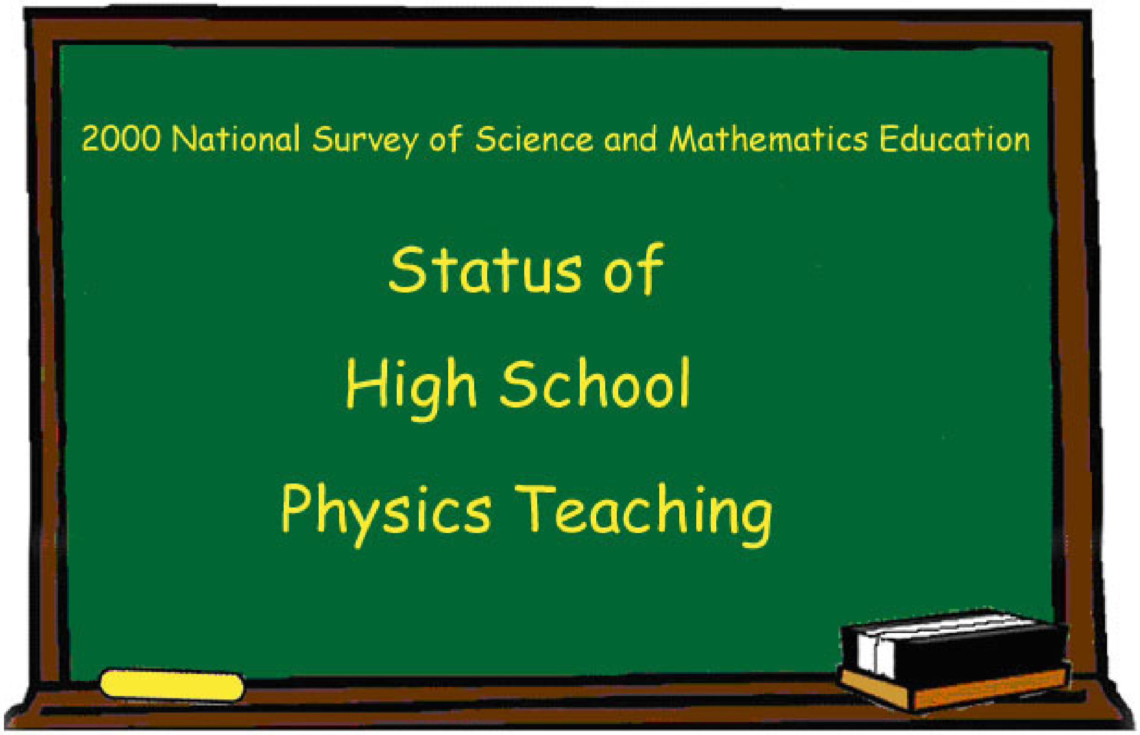

December 2002

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The *2000 National Survey of Science and Mathematics Education: Status of High School Physics Teaching* was prepared with support from the National Science Foundation under grant number REC-9814246. These writings do not necessarily reflect he views of the National Science Foundation.

Status of High School Physics Teaching

Introduction

The 2000 National Survey of Science and Mathematics Education was designed to provide up-to-date information and to identify trends in the areas of teacher background and experience, curriculum and instruction, and the availability and use of instructional resources. A total of 5,728 science and mathematics teachers in schools across the United States participated in this survey, a response rate of 74 percent. Among the questions addressed by the survey:

- How well prepared are science and mathematics teachers in terms of both content and pedagogy?

- What are teachers trying to accomplish in their science and mathematics instruction, and what activities do they use to meet these objectives?

The 2000 National Survey is based on a national probability sample of schools and science and mathematics teachers in grades K–12 in the 50 states and the District of Columbia. The sample was designed to allow national estimates of science and mathematics course offerings and enrollment; teacher background preparation; textbook usage; instructional techniques; and availability and use of science and mathematics facilities and equipment. Every eligible school and teacher in the target population had a known, positive probability of being drawn into the sample.

Since biology is by far the most common science course at the high school level, selecting a random sample of science teachers would result in a much larger number of biology teachers than chemistry or physics teachers. In order to ensure that the sample would include a sufficient number of chemistry and physics teachers for separate analysis, information on teaching assignments was used to create a separate domain for these teachers, and sampling rates were adjusted by domain. This report describes the status of high school (grades 9–12) physics instruction based on the responses of 282 physics teachers.[1] For comparison purposes, many of the tables include data from the 1038 teachers who do *not* teach physics; i.e., all other high school science teachers. These data include responses from high school biology, chemistry, earth science, and physical science teachers.

Technical detail on the survey sample design, as well as data collection and analysis procedures, is included in the *Report of the 2000 National Survey of Science and Mathematics Education* (Weiss, Banilower, McMahon, & Smith, 2001). The standard errors for the estimates presented in this report are included in parentheses in the tables. The narrative sections of the report

[1] A physics teacher is defined as someone who teaches at least one class of general, advanced, or Advanced Placement physics.

generally point out only those differences which are substantial as well as statistically significant at the 0.05 level or beyond.

This status report of high school physics teachers is organized into major topical areas:

- Characteristics of the physics teaching force in the United States;
- Professional development of physics teachers, both needs and participation;
- Physics classes offered;
- Physics instruction, in terms of both objectives and class activities; and
- Resources available for physics instruction.

Characteristics of the Physics Teaching Force

General Demographics
Sixty percent of physics teachers in the United States are male, and 94 percent are white, as shown in Table 1. More than half have a master's degree. Judging by the age of physics teachers, it appears that as many as one-third may be nearing retirement in the next 10 years.

Physics teachers are more likely to teach multiple courses than are other high school science teachers; only 1 in 10 physics teachers have one preparation compared to just over one-third of all other high school science teachers. This difference is likely due to the fact that most schools offer only a small number of physics courses.

Table 1
Characteristics of the
High School Physics Teaching Force

	Percent of Teachers			
	Physics		All Other Sciences	
Sex				
Male	60	(6.6)	48	(2.1)
Female	40	(6.6)	52	(2.1)
Race				
White	94	(1.5)	89	(1.3)
Hispanic or Latino	3	(1.0)	3	(0.5)
Asian	1	(0.5)	2	(0.7)
Black or African-American	1	(0.7)	5	(0.9)
American Indian or Alaskan Native	0	(0.2)	2	(0.6)
Native Hawaiian or Other Pacific Islander	0	(0.1)	0	(0.2)
Age				
≤ 30 years	23	(8.2)	19	(2.1)
31–40 years	21	(4.1)	24	(1.8)
41–50 years	28	(5.0)	29	(2.0)
51+ years	28	(5.1)	28	(1.6)
Experience				
0–2 years	22	(7.9)	15	(1.3)
3–5 years	12	(3.0)	17	(1.8)
6–10 years	14	(2.8)	19	(1.6)
11–20 years	20	(3.6)	21	(1.8)
≥ 21 years	33	(5.3)	28	(1.8)
Master's Degree				
Yes	57	(6.6)	56	(2.4)
No	43	(6.6)	44	(2.4)

Content Preparedness

In terms of the number of college courses they have taken in their subject, physics teachers are not as well prepared in their subject as are chemistry and biology teachers. Only 56 percent of physics teachers have taken six or more courses in their subject (Table 2) compared to 67 percent of chemistry teachers and 92 percent of biology teachers.[2] Looking at high school science classes, 64 percent of physics classes are taught by teachers who have completed six or more courses in their field (Table 3), 26 percent of physics classes are taught by teachers with six or more courses in a science other than physics, and 10 percent by teachers who do not have in-depth preparation in any science discipline.

[2] Detailed information for high school chemistry and biology teachers can be found in the *Status of High School Chemistry Teaching* (Smith, 2002) and the *Status of High School Biology Teaching* (Wood, 2002).

Table 2
Number of Semesters[†] Completed by High School Physics Teachers in Various Course Categories

	Percent of Teachers							
	Zero Semesters		1–2 Semesters		3–5 Semesters		6 or More Semesters	
Physics/physical science	1	(0.4)	17	(4.2)	26	(4.9)	56	(5.2)
Life science	19	(3.9)	30	(5.9)	14	(2.9)	37	(6.3)
Chemistry	2	(1.2)	24	(6.0)	39	(5.9)	34	(5.2)
Earth/space science	31	(7.8)	28	(4.5)	21	(4.3)	20	(3.8)
Science education	25	(8.2)	31	(5.2)	26	(4.8)	19	(3.6)

[†] The highest number of courses a teacher could indicate for each of the four categories—life science, chemistry, physics/physical science, and earth/space science—was "> 8," and 9 was used as the number of courses in those cases. As a result, these figures underestimate the total for any teacher who completed more than eight courses in a particular category.

Table 3
High School Science Classes Taught by Teachers with Six or More College Courses in Field, in Another Science Field, and Lacking In-Depth Preparation in Any Science

	Percent of Classes					
	Six or More Courses In Field		Not In-Depth in Field, But Six or More in Another Science		Not In-Depth in Any Science	
Biology	94	(1.8)	1	(0.8)	4	(1.6)
Chemistry	74	(4.2)	17	(3.3)	9	(2.8)
Physics	64	(5.8)	26	(5.4)	10	(3.7)
Earth science	58	(6.1)	34	(5.4)	8	(3.7)

As can be seen in Table 4, teachers assigned to physics classes are similar to the rest of the secondary science teaching force in preparation in science education, with 80 percent having completed a course in general methods of teaching, and 69 percent having taken a methods course specific to science teaching. Not surprisingly, physics teachers are more likely to have completed college coursework in physics than are other high school science teachers. Ninety-two percent of physics teachers have taken an introductory physics course, 62 percent have taken at least one course in mechanics, and 60 percent have taken coursework in electricity and magnetism. Still, 52 percent or fewer physics teachers more have taken courses in other areas of physics including heat and thermodynamics, modern or quantum physics, and optics.

Table 4
High School Physics Teachers
Completing Various College Courses

	Percent of Teachers			
	Physics		All Other Sciences	
General methods of teaching	80	(8.1)	93	(1.1)
Methods of teaching science	69	(7.2)	78	(2.5)
Supervised student teaching in science	61	(7.9)	72	(1.9)
Instructional uses of computers/other technologies	42	(6.1)	49	(2.4)
General/introductory physics	92	(2.7)	80	(1.7)
Mechanics	62	(5.9)	16	(1.9)
Electricity and magnetism	60	(6.0)	20	(1.9)
Heat and thermodynamics	52	(5.6)	15	(1.9)
Physical science	51	(6.8)	43	(2.1)
Modern or quantum physics	40	(5.6)	7	(1.2)
Optics	39	(5.6)	9	(1.7)
Other physics	35	(5.5)	12	(1.3)
Nuclear physics	26	(4.7)	7	(1.1)
Solid state physics	15	(3.7)	3	(0.8)

The survey also asked teachers to rate how qualified they felt to teach each of a number of fundamental topics in physics:

- Forces and motion;
- Energy;
- Light and sound;
- Electricity and magnetism; and
- Modern physics.

A large majority of physics teachers feel very well qualified to teach about forces and motion, energy, and light and sound (Table 5) and 50 percent or more feel very well qualified to teach electricity and magnetism and modern physics. Few physics teachers feel not well qualified in any of these areas.

Table 5
High School Physics Teachers' Perceptions of Their Qualifications to Teach Each of a Number of Physics Topics

	Percent of Teachers					
	Not Well Qualified		Adequately Qualified		Very Well Qualified	
Physics						
Forces and motion	3	(2.7)	14	(2.8)	83	(4.2)
Energy	3	(2.7)	18	(3.2)	79	(4.5)
Light and sound	5	(2.9)	21	(3.8)	74	(4.4)
Electricity and magnetism	10	(4.0)	28	(4.7)	61	(5.5)
Modern physics (e.g., special relativity)	15	(3.5)	35	(5.5)	50	(6.4)
All Other Sciences						
Forces and motion	30	(2.1)	46	(2.0)	24	(2.0)
Energy	29	(2.0)	47	(1.8)	24	(2.0)
Light and sound	36	(2.2)	43	(2.3)	21	(1.8)
Electricity and magnetism	48	(1.8)	35	(1.9)	17	(1.8)
Modern physics (e.g., special relativity)	68	(2.0)	26	(2.0)	7	(1.1)

A similar question was asked of teachers in the various high school science disciplines, with topics appropriate to the discipline (e.g., biology teachers were asked how well qualified they felt to teach about the structure and function of human systems, among other topics). Each discipline-specific series was combined into a composite variable. (Definitions of all composite variables, descriptions of how they were created, and reliability information are included in the Appendix.) Each composite has a minimum possible score of 0 and a maximum possible score of 100. In terms of being prepared to teach physics content, physics teachers have an average preparedness composite score of 82, compared to an average score of 55 for non-physics teachers. (See Table 6.)

Table 6
Content Preparedness Composite Scores of High School Science Teachers

	Mean Score			
	Teach Subject		Do Not Teach Subject	
Chemistry	90	(1.2)	70	(1.1)
Biology/Life science	84	(1.4)	60	(1.6)
Physics	82	(3.1)	55	(1.1)
Earth science	81	(1.5)	63	(0.9)
Environmental science	73	(2.8)	68	(0.9)
Physical science	66	(3.3)	60	(1.0)
Integrated/general science	64	(1.4)	62	(0.9)

Taken together, the data presented above indicate that the majority of physics teachers feel well qualified in their subject area, though perhaps not as well qualified as do teachers of biology and chemistry. In addition, there appears to be a substantial number of physics teachers who are teaching out-of-field with roughly 1 in 5 having had two or fewer college physics courses. By and large, though, students appear to be receiving instruction from teachers with adequate content backgrounds. This conclusion is supported by a recent report from the National Center for Education Statistics based on data from the 1999–2000 Schools and Staffing Survey. This study found that about 80 percent of physics students nationwide are taught by a teacher who has a major, minor, or certification in physics.[3]

Pedagogical Preparedness

The National Research Council (NRC) *National Science Education Standards*, while not specific to physics, provide a useful frame for interpreting data on physics teachers' pedagogical preparedness. Responding to an item about the NRC *Standards*, 61 percent of physics teachers indicated they were at least somewhat familiar with the document, and of these, 67 percent said they agreed with the *Standards*. (See Table 7.) These percentages are consistent with those for other science teachers.

Table 7
High School Physics Teachers' Familiarity with, Agreement with, and Implementation of the NRC *Standards*

	Percent of Teachers			
	Physics		All Other Sciences	
Familiarity with NRC *Standards*				
Not at all familiar	39	(6.3)	37	(1.8)
Somewhat familiar	40	(5.6)	33	(2.3)
Fairly familiar	15	(2.9)	19	(1.6)
Very familiar	6	(1.6)	11	(1.4)
Extent of agreement with NRC *Standards*[†]				
Strongly Disagree	0	—[§]	1	(0.3)
Disagree	13	(6.0)	5	(1.2)
No Opinion	21	(5.1)	22	(2.5)
Agree	62	(6.7)	66	(3.0)
Strongly Agree	5	(1.9)	6	(1.0)
Extent to which recommendations have been implemented[†]				
Not at all	1	(0.5)	5	(1.4)
To a minimal extent	37	(6.7)	25	(2.3)
To a moderate extent	55	(6.4)	57	(2.5)
To a great extent	7	(2.2)	13	(2.1)

† Only those teachers indicating they were at least somewhat familiar with the *Standards* were included in this analysis.

§ No teachers in the sample selected this response option. Thus, it is not possible to calculate the standard error of this estimate.

The survey asked teachers how well prepared they felt to use a number of instructional strategies in their teaching. As with content preparedness items, composite variables were created from these individual strategies. Mean scores on these composites suggest that physics teachers are

3 U.S. Department of Education, National Center for Education Statistics. *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching,1987–88 to 1999–2000*, NCES 2002–603, by Marilyn McMillen, Seastrom, Kerry J. Gruber, Robin Henke, Daniel J. McGrath, and Benjamin A. Cohen. Washington, DC: 2002.

least likely to feel prepared in technology-related areas. (See Table 8.) In particular, relatively few physics teachers indicated they felt well prepared to use the Internet for collaborative projects across classes or schools. (See Table 9.) With one exception (recognize and respond to cultural diversity), 80 percent or more rated themselves as being well prepared to implement a number of practices thought of as being closely aligned with the *Standards*:

- Take students' prior understanding into account when planning curriculum and instruction;
- Develop students' conceptual understanding of science;
- Provide deeper coverage of fewer science concepts;
- Make connections between science and other disciplines; and
- Lead a class of students using investigative strategies.

Table 8
Composite Scores of High School
Physics Teachers' Pedagogical Preparedness

	Mean Score			
	Physics		All Other Sciences	
Preparedness to Teach Students from Diverse Backgrounds	76	(2.7)	77	(0.8)
Preparedness to Use Standards-Based Teaching Practices	75	(1.9)	77	(0.8)
Preparedness to Use Calculators/Computers	62	(3.3)	52	(1.4)
Preparedness to Use the Internet	44	(3.6)	51	(1.4)

Table 9
High School Physics Teachers Considering Themselves Well Prepared† for Each of a Number of Tasks

	Percent of Teachers			
	Physics		All Other Sciences	
Encourage participation of females in science	98	(0.8)	95	(0.9)
Develop students' conceptual understanding of science	96	(1.7)	91	(1.1)
Listen/ask questions as students work in order to gauge their understanding	95	(2.3)	96	(0.8)
Encourage students' interest in science	92	(4.2)	96	(0.8)
Manage a class of students engaged in hands-on/project-based work	90	(3.7)	92	(1.3)
Provide deeper coverage of fewer science concepts	89	(2.4)	87	(1.4)
Make connections between science and other disciplines	88	(3.6)	90	(1.2)
Encourage participation of minorities in science	87	(3.9)	90	(1.3)
Use the textbook as a resource rather than the primary instructional tool	84	(3.5)	85	(1.6)
Have students work in cooperative learning groups	83	(4.0)	87	(1.6)
Lead a class of students using investigative strategies	82	(5.2)	82	(1.6)
Use calculators/computers for drill and practice	82	(5.0)	64	(2.0)
Take students' prior understanding into account when planning curriculum and instruction	80	(3.5)	76	(1.8)
Use calculators/computers to collect and/or analyze data	77	(4.8)	64	(2.0)
Teach groups that are heterogeneous in ability	73	(5.8)	82	(1.5)
Use the Internet in your science teaching for general reference	58	(5.4)	66	(2.2)
Recognize and respond to student cultural diversity	55	(5.6)	63	(2.3)
Use calculators/computers for science learning games	55	(5.7)	46	(2.3)
Use computers for laboratory simulations	55	(5.5)	43	(2.4)
Use computers to demonstrate scientific principles	53	(5.4)	51	(2.5)
Use the Internet in your science teaching for data acquisition	48	(5.7)	59	(2.2)
Involve parents in the science education of their children	34	(5.4)	46	(2.1)
Use the Internet in your science teaching for collaborative projects with classes/individuals in other schools	22	(3.6)	32	(2.4)
Teach students who have limited English proficiency	17	(6.3)	22	(1.7)

† Includes responses of "Fairly well prepared" or "Very well prepared" to each statement.

Teachers' ratings of their pedagogical preparedness are reflected in the areas they identify as needs for professional development. The survey asked about six different areas, shown in Table 10, and in terms of professional development needs, physics teachers are not very different from other science teachers. Learning how to use technology in science instruction, along with learning to accommodate students with special needs, were two areas rated as a moderate or substantial need by about 60 percent of physics teachers. It may be that the trend toward mainstreaming over the last decade accounts for teachers recognizing they need help accommodating students with special needs. Similarly, the infusion of technology in classrooms and the push for its use has likely made teachers more aware of their needs in this area.

Half of the physics teachers indicated they need professional development related to teaching through inquiry/investigation. Roughly 2 out of 5 physics teachers perceived a need for help in understanding student thinking, assessing student learning, and in deepening their own content knowledge. (See Table 10.)

Table 10
High School Physics Teachers Reporting They Perceived a Moderate or Substantial Need for Professional Development in the Preceding Three Years

	Percent of Teachers			
	Physics		All Other Sciences	
Learning how to use technology in science instruction	64	(5.6)	72	(1.9)
Learning how to teach science in a class that includes students with special needs	59	(5.9)	59	(2.5)
Learning how to use inquiry/investigation-oriented teaching strategies	50	(5.6)	52	(2.0)
Understanding student thinking in science	44	(5.1)	48	(2.2)
Learning how to assess student learning in science	40	(5.2)	42	(2.3)
Deepening my own science content knowledge	36	(5.2)	39	(1.9)

Professional Development of Physics Teachers

Physics teachers, like high school science teachers in general, report low levels of participation in professional development specific to science teaching. Only 40 percent of physics teachers have spent more than 35 hours in science-related professional development in the previous three years. (See Table 11.)

Table 11
Time Spent on Science-Related In-Service Education by High School Physics Teachers in the Preceding Three Years

	Percent of Teachers			
	Physics		All Other Sciences	
None	10	(2.4)	7	(1.2)
Less than 6 hours	11	(5.5)	8	(1.2)
6–15 hours	15	(3.9)	17	(1.4)
16–35 hours	24	(4.7)	22	(1.9)
More than 35 hours	40	(5.1)	46	(2.1)

As to how this time is spent, the workshop is by far the most common form of professional development, with 62 percent of physics teachers having attended one in the previous three years (Table 12). Forty-nine percent of physics teachers have observed other teachers' classrooms and 43 percent have met regularly with a local group of teachers to discuss science teaching. Thirty-eight percent reported attending a state or national science teachers meeting in the previous three years, and 29 percent have taken a college/university science course.

Table 12
High School Physics Teachers Participating in Various Professional Development Activities in the Preceding Three Years

	Percent of Teachers			
	Physics		All Other Sciences	
Attended a workshop on science teaching	62	(7.7)	72	(1.8)
Observed other teachers teaching science as part of your own professional development (formal or informal)	49	(6.2)	59	(2.4)
Met with a local group of teachers to study/discuss science teaching issues on a regular basis	43	(6.4)	56	(2.4)
Attended a national or state science teacher association meeting	38	(5.8)	45	(2.1)
Taken a formal college/university science course	29	(4.5)	40	(2.1)
Taken a formal college/university course in the teaching of science	20	(3.5)	28	(1.9)
Collaborated on science teaching issues with a group of teachers at a distance using telecommunications	17	(3.5)	17	(1.6)
Served as a mentor and/or peer coach in science teaching, as part of a formal arrangement that is recognized or supported by the school or district	16	(4.2)	26	(2.3)

Teachers were asked to consider their professional development as a whole and characterize it in terms of different potential emphases. (See Table 13.) About half of all physics teachers indicated that their professional development experiences emphasized learning how to use technology in science instruction, about one-third indicated that their professional development emphasized learning to teach through inquiry/investigation, and one-quarter indicated that their professional development emphasized deepening their science content knowledge.

There seems to be a very poor match between professional development needs and opportunities in learning to accommodate students with special needs; this was one of the most prevalent needs (59 percent of teachers), but only 12 percent of high school physics teachers indicated their professional development emphasized this area.

Table 13
High School Physics Teachers Reporting that Their Professional Development Gave Heavy Emphasis† to Various Areas

	Percent of Teachers			
	Physics		All Other Sciences	
Learning how to use technology in science instruction	46	(6.2)	47	(2.3)
Learning how to use inquiry/investigation-oriented teaching strategies	32	(6.6)	36	(2.2)
Deepening my own science content knowledge	26	(5.4)	27	(2.1)
Learning how to assess learning in science	15	(2.4)	26	(2.3)
Understanding student thinking in science	17	(3.8)	22	(2.1)
Learning how to teach science in a class that includes students with special needs	12	(7.5)	13	(1.7)

† Teachers responding with 4 or 5 on a five-point scale, where 1 was "Not at all" and 5 was "To a great extent."

Physics Classes Offered

Of the high schools (schools including grades 10, 11, or 12, and no grade lower than 9) in the United States, 88 percent offer at least one 1st year physics course, meaning about 1 in 10 high schools do not. (See Table 14.) Roughly one-quarter of high schools offer a second-year course in physics, with 1 in 5 offering Advanced Placement (AP) physics. There is a large disparity between the percentage of high schools offering AP Physics, and the percentage of high school students with access to the course. This is almost certainly due to the fact that larger schools are more likely than small ones to offer advanced physics courses, and that small schools outnumber large schools in the United States.

Table 14
Availability of Physics
Courses at the High School† Level

	Percent of High Schools Offering Course		Percent of Students with Access to Course	
1st Year	85	(2.7)	89	(2.0)
1st Year, Applied	17	(2.8)	17	(2.2)
Any 1st Year	88	(2.4)	92	(1.5)
2nd Year, AP	21	(2.1)	31	(2.8)
2nd Year, Advanced	8	(1.5)	9	(1.8)
Any 2nd Year	26	(2.5)	38	(3.2)

† A high school is defined as any school containing grades 10, 11, or 12, and no grades lower than 9.

In terms of the percentage of classes offered in the nation, physics (1st year or advanced) accounts for 12 percent of all high school science classes; this percentage ranks third behind biology (36 percent) and chemistry (22 percent). (See Table 15.)

Table 15
Most Commonly Offered
Grade 9–12 Science Courses

	Percent of Classes	
1st Year Biology	30	(2.1)
Advanced Biology	6	(0.8)
1st Year Chemistry	19	(1.2)
Advanced Chemistry	3	(1.6)
1st Year Physics	10	(1.0)
Advanced Physics	2	(0.3)
Physical Science	7	(1.0)
Earth Science	7	(1.0)
General Science	3	(0.7)
Integrated/Coordinated Science	6	(0.8)
Other Science	8	(1.1)

The typical physics class has approximately 16 students; two-thirds of the classes have between 12 and 20 students. Forty-six percent of physics students are female, compared to 52 percent in biology and 56 percent in chemistry. (See Table 16.) Nineteen percent of students in physics classes are non-Asian minorities.

Table 16
Female and Non-Asian Minority
Students in 1st Year Science Classes

	Percent of Students			
	Female		Non-Asian	
1st Year Biology	52	(1.0)	25	(2.1)
1st Year Chemistry	56	(1.3)	21	(2.4)
1st Year Physics	46	(1.9)	19	(3.5)

Regarding the ability level of physics students, teachers in 46 percent of physics classes describe their students as homogeneous and high in ability, 20 percent as homogeneous and average, and 33 percent as heterogeneous. Only 1 percent of physics classes were categorized as "low ability." (See Table 17.) The relatively high ability level of students in physics classes is most likely due to the fact many states require students to take only two years of science to graduate from high school and that physics courses usually have an advanced mathematics prerequisite.

Table 17
Ability Grouping in Selected
High School 1st Year Science Classes

	Percent of Classes							
	Low		Average		High		Heterogeneous	
1st Year Biology	9	(1.8)	34	(4.5)	17	(2.5)	41	(3.9)
1st Year Chemistry	3	(0.9)	30	(3.7)	33	(3.9)	35	(4.2)
1st Year Physics	1	(0.4)	20	(4.5)	46	(6.2)	33	(6.7)

Physics Instruction

Each teacher responding to the survey was asked to provide detailed information about a randomly selected class. Science teachers who were assigned to teach both physics and other science classes may have been asked about any of those classes. Accordingly, the number of physics classes included in the analyses reported below (189) is less than the 282 responding teachers of physics. Generally, the larger standard errors are a reflection of the reduced sample size. The data reported in the "All Other Sciences" column are based on 1,131 non-physics high school science classes.

The next two sections draw on teachers' descriptions of what transpires in physics classrooms, in terms of both instructional objectives and class activities.

Instructional Objectives

Teachers were given a list of potential objectives and asked to rate each in terms of the emphasis they receive in the randomly selected class. As can be seen in Table 18, teachers in 78 percent of physics classes report giving a heavy emphasis to learning basic science concepts, and in 65 percent of physics classes to learning science process/inquiry skills. In fewer than half the physics classes did teachers report a strong focus on learning facts and terms of science.

Table 18
High School Physics Classes with Heavy Emphasis on Various Instructional Objectives

	Percent of Classes			
	Physics		All Other Sciences	
Learn basic science concepts	78	(3.9)	80	(1.3)
Learn science process/inquiry skills	65	(6.0)	65	(2.3)
Prepare for further study in science	56	(5.3)	47	(2.3)
Increase students' interest in science	46	(5.7)	45	(2.6)
Learn important terms and facts of science	42	(5.1)	52	(2.5)
Learn how to communicate ideas in science effectively	39	(5.4)	39	(2.3)
Learn about the relationship between science, technology, and society	34	(5.2)	29	(2.0)
Learn about the applications of science in business and industry	32	(5.1)	19	(2.3)
Learn to evaluate arguments based on scientific evidence	25	(4.3)	28	(2.0)
Prepare for standardized tests	17	(3.4)	22	(1.7)
Learn about the history and nature of science	10	(2.6)	11	(1.0)

Given the reports of emphasis on process/inquiry skills in physics classes, it is somewhat surprising that other objectives commonly thought of as being aligned with the *Standards* are heavily emphasized in under 40 percent of the nation's physics classes. These include:

- Learning how to communicate ideas in science effectively;
- Learning about the applications of science in business and industry;
- Learning about the relationship between science, technology, and society;
- Learning to evaluate arguments based on scientific evidence; and
- Learning about the history and nature of science.

This contrast is captured again in two composite variables created from the list of objectives in Table 18. The two composites are shown here with the objectives that comprise them:

Nature of Science

- Learn to evaluate arguments based on scientific evidence
- Learn about the history and nature of science
- Learn how to communicate ideas in science effectively
- Learn about the applications of science in business and industry
- Learn about the relationship between science, technology, and society

Science Content

- Learn basic science concepts
- Learn important terms and facts of science
- Learn science process/inquiry skills
- Prepare for further study in science

As shown in Table 19, Science Content objectives are much more likely than Nature of Science objectives to receive heavy emphasis in physics instruction, a pattern found in the other high school sciences as well.

Table 19
Mean Composite Scores Related to
High School Physics Class Objectives

	Mean Score			
	Physics		All Other Sciences	
Science Content	83	(1.1)	85	(0.6)
Nature of Science	66	(1.7)	66	(0.8)

Class Activities

The 2000 National Survey of Science and Mathematics Education provides three sources of information about how physics is taught at the high school level. One series of items listed various instructional strategies and asked teachers to indicate the frequency with which they used each in a randomly selected class. A second item listed a number of activities and asked teachers to indicate which occurred in the most recent lesson in their randomly selected class. Finally, a third item asked teachers to indicate the number of minutes devoted to each of several activities in their most recent lesson. The data for physics instruction from these three items are presented in Tables 20–22. Each source paints the same picture of physics instruction: the predominant instructional strategies are lecture/discussion and practice using textbook/worksheet problems, with the occasional lab.

Table 20
High School Physics Classes Where Teachers Report That Students Take Part in Various Instructional Activities at Least Once a Week

	Percent of Classes			
	Physics		All Other Sciences	
Use mathematics as a tool in problem-solving	94	(2.5)	46	(2.5)
Work in groups	90	(2.5)	79	(2.1)
Listen and take notes during presentation by teacher	87	(3.2)	86	(1.4)
Do hands-on/laboratory science activities or investigations	84	(3.1)	70	(2.6)
Answer textbook or worksheet questions	84	(3.2)	71	(2.1)
Record, represent, and/or analyze data	69	(6.1)	54	(2.6)
Follow specific instructions in an activity or investigation	68	(5.3)	72	(2.6)
Watch a science demonstration	61	(5.8)	41	(2.1)
Prepare written science reports	31	(4.3)	24	(2.1)
Use computers as a tool	23	(4.1)	16	(2.4)
Read from a science textbook in class	21	(4.0)	29	(2.3)
Watch audiovisual presentations	15	(3.0)	22	(1.8)
Design or implement their *own* investigation	15	(3.3)	9	(1.3)
Write reflections	13	(2.8)	15	(1.5)
Read other science-related materials in class	11	(2.3)	21	(2.5)
Work on extended science investigations or projects	11	(3.3)	7	(1.1)
Make formal presentations to the rest of the class	7	(2.4)	6	(0.9)
Participate in field work	3	(1.8)	4	(0.8)
Take field trips	1	(1.4)	2	(0.6)

Table 21
High School Physics Classes Participating in Various Activities in Most Recent Lesson

	Percent of Classes			
	Physics		All Other Sciences	
Lecture	73	(5.4)	71	(2.1)
Discussion	71	(5.6)	82	(1.5)
Students using calculators	66	(5.2)	23	(2.0)
Students working in small groups	53	(5.6)	52	(2.1)
Students completing textbook/worksheet problems	46	(5.4)	52	(2.4)
Students doing hands-on/laboratory activities	43	(5.4)	42	(2.1)
Students reading about science	12	(2.5)	27	(2.3)
Students using other technologies	10	(3.0)	10	(1.4)
Test or quiz	10	(2.9)	13	(1.2)
Students using computers	9	(2.9)	7	(1.1)
None of the above	1	(1.0)	2	(0.5)

Table 22
Average Percentage of High School Physics Class Time Spent on Different Types of Activities

	Average Percent			
	Physics		All Other Sciences	
Whole class lecture/discussion	36	(3.0)	37	(1.1)
Working with hands-on, manipulative, or laboratory materials	22	(4.5)	22	(1.2)
Individual students reading textbooks, completing worksheets, etc.	14	(3.0)	14	(0.9)
Non-laboratory small group work	11	(2.0)	9	(0.8)
Daily routines, interruptions, and other non-instructional activities	10	(0.7)	11	(0.3)
Other activities	7	(2.1)	7	(0.6)

Lecture/Discussion

Teachers in 87 percent of physics classes report their students listening and taking notes at least once a week. (See Table 20.) In 73 percent of most recent physics lessons, teachers reported lecturing, and in 71 percent discussion occurred. (See Table 21.) On average, 36 percent of instructional time is devoted to lecture/discussion, a much higher percentage of time than in any other activity. (See Table 22.)

Students Working Problems

Teachers in 94 percent of physics classes indicated that at least once a week, their students use mathematics as a tool in problem-solving, and 84 percent indicated that students answer textbook or worksheet problems that often, two activities that likely go together and that occur more frequently in physics classes than in other science classes. (See Table 20.) In their most recent lesson, students in 66 percent of physics classes used calculators and in 46 percent they completed textbook/worksheet problems. (See Table 21.)

Laboratory Activities

As can be seen in Table 20, teachers in a higher percentage of physics classes than in other science classes report students doing a laboratory activity or investigation at least weekly (84 and 70 percent, respectively). However, there is no significant difference between the percent of physics and non-physics classes where students did a hands-on activity in the most recent lesson or in the amount of instructional time spent working with hands-on, manipulative, or laboratory materials. (Tables 21 and 22).

Other Frequent Activities

From the three data sources described above, it is clear that some other activities are frequent in addition to lecture/discussion, working problems, and laboratory activities. Students working together in small groups is quite frequent (Tables 20–22), which is likely a combination of students working problems and doing laboratories together.

It is surprising that 10 percent of the time in physics classes is devoted to non-instructional activities. (See Table 22.) Over a year, this amounts to a loss of 3–4 weeks of instructional time. The amount of non-instructional time, however, is no different than in other high school science classes.

The amount of homework assigned in physics classes is not significantly different than in other high school science classes. In the vast majority of physics classes (89 percent), teachers assign more than ½ hour of homework per week. In 41 percent of high school physics classes, teachers assign more than 1½ hours per week. (See Table 23.)

Table 23
Amount of Homework Assigned in High School Physics Classes per Week

	Percent of Teachers			
	Physics		All Other Sciences	
0–30 minutes	11	(3.1)	11	(1.2)
31–60 minutes	20	(4.8)	28	(1.9)
61–90 minutes	28	(5.2)	25	(1.7)
91–120 minutes	12	(3.3)	16	(1.4)
2–3 hours	19	(3.2)	14	(2.0)
More than 3 hours	10	(2.4)	7	(1.7)

Activities That Are Not Frequent

Survey data also point to some activities that are not very frequent, but might be expected to be. The NRC *Standards* call for a shift from "cookbook" laboratory activities to ones where students are involved in designing the question and the experimental procedure. In only 15 percent of physics classes do teachers report that students design their own investigations at least once a week and in only 13 percent of the physics classes do students write reflections on what they are learning at least weekly. (See Table 20.)

In addition, the frequency of computer and other technology use is surprisingly low. Only about 1 in 10 physics lessons appear to incorporate computers or other technologies. (See Table 21.) About 15 percent of high school physics classes use computers for retrieving, exchanging, or collecting data with sensors or probes at least weekly, and about 10 percent use them for simulations and demonstrations. (See Table 24.)

Table 24
High School Physics Classes Where Teachers Report that Students Use Computers to do Particular Activities at Least Once a Week

	Percent of Classes			
	Physics		All Other Sciences	
Collect data using sensors or probes	15	(3.3)	4	(0.9)
Retrieve or exchange data	14	(3.4)	7	(1.1)
Do laboratory simulations	9	(3.0)	6	(1.0)
Demonstrate scientific principles	8	(2.1)	7	(1.0)
Solve problems using simulations	7	(1.9)	4	(0.7)
Take a test or quiz	3	(1.0)	9	(1.9)
Do drill and practice	3	(1.3)	5	(1.0)
Play science learning games	1	(0.7)	4	(0.8)

With the abundance of probes and sensors available for the teaching of physics, the infrequency of technology use is somewhat perplexing. One potential explanation is that teachers have not received the professional development they need in order to know how to integrate technology in their instruction. Data presented earlier in this report show that physics teachers identify instructional technology as an area where they are in particular need of professional development. (See Table 10.) At the same time, other survey data show that teachers participated in very little professional development that was focused on science instruction, so even though many of those experiences emphasized technology use, the total amount of professional development time devoted to this area was low. (See Tables 11 and 13.)

Another potential explanation is a lack of access to technology; however, as can be seen in Table 25, few teachers reported that computers or lab interfacing devices were needed for instruction, but that they were not available in their classes (5 and 16 percent, respectively). Although 85 percent of physics classes use computers and 60 percent use interfacing devices at least once during the year, the frequency of use is clearly very low.

Table 25
Equipment Need, Availability, and Use in High School Physics Classes

	Percent of Classes					
	Not Needed		Needed, but Not Available		Used	
Overhead projector						
Physics	22	(6.6)	0	—§	78	(6.6)
All Other Sciences	10	(2.7)	0	(0.1)	90	(2.7)
Videotape player						
Physics	5	(2.4)	0	—§	95	(2.4)
All Other Sciences	5	(0.9)	0	(0.2)	95	(0.9)
Videodisc player						
Physics	44	(6.3)	3	(1.4)	53	(6.3)
All Other Sciences	38	(2.3)	7	(1.3)	55	(2.5)
CD-ROM player						
Physics	42	(5.7)	8	(5.5)	50	(6.0)
All Other Sciences	35	(2.5)	8	(1.1)	57	(2.7)
Four-function calculator						
Physics	24	(4.2)	3	(2.2)	73	(4.6)
All Other Sciences	38	(2.3)	5	(1.1)	57	(2.4)
Fraction calculators						
Physics	59	(5.6)	1	(0.8)	40	(5.6)
All Other Sciences	71	(2.9)	4	(1.2)	25	(2.8)
Graphing calculators						
Physics	31	(6.0)	5	(2.3)	64	(5.9)
All Other Sciences	63	(2.9)	5	(1.0)	32	(2.8)
Scientific calculators						
Physics	5	(1.8)	2	(1.4)	93	(2.3)
All Other Sciences	43	(2.9)	4	(1.0)	53	(2.8)
Computers						
Physics	11	(3.0)	5	(1.9)	85	(3.6)
All Other Sciences	9	(1.4)	6	(1.0)	85	(1.8)
Computers with Internet connection						
Physics	28	(5.9)	6	(1.7)	66	(6.0)
All Other Sciences	12	(1.6)	9	(1.2)	79	(1.9)
Calculator/computer lab interfacing devices						
Physics	24	(4.4)	16	(5.5)	60	(6.0)
All Other Sciences	42	(2.8)	18	(2.1)	40	(2.8)
Running water						
Physics	12	(3.1)	1	(0.3)	87	(3.1)
All Other Sciences	1	(0.5)	2	(0.5)	97	(0.7)
Electric outlet						
Physics	2	(1.6)	0	(0.3)	98	(1.7)
All Other Sciences	2	(0.7)	1	(0.6)	97	(0.9)
Gas for burners						
Physics	44	(5.8)	4	(2.4)	52	(5.8)
All Other Sciences	19	(2.0)	6	(1.1)	75	(2.2)
Hoods or air hose						
Physics	56	(5.1)	4	(1.8)	40	(5.2)
All Other Sciences	30	(2.0)	12	(1.6)	58	(2.4)

§ No teachers in the sample selected this response option. Thus, it is impossible to calculate the standard error of this estimate.

Resources Available for Physics Instruction

Physics teachers' apparent access to computers is similar to that for other instructional resources. In only one instance did as many as 10 percent of physics teachers report needing a particular resource and not having it—calculator/computer lab interfacing devices. (See Table 25.) Although most physics teachers report that their classes have access to the instructional resources they need, teachers still spend their own money on class supplies; the median amount spent is $70 per class.

Teachers in the vast majority of physics classes (96 percent) report using one or more textbooks, with the most commonly used physics texts being:

- *Physics—Principles and Problems* (McGraw-Hill/Merrill Co.);
- *Conceptual Physics* (Addison/Wesley Longman, Inc./Scott Foresman); and
- *Physics* (Prentice Hall, Inc.).

As can be seen in Table 26, teachers in 82 percent of physics classes rated their textbook as good or better in quality. Despite these ratings, there does seem to be an issue with the amount of material in physics textbooks. Only 53 percent of physics classes address more than three-fourths of their textbook, possibly a reflection of publishers' efforts to meet as many state and district criteria as possible by including all of the content anyone might seek. (See Table 27.)

Table 26
High School Physics Teachers' Perceptions of Quality of Textbooks/Programs Used in Science Classes†

	Percent of Classes			
	Physics		All Other Sciences	
Very poor	0	(0.2)	1	(0.4)
Poor	7	(4.8)	4	(0.6)
Fair	12	(2.5)	18	(2.0)
Good	38	(5.3)	38	(2.3)
Very good	32	(4.7)	30	(2.2)
Excellent	12	(3.7)	8	(1.1)

† Only classes using published textbooks/programs were included in these

Table 27
Percentage of High School Physics Textbook/Program Covered During the Course†

	Percent of Classes			
	Physics		All Other Sciences	
Less than 25 percent	3	(1.9)	3	(0.6)
25–49 percent	12	(2.7)	13	(1.4)
50–74 percent	31	(4.4)	39	(2.4)
75–90 percent	48	(5.6)	35	(2.3)
More than 90 percent	5	(2.1)	9	(1.2)

† Only classes using published textbooks/programs were included in these analyses.

Summary

The typical teacher of high school physics is not as well prepared in his/her content area as is the typical chemistry or biology teacher—slightly more than half of physics teachers have had six or more semesters of physics or physical science. However, nearly two-thirds of physics classes are taught by teachers who have had substantial course work in physics and are confident in their content knowledge and in their ability to teach the content, suggesting that the best prepared physics teachers are more likely to teach multiple sections.

Asked about their professional development needs, high school physics teachers expressed a need for help in a number of ways, especially in using instructional technology. At the same time, they spend very little time in professional development specific to science teaching, where they might receive such help. Physics teachers also called for help in accommodating students with special needs. However, very little of the professional development they do participate in is focused on this area.

The data strongly suggest a pattern of instruction that relies heavily on lecture/discussion, students working problems, and an occasional laboratory activity. Lecture/discussion accounts for far more instructional time than any other single activity (e.g., doing labs, non-laboratory small group work, individual student work). The use of demonstrations and the integration of computers into physics instruction are surprisingly infrequent; the latter is perhaps explained by teachers' lack of preparation. The image of high school physics instruction is quite similar to what these teachers likely experienced in their college physics courses, and perhaps explains the prevalence of certain instructional strategies.

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Appendix

Description of Composite Variables

To facilitate the reporting of large amounts of survey data, and because individual questionnaire items are potentially unreliable, HRI used factor analysis to identify survey questions that could be combined into "composites." Each composite represents an important construct related to science education.

Each composite is calculated by summing the responses to the items associated with that composite and then dividing by the total points possible. In order for the composites to be on a 100-point scale, the lowest response option on each scale was set to 0 and the others were adjusted accordingly; so for instance, an item with a scale ranging from 1 to 4 was re-coded to have a scale of 0 to 3. By doing this, someone who marks the lowest point on every item in a composite receives a composite score of 0 rather than some positive number. It also assures that 50 is the true mid-point. The denominator for each composite is determined by computing the maximum possible sum of responses for a series of items and dividing by 100; e.g., a 9-item composite where each item is on a scale of 0–3 would have a denominator of 0.27.

Composite definitions for the science teacher questionnaire are presented below along with the item numbers. Reliability information is based on the entire sample of K–12 science teachers.

Table A-1
Science Teacher Content Preparedness*

	Biology/ Life Science	Chem- istry	Earth Science	Environ -mental Science	Integrated/ General Science	Physical Science	Physics
Earth's features and physical processes			Q15a1a	Q15a1a	Q15a1a	Q15a1a	
The solar system and the universe			Q15a1b		Q15a1b	Q15a1b	
Climate and weather			Q15a1c	Q15a1c	Q15a1c	Q15a1c	
Structure and function of human systems	Q15a2a				Q15a2a		
Plant biology	Q15a2b				Q15a2b		
Animal behavior	Q15a2c				Q15a2c		
Interactions of living things/ecology	Q15a2d			Q15a2d	Q15a2d		
Genetics and evolution	Q15a2e				Q15a2e		
Structure of matter and chemical bonding		Q15a3a			Q15a3a	Q15a3a	
Properties and states of matter		Q15a3b			Q15a3b	Q15a3b	
Chemical reactions		Q15a3c			Q15a3c	Q15a3c	
Energy and chemical change		Q15a3d			Q15a3d	Q15a3d	
Forces and motion					Q15a4a	Q15a4a	Q15a4a
Energy					Q15a4b	Q15a4b	Q15a4b
Light and sound					Q15a4c	Q15a4c	Q15a4c
Electricity and magnetism					Q15a4d	Q15a4d	Q15a4d
Modern physics (e.g., special relativity)					Q15a4e	Q15a4e	Q15a4e
Pollution, acid rain, global warming				Q15a5a	Q15a5a		
Population, food supply, and production				Q15a5b	Q15a5b		
Formulating hypothesis, drawing conclusions, making generalizations	Q15a6a	Q15a6a	Q15a6a	Q15a6a	Q15a6a	Q15a6a	Q15a6a
Experimental design	Q15a6b	Q15a6b	Q15a6b	Q15a6b	Q15a6b	Q15a6b	Q15a6b
Describing, graphing, and interpreting data	Q15a6c	Q15a6c	Q15a6c	Q15a6c	Q15a6c	Q15a6c	Q15a6c
Number of Items in Composite	**8**	**7**	**6**	**8**	**22**	**15**	**8**
Reliability (Cronbach's Coefficient Alpha)	**0.87**	**0.87**	**0.76**	**0.79**	**0.87**	**0.89**	**0.88**

* Questions comprising these composites were asked of only those teachers in non-self-contained settings.

Table A-2
Science Teacher Preparedness to
Use Standards-Based Teaching Practices

Take students' prior understanding into account when planning curriculum and instruction	Q3a
Develop students' conceptual understanding of science	Q3b
Provide deeper coverage of fewer science concepts	Q3c
Make connections between science and other disciplines	Q3d
Lead a class of students using investigative strategies	Q3e
Manage a class of students engaged in hands-on/project-based work	Q3f
Have students work in cooperative learning groups	Q3g
Listen/ask questions as students work in order to gauge their understanding	Q3h
Use the textbook as a resource rather than the primary instructional tool	Q3i
Teach groups that are heterogeneous in ability	Q3j
Number of Items in Composite	**10**
Reliability (Cronbach's Coefficient Alpha)	**0.88**

Table A-3
Science Teacher Preparedness to
Teach Students from Diverse Backgrounds

Recognize and respond to student cultural diversity	Q3l
Encourage students' interest in science	Q3m
Encourage participation of females in science	Q3n
Encourage participation of minorities in science	Q3o
Number of Items in Composite	**4**
Reliability (Cronbach's Coefficient Alpha)	**0.81**

Table A-4
Science Teacher Preparedness to
Use Calculators/Computers

Use calculators/computers for drill and practice	Q3q
Use calculators/computers for science learning games	Q3r
Use calculators/computers to collect and/or analyze data	Q3s
Use computers to demonstrate scientific principles	Q3t
Use computers for laboratory simulations	Q3u
Number of Items in Composite	**5**
Reliability (Cronbach's Coefficient Alpha)	**0.89**

Table A-5
Science Teacher Preparedness to
Use the Internet

Use the Internet in your science teaching for general reference	Q3v
Use the Internet in your science teaching for data acquisition	Q3w
Use the Internet in your science teaching for collaborative projects with classes/individuals in other schools	Q3x
Number of Items in Composite	**3**
Reliability (Cronbach's Coefficient Alpha)	**0.86**

Table A-6
Nature of Science Objectives

Learn to evaluate arguments based on scientific evidence	Q23f
Learn about the history and nature of science	Q23j
Learn how to communicate ideas in science effectively	Q23g
Learn about the applications of science in business and industry	Q23h
Learn about the relationship between science, technology, and society	Q23i
Number of Items in Composite	**5**
Reliability (Cronbach's Coefficient Alpha)	**0.84**

Table A-7
Science Content Objectives

Learn basic science concepts	Q23b
Learn important terms and facts of science	Q23c
Learn science process/inquiry skills	Q23d
Prepare for further study in science	Q23e
Number of Items in Composite	**4**
Reliability (Cronbach's Coefficient Alpha)	**0.60**