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ABSTRACT

This study examined state and national benchmarks and standards for K-12 science instruction, curricular goals, and objectives for K-12 science, state, and national assessments that measure student achievement in science and student use of computers and technology for science in grades K-12. The study used survey data and student achievement scores from the 1996 and 2000 National Assessment of Educational Progress science assessments for a national sample and the states of Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, and Tennessee. Standardized mean difference in achievement of students who used computers and those who did not suggested that, with the exception of students at grade 12, students who used computers more often for science had significantly lower science achievement scores than students who used computers less often. Curriculum mapping revealed that computer use for science was not an integral part of many formal science curriculum standards, resulting in discontinuity between the standards and the taught and tested curriculum. Another significant finding was that the percentage of teachers who reported that their students had access to a computer for science at school had increased from 1996 to 2000, with nearly 90% of grade 8 science classrooms in the year 2000 having access to at least one computer, although fewer than 25% had access to two or more computers. Five appendixes contain supplemental materials, including information on state standards. (Contains 11 tables and 19 references.) (SLD)

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Computer Use and Science Achievement: Linking Science Standards and the Assessments

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Computer Use and Science Achievement: Linking Standards and Assessments

Executive Summary

This report examined state and national benchmarks and standards for K-12 science instruction, curricular goals and objectives for K-12 science, state and national assessments that measure student achievement in science, and student use of computers and technology for science in grades K-12. The study used survey data and student achievement scores from the 1996 and 2000 NAEP science assessments for a national sample and the states of Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, and Tennessee.

Standardized mean difference in achievement of students who used computers and those who did not suggested that, with the exception of students at Grade 12, students who used computers more often for science had significantly lower science achievement scores than students who used computers less often. Nationally, Grade 12 NAEP science achievement scores were slightly lower in 2000 than in 1996. Although a causal relationship between computer usage and science achievement should be viewed with caution, several sources for these differences were considered Curriculum mapping revealed that computer use for science was not an integral part of many formal science curriculum standards, resulting in discontinuity between the standards and the taught and tested curriculum. Thus, students who spent more time using computers may have been engaged in learning skills such as computer technology that might not be assessed on state and national science achievement tests. None of the public release items from the 1996 NAEP science assessment required that students complete a computer task to answer a science question. The small percentages of students who reported using computers every day for science suggested that these populations of students may not have been representative of the general population of students studying science.

Significant findings were that the percentage of teachers who reported that their students had access to a computer for science at school had increased from 1996 to 2000, with nearly 90% of Grade 8 science classrooms in the year 2000 having access to at least one computer, although less than 25% of Grade 8 science classrooms had access to two or more computers. Current reform efforts continue to examine the integration of science, math, and technology standards and benchmarks, and trends in assessment indicate more emphasis on performance assessment, including the use of computer technology in science teaching and learning. Test publishers and other assessment experts may be reluctant to include additional computer technology skills in science assessments until there are more computers available for science classrooms.

Background

In today's increasingly technology-driven world it would seem to be a given that students who have had access to computers in their science classrooms would do better on science assessments than those who had not. However, there is some evidence to the contrary: i.e., that students who use computers more often actually have lower science achievement scores than students who use computers less often. Is this true, or is it a misconception that may lend fuel to the fire for critics of technology-driven instruction? Almost everyone believes that it is important for students to acquire computer literacy, and what better place than in the science classroom? After all, computers are tools for doing science, aren't they? However, all educators know that the linkages between the standards, the curriculum, classroom expectations and practices, and assessments are not always perfect. All too often these components of education seem to operate independently of each other. It is as if those of us in education have been given a jigsaw puzzle, completely disassembled, and expected to make a coherent whole. We can solve these puzzles, but the larger and more complex they become, with smaller and smaller pieces, the longer it takes. A 1996 report to the National Science Foundation on undergraduate preparation in science, mathematics, engineering and technology identified "widely varying levels of student ability, ... poor preparation for SME&T studies...," "ineffective use of instructional technology" and "lack of resources" to be among the barriers to improving undergraduate education in SME&T (George et al., 1996, p. 40).These findings were reported for colleges and universities at the national level, not endemic to any particular state or region of the United States. Thus it would not be surprising to find similar barriers to improving science education at the K-12 level. These might include access to computers, state-of-the-art technology, lower pupil-teacher ratio, smaller class size, and better instructional methods. The question is, are there significant differences in science achievement between students who report using computers in science class and those who do not? If there are, what are possible sources of the differences? When there appears to be a relationship between two variables such as computer usage and science achievement it is all too easy to assume that a causal relationship exists when in fact it may not. Often, the relationship is explained by another variable for which information is unknown or unavailable. Therefore, even if data confirm that there are significant differences in achievement between computer users and non-computer users the differences may be explained by underlying factors.

First, let's examine the evidence that we have on the possible correlations between computer usage and student achievement. What do the results of the assessments tell us? What assessments can we use? Classroom assessments provide the most direct evidence, but they are generally not standardized; thus one teacher's standards and expectations for student performance and achievement may not be the same as another's. Students in one teacher's class may do better than students in another teacher's class, and these differences may be due to a combination of student ability, quality of teaching, method of assessment, school effects (class size, school climate, quality of materials, availability of computers in the classroom, students' access to a home computer, etc.), and curriculum alignment, to mention only a few.

The battery of standardized tests that most states require provides yet another measure of achievement to standards; however, it is more difficult to determine whether students who did well on these tests also used computers in the classroom, as statewide tests and district education report cards usually include a limited amount of information about student study habits and access to technology (Miller-Whitehead, 2002). However, several states in this study, such as Alabama and Kentucky, include a technology indicator on their State Education Report Card. Also, many states that do have mandated state tests for students at designated grade levels do not test in all subject areas, such as science (Miller-Whitehead; Zucker, Shields, Aldeman, & Humphrey, 1997). Some states only require that all students be assessed in reading or language arts, math, and writing.

Therefore it is often difficult to establish a linkage between using computers in science class and science achievement on state-mandated assessments.

Although the most widely-used standardized tests have much in common, there are substantial differences among the tests in both format and in how students are tested. Some tests have separate sections for reading, language arts, math, science, and social studies while others use a thematic approach to assess across the curriculum, with interrelated questions for each of the tested subject areas embedded in the same reading passages and tasks. Some tests are timed and others are untimed. Some tests assess mastery to standards or criteria and others compare student performance to national or state norms. Table 1 provides information about state-mandated assessments and grade levels assessed for the states of Alabama, Arkansas, Georgia, Louisiana, Kentucky, Mississippi, and Tennessee.

In Table 1, NRT refers to a "norm-referenced" test and CRT to a "criterion-referenced test." Although it is not the purpose of this report to provide an extended discussion of assessment methodology, a brief explanation follows. There are distinct differences between the CRT and NRT approach to student assessment and in some instances test reports may be generated for both student achievement compared to national norms and to criteria such as state or national standards for the same test. One difference is that norm-referenced tests are usually timed tests while criterion-referenced tests are untimed, or "power tests." Thus, assessments and tests generally are specifically designed to be scored either as norm-referenced or criterion-referenced. While there are a variety of methods used by test experts to equate or compare student scores on different types of tests such as norm-referenced or criterion-referenced it is important to understand that some students may do better on one kind of test than on another. For this reason many states have chosen to assess students with CRT and NRT tests at alternate grade levels. Table 1 also indicates that most states administer grade level state-wide assessments each year to students from Grades 3 to 11 or at alternate grade levels, such as students in Grades 4, 8, and 10 or in Grades 5, 7, and 10. Unless they take the ACT or SAT test many Grade 12 students are not assessed in science, unless their state requires that they demonstrate competency on "end of course" exams in science areas such as Biology or Chemistry, or on a high school exit exam that includes a science subtest. For example, 35% of a national sample of 7,993 public school Grade 12 NAEP respondents indicated that they were not currently enrolled in a science course. The fact that students may or may not study science each year in Grades K-12, that they may not be tested in science at all on state-wide assessments, and that 35% of a national sample of Grade 12 respondents indicated that they were not currently enrolled in a science class is an indication that formal science education may not receive the same emphasis as other areas of the curriculum. In some cases the overlap between content areas of math, technology, and science may make it appear that students are not studying science when in fact they may be.

Table 1

Tests and Grade Levels of State-Mandated Science Assessments

State	Test	Type	Science Subtest Scores Reported	Grades Science Tested
Alabama	Stanford 9	NRT	Total battery only	3 - 11
Arkansas	Stanford 9	NRT	Total battery only	5,7, 10
Georgia	Iowa Test of Basic Skills	NRT	Yes	3,5, 8
Mississippi	TerraNova	CRT NRT	Total battery only	2 - 8
Kentucky	California Achievement Tests	CRT	Yes	4,7, 11
Louisiana	Iowa Tests Gee21, Leap21	NRT	Yes	4, 8, 10
Tennessee	TerraNova	CRT NRT	Yes	3 - 8

Note. Alabama was considering the adoption of a new assessment for the year 2003 at the time of this report.

If the diversity of state-wide testing programs unduly complicates examinations of student achievement in science, what alternative measures are there for those who are concerned with improving curricular planning and teaching and learning in science? There are the so-called national assessments such as the National Assessment of Educational Progress (NAEP) that are administered to selected samples of schools and students at schools across the U.S. at Grades 4, 8 and 12. The NAEP assessments include questionnaires that provide more information than most other standardized tests about the school's learning environment, about how teachers teach, and about how and what students study. Another nationally administered assessment is the Third International Mathematics and Science Study (TIMSS). The results of the last administration of the TIMSS indicated that U.S. students did not do as well in math and science as many of their international counterparts. TIMSS evaluators identified multiple areas for improvement necessary to bring U.S. science and math achievement to expected levels, including changes in "teacher preparation, working conditions in schools, the quality of curricula and textbooks, and other aspects of American education" (Zucker et al., p. A-3). Thus, there is some evidence based on the results of internationally administered standardized assessments that even though the U.S. continues to excel in science research and development, U.S. students do not perform as well in science and math as students in some other countries.

However, there are several issues that must be addressed when examining the possible correlations between using computers to analyze data and the results of "national" assessments. First, there have been questions as to the extent to which national assessments such as NAEP reflect state and local curriculum objectives for computer literacy. If the test objectives of national assessments in science are not the same as the test objectives of state-mandated assessments, then using computers to analyze data in science class may not help students do well on national science assessments such as the TIMSS or NAEP. Most large-scale assessments, including the NAEP and state assessments provided in Table 1, test only a certain percentage of the knowledge and skills found in the state and national science curriculum standards: this fact, well-known by students, results in their oft-repeated question, "will this be on the test?" (Mills, 1994). Quite obviously, teachers believe that all components of their science curriculum are important, whether they will be on the test or not, while students generally concentrate on those objectives for which they will be held accountable. However, unlike classroom tests, college entrance tests, and state-mandated assessments, students are not held accountable for their performance on national assessments such as the NAEP; in fact, no individual student scores are reported for the NAEP. This study revealed little evidence to suggest that students did not try to do their best on these tests, so aggregate student scores were assumed to be more reflective of teaching and learning practices and available resources than of student attitudes about the test.

A comprehensive RAND study (Grissmer, Flanagan, Kawata, & Williamson, 2000) which examined outcomes for NAEP math and reading tests and for NAEP composite scores by state, did not report specific results for the NAEP science tests at Grades 4, 8, and 12 but did provide analyses of such initiatives as the Tennessee class size study. The RAND study did, however, confirm findings from the Tennessee STAR longitudinal studies that students in smaller classes (13 to 17 students) did better than similar students in larger classes on every subject tested, including science.This finding confirmed that state-level and school district-level priorities and allocation of resources had an effect on student science achievement, and thus served to reinforce the importance of continuation of efforts to improve both assessments and instructional practices in all subject areas, including science.

Therefore, we should take a look at what students are expected to know and be able to do in order to do well on science assessments such as the NAEP or on the science subtests of the state-mandated achievement tests. What are the specific goals and objectives of the science standards, and what are some sample questions that students might encounter on the tests? Are these the kinds of things that students can practice and become proficient at using a computer? Computer literacy and science achievement are not the same; students who use computers frequently may be learning more computer literacy skills than the skills they need to have to do well on science achievement tests. In fact, such initiatives as "technology across the curriculum" are intended to keep students current with emerging technology tools so that students "[use] tools for data analysis" (Boettcher, 2000, p. 44). And so a question is whether or not standardized science tests such as the NAEP measure (or should measure) the actual skills that the students are learning when they use computers in science class. Given increasing demands on instructional time and more goals and objectives than can possibly be covered adequately, many teachers when planning for instruction and deciding how to prioritize their teaching time, ask themselves the classic student question, "will this be on the test?" Another question that arises is whether computer software is selected to complement student ability and learning styles. For example, computer software in the science classroom may be used for programmed instruction, for exploration and discovery, science games, for data tracking and analysis, or for desktop publishing of results of science projects.

Goals and objectives for computer literacy usually include some math and science related activities such as using spreadsheets and databases to graph and analyze data (Appendix D), although this may not be the equivalent of the higher-order problem solving skills required to do well on some types of science questions. Teachers who have eschewed the use of formerly popular programmed texts, equating them with so-called "drill and kill" methods that turned off students to science (Warschauer, 2000), have turned instead to computer-assisted instruction (CAI). However, educators who have evaluated the results of both methods believe that good programmed texts may be more effective for some students than many of the currently available and often more expensive CAI programs (Scriven, 1995). Thus, even when computers are used for direct instruction in science, student achievement may be affected by the degree to which selected programs are aligned with test objectives. A study of state indicators for math and science conducted by the Council of Chief State School Officers found that in 1993-1994 the average public school spent only $50 on science computer software and $100 on math computer software (Blank & Gruebel, 1995). Such figures do not indicate that nationally there was a high priority given to the use of computers for science in 1993-1994.

Initiatives designed to connect schools to the Internet may serve to reduce teachers' feelings of isolation in the classroom, make them feel a true part of the global community, and provide them with a sense of renewal as well as unlimited access to teaching resources (Rogan, 1995). Therefore, computers in the classroom may yield significant positive outcomes that are not measurable by student achievement alone and these outcomes may provide significant cost benefits to school systems, such as improving faculty retention rates and reducing administrative and record-keeping costs. Table 2 shows that in 1996 as many as 50% of students in 7 southeastern states did not have access to even one computer in their science class, although in at least one state, Kentucky, all students had access to a computer to study science. By the year 2000, all states in this study had improved in providing access to at least one computer in science class. However, when there is only one computer in a K-12 classroom, it may be provided as an administrative tool to facilitate central office and teacher record-keeping rather than for instructional purposes or for Internet access.

Recent reports on computer ownership and use of the Internet by minorities found that white students were more than twice as likely to own a computer as African-American students, and that while 56% of white households with children under the age of 17 owned a computer, for African-American families computer ownership ranged from 34% to 40%. However, for households with incomes above $40,000 from 61% to 65% of both white and African-American families owned a PC (Hoffman, Novak, & Schlosser, 2000; Novak, Hoffman, & Project 2000 Vanderbilt University, 1998). Researchers at Vanderbilt's Owen School of Management have conducted extensive studies on the relationship between computer access and Internet use. One such effort resulted in a technology transfer initiative, the Vanderbilt Virtual School Project, which provided free Internet access and in some cases a computer and modem to participating K-12 teachers across Tennessee. Teachers and administrators were encouraged to explore available Internet resources for lesson plans, teaching ideas, and collaborative partnerships with teachers and students in their subject areas. In the early years of the project (I participated in the early 90's) modems and dial-up connections were slow and accessible web sites were text-based. Consortia of researchers at BellSouth and participating universities, including Jackie Shrago and Elliott Mitchell of Vanderbilt and Steve Shao at Tennessee State, were searching for efficient ways to transmit graphics and video over regular telephone lines to improve communication between K-12 and university partners studying classroom teaching and learning methods: the DIANE project and the popular CUSeeMe program were among the products of such school and university collaborations. By 1996 these incubation efforts had been reincarnated as the ConnecTEN Project in preparation for Tennessee's Bicentennial celebration. During the Bicentennial, Governor Sundquist and the State Superintendent of Education Jane Walters officially declared that every public school in Tennessee had at least one graphical interface connection to the World Wide Web. Of the southeastern states in this report, in 1996 only Kentucky and Georgia led Tennessee in percent of science classrooms with access to a computer for students in Grade 8 science.

A recent report by the Council of Chief State School Officers found a great deal of variability in the time that middle school science teachers reported spending on teaching different components of the science curriculum; for example, they spent approximately 5% of their time on *Measurement and Calculation* in science but they reported spending anywhere from 10% to 40% of their time on *Life Science* (Kim, Crasco, Smithson, & Blank, 2000). Their findings indicated that elementary and middle school students spent from 3% to approximately 10% of their instructional time in science class using computers, calculators, or other technology to learn about science. These findings seem to indicate that science teachers exercised a great deal of autonomy in the areas of science that they emphasized, perhaps due to community expectations for student learning and to local curriculum development initiatives. In fact, a great deal of what is taught may be dependent upon whether the curriculum is "frontloaded" or "backloaded" (English, 1992). In essence, this is a question of whether the curriculum determines what is tested or whether the test items determine what is taught in the curriculum. Most educators prefer to reach consensus on what students should know and be able to do and then select a test that is an appropriate measure of those skill areas; this is known as frontloading. "Teaching to the test" is an example of backloading (English). The test or assessment that is either selected or already in place drives curricular goals and objectives and teaching modules are then designed to align with the test objectives.

It is not difficult to see that discontinuity between assessment and curriculum may occur if local goals and objectives are not aligned to state curricular standards as well as to the tests that students will be expected to take. Community curricular goals and objectives may be quite influential in determining the kind of education that children receive. Local goals and objectives may be developed, written, and disseminated through a formal process, or they may evolve as an informal curriculum. Informal curricula are often largely undocumented but commonly followed by tradition within a community and may focus on unique features of a community, such as its environment, history, or economy. These unique features may have a great deal of influence on a school district's education programs and may also have an effect on the amount of time teachers spend teaching specific science units or skill areas. For example, Romberg (1998) examined various initiatives to improve the math curriculum in California and found that although the stated objective was to align the math curriculum with NCTM standards, many of the documents produced contained a wealth of project-based methodology and pedagogy about student projects but a paucity of emphasis on student attainment of math standards.

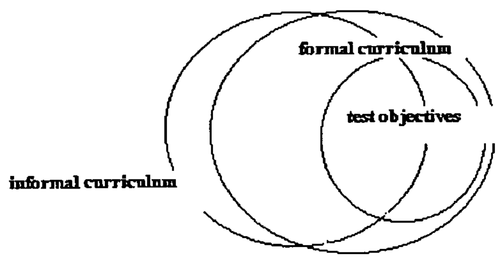

Figure 1. Theoretical correlation of formal and informal curriculum with test objectives

Figure 1 shows that while there may be considerable overlap and a high correlation between the formal and informal curriculum, 100% of test objectives on the typical state-wide standardized test fall within the formal curriculum but may not be encompassed completely by the informal curriculum. It is a rare but occasional occurrence that items on a standardized test do not match national and state curricular goals and objectives. On the other hand, it is more likely that many state and national curricular standards will not be tested on many standardized tests and that standardized tests will not include a certain percentage of the knowledge and skill areas taught as part of the informal curriculum.

A combination of curriculum mapping to examine linkages between state standards and tests and meta-analysis techniques were used to identify effects on student NAEP science achievement. Figure 2 provides a conceptual diagram of linkages and alignment that affect student achievement at the national and state level of assessment. Student achievement at the national level may be affected by the extent of overlap or commonalities of state and national assessments and tests, state and national curricular goals and objectives, the tested student populations, and available resources. If national and state assessments, curricular goals and objectives, tested populations, and resources are not aligned both vertically and horizontally, disparities may be assumed to have an effect on how well students perform on assessments. Such disparities may reflect community and state autonomy and priorities in making decisions about the education of children including teaching methods and time-on-task, or disparities in state and community resources necessary for students to achieve to the highest standards. Curriculum mapping is a technique that is often used to depict the relationship between the tested and taught curriculum or between curricular goals and objectives and time-on-task. For the meta-analysis, Glass's Δeffect sizes and *t* tests of statistical significance for standardized mean differences in NAEP science achievement were calculated for students in Grades 12 and 8.

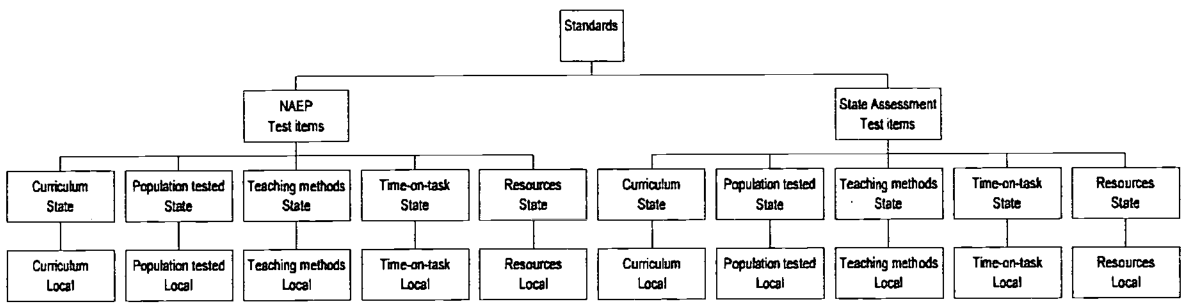

Figure 2. Theoretical vertical and horizontal alignment of state and national assessments

This report used composite science scores and response data for Grade 4, 8, and 12 students from both the 1996 and 2000 administrations of the National Assessment of Educational Progress in Science. Students and their teachers who participated in the 1996 or 2000 NAEP Science tests responded to questions such as the following to describe the availability and instructional use of computers in science class:

1. "If you are taking science this year, about how often do you use a computer to do the following: Analyze data using the computer." Student responses were coded, "Not taking science," "1-2 times a month," "Less than once/month," or "Never." Because so few Grade 8 students responded that they were not taking science, data for that response is not reported in this analysis.
2. "How do you use computers for instruction in science? Drill and practice." (teacher reported).
3. "Which best describes the availability of computers for your science students?" (teacher reported).
4. "During the past five years, have you taken courses or participated in professional development activities in any of the following areas? Use of computers for data analysis (databases, spreadsheets, graphing software)." (teacher-reported)
5. "When you study science in school how often do you use a computer for science?" (student-reported)

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Table 2

Availability of Computers in Science Class for Grade 8 Science Students (Teacher reported)

State	At least one		Two or more	
	1996	2000	1996	2000
National	84%	90%	16%	20%
Alabama	71%	93%	15%	16%
Arkansas	56%	86%	4%	6%
Georgia	87%	95%	8%	21%
Kentucky	93%	100%	11%	26%
Louisiana	53%	90%	3%	26%
Mississippi	50%	89%	2%	10%
Tennessee	76%	87%	18%	21%

Note. Responses from national sample of 1996 and 2000 NAEP survey data for 26,054 students at the state level and 16,558 students at the national level.

According to NAEP data in Table 2, science teachers reported that in the year 2000 less than 10% of Grade 8 science students did not have access to at least one computer; however, less than 25% of Grade 8 science classrooms had more than one computer available for use by science students.

Table 3 provides aggregated scores for a national sample of 7,993 Grade 12 public school students. According to data provided in Table 3, in 2000 Grade 12 students who self-reported using a computer to analyze data in science class at least 1 or 2 times per month scored higher than students who never used a computer or students who used a computer less than once per month. Table 4 provides 1996 NAEP average composite Grade 8 student science scores and responses for the states of Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, and Tennessee. Table 4 provides data for Grade 8 students and in comparison indicates that those who never used a computer to analyze data did consistently better on the 1996 NAEP science assessment than those who used a computer at least 1 to 2 times per month.

Table 3

2000 NAEP Grade 12 Science Composite Scores By How Often Students Self-Reported Using a Computer to Analyze Data (N = 7,993).

National		Avg Score Computer Use			ES	Test
	N	Never	N	1-2 month	Glass' Δ	*t*
2000	3517	145	879	162	.2	7.3

Table 4

1996 NAEP Grade 8 Science Composite Scores By How Often Students Self-Reported Using a Computer to Analyze Data in Science Class (N = 15,956).

State		Avg Score Computer Use			ES	Test
	N	Never	N	1-2 month	Glass' Δ	*t*
Alabama	1579	144	279	133	.2	3.7
Arkansas	1448	145	227	141	.1	1.9
Georgia	1422	146	417	140	.1	1.9
Kentucky	1447	154	317	147	.1	2.7
Louisiana	1481	139	296	133	.1	1.9
Mississippi	1573	137	315	131	.1	2.8
Tennessee	1379	149	302	143	.1	2.5

When numbers of participants are sufficiently large, differences between groups are almost always statistically significant. Computation of the standardized mean difference in science achievement for computer users compared to non-computer yielded very small positive effect sizes for science achievement of non-computer users. In this case, the number of students who used computers for science represented a very small percentage of science students. Thus, computer users would be considered an experimental group and non-computer users a comparison group. For this analysis, the standardized mean difference was calculated using the standard deviation of the comparison group as being more representative of the true variability of the population of Grade 8 students rather than the pooled standard deviation of both groups. However, there may be populations for which the standardized mean difference is best represented by using the pooled standard deviation, such as Cohen's *d* or Hedge's *g* measures of effect size

Table 5

NAEP Grade 12 Science Composite Scores By How Often Students Self-Reported Using a Computer When They Study Science (N = 14,122).

National		Avg Score Computer Use			ES	Test
	N	Never	N	1-2 month	Glass' Δ	*t*
1996	3808	147	1154	159	.2	6.3
2000	4594	141	2172	152	.2	6.2

Table 5 provides information from a comparison national sample of Grade 12 students who responded to the question, "When you study science in school how often do you use a computer for science?" This question does not specify use of computers to analyze data, but would include student use of computerized science games, computer simulations, and science drill and practice activities. Grade 12 science achievement was slightly lower in 2000 than in 1996 for the national sample.

In the national sample, Grade 12 NAEP science composite scores were higher in 2000 for students who reported using computers for science at least one or two times per month than for students who never used computers for science. The effect size was small but statistically significant, given the large number of participants, with less than a 5% probability of the .2 effect size being the result of chance (McLean & Barnette, 2000).

Thirty-five percent of the national sample of Grade 12 students indicated that they were not currently taking science. For both 1996 and 2000, Grade 12 science composite scores were higher for students who used computers for science at least occasionally than for students who never or hardly ever used computers for science. The percent of Grade 12 students who reported that they used computers for science at least 1 or 2 times per month increased from 34% in 1996 to 45% in the year 2000.

Tables 4 and 6 indicate that most Grade 8 students did not use computers for science. Grade 8 students' science achievement scores were consistently higher for students who self-reported never using a computer for science than for those who reported using a computer for science as often as once or twice per month. From 12% to 17% of Grade 8 students reported using computers to analyze data in science class compared to 58% to 68% of students who reported never using computers to analyze data in science class. The science achievement scores for the 4% to 8% of Grade 8 science students who reported using computers for science every day was consistently lower than for the 92% to 96% of Grade 8 students who used computers for science less often or not at all (Table 6).

Table 6

1996 NAEP Grade 8 Science Composite Scores By How Often Students Self-Reported Using a Computer When They Study Science (N = 15,757)

State		Avg Score Computer Use			ES	Test
	N	Never	N	Nearly every day	Glass' Δ	*t*
Alabama	1512	141	126	126	.2	4.6
Arkansas	1322	146	71	136	.2	3.2
Georgia	1602	145	143	122	.4	7.5
Kentucky	1404	150	143	139	.2	4.4
Louisiana	1840	135	151	123	.2	4.2
Mississippi	1922	136	96	114	.4	8.2
Tennessee	1371	144	174	134	.2	3.0

Computation of the standardized mean effect size and *t* values for science achievement of computer users compared to non-computer users indicated that differences were statistically significant and that effect sizes were all positive for non-computer users at Grade 8. Given the large sample and number of groups there would be less than a 5% probability of obtaining effect sizes of these magnitudes by chance (McLean & Barnette, 2000).

Table 7

Test Blueprint Showing Number of Grade 8 State Curricular Objectives and Test Items on a Typical State Assessment

Reporting Category	Number of State Curricular Objectives	Number of Test Items on State Assessment	Percent of Tested Objectives
Scientific Investigation	33	11	33%
Force, Motion, Energy, Matter	37	18	49%
Life Systems	21	7	33%
Ecosystems	23	8	35%
Earth & Space Systems	14	6	43%
TOTAL	128	50	39%

Table 7 indicates that state assessments may test between one-third and one-half of state course content and curriculum standards at a given grade level. Additionally, students are responsible for course content and standards taught at earlier grade levels. Thus, standardized science test items for the Grade 8 assessment include curricular objectives from Grade 6 and 7 science course content.

Table 8

1996 Grade 4 Science NAEP Release Item Descriptions and Item Difficulty by Content Strand

Content Strand	Item Description	Item Difficulty
Physical Science	Reading a graduated cylinder of water	.540
	Identify water level of pencil	.519
	Length of pencil above water	.260
	Identify mystery water	.500
	Reading graduated cylinder	.757
	Identify patterns and ripples of dropped stone	.671
	Reason for non-working radio	.847

Content Strand	Item Description	Item Difficulty
Physical (cont.)	Why does nail become warm	.114
	Properties of metals	.362
Earth and Space	Water volume after pencil added	.070
	Water volume after pencil added	.097
	How does pencil float in salt water	.728
	Effect of more salt on level of pencil	.684
	Easier to float pencil in fresh/salt water	.283
	Major source of gasoline	.639
	Size of stars and Sun	.746
	Identify how rivers and mountains look now	.072
	What covers most of Earth's surface	.776
	Why can moon be seen from Earth	.697
	Causes of smog	.555
	Best evidence Earth is very old	.297
	Forces that change Earth's surface	.167
	Identify Pacific/Atlantic Ocean	.516
	User/conservation of water	.441
Life Science	Circle youngest tadpole	.716
	Why do tadpoles differ	.366
	Source for tadpole	.244
	Source for frog	.286
	Correct cycle for salamander	.920
	Draw and label pupa	.691
	Compare grasshopper and butterfly	.369
	List similar functions	.450

Content Strand	Item Description	Item Difficulty
Life (cont.)	Man/frog/grasshopper	.189
	Where do beetles like to live	.254
	Where do beetles like to live	.357
	Where do beetles like to live	.435
	Transfer of data in table to graph	.642
	Mealworm life cycle: what happens if larva eaten	.574
	Name/function of parts of plant	.416
	Identify three mammals	.666

At Grade 4, NAEP item difficulties for a representative sample of items ranged from .114 to .85 for Physical Science items, from .07 to .78 for Earth and Space science items, and from .19 to .92 for Life Science items. Sample items, student responses, and scoring rubrics may be found in Appendix E. Item types included multiple choice, short constructed response, extended constructed response, and open-ended items. Some items required students to use materials such as rulers, pencils, water, salt, and graduated cylinders. One item of the 41 sample items, or 2% of the sample items, required the transfer of table data to a graph, a skill related to several of the computer technology standards and to two content areas of one state's Minimum Required Content: Science Skills (Appendix C).

Table 9

1996 Grade 8 Science NAEP Release Item Descriptions and Item Difficulty by Content Strand

Content Strand	Item Description	Item Difficulty
Physical Science	Measure pencil	.594
	Determine average measure of pencil	.681
	Why measure twice	.166
	Properties of windows and mirrors	.160
	Identify input/output of energy forms	.461
	Cause of gap in steel joint	.328
	Conversion of matter: popcorn and popper	.260
	Example of nonrenewable resource	.609
	Cause/prevention of hearing loss	.535
	Explain which of two bulbs most efficient	.524
	How insulated bottle works	.305
	Soil/water heating rate	.216
	Prediction of heating rates from data	.200
Earth and Space	Why does pencil float	.265
	Floating in salt solutions	.919
	Why different in salt water	.194
	Effect of more salt	.814
	Plot graph of salt vs. length of pencil	.380
	Relating length to salt concentration	.764
	Cluster	.503
	Concentration of unknown	.306
	Complete model of solar system	.566

Content Strand	Item Description	Item Difficulty
Earth, Space (cont.)	Similarities of real/model solar system	.281
	Differences of real/model solar system	.380
	Show more correct relative size of planets	.292
	Problems in adding outer planets	.282
	Time for Mercury to circle Sun	.670
	Planets with shorter Earth year	.531
	Identify statement about planet movement	.849
	Distance new planet from Sun	.343
	Mercury/Earth revolution	.258
	Closest planet to Earth	.645
	Closest planet to Earth	.280
	Account for seasons	.142
	Property of Earth caused by organisms	.812
	Identification and use of anemometer	.648
	Identify lunar eclipse	.206
	Weather data: day when it snowed	.717
	Weather data: day of lowest windchill	.408
	How rain caused by cold air meeting warm	.035
	Pattern/frequency of earthquakes	.597
	2 most common elements of crust	.090
	Location of space station	.149
	Advantage/disadvantage of garden by stream	.514
	Protection of soil from erosion	.347
	Force responsible for solar system formation	.594
Life Science	Inheritance of hair color	.160

Content Strand	Item Description	Item Difficulty
Life (cont.)	Where bread is digested	.088
	How digested bread gets to tissues	.272
	Hydra: explain appearance and number change	.403
	Hydra: design experiment based on 2 x food	.251
	Hydra: Results of 10 x amount of feed	.171
	Classification of food-making organisms	.719
	Function of mitochondrion	.278
	Causes/prevention of food poisoning	.399
	Advantages/disadvantages of parasites to control mice	.323

Table 9 shows that at Grade 8, item difficulty levels for sample items ranged from .16 to .68 for Physical Science, from .04 to .92 for Earth and Space items, and from .09 to .72 for Life Science items. Of the 53 sample items at Grade 8, one item required computing an average measurement and one item required plotting a graph (approximately 4% of sample items), skills related to several of the computer technology standards. Several items appeared in more than one content strand. Sample items, scoring rubrics, and student responses are provided in Appendix E.

Table 10 provides data for 51 NAEP Grade 12 sample items. Item difficulties ranged from .09 to .68 for Physical Science, from .12 to .93 for Earth and Space Science, and from .09 to .76 for Life Science. Of the 51 Grade 12 sample items 6 items or approximately 12% of sample items required that students be able to graph or interpret graph data. Sample items, scoring rubrics, and student responses are provided in Appendix E.

Table 10

1996 Grade 12 Science NAEP Release Item Descriptions and Item Difficulty by Content Strand

Content Strand	Item Description	Item Difficulty
Physical Science	Use of equipment to separate substances	.179
	Separation of mixture	.653
	Describe separation of mixture	.570
	Separation of substance in water	.390
	Evaporation vs. temperature	.676
	Decrease in heat content	.638
	Determination of grams of reactant	.763
	Path of car on ice	.540
	Passing of trains	.429
	Movement of particles of water	.093
	Factors considered when planning nuclear plant	.327
	Graph: greatest acceleration	.518
	Graph: greatest mass	.526
	How to keep ice cream cooler than 0 x C	.219
	Effect of waves on boat movement	.157
	Relative speed of flight attendant	.403
	Energy transformations and energy differences	.162
Earth and Space	Water cycle: gaseous forms	.927
	Water cycle: solid form	.607
	Water cycle: separation of impurities	.576
	Water cycle: role of forests	.269
	Water cycle: cause of evaporation	.830

Content Strand	Item Description	Item Difficulty
Earth, Space (cont.)	Water cycle: test to recognize water	.456
	Water cycle: cloud formation	.175
	Water cycle: Lake water to snow on mountain	.548
	Water cycle: water as a renewable resource	.175
	Water cycle: prevailing winds	.392
	Water cycle: cause of desert conditions	.369
	Water cycle: fresh water from ocean water	.244
	Water cycle: SO_2 pollution	.218
	Explain activity at Ring of Fire	.264
	Cause of color of setting Sun	.467
	Process needed for rock transformations	.120
	Recognize eclipse progression	.804
	Property shown by star color	.572
	Testing soil after flood	.521
	Evidence for continental drift theory	.576
	Climate/ecology of Alaska long ago	.375
Life Science	Location of fertilization in humans	.322
	Graph: frequencies heard and produced	.622
	Interpretation of frequency data	.370
	Interpretation of frequency data	.330
	Interpretation of frequency data	.240
	3 frog populations: same/different species	.276
	3 isolated frog populations: mating chances	.093
	Ecology study: mowing vs. nonmowing	.159
	Cause of size change of cells in fluid	.330

Content Strand	Item Description	Item Difficulty
Life (cont.)	Cells in fluid: accuracy of conclusion	.431
	How to reduce risk of heart disease	.757
	Risk of infection from person with malaria	.112
	Use of amniocentesis	.639
	Genotype prediction based on earlobe phenotype	.278

Table 11

1996 NAEP Grade 4, 8, and 12 Science Release Items by Domain and Way of Knowing and Doing

		Items Grade 4		Items Grade 8		Items Grade 12	
		N	%	N	%	N	%
Domain	Physical Science	9	23	13	23	17	33
	Earth & Space	15	38	33	59	21	41
	Life Science	16	40	10	18	13	25
Process	Scientific Investigation	12	30	10	19	9	18
	Practical Reasoning	12	30	13	25	10	20
	Conceptual Understanding	16	40	30	57	32	63

Table 11 indicates that while the learning areas or strands are very similar, the content strands from the state assessment test blueprint of Table 7 are not organized exactly the same way as the domains of the NAEP (Tables 8, 9, 10, and 11). For example, the NAEP identifies Scientific Investigation as a process or way of doing, rather than as a separate content area. However, in this case the domains of the state curriculum - physical science, earth and space science, and life science - are the same as those of the NAEP.

Burz and Marshall (1997) list five learning actions that characterize the performances of the purposeful science learner: accessing, interpreting, producing, disseminating, and evaluating. These actions are aligned to performance standards and benchmarks of the *Benchmarks for Science Literacy* of the National Science Teachers Association and the American Association for the Advancement of Science's Project 2061. Their model for science achievement integrates the use technology as a component of performance-based science rather than relegating it to a separate and distinct subject area is the case with many state and national standards (Appendix D). Therefore, while the science content strands of Life Science, Physical Science, and Earth Science are essentially congruent with NAEP content strands, Burz and Marshall include technology criteria and performance standards that provide a linkage from knowledge to performance. In a call for "curriculum coherence," Ahlgren and Kesidou (1995) include math, technology, natural, and social sciences under the umbrella term "science." Their rationale is that these fields are so closely interconnected that reform in one area necessarily affects the others. The implementation of this approach to the integration of science and technology performance standards becomes more feasible as more science classrooms gain computer access (Table 2). Such an approach to the assessment of science achievement would not be possible where the majority of students do not have access to computers for science.

National standards and benchmarks for science at McRel (http://www.mcrel.org) are organized into four main categories and thirteen subcategories (Appendix A). Of these, computer use for data analysis is specifically mentioned as a standard or benchmark for understanding the Nature of Science at Grades 6 - 8 and Grades 9 - 12. Of the 62 Science Standards and 83 substandards (145 in all) listed in the Alabama Course of Study for Grade 8 Science (Appendix B), several might be accomplished by the use of a computer although using a computer is not specifically mentioned. However, the Alabama Minimum Content for Science lists 16 main skill areas (Appendix C), one of which specifically requires that students "demonstrate the use of computer skills in scientific investigations." Therefore, approximately 6% of the Alabama Minimum Content for Science standards specifically require the use or demonstration of computer skills for scientific investigation.

The standards/curriculum/test/test item alignment process addresses each standard and objective in turn to determine whether it should be formally tested or if formal assessment of the objective is feasible. Therefore, the following list is only an outline and does not address such issues as the kinds of manipulatives (such as science kits, protractors, rulers, calculators, or computers) that students may be allowed to use during a test, whether a test will be timed or untimed, or whether students should be tested individually or in groups. Nor does this brief outline address the various methods of determining the relative difficulty level of test items.

Outline of Steps in the District-Wide Testing and Curriculum Alignment Process

1. List all district and state curricular science standards and objectives. Do any specifically mention computer use? What percentage of science standards and objectives require the use of a computer?
2. Determine from Test Blueprint which are "tested objectives" (see, for example, Table 7 and Appendix A). What percent of the state and local curriculum objectives in each content strand are included on the Test Blueprint?
3. Decide how many items the total assessment should contain and length of time to administer. Will items be multiple choice, constructed response, or performance items?
4. If a standard or objective is not tested, should it be? If no, omit and proceed to next objective. Do any standards or objectives appear in more than one domain or content strand?
5. Is the standard or objective "testable" in a multiple choice, constructed response, or performance format? Can testing conditions and student responses for an objective be standardized? If no, omit from test and proceed to next objective.
6. If 4 and 5 are yes, are there test items already in the test item bank to test the objective? If no, write test items.
7. If 6 is yes, are there sufficient items in the test item bank? If there are 4 test items for an objective, the student must respond correctly to 3 to achieve 75% mastery. If there are 2 items, the student can only be at 0%, 50%, or 100% mastery on the objective. Write additional items if necessary.
8. If 6 and 7 are yes, are there scoring rubrics for constructed response and performance items? If no, develop scoring rubrics for each item.
9. Recheck to make sure that tested objectives receive the same weight as shown on Test Blueprint.
10 Proceed until all state and district science standards have been addressed.

Appendix E provides sample items from the 1996 NAEP science assessments for Grades 4, 8, and 12, student responses, and scoring rubrics for several constructed response items.

Findings and Conclusions

The findings of this report lead to the following conclusions about student science achievement and computer use:

- Nationally, approximately 65% of Grade 12 students were enrolled in a science class in 2000; NAEP science achievement scores were higher for Grade 12 computer-users than for non-computer users.
- Nearly all Grade 8 students were enrolled in a science class in 2000; NAEP science achievement scores were generally higher for Grade 8 non-computer users than for computer users.
- In 1996 and 2000, from 55% to 80% of students indicated that they never used a computer for science.
- In 1996 and 2000, from 3% to 8% of students indicated that they used a computer for science nearly every day.
- As of this report, computer skills were not generally included in most science standards; they were more likely to be assessed and taught separately as computer technology standards (Appendix D).
- Not all science standards and objectives that are taught are tested; from 25% to 60% of a content strand or domain may be tested on a state or national assessment.
- When included within the framework of science assessments and standards rather than as separate course content, computer-related skills represented from 2% to 6% of science course content, standards and objectives (Appendix C).
- The percentage of items on assessments is often reflective of the percentage of instructional time devoted to a particular content strand or domain at a given grade level.
- In 1996 and 2000, only from 2% to 26% of the students in this report indicated that there were two or more computers available for use by students in their science class.
- None of the 1996 NAEP sample science assessment items required that students demonstrate computer knowledge (Appendix E).
- It is unlikely that national or state assessments will require students to demonstrate computer skills until computers are more universally available in K-12 classrooms.

References

Ahlgren, A., & Kesidou, S. (1995). Attempting curriculum coherence in Project 2061. In J. Beane (Ed.), *Toward a coherent curriculum* (pp. 44-54). Alexandria, VA: Association for Supervision and Curriculum Development.

Alabama Department of Education. (2001). *Alabama Course of Study: Science*. Montgomery, AL: Author.

Blank, R., & Gruebel, D. (1995). *State indicators of science and math education 1995: State-by-state trends and new indicators from the 1993-1994 school year*. Washington, DC: Council of Chief State School Officers. (ERIC Document Reproduction Service No. ED 392 633)

Boettcher, J. (2000). Computer literacy spiral: What do students need to know? *Syllabus, 14*, 42-45.

Burz, H. L., & Marshall, K. (1997). *Performance-based curriculum for science: From knowing to showing*. Thousand Oaks, CA: Corwin Press.

English, F. W. (1992). *Deciding what to teach and test: Developing, auditing, and aligning the curriculum*. Newbury Park, CA: Corwin Press.

George, M., Bragg, S., de los Santos, A., Denton, D., Gerber, P., Lindquist, M., Rosser, J., Sanchez, D., & Meyers, C. (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology*. Arlington, VA: National Science Foundation.

Grissmer, D., Flanagan, A., Kawata, J., & Williamson, S. (2000). *Improving student achievement: What State NAEP test scores tell us*. Santa Monica, CA: RAND.

Hoffman, D., Novak, T., & Schlosser, A. (2000). The evolution of the Digital Divide: How gaps in Internet access may impact electronic commerce. *Journal of Computer-Mediated Communication, 5*(3).

Kim, J., Crasco, L., Blank, R., & Smithson, J. (2001). *Survey results of urban school classroom practices in mathematics and science: 2000 report*. Norwood, MA: Systemic Research, Inc.

McLean, J. & Barnette, J. (2000, November). *Avoiding decision-making by chance: Protecting effect size estimates*. Paper presented at the Annual Meeting of the Mid-South Educational Research Association (Bowling Green).

Miller-Whitehead, M. (2002). School district accountability: Let me count the ways. Special issue. *TVEE Monitor*, April.

Mills, R. P. (1994). "Will this be on the test?" Reflections on state curriculum leadership. In R. Elmore and S. Fuhrman (Eds.), *The governance of curriculum* (pp. 131-136). Alexandria, VA: Association for Supervision and Curriculum Development.

Novak, T. P., Hoffman, D. L., & Project 2000 Vanderbilt University (1998). *Bridging the digital divide: The impact of race on computer access and Internet use.*

Rogan, J. (1995, April). *The use of the Internet by math and science teachers: A report on five rural telecommunications projects.* Paper presented at the Annual Meeting of the American Educational Research Association (San Francisco).

Romberg, T. A. (1998). Standards in the context of democracy. In T. A. Lockwood (Ed.), *Standards: From policy to practice* (pp. 9-17). Thousand Oaks, CA: Corwin.

Scriven, M. (1995). Overview. In J. Frechtling (Ed.), *Footprints: Strategies for non-traditional program evaluation* (pp. 131-138). NSF 95-41. Arlington, VA: National Science Foundation.

Warschauer, M. (2000). Technology and school reform: A view from both sides of the tracks. *Educational Policy Analysis Archives, 8* (4). [On-line]. http://epaa.asu.edu/epaa/v8n4.html.

Zucker, A., Shields, P., Adelman, N., & Humphrey, D. (1997). Reflections on state efforts to improve mathematics and science education in light of findings from TIMSS. *Implementing academic standards: Papers commissioned by the National Education Goals Panel.* Washington, DC: NEGP.

APPENDIX A

Science Standards: Major Content Areas[1]

I. Earth and Space Sciences
   1. Understands atmospheric processes and the water cycle
   2. Understands Earth's composition and structure
   3. Understands the composition and structure of the universe and the Earth's place in it

II. Life Sciences
   4. Understands the principles of heredity and related concepts
   5. Understands the structure and function of cells and organisms
   6. Understands relationships among organisms and their physical environment
   7. Understands biological evolution and the diversity of life

III. Physical Sciences
   8. Understands the structure and properties of matter
   9. Understands the sources and properties of energy
   10. Understands forces and motion

IV. Nature of Science (Scientific Inquiry)
   11. Understands the nature of scientific knowledge
   12. Understands the nature of scientific inquiry
   13. Understands the scientific enterprise

National Science Standards Related to Computer Use

IV. Nature of Science (Grade 6 - 8):

Uses appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific data

IV. Nature of Science (Grade 9 - 12):

Uses technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications

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[1]Adapted from McRel

APPENDIX B

Alabama Course of Study: Science, Grade 8

1. Explain the need for peer review of scientific investigations.
2. Understand the need for continual re-evaluation of knowledge.
3. Discuss the limitations of scientific study.
4. Investigate purposes for inquiry in science.
   - 4.1 Exploring new phenomena
   - 4.2 Verifying previous results
   - 4.3 Evaluating predictive nature of a theory or law
   - 4.4 Comparing different theories
5. Analyze uses of hypotheses in scientific investigations.
   - 5.1 Evaluating relevance of data
   - 5.2 Determining data to be obtained
   - 5.3 Interpreting old and new data directly
6. Cite examples of the global nature of the scientific enterprise.
7. Discuss the ethical issues of science.
   Examples: use of animals and humans in research, use of military technology
8. Exhibit habits necessary for responsible scientific investigation.
   - 8.1 Curiosity
   - 8.2 Creativity
   - 8.3 Imagination
   - 8.4 Honesty
   - 8.5 Patience
   - 8.6 Logical reasoning
   - 8.7 Attention to detail
   - 8.8 Critical thinking
9. Evaluate the reasonableness of an answer to a scientific problem.
10. Use technology for investigation and communication in science.
11. Use basic scientific process/thinking skills as developmentally appropriate.
    - 11.1 Observing
    - 11.2 Interpreting
    - 11.3 Classifying
    - 11.4 Measuring
    - 11.5 Communicating
    - 11.6 Predicting
    - 11.7 Inferring
    - 11.8 Problem solving
12. Demonstrate developmentally appropriate applications of higher-order science process/thinking skills.
    - 12.1 Recognizing cause and effect
    - 12.2 Designing experiments to test ideas

12.3 Planning procedures for investigations
12.4 Controlling and manipulating variables
12.5 Making inferences from data and graphs
12.6 Formulating questions leading to further investigations
12.7 Following the logic of "if ... then" statements
12.8 Interpreting some formulas as scientific laws

13. Apply manipulative skills to the scientific process.
    13.1 Maintenance of accurate records
    13.2 Correct use of laboratory procedures and techniques
    13.3 Effective communication or display of results
14. Apply appropriate units and significant figures to express measurements and calculated results.
15. Apply mathematical concepts and skills in science and in scientific investigations.
    15.1 Probability
    15.2 Graphing skills
    15.3 Scientific notation
    15.4 Variable notation
    15.5 Integers
    15.6 Fractions, decimals, and percents
    15.7 Ratio and proportion
    15.8 Arithmetic mean, mode, and median
16. Use scientific equipment, apparatus, and technologies safely and efficiently in investigations.
    Examples: thermometers, microscopes, balances, computers, electronic probe-ware
17. Use proper procedures in the handling and care of living organisms and specimens derived from living things.
18. Describe scientific evidence for the origin and evolution of the Universe.
19. Recognize the role of gravity in forming and maintaining planets, stars, and the solar system.
20. Identify tools and their uses in obtaining information about the Universe.
    Examples: telescope, spectroscope, computer simulations, star finders
21. Describe the components of the Universe and their apparent relationships.
    21.1. Components: galaxies, stars, planets, moons, asteroids, comets, meteoroids, space dust
    21.2 Relationships: membership in systems, effects on each other, relative size, distance, motion
22. Explain origins and differences in the physical characteristics of meteors and comets.
23. Compare masses within the solar system as to composition, size, and orbital motion.
    23.1 Sun
    23.2 Planets
    23.3 Satellites
    23.4 Debris
24. Apply scale to models of the solar system.

25. Discuss discovery of the speed of light and its application to the measure of distance in the Universe.
26. Explain and use information from solubility curves.
27. Develop an understanding of the relationship between the organization and the predictive nature of the periodic table.
    27.1 Number of protons and electrons in an atom of an element
    27.2 Kind of element
    27.3 Reactivity of some elements
    27.4 Electron configuration of some elements
    27.5 Mass of an element
28. Classify types of elements using atomic electron configuration.
    28.1 Metals
    28.2 Nonmetals
    28.3 Metalloids
    28.4 Noble gases
29. Analyze the properties of different types of matter in relationship to specific intended uses.
    Examples: properties of gold in jewelry, tungsten in light bulb filaments, viscosity of petroleum components
30. Compare the roles of electrons in covalent, ionic, and metallic bonding.
31. Describe chemical reactions as word equations.
32. Observe factors that affect rates of reaction.
    32.1 Temperature
    32.2 Nature of reactants
    32.3 Catalysts
    32.4 Surface area
33. Identify acids, bases, and salts.
34. Relate chemical concepts derived from several important experiments that resulted in the designation of Antoine Lavoisier as the "father of modern chemistry."
    34.1 Conservation of matter
    34.3 Burning as oxidation
35. Apply Newton's laws of motion to the way the world works.
    35.1 Inertia
    35.2 Acceleration
    35.3 Gravitation
    35.4 Action/reaction
36. Relate change of speed or direction to unbalanced forces acting on an object.
37. Relate force to pressure in fluids.
38. Relate friction to motion of solids and fluids.
39. Relate variables to the speed of sound waves.
    39.1 Wavelength
    39.2 Frequency
    39.3 Density (of medium)
    39.4 State (of medium)

40. Recognize the impact of selective breeding, natural selection, genetic defects, and environmental adaptations on the development and survival of species.
41. Evaluate fossil evidence for change in organisms over time.
42. Analyze the development of Charles Darwin's theory of evolution.
43. Investigate lineage of organisms for traits and features.
    Examples: family genealogy, bloodline of registered pet
44. Describe the role of DNA in the transmission of traits and characteristics in organisms.
45. Describe the role of probability in the study of heredity.
46. Relate selective breeding to the experiments of Gregor Mendel.
47. Discuss major factors affecting human health.
    47.1 Genetics
    47.2 Behavior
    47.3 Environment
48. Relate microorganisms that invade the human body to common diseases.
    Examples: viruses, bacteria, fungi
49. Describe how simple components of the immune system attack blood-borne pathogens and foreign materials in the human body.
    49.1 White blood cells
    49.2 Antibodies
50. Identify natural substances produced by the human body and the alternate sources from which they are obtained today.
    Examples: hormones, amino acids, enzymes
51. Compare the complexity of circulatory and nervous systems in earthworms, frogs, and humans.
52. Predict the potential impact of human activities on long-range changes in the surface and climate of the Earth.
    52.1 Negative impact
    Examples: deforestation, ozone depletion
    52.2 Positive impact
    Example: management and conservation of the Earth's wildlife and natural resources
53. Identify limiting factors that impact plant and animal populations.
54. Relate good health to the monitoring of soil, air, and water for dangerous levels of harmful substances.
55. Apply scientific knowledge and processes from one domain of science (Earth and Space, Physical, Life) to another and to other fields of study.
56. Recognize the importance of science to many careers.
57. Place scientific discoveries in historical, social, economical, and ethical perspective.
58. Discuss the impact of technology on science, human history, and/or society.
59. Discuss the limits of technology in fulfilling human needs.
60. Analyze the constraints on design of technology.
    60.1 Physical
    60.2 Ethical

60.3 Aesthetic
60.4 Societal
60.5 Economic

61. Explain the importance of testing technology and products of technology in a controlled setting before submission to the general public.
62. Serve the community through a science-related project.
    Examples: school-wide recycling, tree planting

APPENDIX C

Minimum Required Content: Science Skills - Alabama

1. Identify questions that can be answered through scientific investigations.
2. Design experiments and use appropriate tools and technology to gather, analyze, and interpret data.
   Examples: thermometers, microscopes, balances, computers, electronic probeware
3. Demonstrate the ability to perform safe and appropriate manipulation of materials, scientific equipment, and technology.
4. Use proper procedures in the handling and care of living organisms and specimens derived from living things.
5. Use appropriate skills to design and conduct a scientific investigation.
   5.1 Acquiring, processing, and interpreting data
   5.2 Identifying dependent and independent variables and their relationships
   5.3 Identifying cause and effect
   5.4 Sorting and classifying
   5.5 Controlling and manipulating variables
   5.6 Designing and analyzing investigations
   5.7 Developing hypotheses
   5.8 Formulating models, tables, charts, and graphs
   5.9 Keeping accurate records
   5.10 Observing
   5.11 Measuring
6. Express measurements in appropriate Systeme International (SI) units.
7. Use scientific evidence to develop descriptions, explanations, predictions, and models.
8. Explain relationships between evidence and explanations.
9. Evaluate how observation, experimentation, and data analysis lead to the development of scientific theories.
10. Communicate orally and in writing scientific procedures and explanations.
    Examples: laboratory reports, science projects, PowerPoint presentations, science journals
11. Use appropriate mathematics in all aspects of scientific inquiry.
12. Explain the use of technology in scientific research.
13. Explain the importance of science and technology to many careers.
14. Exhibit legal and ethical behaviors necessary for responsible scientific investigations.
    Examples: avoiding plagiarism; altering data, hypotheses, or results; caring properly for animals
15. Demonstrate the use of computer skills in scientific investigations.
    Examples: electronic reference sources; data management and analysis; preparation, presentation, and communication of results
16. Explain how scientific discoveries have been influenced by historical events and cultures, including technological advances.

APPENDIX D

Standards for Grade 8 Computer Technology

1. Compose and edit a multipage document at the keyboard, using word processing skills and the writing process steps.
2. Communicate with spreadsheets by entering data and setting up formulas, analyzing data, and creating graphs or charts to visually represent data.
3. Communicate with databases by defining fields and entering data, sorting, and producing reports in various forms.
4. Use advanced publishing software, graphics programs, and scanners to produce page layouts.
5. Integrate databases, graphics, and spreadsheets into word-processed documents.
6. The student will communicate through networks and telecommunication.
7. Use local and worldwide network communication systems.
8. The student will have a basic understanding of computer processing, storing, retrieval, and transmission technologies and a practical appreciation of the relevant advantages and disadvantages of various processing, storage, retrieval, and transmission technologies.

APPENDIX E

NAEP Sample Items, Scoring Rubrics, and Constructed Responses

Exhibit E-1
NAEP Grade 4

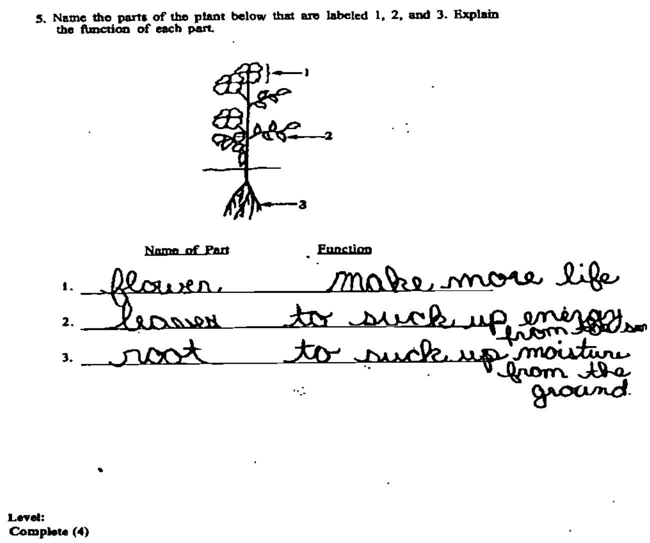


Figure 3. Grade 4 full credit constructed response

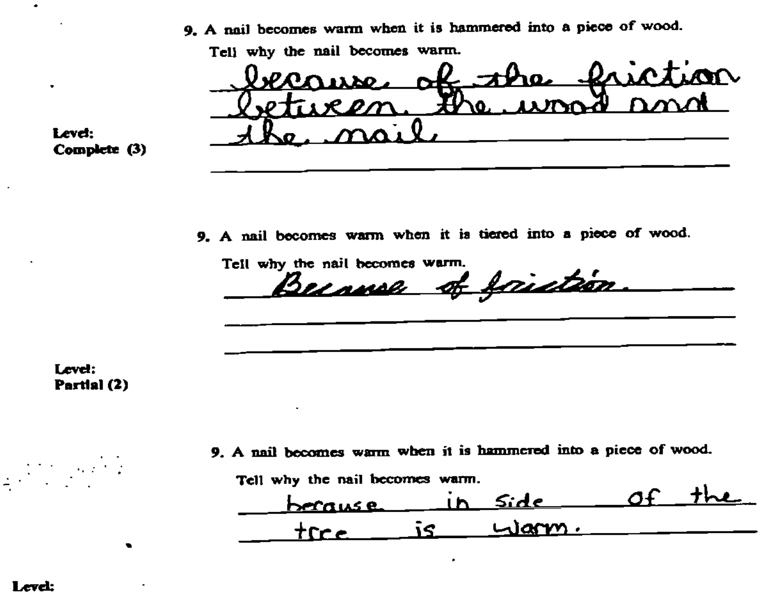
P-value = .416
Scoring Guide:

Scoring Rationale: Student demonstrates understanding of plants by identifying major structures and associating structures with their functions. There are 6 parts that need to be addressed.
4 = Complete - Student response correctly identifies the three structures and gives a function for each (6 parts)
3 = Essential - Students response correctly names 2 or 3 structures and gives 2 corresponding functions (4 -5 parts)
2 = Partial - Student response correctly responds to 1 -3 parts of the item
1 = Unsatisfactory/Incorrect - Student does not correctly name any of the 3 structures or state their function

Credited responses:
a. Flower (blossom, petals, or the name of flower bud) - the reproductive structure where seeds are produced. Accept - store pollen, make pollen, protect seeds, develop into fruit.
b. Leaves - part of the plant where food or sugar is produced, carries out photosynthesis.
c. Roots - part of the plant that takes in nutrients or water, anchors the plant, holds the plant in place.

Note. If the function for a part is correct, but not the name, it is counted as correct because the numbers are pointing to specific parts of the plant.

Exhibit E-2
NAEP Grade 4



9. A nail becomes warm when it is hammered into a piece of wood.
Tell why the nail becomes warm.
because of the friction between the wood and the nail

Level:
Complete (3)

9. A nail becomes warm when it is tiered into a piece of wood.
Tell why the nail becomes warm.
Because of friction.

Level:
Partial (2)

9. A nail becomes warm when it is hammered into a piece of wood.
Tell why the nail becomes warm.
because in side of the tree is warm.

Level:

Figure 4. Grade 4 full, partial, and incorrect constructed response

P-value = .114
Scoring Guide:

Scoring Rationale: Student demonstrates an understanding that heat is a form of energy that can be produced when one form of energy is transformed to another form of energy.

3 = Complete - Student response indicates that the energy of hammering the nail (or movement_ is transferred into heat, or explains that the friction or rubbing between the nail and the wood causes the nail to become warm. (Must specifically mention the wood, but does not have to reiterate that friction causes the heating).
2 = Partial - Student response shows some understanding by saying that the warmth is caused by friction, but an incorrect or no explanation is given.
1 = Unsatisfactory/Incorrect - Student response does not indicate any understanding of why a nail becomes warm when it is hammered into a piece of wood.

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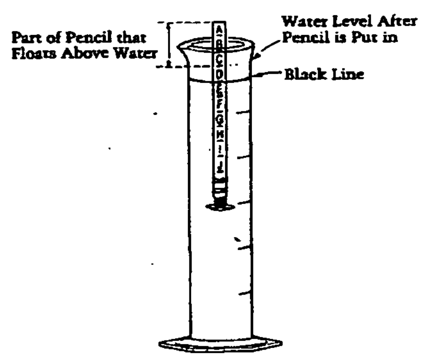
Exhibit E-3
NAEP Grade 8

Student Sample Responses

1. Open the plastic bottle labeled Distilled Water. The salt concentration of this water is very close to 0 percent. Pour the distilled water into the cylinder up to the black line. Put the cap back on the bottle.

Now take the pencil and put it in the water in the cylinder, eraser-end down. Part of the pencil will float above the water, as shown in the picture below.



Explain why the pencil floats when it is put in the water.

It is floating at B A wood is less dense than water so it floats, the tack just keep weighted

Level:
Complete (4)

Figure 5. Grade 8 full credit constructed response.

P-value = .265

Rationale text: Estimating the Salt Concentrate of an Unknown Salt Solution Using the "Floating Pencil Test"

In this task, students observe, measure, and compare the lengths of the portion of a pencil that floats above the water surface in distilled water and in a 25% salt solution. They then predict how the addition of more salt to the salt solution would affect the floating pencil. Students then measure the length of the pencil that floats above the surface of a solution of unknown salt concentration, and use the results of their previous observations to estimate the salt concentration of the unknown solution. The task assesses students' ability to make simple observations, measure length using a metric ruler, apply their observations, and make measurements to test an unknown and make a generalized inference from their observations. The task also assesses students' understanding of the value of performing multiple trials of the same procedure.

Exhibit E-4
NAEP Grade 12

1996 NAEP Grade 12
Student Sample Responses

14. Coal is burned in a power plant that produces electricity. In a house miles away, a lightbulb is turned on. Describe the energy transformations involved.

The fire burns the coal, which releases stored energy, which heats steam, which powers machines, which produces electricity, which travels to the light bulb, which produces light.

Compare the amount of energy released in one hour by burning the coal, the amount of energy received from the power plant in one hour by the house, and the amount of light energy produced in one hour by the lightbulb. Explain any differences among these three amounts of energy. HE001722

The amount of energy decreases with each transformation because some is lost and/or used up each time.

Level:
Complete (4)

Figure 6. Grade 12 full credit constructed response

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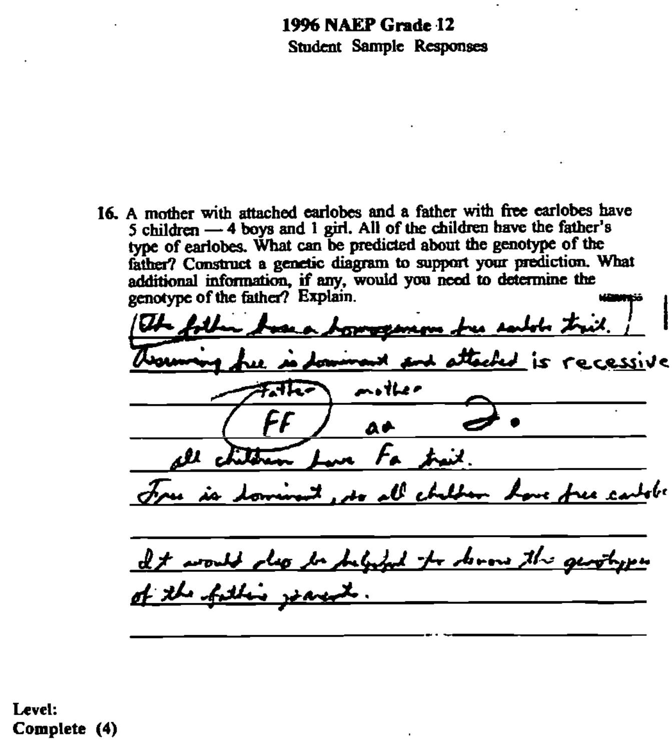
Exhibit E-5
NAEP Grade 12


1996 NAEP Grade 12
Student Sample Responses

16. A mother with attached earlobes and a father with free earlobes have 5 children — 4 boys and 1 girl. All of the children have the father's type of earlobes. What can be predicted about the genotype of the father? Construct a genetic diagram to support your prediction. What additional information, if any, would you need to determine the genotype of the father? Explain.

(The father has a homozygous free earlobe trait.)
Assuming free is dominant and attached is recessive
father mother
FF aa
all children have Fa trait.
Free is dominant, so all children have free earlobe
It would also be helpful to know the genotype of the father's parents.

Level:
Complete (4)

Figure 7. Grade 12 full credit constructed response.

P-value = .278
Scoring Guide: Student demonstrates an ability to predict what the father's genotype might be and list further information that could be used to determine genotype.
4 = Complete - Student response addresses the three elements listed below
3 = Essential - Student response addresses two of the three elements listed below
2 = Partial - Student response addresses one of the three elements listed below
1 = Unsatisfactory/Incorrect - Student response addresses none of the elements listed below

Credited responses include the following:
a. Free earlobes dominant
b. For Punnet Square: the father's genotype is probably homozygous dominant (LL or FF, etc). The mother's genotype is probably homozygous recessive (ll or ff, etc.) All children will be L1, which explains why they all have ears like the father.
c. Additional information about the father's parents genotypes would help determine his genotype

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