ACT National Curriculum Survey® 2012

Science

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Introduction

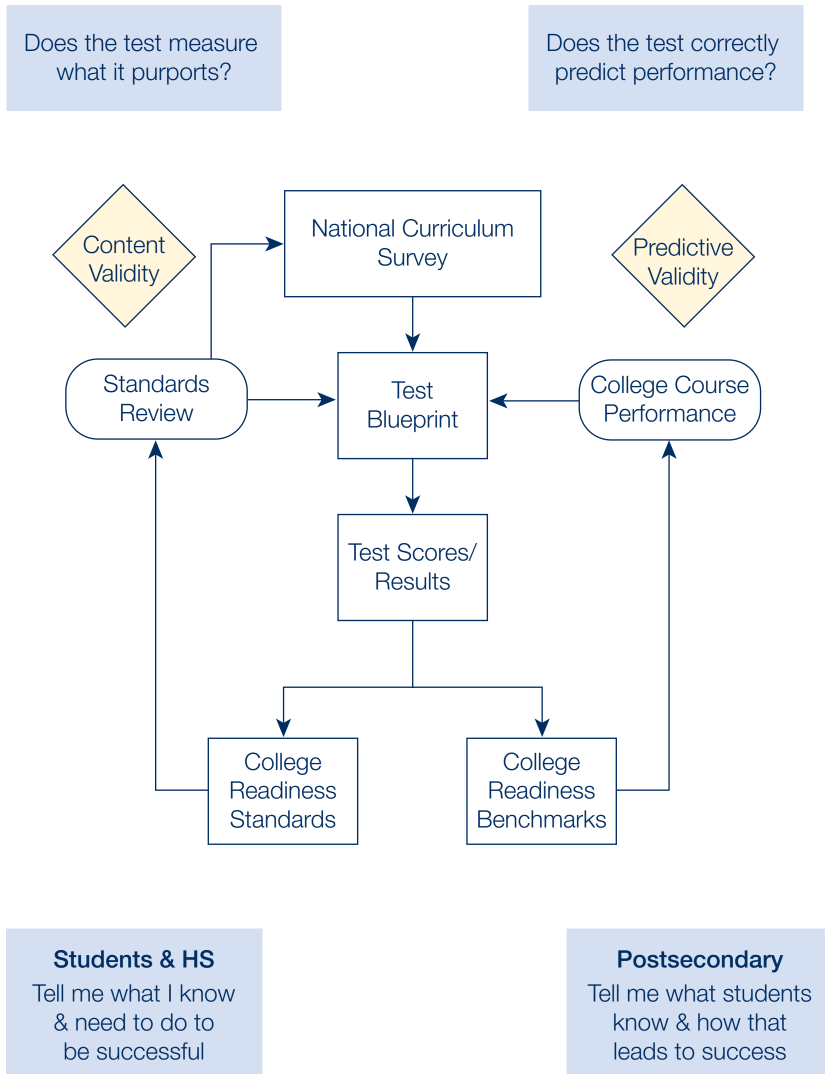
Every three to five years, the ACT National Curriculum Survey® asks educators about what they teach (or don't teach) in their courses and how important they feel various topics in their discipline are for students to know to be successful in these courses and in future coursework. The survey also asks educators for their opinions on educational topics of current interest, such as the college readiness of their students or the implementation of improved standards, such as ACT's College Readiness Standards or the Common Core State Standards.

Prior National Curriculum Survey efforts included educators from middle school through the postsecondary level; for the first time, the National Curriculum Survey 2012 also included elementary school teachers. ACT knows that early learning is important for later high school performance—not only do we have the assessment data to prove it, but we now also have survey data about its importance from the very people who teach it.

The Purpose of the Survey

The National Curriculum Survey is a critical step in the process used to build and regularly update a valid suite of ACT assessments that is empirically aligned to college readiness standards. The survey helps to inform the test blueprint for the assessments (see Figure 1). Results from the assessments are used to validate ACT's College Readiness Standards as well as the College Readiness Benchmarks. (The figure represents only this validation cycle, and does not represent how the Standards and Benchmarks were derived.)

Figure 1: The Science of ACT Assessments



ACT is committed to validity research. The first type is research into content validity, designed to answer the critical question: Does the test measure what it purports to measure? Essentially, this involves the validation of ACT's College Readiness Standards, which are built on a foundation of years of empirical data and continually validated through the National Curriculum Survey as well as frequent external standards reviews. The second type of research, into predictive validity, is equally important. Using actual course performance, we answer a second critical question: Does the test correctly predict performance? Constant monitoring allows ACT to ensure that the answer to both of the aforementioned questions is yes.

This science behind our assessments—the evidence base and ongoing research—is critical to answering the key question of what matters most in college and career readiness. The National Curriculum Survey represents ACT's commitment to:

- use evidence and research to develop and validate our standards, assessments, and benchmarks;
- maintain a robust research agenda to report on key educational metrics (*The Condition of College & Career Readiness*, *Enrollment Management Trends Report*, and *The Reality of College Readiness*); and
- develop assessments, reports, and interventions that will help individuals navigate their personal path to success along a kindergarten-through-career continuum.

Accordingly, the following principles have shaped and will continue to drive our development agenda:

1. Maximize instructional time.
2. Establish reasonable testing times.
3. Provide transparent connections between ACT's College Readiness Standards and the Common Core State Standards.
4. Leverage technology to enhance student engagement, produce more meaningful results, and share results in a timely fashion.
5. Increase the emphasis on evidence-centered design, implementing as quickly as possible given technological advances (such as artificial intelligence scoring).
6. Include science as a critical content area in our assessment batteries.
7. Reflect the reality that there are multiple dimensions of readiness and success (validated by research).

As a nonprofit educational research organization, we will use these principles to drive the development and continuous improvement of ACT's current and future solutions, as well as the research agenda associated with them, thereby enabling ACT to fulfill its mission of helping all individuals achieve success.

The Survey Results

ACT makes the results of each National Curriculum Survey public in recognition that ACT's data can help educational stakeholders make more informed decisions about college readiness standards and about the alignment of those standards with assessment and curricula. (Survey results for the ACT National Curriculum Survey 2012 are available at **http://www.act.org/research-policy/national-curriculum-survey**.)

The present report highlights findings from the Science portion of the survey. Participants in this portion included teachers of elementary school science; teachers of middle school earth science, life science, and physical science; teachers of high school biology, chemistry, earth science, and physics; and instructors of credit-bearing first-year college courses in biology, chemistry, earth science, physics, and physics in an engineering context.

The implications of the survey findings are as follows:

- A discrepancy exists between how middle school and high school science teachers rate the importance of science process skills and how college instructors rate these skills. This suggests a misalignment between the K–12 and postsecondary science curricula that may be hampering students' preparation for college and career.
- Engineering topics appear to receive little attention in current science curricula. This suggests that K–12 teachers may not be prepared to teach to any new standards that include a strong emphasis on engineering in the science classroom.
- Another sign that teachers may not be fully prepared to teach to new science standards is their concern over the need for substantive professional development opportunities to help them understand and implement such standards in the classroom.

In the next section of the report, the findings leading to these implications are described in detail. The final section of the report offers recommendations suggested by the findings and implications, while the Appendix contains detailed information about the survey sampling process.

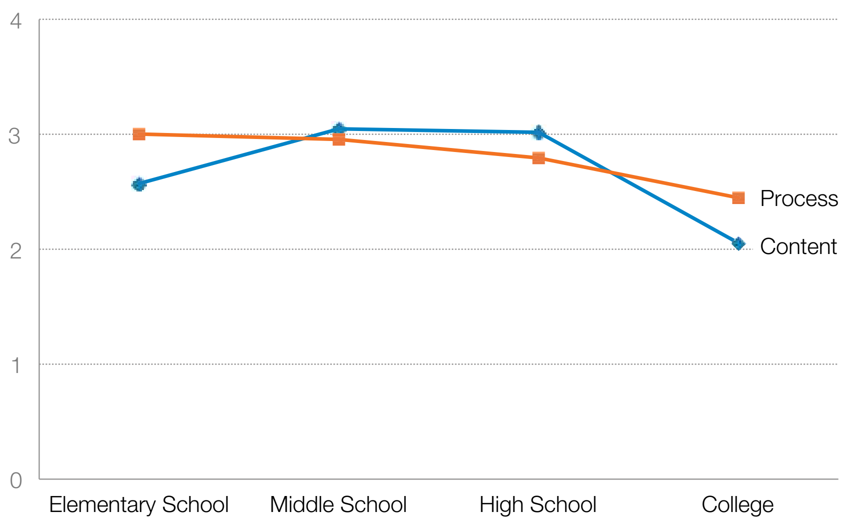
Findings in Science

Finding 1: Overall, college science instructors rate science content topics lower in importance than science process skills; conversely, middle school and high school science teachers rate science content topics higher in importance than science process skills.

Topics in science curricula fall into two broad categories: content (the "what" of science: i.e., the established body of knowledge about physical and natural phenomena) and process (the "how" of science: e.g., making observations and measurements, designing and refining experiments, considering variables, making predictions, drawing inferences and conclusions).

On average, college instructors who teach entry-level courses in all science disciplines rate discipline-specific content topics lower in importance as a prerequisite for success in their course than process skills, but their middle school and high school counterparts generally rate content topics higher in importance in their courses than process skills (Figure 2). Within K–12, only elementary school teachers rated process skills higher than content topics.

Figure 2: Average Importance Ratings for Content Topics and Process Skills[1]



When analyzed by subject area, the trend of content over process in middle school and high school vs. process over content in college is observed in life science/biology, chemistry, and earth science. In physics, however, all three groups of educators rated process skills more highly on average than content skills.

Finding 2: Educators' average importance ratings for process skills provide a progression of how these skills are taught throughout students' educational careers.

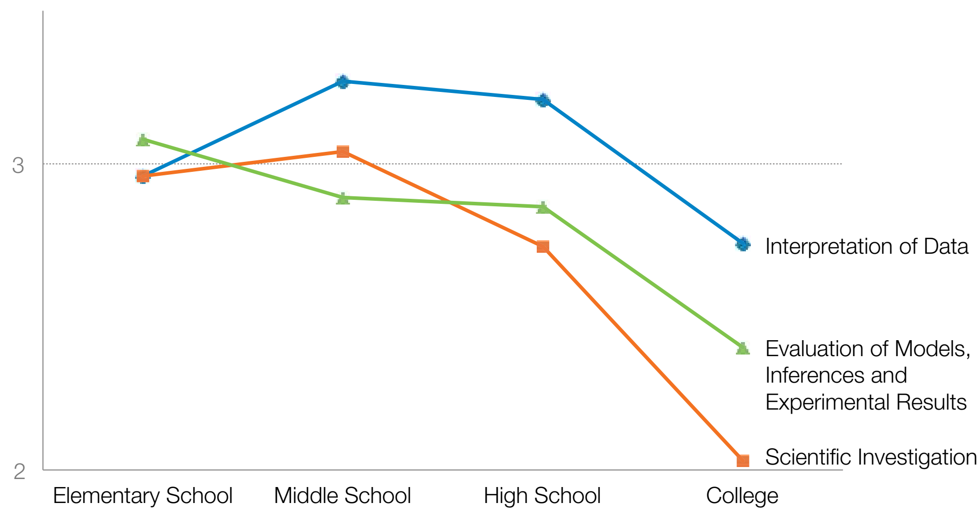
Process skills in the National Curriculum Survey are grouped into three categories:

- *Interpretation of Data*: Interpreting tables, graphs, and diagrams to locate data, examine relationships in the data, and extend those relationships beyond the data
- *Scientific Investigation*: Understanding experimental design and procedures, comparing designs and procedures across experiments, and understanding how changes in design and procedures affect experimental results
- *Evaluation of Models, Inferences, and Experimental Results*: Evaluating multiple explanations for the same phenomena to determine their differences, similarities, strengths, and weaknesses, and evaluating the validity of conclusions based on experimental results

Figure 3 shows the average importance ratings for each of the three categories as determined by elementary school, middle school, and high school teachers and college instructors.

[1] Importance ratings in the survey were labeled as follows: 0=Not Important, 1=Low Importance, 4=High Importance.

Figure 3: Average Importance Ratings for Three Categories of Process Skills[2]



Although elementary school is the first time that students are formally introduced to the science process, elementary school teachers indicate that the skills in the Evaluation category are, by a slight margin, the most important process skills. The focus of the elementary science experience is on observing and explaining natural phenomena, followed closely by learning the foundational skills of experimental design and data analysis.

In middle school, we see an increase in the importance placed by teachers on skills in the Interpretation of Data category, which makes sense because students' math skills begin to increase and thus the types of data presentation skills they can be introduced to also increase. The importance placed on Scientific Investigation skills increases as well (especially relative to Evaluation), as students learn to delve deeper into experimental design skills and then are asked to apply those skills to more complex natural phenomena.

In high school, teachers continue to stress the importance of Interpretation of Data by rating the skills in this category as most important, especially as students' math skills continue to increase and they are asked to use more sophisticated analysis skills to interpret results and present conclusions. Skills in the Evaluation category have more importance than topics in the Scientific Investigation category in high school. This may be due to the fact that many of the foundational and intermediate Scientific Investigation skills taught in elementary school and middle school may be explicitly taught as review in high school.

College instructors prioritize the three categories of process skills in the same way that high school teachers do, but at slightly lower levels of importance. (This partly reflects that college instructors generally tended throughout the survey to assign slightly lower importance ratings to both content and process skills than did other groups of educators, but may also be related to the different definition of importance

[2] The y-axis has been altered to show greater detail.

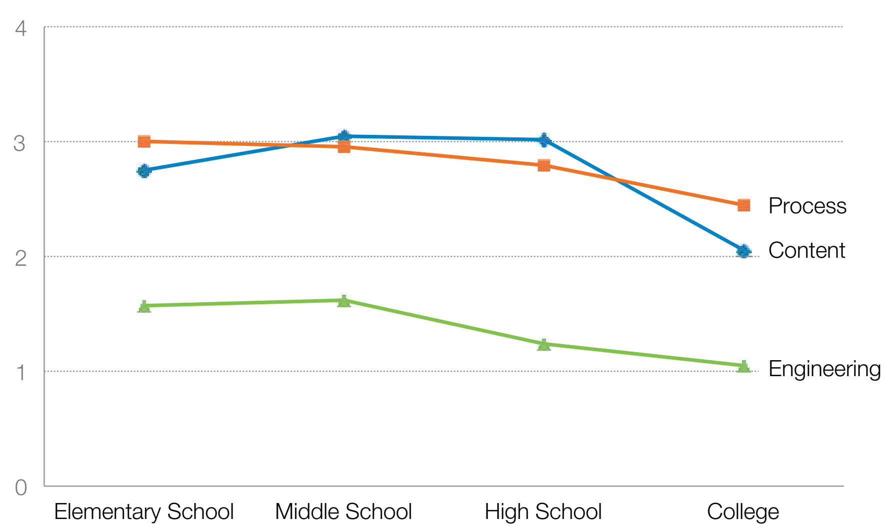
the college instructors were given: importance as a prerequisite for success in their course, as opposed to importance within their course.) While college instructors rated process skills more highly than content topics (see Figure 2), they also teach these skills in increasingly sophisticated ways to help students make sense of the new content they are learning in postsecondary courses. A foundation in high school–level process skills, especially Interpretation of Data and Evaluation, is therefore clearly desirable, but may not necessarily be essential for success, in introductory college coursework.

Finding 3: Instructors at all levels consistently rate engineering practices and topics much lower in importance than both content topics and process skills.

Because the framework for the recently released Next Generation Science Standards includes engineering as a primary component of K–12 science curricula (Achieve, Inc., 2013), we asked survey participants to rate the importance of a group of engineering practices and topics—a mixture of content and process elements dealing specifically with engineering—in addition to the groups of content topics and process skills shown in Figure 2.

Survey participants from elementary through college rated engineering practices and topics as much less important than content topics or process skills (Figure 4). Not only were the average ratings for these engineering items lower than those of both the content topics and process skills, but they were also consistently rated at or very near the bottom of all items surveyed, except by instructors of college physics courses targeted at engineering students. These results suggest that, in contrast to the prominent inclusion of engineering in the Next Generation Science Standards, engineering is currently not an important part of the current science curriculum.

Figure 4: Average Importance Ratings for Content Topics, Process Skills, and Engineering Practices & Topics



Finding 4: Process-skill data from the survey correspond strikingly well with comparable data from the NAEP.

In June 2012, the National Assessment of Educational Progress (NAEP) released the results of a 2009 study of 4th-, 8th-, and 12th-grade science students (National Assessment of Educational Progress, n.d.). These students were assigned either hands-on or computer-based science tasks, in which they were asked to set up and perform simple experiments based on specific themes, and also to interpret their results and generate conclusions from the experiments.[3] The NAEP study and the ACT National Curriculum Survey look at science at similar grade levels, but from different perspectives: the NAEP study measures how well students perform at certain tasks of varying complexity, while the National Curriculum Survey asks teachers to rate the importance of the skills students use in performing many of these tasks, as well as to indicate whether they teach these skills in their classrooms and, if so, whether they are taught mainly as review or as part of standard course content. A comparison of the two studies reveals a great deal of overlap between what teachers do or do not value in the classroom and what tasks students can or cannot perform well.

By analyzing the questions students were asked about the experiments performed in the NAEP study, ACT identified all the tasks that at least 80 percent of students at the three grade levels performed successfully. ACT then determined which process skills from the National Curriculum Survey best match these tasks. Table 1 shows that the NAEP results correlate well with the ranking of the average importance ratings that National Curriculum Survey participants assigned to each skill and the ranking of whether or how they taught each skill.[4]

Note to Table 1: Elementary school teachers (ES) were asked to consider 52 process skills. Middle school (MS) and high school (HS) teachers were asked to consider 43 process skills; variations in the total number of slots (e.g., "of 42," "of 39") reflect the existence of one or more ties above the ranking in question. Ties below the ranking in question were ignored.

Table 1: Comparison of NAEP Study Tasks (≥ 80% Success Rate) to National Curriculum Survey (NCS) Process Skill Rankings

Level	NCS Process Skill Corresponding to NAEP Study Task	NCS Importance Ranking	NCS "Taught" Ranking
ES	Suggest factors that might affect the result of an investigation	10	7
	Understand basic processes and steps of simple experiments	6	6
	Carry out a simple controlled experiment to test the behaviors of an organism or the properties of an object	9	10
	Draw simple conclusions from collected data represented in a simple chart or table	4	3
MS/HS	Understand the critical components of an experimental design or procedure	MS 2 HS 12 of 42	MS 8 HS 12 of 39
	Generate a hypothesis for an experiment	MS 7 HS 15 of 42	MS 10 HS 16 of 39
	Design and conduct experiments	MS 14 of 42 HS 18 of 42	MS 16 HS 17 of 39

[3] The study results can be found at http://nationsreportcard.gov/science_2009/ict_summary.aspx.

[4] See the Appendix for details on the methodology of the rankings.

The table shows that the elementary school process skills corresponding to the tasks performed most successfully by 4th-grade students in the NAEP study were ranked in the top 10 by elementary school teachers with respect to both importance and how they are taught in the classroom. Similarly, the middle school and high school process skills corresponding to the tasks performed most successfully by 8th- and 12th-grade students in the NAEP study were ranked in at least the top 16 by middle school teachers and in at least the top 18 by high school teachers.

ACT also identified all the tasks in the NAEP study that 35 percent or fewer of students at the three grade levels performed successfully. The process skills from the National Curriculum Survey that best match these tasks, along with rankings of the average importance ratings and the "taught" descriptions assigned to each task by National Curriculum Survey participants, are given in Table 2.

Table 2: Comparison of NAEP Study Tasks (≤ 35% Success Rate) to National Curriculum Survey (NCS) Process Skill Rankings

Level	NCS Process Skill Corresponding to NAEP Study Task	NCS Importance Ranking	NCS "Taught" Ranking
ES	Determine how the value of one variable changes as the value of another variable changes in a simple table	32	30
	Develop new questions based on conclusions from an actual investigation or from a scientific text	29	28
	Compare two or more different conclusions that are based on the same experimental results	28	32
MS/ HS	Evaluate the similarities and differences, or strengths and weaknesses in scientific explanations	MS 27 of 42 HS 23 of 41	MS 27 (tied) of 41 HS 22 of 39
	Evaluate the impact of new findings on the validity of a scientific explanation	MS 32 of 42 HS 29 of 41	MS 31 (tied) of 39 HS 26 of 38
	Recognize when key aspects of a proposed scientific investigation are missing	MS 31 of 42 HS 31 of 41	MS 28 (tied) of 40 HS 27 (tied) of 37
	Propose a scientific explanation or model given the results of multiple scientific investigations	MS 39 of 42 HS 36 of 41	MS 35 of 39 HS 31 of 36

Note to Table 2: Elementary school teachers (ES) were asked to consider 52 process skills. Middle school (MS) and high school (HS) teachers were asked to consider 43 process skills; variations in the total number of slots (e.g., "of 42," "of 41," etc.) reflect the existence of one or more ties at or above the ranking in question, with "(tied)" indicating a tie at the ranking itself. Ties below the ranking in question were ignored.

Table 2 shows that the process skills corresponding to the tasks performed least successfully by 4th-, 8th-, and 12th-grade students in the NAEP study were ranked in the bottom half of all process skills by elementary school teachers, middle school teachers, and high school teachers, respectively, with respect to both importance and how they are taught in the classroom.

The NAEP study tasks in Table 1 were generally less complex than those in Table 2. Overall, National Curriculum Survey participants rated the science process skills corresponding to the tasks that students performed least successfully as lower in importance, and assigned them less prominence in course content, than the process skills corresponding to the tasks that students performed most successfully.

In addition, ACT found that the 8th- and 12th-grade NAEP results also correspond well with the middle school and high school teachers' ratings from the National Curriculum Survey 2009, which was conducted during the same year as the NAEP study. (Elementary school teachers did not participate in the 2009 survey.)

Finding 5: The survey was able to elicit only a preliminary sense of science educators' views about the Next Generation Science Standards.

The National Curriculum Survey 2012 collected information about science educators' views on the Common Core State Standards, which, though they deal explicitly with English language arts and mathematics, are also expected to have an impact on science curricula. However, due to timing constraints, the survey was unable to solicit detailed information about educators' opinions on another state-led initiative with a more direct relationship to science education: the Next Generation Science Standards. A first draft of the standards was not released until after the survey was conducted.

Nevertheless, at the time that the survey was constructed and distributed to participants, the Framework for K–12 Science Education—the foundation upon which the Next Generation standards were developed—had been publicly released and was accessible both to ACT and to the survey participants. This enabled ACT to tailor some sections of the survey to the framework and survey respondents to offer their preliminary impressions of it. Some details related to K–12 teachers' thoughts on the Next Generation Science Standards are given in the next finding, and a fuller picture of their opinions will be presented in future National Curriculum Surveys.

Finding 6: K–12 science teachers expressed a need for information and training to help them implement new standards in the classroom.

As part of the National Curriculum Survey 2012, more than 1,500 K–12 science teachers described the kinds of professional development that would be most helpful in the classroom. Many expressed concerns about the upcoming or possible implementation of new standards, such as the Common Core State Standards in English language arts and mathematics or the Next Generation Science Standards.[5] Teachers often confounded or conflated the two sets of standards, which may perhaps have been due to a general confusion about whether or how they are related. Regardless, the most common statements about professional development expressed by K–12 teachers involved a need for:

- More detailed information about the standards
- Training about how to effectively implement the standards
- Adequate time to fully understand the standards and incorporate them into the curriculum

The teachers expressed a desire that professional development be ongoing and flexible, allowing time to explore and revise methodologies for implementation as needed. They also recognized that the Internet is continually changing the ways that professional development can be delivered, citing blogs, websites, and online lists of frequently asked questions as speedy and efficient forms of assistance that also engage teachers throughout the educational community in dialogues about how to best implement the new standards. In addition, teachers expressed concerns about the increased funding and expertise that will be needed to carry out transitions to the new standards. Finally, and perhaps most important, many K–12 teachers were concerned that the developers of the Next Generation Science Standards would not have received vital input from the postsecondary community about which science skills are most important for college and career readiness.

Although K–12 teachers at all levels expressed these concerns, a particular concern about funding increased in frequency the farther along in the educational pipeline the participants taught: the potentially prohibitive cost of upgrading classroom infrastructure (for example, laboratory equipment) to better enable the more hands-on approach to science education recommended by the framework for the Next Generation Science Standards. Another notable trend was the relatively low number of comments about the need for new technology (such as tablet computers or interactive whiteboards) to aid educators in teaching to the new standards. This would seem to run counter to a prevalent public perception that classrooms must become technologically enhanced before they can improve. Rather, the overall trend of the survey responses suggests that teachers may be less concerned with technology than with ensuring that they get the information, time, and training they will need to understand and implement the new standards.

[5] As mentioned in the previous finding, only the framework for the Next Generation Science Standards had been publicly released at the time of the survey, not any drafts of the standards themselves.

Recommendations

In light of the preceding results from the National Curriculum Survey 2012 in science, ACT offers the following recommendations to help in the pursuit of college and career readiness in science for all students:

1. **Increase the emphasis on teaching science process skills in middle school and high school.**

   The survey results show that both middle school and high school teachers rate process skills lower in importance than do instructors of first-year college science courses. College instructors generally regard mastery of science process skills as a more important prerequisite for success in their introductory courses than the attainment of science content knowledge. The lower importance of science process skills in middle school and high school is also reflected in the comparison between the survey results and the NAEP study of interactive computer and hands-on science tasks, especially with regard to higher-order process skills. For these reasons, middle school and high school science teachers should provide their students with more extensive opportunities to learn and apply both foundational and higher-order process skills as an integral part of the curriculum.

2. **Provide K–12 science teachers with the professional development opportunities needed to properly implement new standards in the classroom.**

   Many teachers indicated a need for professional development to allow them to fully understand and integrate new standards, such as the Common Core State Standards or the Next Generation Science Standards, into their curricula. (This need may become even more urgent if standards with an emphasis on engineering are implemented, because the survey results clearly show that engineering is currently not a significant component of elementary, middle, or high school science coursework.) States, districts, and schools should therefore ensure that all K–12 science teachers are given adequate time, tools, and other necessary supports so that they can make meaningful adjustments to any new goals for science education that may ultimately be implemented in the classroom.

Appendix: Description of Survey Sample and Process

The ACT National Curriculum Survey is a one-of-a-kind nationwide survey of educational practices and expectations conducted by ACT approximately every three years. ACT surveys thousands of teachers and college instructors in English/writing, mathematics, reading, and science for the purpose of determining what skills and knowledge are currently being taught at each grade level—and which are considered essential for college readiness. The survey also asks educators for their opinions on educational topics of current interest.

For the ACT National Curriculum Survey 2012, we sent surveys by postal mail and email to a nationally representative sample of elementary school, middle school, high school, and college instructors who teach courses in English/writing, mathematics, reading (including English language arts and social studies), and science (including Biology, Chemistry, Physics, and Earth/Space Science) in public and private institutions across the United States. We also included a sample of instructors of developmental (i.e., remedial) college courses in English/writing, mathematics, and reading. We included these instructors because they should be uniquely qualified to identify the critical skills and knowledge that high school graduates are typically missing and the set of knowledge and skills that, when emphasized, result in student readiness for success in entry-level college courses. Table 3 gives the numbers of survey participants at each educational level.

Table 3: ACT National Curriculum Survey 2012 Participants

Educational Level	Number of Participants
Elementary school	1,052
Middle school	1,806
High school	2,943
College developmental	540
College	3,596
TOTAL	9,937

The numbers of participants listed in Table 3 compare favorably to those from past surveys. Excluding elementary school teachers, who are new to the survey, the total number of participants in 2012 is 16 percent higher than the number who participated in 2009, and 35 percent higher than the number who participated in 2005–06.

ACT uses the results from the main body of the ACT National Curriculum Survey to guide the test development of ACT's college readiness assessments. ACT conducts this portion of the survey to ensure that its assessments are measuring the current knowledge and skills that instructors of credit-bearing first-year college courses identify as important for success in each content area. As in past years, the results of this section affirm that the knowledge and skills that are important for readiness and success in college and in workforce training, and the relative emphasis accorded to each, are reflected in the content of ACT Explore®, ACT Plan®, and the ACT® college readiness assessment.

All participants surveyed were asked to perform two primary tasks with respect to course content. First, they were asked to rate discrete content knowledge and skills with respect to how important each is to student success in the content area. (Specifically, high school teachers and college developmental instructors were asked to rate the importance of each content or skill in a given class they teach, while instructors of credit-bearing college courses were asked to rate the importance of each content or skill as a prerequisite to success in a given class they teach.) Second, they were asked to rank groups of content and skills, known as strands, with respect to their relative importance to student readiness for college.

We also asked the K–12 teachers to indicate whether or not they teach a particular content or skill and, if so, whether they teach it as a standard part of their course or as part of a review of material that should have been learned earlier. Finally, we asked all educators a number of questions about, e.g., the amount and type of reading and writing they assign; the textbooks they use; their awareness of the Common Core State Standards and of their state's, school's, or district's alignment efforts across K–13; their students' readiness for particular kinds of coursework; and their students' degrees of reading comprehension, computer literacy, and computer access.

Rankings in Tables 1 and 2 of the report were determined as follows: Importance rankings were determined by sorting the averages of the ratings assigned to each skill by a given group of science educators from highest to lowest, with a ranking of 1 indicating the highest average rating within each group. "Taught" rankings were determined by first assigning numerical values to the response choices (1=not taught, 2=taught mainly as review, 3=taught as part of standard course content) and then, for each skill, calculating a weighted average reflecting the percentages of educators within a given group who chose each of the responses. For example, a skill that 25 percent of the educator group indicated they did not teach, 20 percent indicated they taught mainly as review, and 55 percent indicated they taught as part of standard course content would have a weighted average of $(0.25)1 + (0.20)2 + (0.55)3 = 2.30$. These weighted averages were sorted from highest to lowest within each educator group, with a ranking of 1 indicating the highest weighted average in each group.

Because some content areas were surveyed in larger numbers than others, the values displayed in educational-level totals were averaged across English/language arts, mathematics, and science. This ensured that, in these results, no one content area would have more influence than another.

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