the feedback provided during the public comment period to prepare a second draft of the revised standards. Three nationally recognized science education experts reviewed this second draft and provided detailed feedback. The committee and MDE considered this feedback, as well as the feedback provided by a team of special education experts, when preparing the final draft of the proposed standards.

By the time the final draft of the standards was submitted to the commissioner, the Standards Committee had consulted numerous reports and standards documents and considered the concerns and suggestions of hundreds of individuals and organizations interested in the science education of Minnesota's K-12 students.

ALTERNATIVE FORMAT

Upon request, the Statement of Need and Reasonableness can be made available in an alternative format. To make a request, contact Kerstin Forsythe at the Minnesota Department of Education, 1500 Highway 36 West, Roseville, MN 55113; phone 651-582-8583. TTY users may call the Minnesota Department of Education at 651-582-8201.

STATUTORY AUTHORITY

In 2006, the legislature gave the department general rulemaking authority to revise and align the state's academic standards and high school graduation requirements in mathematics, arts, science, language arts and social studies beginning in the 2006-07 school year and continuing through the 2019-2020 school year. *See* Minn. Stat. § 120B.023, subd. 2. The department also has general rulemaking authority to adopt science academic standards under Minnesota Statutes section 120B.02.

Under these statutes, the department has the necessary statutory authority to adopt the proposed rules.

REGULATORY ANALYSIS

Minnesota Statutes section 14.131, sets out seven factors for a regulatory analysis that must be included in the SONAR. Paragraphs (1) through (7) quote these factors followed by the agency's response.

(1) A description of the classes of persons who probably will be affected by the proposed rule, including classes that will bear the costs of the proposed rule and classes that will benefit from the proposed rules.

The following classes of persons are affected by the proposed rules: Minnesota parents and students; Minnesota school districts, including charter schools; science educators; and curriculum directors. The department does not believe that there will be significant costs associated with the proposed rules, as discussed elsewhere in this SONAR; however, if there are any minimal costs they are likely to be borne by the department and by Minnesota school districts and Minnesota charter schools. The classes that will benefit from the proposed rules include parents and Minnesota students by achieving greater levels of scientific knowledge and acquiring skills necessary for success in the fields of science and engineering.

(2) The probable costs to the agency and to any other agency of the implementation and enforcement of the proposed rule and any anticipated effect on state revenues.

The proposed rules will create, at most, minimal costs for the department through the 2010-11 school year. The department is already staffed to provide training and support regarding the proposed rules and staff assignments until FY 2011. The legislature provided a one-time appropriation of $3 million to deliver regional services for mathematics and science teacher education. The department will seek to have this funding made permanent in FY 2011 and beyond and resources will be reallocated accordingly.

Other state agencies are not fiscally impacted by these proposed rules.

(3) A determination of whether there are less costly methods or less intrusive methods for achieving the purpose of the proposed rule.

Because establishing state standards in science is a legislative requirement, there is no less costly or less intrusive method for achieving the purpose of the proposed rules.

(4) A description of any alternative methods for achieving the purpose of the proposed rule that were seriously considered by the agency and the reasons why they were rejected in favor of the proposed rule.

Because rules containing state academic standards in science are a legislative requirement, there is no alternative method for achieving the purpose of the proposed rule.

(5) The probable costs of complying with the proposed rule, including the portion of the total costs that will be borne by identifiable categories of affected parties, such as separate classes of governmental units, businesses, or individuals.

School districts may face initial increased costs to implement the new rules. However, districts currently must implement science standards in Grades K-12. In addition, school districts typically undertake a six- or seven-year curriculum adoption cycle, so many of these costs would be borne regardless of the adoption into rule of statewide science academic standards.

(6) The probable costs or consequences of not adopting the proposed rule, including those costs or consequences borne by identifiable categories of affected parties, such as separate classes of government units, businesses, or individuals.

If the state does not adopt science standards, it risks the loss of federal funding. Section 1111(g)(1) of the *No Child Left Behind Act*, Pub. L. 107-110, states that for failure to meet deadlines enacted in 1994, in general,

> If a State fails to meet the deadlines established by the Improving America's Schools Act of 1994 (or under any waiver granted by the Secretary or under any compliance agreement with the Secretary) for demonstrating that the State has in place challenging academic content

> standards and student achievement standards, and a system for measuring and monitoring adequate yearly progress, the Secretary shall withhold 25 percent of the funds that would otherwise be available to the State for State administration and activities under this part in each year until the Secretary determines that the State meets those requirements.

Furthermore, section 1111(g)(2), states that for failure to meet the requirements enacted in 2001, "the Secretary may withhold funds for State administration under this part until the Secretary determines that the State has fulfilled those requirements."

(7) An assessment of any differences between the proposed rule and existing federal regulations and a specific analysis of the need for and reasonableness of each difference.

The *No Child Left Behind Act* requires states to have academic standards in mathematics, language arts or reading, and science. *No Child Left Behind Act of 2001*, Pub. L. 107-110, § 1111(b)(1)(C) (2001), codified at 20 U.S.C. § 6311(b)(1)(C). In addition, the *No Child Left Behind Act*'s definition of core academic subjects includes science. *No Child Left Behind Act,* Pub. L. 107-110, § 9101(11), (codified at 20 U.S.C. § 7801(11). Thus, by adopting into rule the state's science academic standards, the rules will be consistent with existing federal requirements.

PERFORMANCE-BASED RULES

Throughout the development of the proposed rules and this SONAR, the department made every attempt to develop rules that will be understandable to and workable for practitioners and families, ensuring efficient and effective delivery of services while achieving the best possible results for students.

ADDITIONAL NOTICE

Minnesota Statutes, sections 14.131 and 14.23 require that the SONAR contain a description of the department's efforts to provide additional notice to persons who may be affected by the proposed amendments to the rules.

In addition to mailing the proposed rules and the dual notice to all persons who have registered to be on the department's rulemaking mailing list under Minnesota Statutes section 14.14, subd. 1a, the Additional Notice Plan calls for notifying the following groups:

- Science Standards Revision Committee members;
- Minnesota Science Teachers Association;
- SciMathMN;
- Minnesota Academy of Science;
- Minnesota High Technology Association;

- Minnesota P-16 Education Partnership members;
- Minnesota Association for College Teacher Education (MACTE);
- Metro Education Service Cooperative Unit (ESCU) Science Leadership Network;
- Nexus Professional Development program;
- Minnesota Association for Supervision and Curriculum Development (Minn. ASCD);
- Minnesota Association for Environmental Education;
- Environmental Education Advisory Task Force;
- Education organizations;
- Parent and student advocacy organizations;
- Attorney lists maintained by the agency;
- Minnesota superintendents listerv, via the agency's weekly superintendent's informational email;
- Charter school directors via email lists maintained by the agency;
- School Improvement listerv;
- Minnesota Association of Colleges of Teacher Education;
- Science groups;
- Other interested parties; and
- Posting on the agency's Website.

Finally, the department will notify the Minnesota Legislature. This will include sending the proposed rules, SONAR and Dual Notice to the chairs and ranking minority members of the legislative policy and budget committees with jurisdiction over the subject matter.

CONSULT WITH FINANCE ON LOCAL GOVERNMENT IMPACT

As required by Minnesota Statutes 14.131, the department has consulted with the Commissioner of Management and Budget. On November 6, 2009, prior to the department publishing the Notice of Intent to Adopt, the documents that were sent to the Governor's office for review and approval were also sent to the Commissioner of Management and Budget. The documents included the Governor's Office Proposed Rule and SONAR Form; final proposed rules; and Statement of Need and Reasonableness. In a November XX, 2009, memorandum, the Office of Management and Budget stated that the proposed rules will not impose a significant cost on local governments.

COST OF COMPLYING FOR SMALL BUSINESS OR CITY

As required by Minnesota Statutes section 14.127, the department has considered whether the cost of complying with the proposed rules in the first year after the rules take effect will exceed $25,000 for any small business or small city. The department has determined that the cost of complying with the proposed rules in the first year after the rules take affect will not exceed $25,000 for any small business or small city.

This determination was made because the proposed rules do not affect small businesses and small cities.

LOCAL GOVERNMENT ACTION

Pursuant to Minnesota Statutes section 14.128, the department must determine if a local government will be required to adopt or amend an ordinance or other regulation to comply with a proposed agency rule. Local government means a town, county or home rule charter or statutory city. Minn. Stat. § 14.128, subd. 1. The department has determined that no local government will be required to adopt or amend an ordinance or other regulation in order to comply with these proposed rules.

This determination was made because the proposed rules do not effect any of the local governments included in the scope of § 14.128.

LIST OF WITNESSES

If these rules go to a public hearing, the department anticipates having the following witnesses testify in support of the need for and reasonableness of the rules:

1. Karen Klinzing, Assistant Commissioner, Department of Education, will testify about the need for the proposed science academic standards rules.
2. Beth Aune, Director of Standards, Department of Education, will testify about the need for the proposed science academic standards.
3. John Olson, Science Specialist, Department of Education, and co-chair of the Science Standards Revision Committee, will testify about the development of the proposed standards.
4. Laurie Peterman, co-chair of the Science Standards Revision Committee and a science teacher with the Anoka-Hennepin School District, will testify about the development of the proposed standards.

RULE-BY-RULE ANALYSIS

The proposed science academic standards can be approached, and were drafted, in two ways. First, they comprise a single document that addresses overall K-12 science education in Minnesota's schools. As such, several important factors influenced the overall development of the proposed science academic standards as an all-encompassing document. This SONAR will discuss these overall factors first, discussing the need and reasonableness of content and drafting choices that affect the proposed science academic standards as a whole document.

Second, the proposed standards also are individual standards that present learning expectations in four different science content standards in each of the 13 grade levels from kindergarten through grade 12. In the final and most lengthy sections of this Rule-by-Rule Analysis, the SONAR will discuss the specific proposed science standards language.

The standards are written as broad statements of concepts or skills that students should develop or know. Each standard is supported by one or more benchmarks, which contain additional learning expectation nuances in each grade level. Minnesota state law requires both academic standards and benchmarks for science in grades K-12, although only the standards are required to be in rule. Minn. Stat. § 120B.023, subd. 1. Academic standards describe the expectations in science that all students must satisfy to meet state requirements for credit and graduation. Benchmarks supplement the academic standards by providing details about "the academic knowledge and skills that schools must offer and students must achieve to satisfactorily complete" the standards. *See* Minn. Stat. § 120B.023, subd. 1. The benchmarks are written as learning outcomes, and are intended to both inform the implementation of the standards and to guide assessment, without being overly prescriptive, task-oriented or detailed. Many of the benchmarks include examples that clarify the meaning of the benchmark or indicate the expected level of student understanding. The examples may suggest learning activities or instructional topics. They are not intended to be directives for curriculum or a comprehensive fulfillment of the benchmarks.

Although only the standards are officially the subject of this rulemaking, the proposed standards and benchmarks are highly interdependent. They were developed together in the same discussions and drafting process, sometimes with content moving from the standard level to the benchmark level, or with benchmark content influencing the language of a proposed standard. Because of the interdependent nature between standards and benchmarks, this SONAR will refer to the benchmarks at times, to better explain how the standard is intended to be implemented or when the benchmarks play a role in those proposed changes.[39]

Resources for the Standards

MDE and the committee relied on national documents that are widely respected in the field of science and engineering as the foundation for the development of these proposed science academic standards. The following documents significantly influenced the standards development process:

1) *National Science Education Standards* (NSES), National Academy of Science (1995).[40] This document provides content standards in Inquiry, Physical Science, Life Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science. The standards from Inquiry, Science and Technology, Science in Personal and Social Perspectives and History and Nature of Science were used in writing Minnesota's Nature of Science and Engineering Strand.

2) *Benchmarks for Science Literacy* (1993) (BSL) and accompanying documents,

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40 *See* NAP, *National Science Education Standards, supra* note 5.

American Association for the Advancement of Science Project 2061.[41] The BSL provides statements of science concepts that students should learn; these statements are similar to language found in standards documents. A second document from the American Association for the Advancement of Science Project 2061, *Atlas of Science Literacy* (2001, 2007),[42] was particularly helpful. The *Atlas* maps the development of concepts between grade levels, and provides resources on thinking and misconceptions that are common among students. It provides standards in all of the major science areas addressed by the NSES and expands on ideas related to the designed world, mathematics, society and technology.

3) *2009 National Assessment of Educational Progress (NAEP) Framework.*[43] The NAEP assessment compares states by assessing a sampling of students from each state. This *Framework* document combines the ideas from the NSES, the BSL, and the *Atlas* with additional current research. It has a concise set of standards and the committee used them as a final check on Minnesota's proposed standards and benchmarks. Generally, although there are some differences between the *Framework* and Minnesota's proposed standards in terms of grade banding and statement presentations, the proposed standards align well with the *Framework.*

4) *Standards for Technological Literacy,*[44] International Technology Education Association. The committee referenced these standards when it developed the engineering substrand.

5) The *Greenprint for Minnesota*[45] and the *Environmental Literacy Scope and Sequence*[46] published by the Minnesota Pollution Control Agency served as the basis for the environmental standards found in each of the content areas.

6) The *Minnesota Educational Media Organization (MEMO) Standards for Information and Technology Literacy*[47] provided guidance for standards related to the use of educational technology and the evaluation of resources.

7) The *2007 Minnesota Academic Standards in Mathematics*[48] were used to determine the appropriate level of mathematical skills expected by the science benchmarks.

8) The *Report of the Postsecondary and Workforce Science Readiness Working Group*[49]

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41 *See* AAAS, *Benchmarks for Science Literacy, supra* note 28.
42 American Association for the Advancement of Science (AAASP), Project 20161, *Atlas of Science Literacy* (2001, 2007) [hereinafter AAASP, *Atlas*]. *Available at* http://www.project2061.org/publications/atlas/default.htm.
43 *See* WestEd, *Science Framework, supra* note 29.
44 *See* ITEA, *Standards, supra* note 30.
45 *See* Kennedy, *GreenPrint, supra* note 31.
46 *See* MOMA, *Environmental Literacy, supra* note 32.
47 *See* MEMO, *Recommended Standards, supra* note 33.
48 *See Minnesota Academic Standards in Mathematics, supra* note 34. These standards were adopted into law in 2008 and can be found at the Revisor of Statutes website.
49 *See* Postsecondary and Workforce Working Group Report, *supra* note 35.

sponsored by the Minnesota P-16 Education Partnership provided guidance for ensuring that the standards prepare students for college and career opportunities after they graduate. Recommendations in the Report reflect an analysis of standards from high performing countries, results of international assessments of science achievement, and science education reports of international significance. Among its recommendations is a call to focus standards on the "big ideas" in science and engineering.

9) The committee referred to exemplary standards documents from other states, especially Massachusetts, Virginia and Michigan, to gain ideas about possible structure or organizational schemes for the standards, and ways to address particular topics, such as engineering.

The Standards Drafting Process

The committee began the standards revision process by analyzing the degree to which Minnesota's science standards aligned with key reference documents and the expectations of the public. The Committee compared Minnesota's standards to the national science standards and model science standards from other states. The Committee also analyzed public feedback for common themes. Finally, to foster understanding of how engineering could be incorporated into the proposed science standards, MDE arranged for Dr. Yvonne Spicer, of the National Center for Technological Literacy at the Museum of Science in Boston, Massachusetts to make a present on this subject to the committee.

After the analysis and information gathering stage was complete, the committee considered the organizational framework of the standards. MDE charged the committee with including four content strands at all grade levels: 1) the nature of science and engineering, 2) physical science, 3) earth and space science, and 4) life science. The committee worked to determine the key ideas to include in each of the four content areas, and how to present the standards in the most usable, understandable format. It formed subcommittees in each of the four content areas to determine the overall goals and requirements of each strand. Based in part on early organizational work of these four subcommittees, the committee determined that maintaining organizational consistency between the four science content strands would result in a more accessible and more useful set of science standards. Thus, each of the four content strands features the same three primary content substrands and a fourth substrand focusing on human interaction with the content area.

The committee broke into its four subcommittees to develop the standards and benchmarks, emphasizing a smooth progression of learning from kindergarten through grade 12 in each content area. Although the subcommittees had different approaches to drafting the standards, generally they began by determining the science standards that Minnesota students should meet at the high school level. Then, they mapped the standards backwards to determine the prerequisite knowledge and skills students would need in earlier grades in order to be prepared for the high school standards. The subcommittees relied on the national science standards documents and other reference documents throughout the drafting process.

The technical writing team, a subset of the committee, worked between committee meetings to draft standards and benchmarks language. This work was reviewed by the whole committee. Often, standards and benchmarks were moved between strands and grade levels.

After the content strand work was completed, the committee regrouped into grade band groups of K-5, 6-8 and 9-12. Each group worked to ensure the following for its assigned band of grades: 1) a consistent level of rigor between the strands, 2) developmental appropriateness of the concepts and skills within each strand and 3) a smooth learning progression or sequence of concepts from one grade level to the next. Some standards were moved during this stage; for example, if certain grades were overloaded with science concepts in multiple content areas, standards were moved to grade levels that had fewer science concepts. In addition, some of the content area standards that originally were drafted to be achieved over a span of several grades were consolidated into a single grade. This change was based on feedback from classroom teachers who pointed out that, for some subjects, it is easier to teach to standards that require a large chunk of learning on a specific subject in one grade, rather than several smaller pieces of learning spread over several grades. The change allows teachers greater flexibility to organize their units in response to local curriculum needs, student interests and abilities, availability of instructional materials and teacher preferences. This benefit is especially significant in the K-5 grade range where, in the past, learning in the various science content areas was fragmented throughout grades K-5. To avoid fragmentation at the intermediate level, , the content strands were assigned to specific grades:

6th – Physical Science
7th – Life Science with some Physical Science
8th – Earth Science with some Physical Science

This content-focused approach allows teachers to be assigned based on their licenses and their areas of content strength. Conversely, an integrated approach would require teachers to instruct in all areas of science, including their areas of weakness.

Because of the content-based approach , the committee considered and drafted the standards holistically first from a content perspective and only secondarily from a grade level perspective. As a result, the discussion in this SONAR will be organized by content area rather than by grade level.

Grade-Specific Standards and Benchmarks

The 2009 science academic standards and benchmarks, and these proposed rules, are grade-specific at the K-8 level. They contain learning expectations tied to each specific grade level from kindergarten through grade 8. This represents a significant change from the existing standards and benchmarks. Like these proposed standards, the existing standards and benchmarks were presented at specific grade levels from kindergarten through grade 8, but schools were allowed to implement them by grade bands of K-2, 3-5, 6-8 and 9-12. The grade bands allowed individual school districts to teach the standards in the same grade levels as presented in the statewide standards, or in different grade levels within the grade band if desired, so long as all standards were mastered by the end of the grade band. With the 2009 proposed standards, school districts will be required to implement the standards at the specific grade level in which they are presented, and will not have the option of implementing the standards in different grades.

When MDE began the process of revising its science standards, it carefully reviewed the statutory requirements for academic standards. In addition to the new requirements for standards that are addressed elsewhere in this SONAR, MDE reviewed the overall statutory requirements for standards and benchmarks. Minnesota Statutes section 120B.023, subd. 1(a) requires the commissioner to

> supplement required state academic standards with ***grade-level benchmarks***. High school benchmarks may cover more than one grade. The benchmarks must implement statewide academic standards by specifying the academic knowledge and skills that schools must offer and students must achieve to satisfactorily complete a state standard.

(emphasis added). After consideration of that language, MDE determined that, in order to ensure the standards and benchmarks it develops are consistent with the governing statute, the revised benchmarks must be grade-specific. Furthermore, in order to achieve high-quality and effective grade-specific benchmarks, MDE determined that the academic standards must be implemented in a uniform, grade-specific format around the state.

MDE believes this approach not only is more consistent with the governing statute, but also will improve student learning statewide, so that all Minnesota students have equivalent access to science education. A grade-specific approach also will help to ensure that districts' curricula, at least in terms of the "big ideas," are more consistent across grade levels. This will result in a more comprehensive and seamless K-12 science education for Minnesota students.

When students learn science concepts, each new learning step builds on previously learned concepts. Without the appropriate previously learned concepts, students will have difficulty learning new science concepts. As a result, students whose classroom exposure lacks the necessary sequence of science concepts may not become successful science learners who complete high school with the scientific knowledge needed for success in college, work and life. Therefore, it is critical that the curriculum presents science concepts in a sequence that leads logically from one concept to the next. The committee used national research to design a sequence of standards that provides a progression of learning science concepts that will result in an appropriate science education for all Minnesota students.

As Minnesota school districts applied the existing standards and benchmarks in their classrooms, MDE observed much variation in the sequence of standards and topics used by different school districts. This variation was particularly evident in the middle school grades, generally grades 6 to 8, where courses in earth, life and physical sciences were taught in different grade sequences depending on each individual district's approach. For example, some districts might teach life science in grade 6, followed by earth and physical science, while others might choose to start with physical or earth science. Still other districts might teach all three subjects as integrated science throughout grades 6-8. As a result of this variation in the sequence of science learning around the state, students who transferred between schools frequently missed instruction on critical concepts, or repeated concepts that they had already learned. Due to student mobility, consistency in learning expectations between districts and schools is more important to individual student success than it has been in the past. This factor influenced MDE's decision to propose grade-specific science academic standards.

Variation in teaching sequence also may lead to poor alignment and development of concepts between grade levels as teachers make individual judgments regarding which concepts to teach at a specific grade level. The grade-specific approach eases the transition that science educators may face when moving between districts or grade levels. Furthermore, it will be easier for districts and statewide entities, such as MDE, the colleges and universities and others, to develop and apply professional development and curriculum development resources.

MDE believes that its standards and benchmarks must be designed to ensure that every student, no matter where they attend school or how mobile they are, receives a sound science education that includes all the key science concepts. This educational background will give each individual student the opportunity for success in their future career and civic life. It will benefit Minnesota employers by preparing a workforce that is ready for tomorrow's science, engineering and technology challenges. It will benefit the state by empowering a citizenry that can make important personal and community decisions in an ever-changing complex world. For all of those reasons, grade-specific standards are necessary and reasonable.

During the drafting process, a substantial number of the comments MDE received through online feedback and public forums addressed this issue. Many commenters, primarily teachers and school administrators, strongly expressed the concern that the change from a grade band flexibility approach to a requirement for grade-specific standards will place an additional burden on a significant number of Minnesota schools. These commenters stressed that moving from standards with grade band flexibility to grade-specific standards could require significant curriculum planning for many school districts as well as additional costs associated with purchasing new curriculum materials; a phase-in period to adjust courses for students already in the midst of middle school-level science courses; professional development to prepare teachers who will need to teach new science subject areas; and potential staffing changes to match the licenses of teachers to new courses.

The committee recommended a return to presenting the standards in grade bands, as demonstrated in a letter that accompanied the recommendation of the revised standards, in which the committee co-chairs stated the following:

> To provide some flexibility for districts in matching curriculum resources to the standards, it would be helpful to allow districts to move K-8 standards and benchmarks within bands of grade levels. We recommend bands of K-2, 3-5, and 6-8 to match the grade ranges of the MCA-II assessment.[50]

MDE values the needs and concerns of school districts, which have the important job of educating most students across the state of Minnesota. To do that job well, school districts must – and did – have a strong voice in the development of new academic standards, and they must have flexibility to apply those standards to their own local needs and interests. MDE also takes seriously the recommendations of its committee. During the year that the committee worked to develop the proposed standards, all of the committee members made strong contributions to improving science education in Minnesota. Therefore, MDE carefully considered the concerns of some school districts regarding the move to grade-specific standards without grade band flexibility. It also closely assessed the recommendation of its committee.

After weighing all of the factors, MDE determined that grade-specific standards and benchmarks are the best way to ensure that all Minnesota students have access to a strong science education. MDE further believes that a variety of factors will allay the concerns of some school districts and committee members about curriculum and teacher resources.

MDE understands that school districts may need to make changes to curriculum, staffing and programming associated with these proposed science academic standards. However, this would be true even if the proposed standards had been presented with the option of flexibility within grade bands. In fact, school districts in Minnesota regularly review and refine local curriculum for a variety of reasons. In Minnesota, the legislature has mandated that both standards and assessments be revised on an ongoing basis, so schools around the state undergo regular curriculum reviews to ensure that their local curriculum meets current standards and assessment requirements in several subject areas. The federal government also places requirements on schools that may necessitate ongoing curriculum and refinement. Finally, school districts regularly update their curriculum in response to changes in local educational needs and goals, and to incorporate new developments and trends in education policy, and schools regularly face staffing change needs as a result of internal changes at the district level, or due to individual needs and desires of teachers. Therefore, while it is true that these proposed standards likely will require some school districts in Minnesota to make changes at the local level, including curriculum updates and staffing shifts, MDE does not believe that the grade-specific standards will necessitate unusual or burdensome changes on the part of school districts.

Furthermore, while some school districts will need to make curriculum, staffing and other changes to ensure that their local programs match the grade-level specifications of these science standards, many other school districts have curricula in place that already match the grade-level requirements of these proposed standards. Districts that have already

50 Letter from Science Standards Revision Committee Co-Chairs to Commissioner Alice Seagren, March 5, 2009.

voluntarily aligned with the specific grade-level placement of standards and benchmarks will find it relatively easy to align with the 2009 proposed standards. It is likely that the proportion of districts facing significant curriculum and related changes will be low – most school districts will face only regularly scheduled and anticipated changes as a result of these proposed standards. An informal survey conducted by committee co-chair Laurie Peterman found that the majority of the school districts sampled followed the grade-level placement of the existing standards, even though districts were given the option of grade banding.[51] Therefore, both the committee and MDE anticipate that most school districts likely will not face major curriculum and staffing changes directly as a result of the decision not to allow the grade banding option in these proposed standards.

Similarly, MDE understands that licensing requirements can be complicated for local school districts. The emphasis on ensuring that teachers are qualified to teach in particular subject areas and to specific student populations has increased substantially in recent years. When NCLB was enacted at the beginning of this decade, it also significantly increased the demands on teachers and schools to ensure a highly qualified teaching staff.

The Board of Teaching, along with other entities, including MDE and the higher education institutions that prepare teachers for their classroom careers, works on an ongoing basis to ensure that new and experienced teachers are prepared for the current educational environment, and that the licensing structure is available to support teachers and schools. The Board of Teaching works to match its licensing structure and requirements to the needs of Minnesota's education community. Higher education institutions work to ensure that their teacher education programs provide teachers with the training and background they need in today's classrooms. Ongoing professional development and alternative licensing structures are available to help experienced teachers keep pace with new requirements and new educational theories. However, even with this support from MDE, the BOT, teacher preparation programs and others, teachers and schools sometimes face difficulties accommodating these changing expectations. This reality, though, does not reduce any school's responsibility to ensure that they have well-qualified teachers in their science classrooms.

MDE and the Board of Teaching will continue to support schools and help them meet their licensing and classroom staffing needs, balanced with the expectation that all Minnesota students deserve qualified teachers in their classrooms. As these proposed standards are implemented, MDE will assist schools with their licensing needs by helping teachers to obtain licenses through the portfolio process, and targeted licensure programs.

MDE will provide and support professional development programs to help teachers implement the new standards by providing them with opportunities to maintain or gain the content knowledge and teaching strategies needed to implement the proposed

51 Of the 33 sample districts that responded to Peterman's informal survey, 24 teach the middle school (grades 6-8) standards in the sequence as the statewide standards document, while six districts follow a different sequence and three districts use an integrated approach – teaching all three disciplines of life, physical, and earth sciences in every year.

standards. For example, some standards call for knowledge of new areas of science and engineering that current teachers do not have in their education and training backgrounds. MDE's Math and Science Teacher Partnership Program will focus on integrating the Nature of Science and Engineering standards into content instruction. In 2010-11, this program will be available for teachers of science in grades 3-6. In 2011-12, the program will focus on secondary life science, and in 2012-13, the program will address secondary earth and physical sciences. The program is implemented by partnerships of education service units, higher education and school districts in regions throughout the state. MDE also will encourage professional development programs offered by colleges, museums, environmental centers, school districts, on-line programs and other entities to align to and complement the standards and provide the necessary content knowledge and teaching skills.

Some school districts also argue that the grade banding option coordinates more appropriately with the MCA Science Assessments than does the grade-specific option. Students take the MCA-II Science Assessment in grades 5, 8 and in high school. The grade 5 assessment covers the standard and benchmarks in grades 3-5, while the grade 8 assessment covers the grades 6-8 standards and benchmarks. The high school assessment covers the standards and benchmarks in the 9-12 Life Science and History and Nature of Science content strands, and is given in the year that a district's students take the biology course that meets the Life Science standards. These districts argue that, since the MCA assessment is based on grade bands of 3-5 and 6-8, districts should be free to move the standards around in the same grade bands, allowing them to match the standards to their curriculum resources, and potentially to increase their ability to review all the content areas before the assessment.

It is true that the current MCA assessment schedules call for testing of science learning in grade bands, but this assessment schedule does not reflect a preference for grade banding. Rather, it reflects the changing importance of science learning and push-pull views about the value and role of assessments in learning. In the recent past, educational policy placed an emphasis on the basics of reading, writing and mathematics. As a result, these subjects are tested more frequently than is science. However, current educational philosophy places a much greater emphasis on the role of and need for science learning for all students. Thus, science assessments now are required, and it is possible that in the near future, science assessments will expand to be tested yearly in grades 3-8, as reading and mathematics are now. Thus, the argument that science learning should remain in grade bands because of assessments is a potentially faulty one. Furthermore, not only are the assessments based on the standards – rather than the standards being built around the assessments – there is no evidence that grade band flexibility has any impact on success with the MCA science assessment. The assessment covers three grades of learning, regardless of whether there is flexibility in teaching particular standards requirements within those three grades.

Standards that Address College and Work Readiness

As part of the standards drafting process, and in compliance with Minnesota Statutes section 120B.023, subd. 2, MDE and the committee specifically focused on how to align the proposed standards with the knowledge and skills needed for college readiness and advanced work. MDE shared an early draft of the revised standards with the Minnesota P-16 Education Partnership's Postsecondary and Workforce Science Readiness Working Group,[52] which offered feedback and recommendations for strengthening the K-12 science standards to better reflect college and work readiness expectations. The working group reviewed the existing science academic standards and made recommendations for improving the standards. Those recommendations are found in a 2008 *Report of the Postsecondary and Workforce Science Readiness Working Group*. This task force developed the following definition:

> Postsecondary and workforce readiness includes the knowledge and skills that high school graduates need in order to do credit bearing coursework at a [two or four-year] college or university and/or to embark successfully on a career-track employment position that pays a living wage, provides benefits (and offers clear pathways for advancement through further education and training).

This definition helped the drafting the committee to define the areas of learning and the level of rigor that all students will need in science, regardless of their future career paths. The committee incorporated many recommendations of the P-16 Postsecondary and Workforce Readiness Working Group into later drafts of the standards. For example, the P-16 Report placed an emphasis on "big ideas" of science and systems thinking, and that emphasis influenced the way the committee drafted the proposed standards in each of the content areas. The particular big ideas addressed by these proposed standards are described below, in the discussion of proposed rule language in each of the content areas.

The working group also observed that a science learning gap exists in Minnesota, and that this gap must be corrected in order for all students to achieve post-secondary and career success. As the working group pointed out:

> Minnesota student scores rank near the top of national science tests such as the National Assessment of Educational Progress. However, the average score obscures the fact that a significant number of students are not completing high school with the requisite scientific and mathematical understandings for success in the workforce or entry level college courses. Standards for all students accompanied by differentiated instruction are critical to closing the existing achievement and opportunity gap between the performance of Minnesota students from differing racial, ethnic and income groups.[53]

The committee and MDE agree with the working group that science learning must be improved for all Minnesota students, no matter their demographic background or their career preferences. Many aspects of the proposed science academic standards are influenced by this need to ensure that all students are equipped with the knowledge and

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52 The Minnesota P-16 Education Partnership is a voluntary organization made up of the statewide education groups in Minnesota, plus others from government, business, and other private sectors. MDE is a member of the Partnership, as is the Minnesota Office of Higher Education, the University of Minnesota, the Minnesota State Colleges and Universities, and numerous organizations representing public and private schools, school administrators, parents, teachers and others interested in furthering discussion about education issues and policies in Minnesota.

53 *See* Postsecondary and Workforce Working Group Report, *supra* note 35.

skills they will need post–graduation. The Nature of Science and Engineering strand contains standards and benchmarks designed to build science and engineering skills; to emphasize the connections between science, engineering, mathematics and society; and to expose students to potential related careers. Finally, in drafting the grades 9-12 standards, the committee frequently considered whether the standards and benchmarks are drafted at a level of rigor that is accessible by all students, not just those who are going into science careers. One key example of this attention to accessibility by all students is in the drafting of the new proposed physics and chemistry standards.

Many students do not value science because they do not believe they will need it later in life. However, changes in the workplace require that all students graduate from high school ready to pursue a science or technology-based career, even if they are not so inclined while in high school.[54] More than ever, science skills and knowledge are necessary not only for career purposes, but for everyone to be able to participate in an increasingly technological society, and to make evidence-based decisions as citizens.

The underlying idea behind these proposed standards, that science is for *all* students, is an important one. It is reflected in the new legislative mandate that all students graduate from high school, not only with a credit in biology, but also a credit in either physics or chemistry. Both of those courses traditionally have been organized, designed and taught not for all students, but for a self-selecting group of students. Often these are the students interested in pursuing science careers; hence, the courses are designed to prepare them for entry-level science courses in college. The legislature recognizes the need for all Minnesota students to achieve a certain level of science knowledge in preparation for post-secondary success; careers that increasingly involve more and higher levels of science, technology and engineering; and civic responsibility in an increasingly complex world with decisions that are more than ever informed by an understanding of science and technology. Given that framework, MDE is compelled to consider the educational needs of all its students, and how best to ensure that every student graduates from high school in Minnesota with a solid background in the basic areas of science.

Technology and Information Literacy in the Proposed Science Academic Standards

Pursuant to Minnesota Statutes section 120B.023, subd. 2, technology and information literacy standards, consistent with recommendations from school media specialists, must be embedded into the standards. This includes standards from sources such as the Minnesota Educational Media Organization (MEMO), International Society for Technology in Education (ISTE) and the International Technology and Education Association (ITEA).

The new legislative requirement that technology and information literacy standards be embedded into the standards is both implicitly and explicitly reflected in these proposed rules. Information literacy is reflected in standards and benchmarks in the Nature of Science and Engineering strand, which discusses the evaluation of claims based on

54 *See* Postsecondary and Workforce Working Group Report, p. 2, *supra* note 35.

evidence. For example, proposed standards in the Practice of Science substrand in grades 3, 5 and 8 address the need for students to learn scientific understandings, including how scientific ideas are based on evidence and require verification. This set of proposed standards and supporting benchmarks asks students to learn how to provide evidence to support claims; explain why evidence, communication, recordkeeping, replication by others, and openness to scrutiny are essential to science; and evaluate the reasoning in arguments in which fact and opinion are intermingled.[55] A benchmark supporting the grades 9-12 standards requires students to learn skills related to using scientific literature.[56] The MEMO and ISTE standards were influential in developing these standards and guiding the wording of the proposed standards.

In addition to the inclusion of scientific literacy in these proposed science academic standards, substantial engineering design process standards have been incorporated into the proposed K-12 science academic standards. The Committee and MDE determined that specifically including engineering in the proposed science standards was crucial for several reasons. First, the statutory requirement calls for including not only information literacy, but also technology. Minn. Stat § 120B.023, subd. 2. Technology is closely related to and in many ways commingled with engineering. These two disciplines are discussed and defined in more detail below, in the discussion of the Practice of Engineering substrand at page 36 of this SONAR. In order to focus on technology, the standards also must focus on engineering. Second, this effort is consistent with the work of leading states such as Massachusetts, New Hampshire, Oregon and Washington, which are at the forefront of developing strong science education standards that reflect our society's growing need for and dependence on science, engineering and technology. Finally, incorporating engineering into the proposed standards simply reflects current best practices of integrated STEM education.[57] Technology, engineering and information literacy standards are found in The Nature of Science and Engineering strand.

Incorporating Environmental Literacy into the Science Standards

When MDE began the process of revising Minnesota's science academic standards, the agency determined that the standards should incorporate environmental literacy education that complies with the standards and requirements set out in Minnesota Statutes section 115A.073. That statute requires Minnesota to provide environmental education to students and other citizens, outlined in a state plan known as *A GreenPrint for*

55 These proposed standards are found in the rule language at 3501.0815, subp. 1(A), 3501.0825, subp. 1(A) and 3501.0840, subp. 1(A).

56 In support of the proposed standard 3501.0845, subp. 1(B), which requires students to understand that scientific inquiry uses multiple interrelated processes to investigate and explain the natural world, a benchmark requires students to "[u]se primary sources or scientific writings to identify and explain how different types of questions and their associated methodologies are used by scientists for investigations in different disciplines."

57 *See* ITEA, *Standards*, *supra* note 30; and AAAS, *Benchmarks for Science Literacy*, Chapter 3: Nature of Technology and Chapter 8: The Designed World, *supra* note 28. Benchmarks for Science Literacy chapters 3 Nature of Technology, Ch 8 The Designed World. *See also* NAE, *Engineering in K-12 Education*, p. 2, *supra* note 14.

Minnesota: State Plan for Environmental Education.[58] MDE directed the committee to identify and develop environmental literacy standards in the state's 2009 science academic standards, and to use the *GreenPrint* and a second document, the *Environmental Literacy Scope and Sequence,*[59] as resources for this task.

The *GreenPrint* was developed at the direction of the Environmental Education Advisory Board (EEAB), a state board created by the Minnesota Legislature in 1990 to guide the direction of environmental education in Minnesota and to promote environmental literacy for all Minnesota citizens.[60] *See* Minn. Stat. § 115A.072. The *GreenPrint* identifies the education outcomes that the environmental education community should work toward, as well as the various audiences targeted for this education. It also discusses specific ways that environmental education can be delivered in order to achieve the highest possible degree of environmental literacy amongst Minnesota's citizens. A primary goal of the EEAB, as set out in its *GreenPrint* document, is to "encourage the establishment of environmental education standards and benchmarks in the preK-12 school system by using the benchmarks and concepts of the Environmental Literacy Scope and Sequence as a model."[61] In fact, one of the four *GreenPrint* outcomes is the incorporation of environmental literacy standards and benchmarks into Minnesota's academic standards across all disciplines and grade levels.[62] Those standards and benchmarks are found in the *Environmental Literacy Scope and Sequence*, a framework document developed in 2002 by a committee of educators, including a representative from the state's education agency, then known as the Department of Children, Families and Learning, at the direction of the EEAB and the Minnesota Pollution Control Agency.[63]

The *Environmental Literacy Scope and Sequence* defines the scope of core knowledge for environmental literacy as follows:

> The Earth is a set of interacting natural and social systems. An environmentally literate person must understand the relationship of the parts of a system and the interdependence of human and environmental systems. The content of environmental education is the exploration of the relationships between social and natural systems.[64]

It goes on to establish a set of benchmarks for the knowledge that students should achieve at various stages in their K-12 learning careers, and to support those benchmarks with key systems concepts and examples.

The committee used the definitions, benchmarks and concepts in the *Environmental Literacy Scope and Sequence*, along with the *GreenPrint* and other resources, to draft science academic standards that incorporate environmental literacy throughout the

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58 *See* Kennedy, et. al., *GreenPrint, supra* note 31.
59 *See* MOMA, *Environmental Literacy, supra* note 32.
60 More information about the EEAB, its membership and its current status can be found online *at* http://www.seek.state.mn.us/eemn_i.cfm.
61 *See* Kennedy, et. al., *GreenPrint*, p. 8, (online pdf, p. 12), *supra* note 31.
62 *Id.* at 11 (online pdf, p. 15).
63 *See* MOMA, *Environmental Literacy, supra* note 32.
64 *Id.* at p. 6.

content strands. A focus group of leaders in environmental education also reviewed the first draft of the 2009 science academic standards, and provided input for later revisions. For example, the focus group supported the addition of standards in the human interaction substrand contained in each of the four content strands – Nature of Science and Engineering, Physical Science, Earth Science and Life Science. The focus group particularly commended the integration of these proposed standards throughout the standards document and content areas. Traditionally, human interaction standards have been limited to the life science content area, and have addressed health-related subjects.

Each of the three content strands found in the science academic standards, Physical Science, Earth and Space Science and Life Science, includes a substrand on Human Interactions with the content area. These substrands have an environmental literacy component; the standards within them focus on interactions with the environment. For example, one of the standards in the Earth and Space Science content strand incorporates environmental literacy into the state's science academic standards by requiring students to understand that "in order to maintain and improve their existence, humans interact with and influence Earth systems." Benchmarks that support and expand the standards further the environmental literary knowledge. For example, a grade 8 benchmark supporting that same standard requires students to "recognize that land and water use practices in specific areas affect natural processes and that natural processes interfere and interact with human systems."

The existing science academic standards were not drafted to include a focus on environmental literacy as one of the goals and purposes of science education in Minnesota. MDE now believes that this was a critical oversight. It further believes that the 2009 science academic standards adequately and appropriately incorporate environmental literacy into the science education of all Minnesota students. This focus is consistent with and complies with relevant statutes, including Minnesota Statute section 115A.073, and reinforces an important core value of Minnesota citizens.

For all of the above-mentioned reasons, the environmental literacy content of these proposed science academic standards rules is necessary and reasonable.

Grain Size Focus and the Number of Standards

The standards identify broad learning goals, the "big ideas" in science learning – the major concepts and essential skills. By their breadth and focus on big ideas, the standards establish learning requirements but also allow for a variety of curriculum approaches. The supporting benchmarks indicate the specific knowledge and skills that combine to lead to understanding of a particular standard at each grade level.

The committee worked toward making the benchmarks an appropriate "grain size." This refers to the idea that there should not be a vast difference in the amount of instructional time required for students to learn a benchmark. A benchmark should require more than a single activity to accomplish learning, but less than a two- to three-week unit of instruction.

The substrands within these four strands have been reorganized somewhat to make the standards more coherent and systematic. In addition, as compared to the existing science academic standards, some ideas have been removed, some have been added, and others have moved to different grade levels. These changes are addressed later in the SONAR, in the discussion of the proposed rule language. As a result, the standards and benchmarks are more coherent and the concepts are developed in a more systematic fashion.

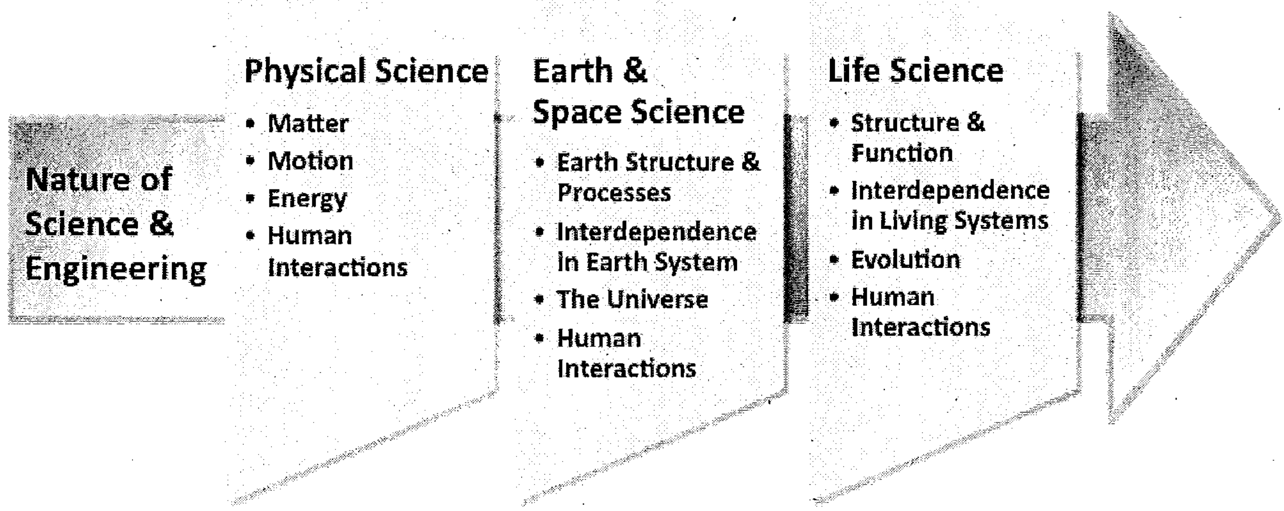
Some schools may need to shift curriculum materials between grade levels. However, schools that aligned to the existing standards should not need major changes in instructional materials.

Organization of the Standards

The proposed Minnesota science academic standards are organized by grade level into four strands:

1) The Nature of Science and Engineering,
2) Physical Science,
3) Earth and Space Science, and
4) Life Science.

These strands are similar to those in the existing standards and to national standards documents. Strand 1 outlines understandings and skills of science and engineering, while strands 2, 3 and 4 address the traditional primary content areas of science. The content and skills in strand 1, the Nature of Science and Engineering strand, are not intended to be taught as a stand-alone unit or an isolated course. Rather, they should be embedded into and used in the teaching, learning and assessment of the content in the other strands. The committee adopted the following diagram of the strands and substrands to illustrate the idea that the Nature of Science and Engineering standards should be taught throughout the three content strands rather than as an isolated subject:



In addition to the four major content strands, which appear in the rules as four rule subparts, the science academic standards were further organized by substrand. Each strand has three or four substrands that represent the major content subdivisions. Often, they are similar to content divisions found in most textbooks or other curriculum materials. These substrands represent the main divisions of each content area. The strands and substrands were chosen based on research of national standards documents and examples from other states, and are discussed more thoroughly below, in the discussion of specific rule language.

Each substrand contains two or more standards. The standards are written as broad statements of concepts or skills that students should develop or know. In many cases, the wording of the standard is repeated in several different grades, as students develop a deeper understanding of the concept or skill.

The proposed science academic standards are organized by grade level, beginning with kindergarten. At each grade level, standards are required in all four major content areas. Thus, the overarching structure of the proposed rules is as follows:

3501.0800 Kindergarten Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0805 Grade 1 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.

Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0810 Grade 2 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0815 Grade 3 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0820 Grade 4 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0825 Grade 5 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0830 Grade 6 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0835 Grade 7 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0840 Grade 8 Standards.
Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0845 Grades 9-12 Standards.

Subpart 1. Nature of Science and Engineering.
Subp. 2. Physical Science.
Subp. 3. Earth & Space Science.
Subp. 4. Life Science.

3501.0850 Grades 9-12 Chemistry Standards.
Subpart 1. The Nature of Science and Engineering.
Subp. 2. Physical Science.

3501.0855 Grades 9-12 Physics Standards.
Subpart 1. The Nature of Science and Engineering.
Subp. 2. Physical Science.

Each subpart represents a content strand. Within each subpart, the standards contain headnotes that indicate the substrand associated with each standard. The standards themselves follow specific content tracks that further categorize and organize specifics of the substrand, introduce new topics and build on previously taught concepts and ideas. Some content tracks are taught in certain grades but not other grades. However, all of the content tracks develop from grade K through grades 9-12, increase in complexity, sophistication and level of knowledge expected. By the time Minnesota students have met the grades 9-12 science academic standards, they will be able to demonstrate a level of learning that will satisfy graduation requirements and college and work-readiness requirements in all four content areas.

These specific content tracks are not delineated in the rule language. However, they guided the committee throughout its standards development process. They also are a useful format in which to talk about the specific rule language; including how each specific content track builds through the grades; why certain content is best taught at a particular grade level; the decisions the committee made; and why the rules are necessary and reasonable. Thus, the next section of the SONAR will discuss the rule language by following the content tracks.

The Proposed Rule Language

As described earlier, the proposed science academic standards were developed using several levels of organization: strands, substrands, standards and benchmarks.[65] The standards are required to be in rule and are the subject of this rulemaking. Standards are broad statements of concepts and skills that students should learn. Each standard is further defined by benchmarks, which are written as more detailed learning objectives. To better show the flow of ideas that students learn as they progress through the grades, the standards will be grouped by substrands and then listed by grade. The associated benchmarks, which are not required to be in rule but which further expand upon and

65 The strands, substrands, standards and benchmarks are perhaps best seen in the document developed by the committee and approved by MDE, the 2009 Minnesota Academics Standards in Science. It is available on the MDE website *at*
http://education.state.mn.us/MDE/Academic_Excellence/Academic_Standards/Science/index.html.

develop the standards concepts, are summarized after each standard. For each strand and substrand, the SONAR discusses the rationale for the standards contained in the strand or substrand, and explains why those standards are necessary and reasonable.

A. Strand One: The Nature of Science and Engineering.

In order to become scientifically literate, students must understand the basic principles and processes of nature, understand how science operates, and be able to use the skills of scientific inquiry. The Nature of Science and Engineering strand (NSE) emphasizes the skills of science and the understanding of the scientific enterprise that seeks to explain the natural world. In response to the need for increased student understanding of the designed world, this strand also includes standards that address engineering processes. In addition, the strand addresses the connections between science and engineering and technology, mathematics and the social environment.

The standards and benchmarks in the NSE strand help students learn the methods and way of thinking that scientists and engineers use in their work. These skills have application beyond the disciplines of science, engineering and mathematics. They include the inquiry and design skills that are used to form scientific explanations for everyday phenomena and conduct problem-solving for unexpected events. Scientific thinking skills are the basis of evidence-based reasoning that provides the foundation of our legal system and the research methods used in many social science areas.

Rather than being taught as separate units of instruction, the standards in the NSE strand are intended to be taught in the context of the other three strands which focus on specific science content areas. The activities, such as experiments, projects and design challenges, typically used in science content instruction can be used to help students understand the underlying engineering design processes and further their engineering problem solving skills. For example, when teaching the concept of heat, a teacher could have students design a container to keep a cup of hot water warm as long as possible. In the discussion of a project like this, the students learn concepts about heat, such as conduction, convection and radiation. They also learn engineering skills and concepts such as the design process, trade-offs in selecting materials and the marketing of products.

The three substrands in the NSE strand are:

1. The Practice of Science,
2. The Practice of Engineering, and
3. Interactions Among Science Technology Engineering Mathematics and Society.

These substrands are incorporated into the proposed rules at the subpart level.

They represent a change from the existing standards, which contained an equivalent strand, the History and Nature of Science. In 2009, both MDE and the committee determined that a strand focusing on NSE would better emphasize the role of engineering and technology in science learning. The concepts that were emphasized in the History and Nature of Science substrands – Scientific World View, Scientific Inquiry, Scientific Enterprise and Historical Perspectives – all remain in the 2009 proposed science academic standards rules. However, based on current national and international best practices in science learning, which place greater emphasis on the need for learning engineering skills and knowledge, the committee significantly reworked this learning strand and its supporting substrands. Thus, the concepts of Scientific World View, Scientific Inquiry and Scientific Enterprise have been incorporated into the Practice of Science substrand. The Historical Perspectives standards have been modified and now emphasize the development of key scientific ideas and theories, rather than describing the contributions of individual scientists.
In addition, two new substrands, the Practice of Engineering and the Interactions among Science, Technology, Engineering and Society, incorporate engineering and technology learning into the proposed science academic standards. The concepts from the Scientific Enterprise substrand, were distributed into the Practice of Engineering and the Interactions among Science, Technology, Engineering and Society. Many existing standards related to technology have been incorporated into the Practice of Engineering substrand.

1. Substrand One: The Practice of Science.

Science is a way of studying the natural world; science is also the knowledge gained from that study. A central component of science is the process of inquiry, which itself involves many different processes, including observations and experiments. The conclusions from this inquiry must be verified by further investigations in order to be considered valid. As explained by the National Academy of Sciences, "science is a particular way of knowing about the world. In science, explanations are limited to those based on observations and experiments that can be substantiated by other scientists. Explanations that cannot be based on empirical evidence are not part of science."[66]

MDE believes that a substrand focusing on the Practice of Science is critical to science learning. It is not enough for Minnesota students to gain knowledge about the basic science concepts of physical science, life science and earth science. To be successful as citizens, post-secondary learners and job seekers, our students also must learn about how science is conducted. This belief is supported by the National Science Education Standards (NSES), which were developed under the leadership of the National Research Council. The NSES includes Science as Inquiry as one of its eight categories of content standards. According to the NSES, "engaging students in inquiry helps students develop

- Understanding of scientific concepts;
- An appreciation of how we know what we know in science;
- Understanding of the nature of science;
- Skills necessary to become independent inquirers about the natural worlds; and
- The dispositions to use the skills, abilities, and attitudes associated with science."[67]

The Benchmarks for Science Literacy, developed under the leadership of the American Association for

66 *See* NAP, *National Science Education Standards,* p. 1, *supra* note 5.
67 *Id.* at 105.

the Advancement of Science, also reinforce the importance of learning about the practice of science, explaining that

> [w]hen people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically."[68]

Inquiry also can be used in science classes as a teaching strategy to help students develop science concepts in a way that will make the ideas experiential-based and thus lead to a deep understanding. The NSES supports this approach to inquiry, and defines inquiry not only in terms of how scientists study the natural world and propose explanations derived from that study, but also as the activities of students in which they develop knowledge and understanding of scientific ideas. [69]

This emphasis on inquiry is relatively new in science education. It was introduced in Minnesota with the existing science academic standards and, initially, science educators were slow to accept the new approach Even though there is wide variation in the degree to which teachers have integrated inquiry into their instruction, during the drafting process the committee and MDE received only a few comments in opposition to the inclusion of inquiry in the proposed standards.

This substrand is divided into two standards areas: Understandings about science, and scientific inquiry and investigation.

Understandings about Science.

These standards and benchmarks describe the knowledge that students should have about the processes of science. They help students understand that scientific ideas are based on evidence and that scientific claims require verification. Students gain an appreciation that science is one way of understanding the natural world, and that this way of explaining the world has benefits and limitations.

Grade 1. Proposed rule language.

> <u>3501.0805, subp. 1(A). The student will understand that scientists work as individuals and groups to investigate the natural world, emphasizing evidence and communicating with others.</u>

Grade 3. Proposed rule language.

> <u>3501.0815, subp. 1(A). The student will understand that scientists work as individuals and in groups, emphasizing evidence, open communication and skepticism.</u>

Grade 5. Proposed rule language.

> <u>3501.0825, subp. 1(A). The student will understand that science is a way of knowing about the natural world, is done by individuals and groups, and is characterized by empirical criteria, logical argument and skeptical review.</u>

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68 *See* AAAS, *Benchmarks for Science Literacy*, p. 3, *supra* note 28.
69 *See* NAP, *National Science Education Standards*, p. 23, *supra* note 5.

Grade 7. Proposed rule language.

3501.0835, subp. 1(A). The student will understand that science is a way of knowing about the natural world that is characterized by empirical criteria, logical argument and skeptical review.

Grade 8. Proposed rule language.

3501.0840, subp. 1(A). The student will understand that science is a way of knowing about the natural world and is characterized by empirical criteria, logical argument and skeptical review.

Grades 9-12. Proposed rule language.

3501.0845, subp. 1(A). The student will understand that science is a way of knowing about the natural world that is characterized by empirical criteria, logical argument and skeptical review.

Scientific Inquiry and Investigation.

These standards and benchmarks describe the skills needed by students to participate in scientific inquiry and conduct investigations. They engage students in doing inquiry, developing their own conclusions from investigations and analyzing the claims of investigations done by others.

Grade K. Proposed rule language.

3501.0800, subp. 1(A). The student will understand that scientific inquiry is a set of interrelated processes used to pose questions about the natural world and investigate phenomena.

Grade 2. Proposed rule language.

3501.0810, subp. 1(A). The student will understand that scientific inquiry is a set of interrelated processes incorporating multiple approaches that are used to pose questions about the natural world and investigate phenomena.

Grade 3. Proposed rule language.

3501.0815, subp. 1(B). The student will understand that scientific inquiry is a set of interrelated processes incorporating multiple approaches that are used to pose questions about the natural world and investigate phenomena.

Grade 5. Proposed rule language.

3501.0825, subp. 1(B). The student will understand that scientific inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

Grade 7. Proposed rule language.

3501.0835, subp. 1(B). The student will understand that scientific inquiry uses multiple interrelated processes to investigate questions and propose explanations about the natural world.

Grade 8. Proposed language.

3501.0840, subp. 1(B). The student will understand that scientific inquiry uses multiple interrelated processes to investigate questions and propose explanations about the natural world.

Grade 9-12. Proposed rule language.

3501.0845, subp. 1(B). The student will understand that scientific inquiry uses multiple interrelated processes to investigate and explain the natural world.

These standards are necessary and reasonable to help students understand the processes of science and the way scientific ideas develop. They give students the skills to engage in scientific exploration both in the classroom setting and the outside world.

2. Substrand Two: The Practice of Engineering.

Engineering is "the process of designing the human-made world. In contrast, science is the study of the natural world. Engineers modify the world to satisfy people's needs and wants."[70] Engineering is closely associated with technology, which in turn is defined as the products and processes of the human-made world plus the "processes and knowledge that people use to satisfy human needs and wants."[71]

The potential benefits to students of including engineering concepts and skills in the science academic standards and in school curricula include:

- motivation for learning science concepts by studying technological objects and events that are a large part of the everyday lives of students,
- improved learning of science concepts by applying them to engineering problems and current technology,
- developing skills at problem solving and using the engineering design skills, and
- awareness of the field of engineering and the associated career possibilities.[72]

The Benchmarks for Science Literacy and the National Science Education Standards include standards about engineering and technology. Some standards related to engineering and technology were incorporated into the existing science standards, but more are included in the 2009 proposed standards, and they now have greater emphasis because they are grouped into their own substrand. Many of the engineering and technology standards in Minnesota's proposed science academic standards are based on the Standards for Technology Literacy.

Some of the public comments related to this strand raised concerns about adding more areas for instruction and the lack of training of and for teachers in these areas. In response to concerns about the number of areas requiring instruction, the committee worked to reduce the number of standards in other areas where they found standards that are no longer needed or necessary. This reduced the number of benchmarks – the standards level most often relied on and accessed by teachers. Furthermore, as discussed elsewhere in this SONAR, the Nature of Science and Engineering standards are intended to be taught through, or in combination with, the core science content areas of physical, earth and life sciences. Thus, additional standards in this content strand should not require significant additional instructional

70 *See* NAE, *Engineering in K-12 Education*, p. 55, *supra* note 14; and NAP, *National Science Education Standards*, p. 55, *supra* note 5.
71 *See* ITEA, *Standards*, p. 2, *supra* note 30.
72 *See* NAE, *Engineering in K-12 Education*, p. 49-50, *supra* note 14.

time. Written documents presenting the standards, and other communications related to the standards, have emphasized this teaching practice. In response to the concern about lack of training for teachers, MDE, the Minnesota Science Teachers Association, colleges, museums and other professional development providers will include these new standards areas in their upcoming training activities for teachers. As licensure standards are updated, teacher preparation programs also will work to ensure that new teachers receive the necessary training to teach in these areas.

These standards are reasonable because they teach to all students the problem-solving skills that can be used in everyday life to design solutions to human needs and wants. They are necessary to help students understand the engineering processes that are used to design the human-built world.
This substrand is divided into two standards areas that develop in complexity and depth from grade K through grades 9-12: Understandings about Engineering and Engineering Design.

Understandings about Engineering.

These standards and benchmarks describe the knowledge that students should have about the processes of engineering.

Grade K. Proposed rule language.

> 3501.0800, subp. 1(B). The student will understand that some objects occur in nature. The student will understand that others have been designed and processed by people.

Grade 4. Proposed rule language.

> 3501.0820, subp. 1(A). The student will understand that engineers design, create and develop structures, processes and systems that are intended to improve society and may make humans more productive.

Grade 6. Proposed rule language.

> 3501.0830, subp. 1(A). The student will understand that engineers create, develop and manufacture machines, structures, processes and systems that impact society and may make humans more productive.

Grades 9-12. Proposed rule language.

> 3501.0845, subp. 1(C). The student will understand that engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Engineering design.

Similar to the scientific inquiry process, "[d]esign is the approach engineers use to solve engineering problems – generally, to determine the best way to make a device or process that serves a particular purpose."[73] Both engineering design and scientific inquiry are problem-solving approaches that define and inform their disciplines.

Grade 2. Proposed rule language.

73 *See* NAP, *National Science Education Standards,* p. 38, *supra* note 5.

3501.0810, subp. 1(B). The student will understand that engineering design is the process of identifying a problem and devising a product or process to solve the problem.

Grade 4. Proposed rule language.

3501.0820, subp. 1(B). The student will understand that engineering design is the process of identifying problems, developing multiple solutions, selecting the best possible solution, and building the product.

Grade 6. Proposed rule language.

3501.0830, subp. 1(B). The student will understand that engineering design is the process of devising products, processes and systems that address a need, capitalize on an opportunity, or solve a specific problem.

Grades 9-12. Proposed rule language.

3501.0845, subp. 1(D). The student will understand that engineering design is an analytical and creative process of devising a product or solution to meet a need or solve a specific problem.

These standards are reasonable and necessary because they help students understand the engineering processes that are used to design the human-built world.

3. Substrand Three: Interactions Among Science, Technology, Engineering, Mathematics (STEM) and Society.

Real-world problems require skills and knowledge from several disciplines, including technology, engineering, mathematics and social disciplines. The solutions to these problems affect society and are affected by the societal environment. The proposed standards in this substrand address some of the main unifying ideas that cross these disciplines, as well as the way these areas can be taught in an integrated fashion.

Systems.

Systems is a term that appears prominently in science (respiratory systems), technology (ignition system such as in an automobile), mathematics (systems of equations) and society (political systems). Generally they refer to interacting objects and processes. Being able to think about the interactions of subsystems is a higher-order thinking skill that prepares students to function successfully in a variety of situations. These proposed standards, and supporting benchmarks, start with helping younger students to identify the function of tools. As they advance through school, they improve their skills and their ability to understand the role of subsystems. Finally, students who learn under these academic standards will develop the ability to analyze interacting systems.

Grade 1. Proposed rule language.

3501.0805, subp. 1(B). The student will understand that designed and natural systems exist in the world. The student will understand that these systems are made up of components that act within a system and interact with other systems.

Grade 6. Proposed rule language.

3501.0830, subp. 1(C). The student will understand that designed and natural systems exist in the world. The student will understand that these systems consist of components that act within the system and interact with other systems.

Grades 9-12. Proposed rule language.

3501.0845, subp. 1(E). The student will understand that natural and designed systems are made up of components that act within a system and interact with other systems.

Careers and Contributions in Science and Engineering.

It is important for students to realize that people like them have succeeded in science and engineering. They can feel a stronger connection to the areas they study, and they are more likely to place greater value on their learning for its current and future usefulness. At the same time, they become exposed to potential careers and realize that the skills they are learning will help them prepare for a future career. The proposed standards in this standards content area require students to provide examples of how diverse cultures have contributed ideas and innovations to the body of scientific, engineering and world knowledge and understanding

Several of the standards in this standards content area also meet the legislative mandate that academic standards "must include the contributions of Minnesota American Indian tribes and communities as they relate to the academic standards during the review and revision of the required academic standards." *See* Minn. Stat. § 120B.021, subd. 1.

Grade 1. Proposed rule language.

3501.0805, subp. 1(C). The student will understand that men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in engineering design and scientific inquiry.

Grade 3. Proposed rule language.

3501.0815, subp. 1(C). The student will understand that men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in engineering design and scientific inquiry.

Grade 5. Proposed rule language.

3501.0825, subp. 1(C). The student will understand that men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in engineering design and scientific inquiry.

Grade 8. Proposed rule language.

3501.0840, subp. 1(C). The student will understand that men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in engineering design and scientific inquiry.

Grades 9-12. Proposed rule language.

3501.0845, subp. 1(F). The student will understand that men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in scientific inquiry and engineering design.

Mutual Influence of Science, Engineering and Society.

These standards describe the ways in which scientific and engineering often are inspired by the needs of society, and how society is changed by advances in science and technology. The standards help students learn the role of economics, politics and ethics in science and engineering. These concepts are important for students to learn, and provide a role in their current and future decision making.

Grade 4. Proposed rule language.

3501.0820, subp. 1(C). The student will understand that the needs of any society influence the technologies that are developed and how they are used.

Grade 8. Proposed rule language.

3501.0840, subp. 1(D). The student will understand that science and engineering operate in the context of society and both influence and are influenced by this context.

Grades 9-12. Proposed rule language.

3501.0845, subp. 1(G). The student will understand that science and engineering operate in the context of society and both influence and are influenced by this context.

The Role of Mathematics and Technology in Science and Engineering.

These standards describe how advances in technology and the techniques of mathematics provide opportunities for the expansion of scientific knowledge. They also provide students with skills in collecting data and using mathematical analysis. These skills have direct application to most careers that students may choose to pursue.

Grade 3. Proposed rule language.

3501.0815, subp. 1(D). The student will understand that tools and mathematics help scientists and engineers see more, measure more accurately, and do things that they could not otherwise accomplish.

Grade 5. Proposed rule language.

3501.0825, subp. 1(D). The student will understand that tools and mathematics help scientists and engineers see more, measure more accurately, and do things that they could not otherwise accomplish.

Grade 6. Proposed rule language.

3501.0830, subp. 1(D). The student will understand that current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Grade 7. Proposed rule language.

3501.0835, subp. 1(C). The student will understand that current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Grade 8. Proposed rule language.

3501.0840, subp. 1(E). The student will understand that current and emerging technologies have enabled humans to develop and use models to understand and communicate how natural and designed systems work and interact.

Grades 9-12. Proposed rule language.

3501.0845, subp. 1(H). The student will understand that science, technology, engineering and mathematics rely on each other to enhance knowledge and understanding

B. Strand Two: Physical Science.

Physical Science includes the fundamental concepts about matter and energy. These concepts are important for understanding physical, earth, space and living systems, including human-designed systems. At the high school and college level, physical science includes the disciplines of physics and chemistry. The physical science standards contain concepts that all graduating Minnesota students need to know regardless of whether they choose to take physics or chemistry.

To help implement the requirement that graduates must have a credit in physics or chemistry for the class of 2015 and beyond, the 2009 proposed science academic standards and benchmarks include standards that define the content of those courses. Those proposed standards are contained in a stand-alone proposed rule, discussed later in this SONAR.

The Postsecondary and Workforce Science Readiness Working Group of the Minnesota P-16 Education Partnership recommended that physical science standards emphasize the "big ideas" in science. The following big ideas from the working group were incorporated into the proposed physical science standards and benchmarks:

- Properties of objects and systems;
- Use of fields in explaining interactions;
- Forces causes changes of motion;
- Conservation Laws of matter and energy;
- Waves;
- Particulate nature and states of matter;
- Atomic Structure;
- Patterns arranged in the periodic table; and
- Interactions between atoms.[74]

74 *See Postsecondary and Workforce Readiness Group Report,* p. 9, *supra* note 35.

1. Substrand One: Matter.

The matter substrand contains the scientific concepts that are traditionally considered chemistry. The topic of matter is divided into two areas for standards: Properties and structure of matter, and changes in matter. The big ideas that guide these standards include:

- Conservation of mass and energy: In physical changes and chemical reactions, the total mass remains the same. Energy is involved in physical and chemical changes.
- The particle models of matter and atomic structure: Many properties of matter and their behavior are based on the interactions of small particles and the structures of the atoms.
- The periodic table: The patterns in the properties of elements that can be arranged in a helpful table form.

These standards address the core knowledge about matter and chemistry that students will need to succeed in school, work and life after graduation. They are necessary in order for students to develop an understanding of the properties of matter. The proposed standards will help students develop their knowledge and skills, from the observations they make in daily life to increasingly sophisticated explanations for those observations. Taken as a whole, the proposed standards in the matter substrand move from the macroscopic level in elementary grades to the microscope level in middle school, and finally, in high school, to the atomic and subatomic levels that can only be inferred from indirect evidence. The proposed standards build to an understanding of the atomic theory of matter, which is the fundamental theory that explains the properties and behavior of matter. Without the building blocks of the earlier standards, students cannot grasp this culminating explanation and apply it to explain and work with chemical reactions. Therefore, both the content and the building block structure are necessary and reasonable.

Properties and Structure of Matter.

These proposed standards are reasonable and necessary for students to develop an understanding of the properties of matter. The proposed standards help students' knowledge grow, from the observations they make in daily life to increasingly sophisticated explanations for their observations. The standards move from the macroscopic level in elementary grades, to the microscope level in middle grades and finally to the atomic and subatomic levels and to levels that can only be inferred. They build from the fundamental theory that explains the properties and behavior of matter to an understanding of the atomic theory of matter. Without the building blocks of the earlier standards, students cannot grasp this culminating explanation of matter.

Grade K. Proposed rule language.

> 3501.0800, subp. 2. The student will understand that objects can be described in terms of the materials they are made of and their physical properties.

Grade 2. Proposed rule language.

> 3501.0810, subp. 2(A). The student will understand that objects can be described in terms of the materials they are made of and their physical properties.

Grade 4. Proposed rule language.

3501.0820, subp. 2(A). The student will understand that objects have observable properties that can be measured.

Grade 6. Proposed rule language.

3501.0830, subp. 2(A). The student will understand that pure substances can be identified by properties which are independent of the sample of the substance and the properties can be explained by a model of matter that is composed of small particles.

Grade 7. Proposed rule language.

3501.0835, subp. 2. The student will understand that the idea that matter is made up of atoms and molecules provides the basis for understanding the properties of matter.

Grade 8. Proposed rule language.

3501.0840, subp. 2(A). The student will understand that pure substances can be identified by properties which are independent of the sample of the substance and the properties can be explained by a model of matter that is composed of small particles.

Grades 9-12. Proposed rule language.

3501.0845, subp. 2(A). The student will understand that the structure of the atom determines chemical properties of elements.

Changes in Matter.

These standards are reasonable and necessary for students to understand and explain the changes that occur in matter. Students progress from being able to describe the physical changes that occur when substances change between the states of solid, liquid and gas, to examining chemical changes and the changes in properties that occur. Later, students develop the key concept of conservation of mass, and relate it to the rearrangement of atoms that occur in reactions. This leads to learning about the role of electrons in forming bonds, and to developing the skill of describing reactions through chemical equations. Students' understanding of the changes in matter culminates with an analysis of the role of energy and other factors involved in chemical and physical changes.

Grade 2. Proposed rule language.

3501.0810, subp. 2(B). The student will understand that the physical properties of materials can be changed, but not all materials respond the same way to what is done to them.

Grade 4. Proposed rule language.

3501.0820, subp. 2(B). The student will understand that solids, liquids and gases are states of matter that have unique properties.

Grade 6. Proposed rule language.

3501.0830, subp. 2(B). The student will understand that substances can undergo physical changes which do not change the composition or the total mass of the substance in a closed system.

Grade 8. Proposed rule language.

3501.0840, subp. 2(B). The student will understand that substances can undergo physical and/or chemical changes which may change the properties of the substance but do not change the total mass in a closed system.

Grades 9-12. Proposed rule language.

3501.0845, subp. 2(B). The student will understand that chemical reactions involve the rearrangement of atoms as chemical bonds are broken and formed through transferring or sharing of electrons and the absorption or release of energy.

2. Motion.

The topic of motion is divided into two areas for standards: describing motion and using forces to affect motion. The big ideas include speed, velocity, acceleration, forces and Newton's laws of motion.

Motion is one of the most visible forms of energy. Students begin by describing simple straight-line motion, and progress to describing speed and acceleration in more quantitative forms. They also analyze how forces affect motion, and develop an understanding of how Newton's Laws of Motion explain the relationship between forces and motion. Students begin to have an understanding that total energy remains the same by studying the vertical motion of objects such as roller coasters. The standards progress from descriptions of simple motions, to quantitative analysis of the interactions of the forces, momentum and energy involved in more complicated forms of motion.

These standards are necessary and reasonable to help students understand that universal laws of motion and gravity affect the motion of all objects in the universe. Students build this understanding through examining various kinds of motion and the relationship of forces to motion. The standards progress from descriptions of simple motions to quantitative analysis of the interactions of the forces, momentum and energy involved in more complicated forms of motion.

Describing Motion.

Grade 2. Proposed rule language.

3501.0810, subp. 2(C). The student will understand that the motion of an object can be described by a change in its position over time.

Grade 6. Proposed rule language.

3501.0830, subp. 2(C). The student will understand that the motion of an object can be described in terms of speed, direction, and change of position.

Forces and Motion.

Grade 2. Proposed rule language.

3501.0810, subp. 2(D). The student will understand that the motion of an object can be changed by push or pull forces.

Grade 5. Proposed rule language.

3501.0825, subp. 2. The student will understand that an object's motion is affected by forces and can be described by the object's speed and the direction it is moving.

Grade 6. Proposed rule language.

3501.0830, subp. 2(D). The student will understand that forces have magnitude and direction and govern the motion of objects.

Grades 9-12. Proposed rule language.

3501.0845, subp. 2(C). The student will understand that an object's mass and the forces on it affect the motion of an object.

3. Energy.

The study of energy changes is the domain of physics. The big ideas associated with these standards tell us that when energy changes forms, such as electricity to motion, the total energy remains constant -- there is conservation of energy. These proposed standards ask students to analyze the energy involved in motion, heat, waves (and sound), light, electricity, magnetism, chemical reactions and nuclear reactions. The elementary standards begin with easily observed properties and behaviors of these forms of energy.

These standards are necessary and reasonable to help students understand that energy transfers are involved in most of the actions in the universe, from stars to the processes in a cell. Understanding basic ideas about energy transformation and the conservation of energy is necessary for making sense of a wide variety of phenomena, and for making informed decisions involving energy use.[75]

Kinds of Energy.

Grade 3. Proposed rule language.

3501.0815, subp. 2. The student will understand that energy appears in different forms, including sound and light.

Grade 4. Proposed rule language.

3501.0820, subp. 2(C). The student will understand that energy appears in different forms, including heat and electromagnetism.

Grade 6. Proposed rule language.

3501.0830, subp. 2(E). The student will understand that waves involve the transfer of energy without the transfer of matter.

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75 *See AAAS, Atlas,* p. 24, *supra* note 42.

Grade 8. Proposed rule language.

3501.0840, subp. 2(E). The student will understand that waves involve the transfer of energy without the transfer of matter.

Energy Transformations.

Grade 4. Proposed rule language.

3501.0820, subp. 2(D). The student will understand that energy can be transformed within a system or transferred to other systems or the environment.

Grade 6. Proposed rule language.

3501.0830, subp. 2(F). The student will understand that energy can be transformed within a system or transferred to other systems or the environment.

Grades 9-12. Proposed rule language.

3501.0845, subp. 2(D). The student will understand that energy can be transformed within a system or transferred to other systems or the environment, but is always conserved.

4. Human Interactions with Physical Systems.

This proposed standard is necessary and reasonable because it helps students learn how to make decisions when physical science concepts are involved in societal issues.

Interaction with the Environment.

Grade 7. Proposed Rule Language.

3501.0835, subp. 2(E). The student will understand that there are benefits, costs and risks to different means of generating and using energy.

C. Earth and Space Science.

In Earth and Space Science, students study the structure, processes and origin of the Earth and the universe. This strand encompasses the major disciplines of geology, meteorology and astronomy. Over the last few centuries, these disciplines have moved from being descriptive methods to being theory-based analyses of systems and subsystems which interact with each other. Thus, the proposed standards for these science areas emphasize a systems approach that treats the Earth's interior, surface, atmosphere and the universe as interacting systems.

The standards and benchmarks in this strand generally encompass topics similar to those in the existing standards, with the following differences:

- a stronger effort to make the standards developmentally appropriate;
- a strand for human interactions which highlights environmental connections;
- an effort to make connections to Minnesota examples; and

- a stronger use of a systems approach.

Some of the public comments received during the standards development stage expressed a desire for appropriate inclusion of global concerns, especially global climate change, in the proposed standards. In developing these proposed standards, the committee focused on crafting standards that will guide students toward an understanding of the science concepts that are foundational to the discipline. These foundational concepts can be applied to many current issues and topics in science. Even with this overall focus on foundational concepts, some specific issues, including global climate change, are mentioned in the benchmarks and examples. For example, global climate change is included at least 14 times in the 2009 proposed standards and benchmarks.

By focusing the standards primarily on foundational concepts, MDE seeks to ensure that all students receive learning in the same core areas, while also giving individual schools and teachers the flexibility to tailor their science teaching to their own goals and needs. Schools and teachers choose the particular science issues to include in their instruction based on factors such as relevance to the students and the community, current events, thematic instruction with other disciplines and other factors. MDE also hopes to develop a framework document to provide ideas for curriculum and instruction that address environmental and other issues related to the proposed standards.

The Postsecondary and Workforce Science Readiness Working Group of the Minnesota P-16 Education Partnership recommended that Earth and Space Science standards incorporate an earth systems approach that emphasizes the interactions of the various systems. The following big ideas from the working group guide the Earth and Space Science standards and benchmarks:

- Interactions of the atmosphere, geosphere, hydrosphere and biosphere.
- The transfer of energy through conduction, convection and radiation.
- Circulation patterns in the ocean are driven by density differences.
- Motion of the Earth's plates cause slow and rapid changes in the Earth's surface.

1. Earth Structure and Processes.

The Earth Structure and Processes substrand focuses on the changes that occur or have occurred to the Earth's surface currently and throughout history, and on the processes that cause those changes. The concepts in these proposed standards are part of the field of geology.

In early grades, students make observations of rocks and other materials and look for patterns and uses. In middle grades, they examine processes that cause medium-term changes in the Earth's surface, meaning changes that take place in timeframes of a few days to a few hundred years, as opposed to millions of years. In later grades, students gain an understanding how motions of the Earth's interior cause motion of the Earth's crust. This is the basis for the theory of plate tectonics, which provides an overarching explanation for many large-scale processes on the Earth.

This substrand is divided into three areas for standards: (1) plate tectonics, (2) Earth's changing surface and rock sequences and (3) rock sequence and Earth's history. The big ideas that underlie these proposed standards are the theory of plate tectonics, and the slow and rapid processes that shape Earth's surface and Earth's geologic history. These standards move from observations of Earth's materials, to providing evidence of the formation of Earth's materials, to the analyses of geologic events and time frames. They are necessary and reasonable to help students understand the forces and actions that shape the Earth and its history.

Plate Tectonics.

Grade 8. Proposed rule language.

3501.0840, subp. 3(A). The student will understand that the movement of tectonic plates results from interactions among the lithosphere, mantle and core.

Grades 9-12. Proposed rule language.

3501.0845, subp. 3(A). The student will understand that the relationships among earthquakes, mountains, volcanoes, fossil deposits, rock layers and ocean features provide evidence for the theory of plate tectonics.

Earth's Changing Surface.

Grade 5. Proposed rule language.

3501.0825, subp. 3(A). The student will understand that the surface of the Earth changes. The student will understand that some changes are due to slow processes and some changes are due to rapid processes.

Grade 8. Proposed rule language.

3501.0840, subp. 3(B). The student will understand that landforms are the result of the combination of constructive and destructive processes.

Rock Sequences and Earth History.

Grade 1. Proposed rule language.

3501.0805, subp. 3(A). The student will understand that earth materials include solid rocks, sand, soil and water. The student will understand that these materials have different observable physical properties that make them useful.

Grade 4. Proposed rule language.

3501.0820, subp. 3(A). The student will understand that rocks are Earth materials that may vary in composition.

Grade 8. Proposed rule language.

3501.0840, subp. 3(C). The student will understand that rocks and rock formations indicate evidence of the materials and conditions that produced them.

Grades 9-12. Proposed rule language.

3501.0845, subp. 3(B). The student will understand that by observing rock sequences and using fossils to correlate the sequences at various locations, geologic events can be inferred and geologic time can be estimated.

2. Interdependence within the Earth System.

This substrand focuses on the subsystems of Earth's system. It helps students understand how matter and energy are cycled through the Earth system. Students learn how the energy from the sun and internal sources drive plate motions, air movements and ocean currents. In early grades, students make observations about weather changes and water locations. In middle grades, they relate global patterns to the interactions of heat and materials. In later grades, students understand major driving forces in the interior of the earth and the many factors that affect climate changes.

These standards are necessary and reasonable to help students understand the major processes that drive weather, climate, the cycling of water, the greenhouse effect, ocean currents and the movement of tectonic plates. Students will also understand factors involved in many disasters, such as earthquakes, floods and hurricanes, and appreciate the factors involved in predicting these events.

Sources and Transfer of Energy.

Grade 8. Proposed rule language.

> 3501.0840, subp. 3(D). The student will understand that the sun is the principal external energy source for the Earth.

Grades 9-12. Proposed rule language.

> 3501.0845, subp. 3(C). The student will understand that the Earth system has internal and external sources of energy, which produce heat and drive the motion of material in the oceans, atmosphere and solid earth.

Weather and Climate.

Grade K. Proposed rule language.

> 3501.0800, subp. 3(A). The student will understand that weather can be described in measurable quantities and changes from day to day and with the seasons.

Grade 2. Proposed rule language.

> 3501.0810, subp. 3(A). The student will understand that weather can be described in measurable quantities and changes from day to day and with the seasons.

Grade 8. Proposed rule language.

> 3501.0840, subp. 3(E). The student will understand that patterns of atmospheric movement influence global climate and local weather.

Grades 9-12. Proposed rule language.

> 3501.0845, subp. 3(D). The student will understand that global climate is determined by distribution of energy from the sun at the Earth's surface.

Materials Cycles.

Grade 4. Proposed rule language.

3501.0820, subp. 3(B). The student will understand that water circulates through the Earth's crust, oceans and atmosphere in what is known as the water cycle.

Grade 8. Proposed rule language.

3501.0840, subp. 3(F). The student will understand that water, which covers the majority of the Earth's surface, circulates through the crust, oceans and atmosphere in what is know as the water cycle.

Grades 9-12. Proposed rule language.

3501.0845, subp. 3(E). The student will understand that the cycling of materials through different reservoirs of the Earth's system is powered by the Earth's sources of energy.

3. The Universe.

This substrand introduces the field of astronomy. In the early grades, students describe patterns seen in the sun and the moon and relate them to the motions of the Earth and moon. In middle grades, students understand the forces and other factors that affect the motions and composition of objects of the solar system and relate them to objects in the universe. In later grades, students examine processes at work in the history and interactions of the universe.

These standards are necessary and reasonable to help students develop an understanding of the role of the Earth in the universe. They help students appreciate how the quest for understanding the observations of the sky has led to a deeper understanding of our own planet and its history.

Solar System Motion.

Grade 3. Proposed rule language.

3501.0815, subp. 3(A). The student will understand that the sun and moon have locations and movements that can be observed and described.

Grade 8. Proposed rule language.

3501.0840, subp. 3(G). The student will understand that the Earth is the third planet from the sun in a system that includes the moon, the sun, seven other planets and their moons, and smaller objects.

Formation of the Solar System.

Grade 3. Proposed rule language.

3501.0815, subp. 3(B). The student will understand that objects in the solar system as seen from Earth have various sizes and distinctive patterns of motion.

Grades 9-12. Proposed rule language.

3501.0845, subp. 3(F). The student will understand that the solar system, sun and Earth formed over billions of years.

Age, Scale and Origin of the Universe.

Grades 9-12. Proposed rule language.

3501.0845, subp. 3(G). The student will understand that the big bang theory states that the universe expanded from a hot, dense chaotic mass, after which elements formed and clumped together to eventually form stars and galaxies.

4. Human Interactions with Earth Systems.

In this substrand, students learn how human use of natural resources has improved the quality of human life and has altered natural systems. They consider the benefits and risks of the ways humans interact with the Earth's materials and systems.

These standards are necessary and reasonable to help students make decisions about the choices they make in the use of Earth's resources, These decision-making skills and understanding about the Earth systems are important for daily life and potential careers.

Interaction with the Environment.

Grade 4. Proposed rule language.

3501.0820, subp. 3(C). The student will understand that in order to improve their existence, humans interact with and influence Earth systems.

Grade 5. Proposed rule language.

3501.0825, subp. 3(B). The student will understand that in order to maintain and improve their existence, humans interact with and influence Earth systems.

Grade 8. Proposed rule language.

3501.0840, subp. 3(H). The student will understand that in order to maintain and improve their existence, humans interact with and influence Earth systems.

Grades 9-12. Proposed rule language.

3501.0845, subp. 3(H). The student will understand that people consider potential benefits, costs and risks to make decisions on how they interact with natural systems.

D. Life Science.

The Life Science standards are essential for understanding the functioning of living organisms and their interactions with their environment. They also are important for understanding the advances in life science areas such as medicine, agriculture and biotechnology, and their implications for personal and societal decisions. While medicine, agriculture and biotechnology are not directly addressed by the standards and benchmarks, the concepts that students learn provide the tools and background knowledge for addressing issues such as healthy lifestyles, genetic modified crops, uses of biotechnology and human affects on the environment.

The four substrands in the Life Science strand are:

1. Structure and Function in Living Systems;
2. Interdependence Among Living Systems;
3. Evolution in Living Systems; and
4. Human Interactions with Living Systems.

The P-16 Science Readiness Working Group recommended that the following big ideas in Life Science be incorporated into the proposed standards:

- Evolution explains both the unity and diversity of life.
- Living things are composed of cells that form the basic structure and perform the basic functions of life.
- Living things display varying and profound degrees of interdependence from the cellular to the ecosystem levels.
- Life, from individual cells to ecosystems, requires a constant input of energy to remain organized.
- Organisms grow, reproduce and develop in predictable ways governed by information encoded in sequences of DNA known as genes.[76]

All of these ideas are included in the Life Science proposed standards.

The committee and MDE received some comments, via the public online feedback option and personal communication, about the coverage of evolution in the standards and benchmarks during the standards development stage. Several of these comments advocated the inclusion of "intelligent design" in the standards. However, at the public hearings held during the development stage, this issue received very little comment.

The committee used the practices established in the following resources for guidance in writing the standards in this area:

- The National Science Education Standards, the Benchmarks for Science Literacy and the National Assessment for Educational Progress Frameworks for Science.
- The legal precedent of the Supreme Court and Federal Courts in several cases. Most recently *Tammy Kitzmiller, v. Dover Area School District*, 400 F. Supp. 2d 707 (M.D. Pa. 2005), determined that schools cannot be required to include intelligent design in their science teaching.
- The Teaching of Evolution Position Statement of the National Science Teachers Association, which recommends that "[p]olicy makers and administrators should not mandate policies requiring the teaching of 'creation science' or related concepts, such as so-called 'intelligent design,' 'abrupt appearance,' and 'arguments against evolution.'"[77]

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76 *See* Postsecondary and Workforce Working Group Report, p. 9, *supra* note 35.
77 The position paper is available online *at* http://www.nsta.org/position.

The committee recognized that the concept of evolution rests on a firm base of evidence, and that the basic understanding of this evidence is learned by students over a long period of time. Hence, the substrand Evolution of Living Systems has standards that start in first grade with descriptions of the life cycle changes in plants and animals. The mechanisms for evolution do not appear until the high school standards. Evolution is specifically mentioned in one standard and three benchmarks.

1. Structure and Function in Living Systems.

This substrand helps students understand how living systems are organized by molecules, cells, tissues, organs and organisms. Students learn how these various levels carry out the functions of organisms. In early grades, students observe and compare plants and animals based on their observed characteristics, and start connecting the external structures to their functions. In middle grades, students examine the structures of organs, tissues and cells and how their interactions affect the organism. In higher grades, the students learn the processes that occur at the cellular and molecular levels, and how these processes carry out the functions of the organism.

The substrand has two areas of standards: Levels of Organization and Cells.

Levels of Organization.

Grade K. Proposed rule language.

> 3501.0800, subp. 4(A). The student will understand that living things are diverse with many different observable characteristics.

Grade 1. Proposed rule language.

> 3501.0805, subp. 4(A). The student will understand that living things are diverse with many different observable characteristics.

Grade 2. Proposed rule language.

> 3501.0810, subp. 4(A). The student will understand that living things are diverse with many different observable characteristics.

Grade 3. Proposed rule language.

> 3501.0815, subp. 4(A). The student will understand that living things are diverse with many different characteristics that enable them to grow, reproduce and survive.

Grade 5. Proposed rule language.

> 3501.0825, subp. 4(A). The student will understand that living things are diverse with many different characteristics that enable them to grow, reproduce and survive.

Grade 7. Proposed rule language.

> 3501.0835, subp. 4(A). The student will understand that tissues, organs and organ systems are composed of

cells and function to serve the needs of all cells for food, air and waste removal.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(A). The student will understand that organisms use the interaction of cellular processes as well as tissues and organ systems to maintain homeostasis.

Cells.

Grade 7. Proposed rule language.

3501.0835, subp. 4(B). The student will understand that all organisms are composed of one or more cells which carry on the many functions needed to sustain life.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(B). The student will understand that cells and cell structures have specific functions that allow an organism to grow, survive and reproduce.

2. Interdependence Among Living Systems.

This substrand helps students understand how organisms interact with each other and their environments. It includes the major field of ecology and its applications to agriculture, natural resources, wildlife management and the food industry. The proposed standards in this substrand examine the interactions of various systems and subsystems that affect the populations of organisms on the Earth.

In early grades, students examine the needs of plants and animals for survival, and how their environments supply those needs. In middle grades, they understand the relationship between populations of organisms in an ecosystem, and how matter and energy are transferred among organisms and within their environment. In later grades, students learn the processes involved in the transfer of matter and energy, and the complex relationship between populations in ecosystems.

This substrand has two standards areas: Ecosystems and Flow of Matter and Energy.

Ecosystems.

Grade K. Proposed rule language.

3501.0800, subp. 4(B). The student will understand that natural systems have many components that interact to maintain the living system.

Grade 1. Proposed rule language.

3501.0805, subp. 4(B). The student will understand that natural systems have many components that interact to maintain the living system.

Grade 2. Proposed rule language.

3501.0810, subp. 4(B). The student will understand that natural systems have many components that interact to maintain the living system.

Grade 5. Proposed rule language.

3501.0825, subp. 4(B). The student will understand that natural systems have many parts that interact to maintain the living system.

Grade 7. Proposed rule language.

3501.0835, subp. 4(C). The student will understand that natural systems include a variety of organisms that interact with one another in several ways.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(C). The student will understand the interrelationship and interdependence of organisms generate dynamic biological communities in ecosystems.

Flow of Energy and Matter.

Grade 7. Proposed rule language.

3501.0835, subp. 4(D). The student will understand that the flow of energy and the recycling of matter are essential to a stable ecosystem.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(D). The student will understand that matter cycles and energy flows through different levels of organization of living systems and the physical environment, as chemical elements are combined in different ways.

3. Evolution in Living Systems.

This substrand helps students understand the short-term and long-term changes that occur in organisms and populations. It includes life cycle changes that occur in individuals, the continuity and variations that occur through reproduction and the changes in populations and species that are a result of natural selection.

In the early grades, students notice and describe the changes that various organisms undergo in their life–cycles, and compare the similarities and differences between adults and offspring. In middle years, students learn the cellular processes of reproduction and heredity, and how these processes may make some populations better suited than others for survival in an environment, which can lead to population changes over time. In later grades, students learn the molecular processes involved in the transfer of genetic information and the development of variations in organisms. They also learn how natural and artificial selection can lead to changes in populations and species.

The substrand has the following areas for standards: Reproduction, Variation and Biological Evolution.

Reproduction.

Grade 1. Proposed rule language.

3501.0805, subp. 4(C). The student will understand that plants and animals undergo a series of orderly changes during their life cycles.

Grade 2. Proposed rule language.

3501.0810, subp. 4(C). The student will understand that plants and animals undergo a series of orderly changes during their life cycles.

Grade 7. Proposed rule language.

3501.0835, subp. 4(E). Reproduction is a characteristic of all organisms and is essential for the continuation of a species. Hereditary information is contained in genes which are inherited through asexual or sexual reproduction.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(E). The student will understand that genetic information found in the cell provides information for assembling proteins, which dictate the expression of traits in an individual.

Variation.

Grade 3. Proposed rule language.

3501.0815, subp. 4(B). The student will understand that offspring are generally similar to their parents, but may have variations that can be advantageous or disadvantageous in a particular environment.

Grade 7. Proposed rule language.

3501.0835, subp. 4(F). The student will understand that individual organisms with certain traits in particular environments are more likely than others to survive and have offspring.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(F). The student will understand that variation within a species is the natural result of new inheritable characteristics occurring from new combinations of existing genes or from mutations of genes in reproductive cells.

Biological Evolution.

Grades 9-12. Proposed rule language.

3501.0845, subp. 4(G). The student will understand that evolution by natural selection is a scientific explanation for the history and diversity of life on Earth.

4. Human Interactions with Living Systems.

This substrand helps students learn how people interact with their environment and how this interaction can affect their health. In the early grades, students describe beneficial and harmful interactions with the environment and recognize the body's defenses against diseases. In middle grades, students learn ways that human actions can affect populations of organisms. They learn the role of microorganism in diseases, and how the body's immune system works. In later grades, students examine the risks and benefits of technologies that affect ecosystems, and understand the molecular and cellular processes involved with diseases and cancer.

The substrand has the following standards areas: Interaction with the Environment and Health and Disease.

Interaction with the Environment.

Grade 5. Proposed rule language.

> 3501.0825, subp. 4(C). The student will understand that humans change environments in ways that can be either beneficial or harmful to themselves and other organisms.

Grade 7. Proposed rule language.

> 3501.0835, subp. 4(G). The student will understand that human activity can change living organisms and ecosystems.

Grades 9-12. Proposed rule language.

> 3501.0845, subp. 4(H). The student will understand that human activity has consequences on living organisms and ecosystems.

Health and Disease.

Grade 4. Proposed rule language.

> 3501.0820, subp. 4(A). The student will understand that microorganisms can get inside one's body and they may keep it from working properly.

Grade 7. Proposed rule language.

> 3501.0835, subp. 4(H). The student will understand that human beings are constantly interacting with other organisms that cause disease.

Grades 9-12. Proposed rule language.

> 3501.0845, subp. 4(I). The student will understand that personal and community health can be affected by the environment, body functions and human behavior.

E. Grades 9-12 Standards in Chemistry and Physics.

Beginning with the class of 2015, students are required to have a credit in chemistry or physics as part of their three-credit graduation requirement. Minn. Stat. § 120B.023, subd. 3. In the past, high school students were required to take a biology credit and two additional science credits in order to satisfy graduation requirements. Thus, the requirement that all students must have a credit in either chemistry or physics in order to graduate is a significant change. To support this new requirement, MDE has drafted stand-alone standards in chemistry and physics that will help schools and teachers prepare curriculum and learning requirements in the areas of chemistry and physics. These proposed standards are drafted to make chemistry and physics accessible for students who may pursue many possible careers and post-secondary education programs. Therefore, the standards are not at the same level of rigor as traditional college-prep physics and chemistry courses, which tend to attract a self-selecting category of students who are more likely to pursue college-level science and engineering courses.

These proposed standards, and the supporting benchmarks, define the level of understanding and the skills that are required for all students to meet their graduation requirement through one of these courses.

3501.0850 Grade 9-12 Chemistry Standards.

Subpart 1. The Nature of Science and Engineering.

Interactions among science, technology, mathematics, and society.

A. The student will understand that developments in chemistry affect society and societal concerns affect the field of chemistry.

B. The student will understand that physical and mathematical models are used to describe physical systems.

Subp. 2. Physical Science.

Matter.

A. The student will understand that the periodic table illustrates how patterns in the physical and chemical properties of elements are related to atomic structure.

B. The student will understand that chemical and physical properties of matter result from the ability of atoms to form bonds.

C. The student will understand that chemical reactions describe a chemical change in which one or more reactants are transformed into one or more products.

D. The student will understand that states of matter can be described in terms of motion of molecules. The properties and behavior of gases can be explained using the kinetic molecular theory.

3501.0855. Grade 9-12 Physics Standards.

Subpart 1. The nature of Science and Engineering.
Interactions among science, technology, engineering, mathematics, and society.

A. The student will understand that developments in physics affect society and societal concerns affect the field of physics.

B. The student will understand that physical and mathematical models are used to describe physical systems.

Subp. 2. Physical Science.

Motion.

A. The student will understand that forces and inertia determine the motion of objects.

B. The student will understand that when objects change their motion or interact with other objects in the absence of frictional forces, the total amount of mechanical energy remains constant.

Energy.

C. The student will understand that sound waves are generated from mechanical oscillations of objects and travel through a medium.

D. The student will understand that electrons respond to electric fields and voltages by moving through electrical circuits and this motion generates magnetic fields.

E. The student will understand that magnetic and electric fields interact to produce electromagnetic waves.

F. The student will understand that heat energy is transferred between objects or regions that are at different temperatures by the processes of convection, conduction and radiation.

CONCLUSION

Based on the foregoing, the proposed rules are both needed and reasonable.

Date

Chas Anderson, Deputy Commissioner