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Of Special Interest

Results of a National Survey on College Chemistry Faculty Beliefs and Attitudes of Assessment-of-Student-Learning Practices

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…if faculty were educated about how to measure outcomes such as group skills, then they might be valued more…

Why is assessment of student learning important? The National Science Education Standards chapter on Assessment in Science Education states that assessment is "primary feedback" [1]. Assessment of learning supplies instructors with feedback on how well their students are learning course material, and students are provided information about how well they are meeting teachers' expectations. Assessment of learning is useful for communicating the expectations of an educational program. Communication helps instructors know what to teach, how to teach, and where to find the material to teach. Assessment of student learning can also be used for program planning and improvement. For example, placement tests can

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be used as advising tools. Student work, in the form of portfolios, might serve as partial evidence of the quality of an undergraduate chemistry program. In summary, assessment of learning can provide information to:

- Students, about the extent of their learning and possibilities for success in future courses.
- Faculty, about the extent to which their teaching practices are facilitating student learning, and how they might make modifications to those practices.
- Administrators and other stakeholders, about course articulation, program effectiveness, and what students are able to do as they complete a program.

A comprehensive literature review about assessing learning in K–12 science education has examined assessment of learning techniques as well as policy-related issues [2].

Basic Issues in Assessment of Learning

Assessment is the collection of data about a learner's understanding. Evaluation (or grading) is the passing of judgment on the learner's understanding based on the data collected through assessment. Assessment data may be of a quantitative nature (e.g., test scores, proficiency in carrying out a particular laboratory synthesis) or of a qualitative nature (e.g., interviews with students about their understanding of a particular topic). The accuracy and precision of the data collected through assessment are important issues. When collecting and working with quantitative data sets such as test scores or peer-review responses, the precision of the measurements is estimated through such measures as test–retest reliability or internal consistency estimates (e.g., Cronbach's alpha). After the precision of the measurements has been established, accuracy of the measurements (also known as validity) can be examined by looking at how well the measurements correlate with other measures (e.g., other sets of students' scores, or perhaps students' future performance in other classes). While additional details about reliability and validity can be examined in basic educational psychology or testing and measurements texts [3, 4], the point of assessment is to collect high-quality data about the understanding of an area a student has developed. But these references will not tell us what learning needs to be measured. This is an issue chemistry faculty must address.

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Student understanding of chemistry may be measured across a number of learning outcomes. Almost all chemistry course goals include development of *cognitive* components in which students will be able to understand chemical concepts and apply them to new situations (e.g., solve certain types of stoichiometry problems, or be able to propose a pathway for the synthesis of a certain class of organic compounds). Another type of learning outcome associated with some chemistry courses is *affective* in nature. For example, an intended outcome might be for students to understand and appreciate how a scientific perspective of the world differs from other views. Chemistry laboratory work, and learning how to do it, is associated with cognitive and *psychomotor* goals. For example, students may need to learn how to accurately and quickly use IR and NMR spectrometers to identify unknown compounds.

Curriculum Reform Efforts in Chemistry

There are many efforts underway across the nation to reform the general chemistry curriculum. A great deal of discussion has occurred concerning what content should be taught and how that content should be taught [5]. While little about assessing student learning has accompanied these discussions, a workshop sponsored by the National Science Foundation (*Innovation and Change in the Chemistry Curriculum*) did include a component on assessment of student learning. One of the recommendations in the executive summary addressed this issue:

> The methods we use for assessing our students and our teaching must change so that they no longer focus on the lowest levels of learning and so that they provide us with the insight into our methods and our tools that we need to drive change [6].

But what current practices are being used to measure student learning in college-level chemistry classes? This is an important question to answer as reformers and adopters attempt to make changes in the chemistry curriculum.

The National Science Foundation is a large source of funding for course and curriculum development efforts (CCD) in college-level chemistry. In the four-year period since January 1, 1992 there have been 59 CCD grants awarded in chemistry (2 in 1992, 10 in 1993, 28 in 1994, and 19 in 1995). These projects range from small course-specific changes to large systemic efforts between consortia of colleges and universities. With all these changes going on in terms of content, instruction, and

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articulation of course work, what sorts of changes are taking place in terms of assessing student learning of chemistry? Unfortunately no published data exist to answer this question, although some national surveys have been done in related areas (two focusing on curriculum [7, 8] and one on laboratory instruction [9]). These surveys did not seek in-depth information about assessment because that was not their focus. However, answering questions about practices used for assessing student learning is important because it can provide curriculum reformers with benchmarks for comparing their progress with existing practices. While these projects are being asked to assess their effectiveness in terms of curricular changes that are successful, it is important to note the difference between assessing the effectiveness of a program and assessing what students know. Dwaine Eubanks, Director of the American Chemical Society (ACS) Examinations Institute, noted in a recent newsletter about Institute activities:

> While program assessment is certainly important, and has an essential place in charting the course of educational endeavors, it should not be the tail that wags the dog. We need to spend time with our students—assessing whether they are mastering concepts, ideas, and ways of thinking about the physical universe as they are exposed to them. We need to spend time after blocks of material are considered to find out whether they can assimilate the new material to construct a better, more personal understanding—and which they can extend their knowledge to new situations and applications. This is the real heart of any interaction between teacher and pupil, but it is too often lost, or sorely neglected, in the mass education frenzy of the late twentieth century.

Given the lack of an existing national database about how student learning is assessed in chemistry, the purpose of this paper is to report information from college chemistry faculty, both from CCD-funded reformers and others, about assessment practices that they use at their respective institutions. These results can be an important source of baseline information when examining college chemistry curricula reform efforts. Four broad sets of questions are addressed:

1. What are faculty perceptions of the importance of various learning outcomes, their frequency of measurement of these outcomes, and perceived knowledge of how to measure each outcome as a function of chemistry course being taught, institution type, course size, and CCD funding?

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2. What are faculty perceptions of the accuracy of various assessment techniques, their frequency of measurement using these techniques, and perceived knowledge of how to use such techniques as a function of chemistry course being taught, institution type, course size, and CCD funding?

3. What are various administrative characteristics of assessing student learning as a function of chemistry course being taught, institution type, course size, and CCD funding?

4. What are perceptions of changing assessment practices as a function of chemistry course being taught, institution type, course size, and CCD funding?

These broad questions reflect the survey structure and are examined in terms of major demographic variables (course being taught, public/private institutions, graduate/nongraduate chemistry programs, CCD/non-CCD supported institutions, and class size) to better understand assessment practices across different levels of chemistry courses at a variety of types of institutions.

Method

Because assessment of learning involves a set of multifaceted issues, a survey was developed that asked chemistry faculty questions ranging from demographic characteristics of the institutions and course in which the respondents taught, to their perceived knowledge of measuring various types of student outcomes. The five sections of the survey were:

Course structure and institutional demographics.
This focused on institution and course type, types of student enrolled in the course, instructional support staff available, and availability and use of demonstration and computer facilities.

Learning outcomes being assessed.
Asked faculty to rate the importance of various learning outcomes (e.g., basic facts, laboratory skills, or communication skills), how frequently they believed they measured these outcomes, and their perceived knowledge of how to measure them.

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Techniques of assessing learning.
Questioned respondents about how accurate they believed various assessment techniques were (e.g., written tests, portfolios, laboratory reports, or projects), how frequently they thought the techniques were used in their course, and how knowledgeable they felt about using each technique.

Role of assessment in the curriculum.
Respondents rated the importance that assessing student learning had in various roles related to curriculum (e.g., for accountability or course improvement).

Changes in assessment.
Examined faculty perceptions about the support various groups have for changing assessment practices (e.g., themselves, students, or the ACS), and the sort of activities they had participated in to learn about new assessment techniques.

The respondent samples were drawn from two target populations involved in college-level chemical education: chemistry departments with ACS Committee on Professional Training (CPT) bachelors approved programs, and institutions with Course and Curriculum Development projects taking place in chemistry. The CPT sample was drawn from a list of 603 ACS approved institutions taken from *Chemical and Engineering News* (November 20, 1995). Each institution was assigned a number, and a random sample of 300 was chosen. The CCD sample was randomly drawn from the population identified from the National Science Foundation awards database (using “fldscience = 12 AND nsfprogram = 7410 AND startdate = 1/1/93 TO 1/1/96" as search parameters). The awards dated from 1993 to 1995. There was an overlap of 13 institutions in the two lists, and each overlapping institution was assigned to the CCD population. This resulted in a sampling list of 285 for non-CCD institutions and 44 for CCD institutions.

After both lists of institutions were generated (CPT approved and CCD funded), the surveys were sent out. Chairs of the chemistry departments in the CPT sample were sent a cover letter asking that the four enclosed surveys be distributed to a faculty member teaching in each of the following areas: general chemistry, organic chemistry, physical chemistry, and advanced chemistry. For the CCD institutions, four surveys were sent to principal investigators of the grants asking them to distribute the surveys to faculty teaching in the four areas.

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Two mailings were done to the CPT and CCD institutions. The first mailing was sent out on February 29, 1996. Out of the 113 institutions (109 CPT and 4 CCD) that had replied before the March 31, 1996 deadline, there were 63 general (59 CPT and 4 CCD), 55 organic (55 CPT and 0 CCD), 41 physical (41 CPT and 0 CCD), and 37 advanced (36 CPT and 1 CCD) chemistry surveys received. A second mailing was sent out April 11, 1996. If an institution had not replied at all, a cover letter with four surveys was again sent to the chairs of the departments. For the institutions having at least one respondent, a cover letter was sent to that respondent requesting that the missing surveys be distributed to the faculty teaching in the other areas. By May 15, a total of 205 institutions had responded from the lists (183 CPT and 22 CCD institutions). A total of 436 faculty responded to the survey. Table 1 shows the number of respondents in each of the four areas of chemistry. Table 2 gives the institution type (public/private), and Table 3 indicates whether the respondent's department has graduate students. An additional demographic variable was created based on the number of students that were in the lecture class of each respondent. Table 4 summarizes the number of respondents with the four different class sizes. The overall institutional response rate from these two sampled groups was 64.2% for non-CCD and 50% for CCD respondents.

Results

Although the survey addressed demographic and institutional aspects, the results in this paper will focus only on assessment-related sections. What follows is a brief summary of responses that is broken down to answer the four broad research questions. In each major section the results are provided for all survey items as a function of the course being taught (general chemistry through advanced courses). In order to save space, only those items that show differences are reported when analyses are done by institution type (public/private, graduate/nongraduate, and CCD/non-CCD supported institutions) and class size.

What are faculty perceptions of the importance of various learning outcomes, their frequency of measurement of these outcomes, and perceived knowledge of how to measure each outcome as a function of chemistry course being taught, institution type, and course size?

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TABLE 1. Number and Percentage of Survey Respondents by Area of Chemistry Taught.

Area of Chemistry	Number	Percentage
General	128	29.4
Organic	116	26.6
Physical	97	22.2
Advanced	95	21.8
Total	436	

TABLE 2. Number and Percentage of Survey Respondents by Type of Institution.

Type of Institution	Number	Percentage
Public	255	58.5
Private	180	41.3
Total	436	

TABLE 3. Number and Percentage of Survey Respondents by Program Type.

Graduate Students in Chemistry	Number	Percentage
Yes	186	42.7
No	249	57.1
Total	436	

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TABLE 4. Number and Percentage of Survey Respondents by Course Size.

Lecture Course Size	Number	Percentage
1–30 students	193	44.3
31–50	86	19.7
51–100	70	16.1
>100	87	20.0

Perceived Importance of Various Learning Outcomes

Faculty were asked to rate the perceived *importance* of 14 different learning outcomes for the students in their class on a scale from Not Important (a value of 1) to Very Important (a value of 4). Table 5 summarizes these results. A graphical representation of this data, Figure 1, across all four course areas shows that, the three *most important* reported learning outcomes include: understanding of concepts, reasoning skills, and laboratory skills. Significantly less valued by the respondents, the three *least important* outcomes are: social skills, development of positive attitude, and basic facts. There are several outcomes that were valued more by instructors in some course areas than others. For example, calculation skills are not valued as much by those teaching organic chemistry, nor do these faculty value data presentation and interpretation as much as the other course groups.

When these same learning outcomes are analyzed by institution type, differences are only found on three outcomes (See Table 6). The respondents from private institutions rated self-reliance as a more important outcome than their colleagues at public institutions. In addition, data presentation and interpretation are rated significantly more important at private institutions, and the faculty at private institutions also place higher value on development of observation skills than do their colleagues at public institutions. Table 7 highlights communication skills, self-reliance, and data presentation and interpretation skills as the only detectable differences in learning outcomes as a function of graduate program. The table indicates that institutions that do not have graduate programs rate each of these learning outcomes higher than

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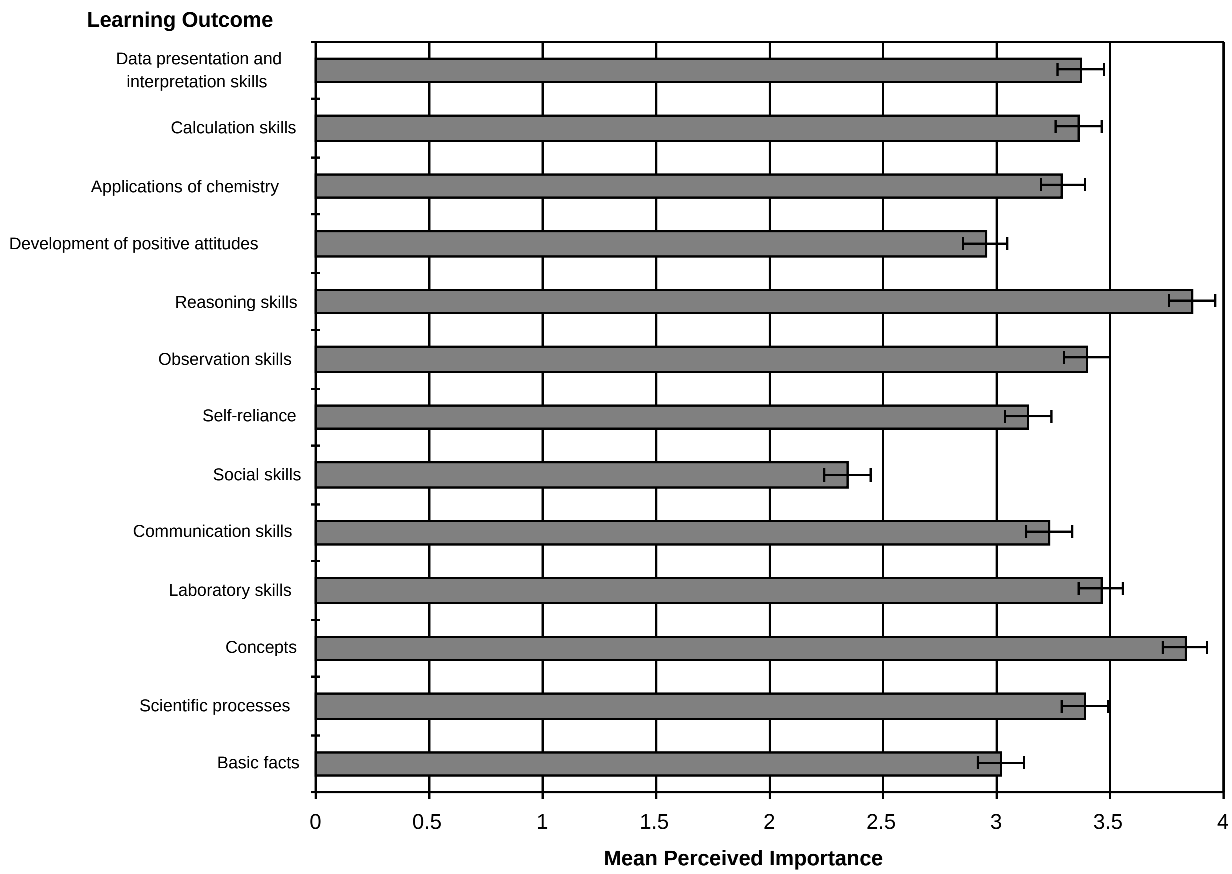

FIGURE 1. MEAN AND 95% CONFIDENCE INTERVAL OF PERCEIVED IMPORTANCE OF VARIOUS LEARNING OUTCOMES.

institutions with graduate programs. No differences in the importance of each of these outcomes could be detected between CCD and non-CCD institution respondents.

Table 8 reveals that respondents with smaller classes put a higher rating on scientific processes, calculation skills, and data presentation and interpretation skills than respondents with larger classes. However, in each of these cases it is important to note the curved nature of this relationship. For all three learning outcomes there is a decrease in perceived importance from the smallest class size (1 to 30 students) to the middle class size (51 to 100 students), and then an increase for class sizes greater than 100 students. This difference may be due to additional instructional resources (e.g., teaching assistants) available for larger classes.

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TABLE 5. Mean, Standard Deviation, and Analysis of Variance of Perceived Importance of Various Learning Outcomes by Area of Chemistry Course.

Learning outcome	Course Area: General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Basic facts	2.87 0.75	3.10 0.86	3.00 0.83	3.14 0.83	3.02 0.82	3,421	0.66	2.66	0.06
Scientific processes	3.31 0.69	3.31 0.71	3.47 0.64	3.55 0.67	3.39 0.69	3,413	0.46	3.07	0.03
Concepts	3.80 0.42	3.79 0.47	3.91 0.28	3.83 0.48	3.83 0.43	3,420	0.18	0.12	0.95
Laboratory skills	3.46 0.65	3.47 0.65	3.48 0.63	3.42 0.95	3.46 0.71	3,379	0.51	3.07	0.03
Communication skills	3.12 0.86	3.21 0.84	3.36 0.69	3.27 0.77	3.23 0.80	3,419	0.64	1.72	0.16
Social skills	2.35 0.88	2.22 0.94	2.4 0.93	2.42 0.90	2.34 0.91	3,417	0.83	1.77	0.15
Self-reliance	2.96 0.85	3.24 0.80	3.27 0.71	3.11 0.84	3.14 0.81	3,418	0.65	3.55	0.01
Observation skills	3.37 0.67	3.42 0.67	3.50 0.67	3.32 0.92	3.40 0.73	3,400	0.53	0.95	0.42
Reasoning skills	3.89 0.31	3.84 0.39	3.84 0.37	3.84 0.45	3.86 0.38	3,424	0.14	0.51	0.68
Development of positive attitude	3.06 0.78	2.89 0.86	2.89 0.85	2.96 0.92	2.95 0.84	3,413	0.71	0.98	0.40

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TABLE 5. Mean, Standard Deviation, and Analysis of Variance of Perceived Importance of Various Learning Outcomes by Area of Chemistry Course (continued).

Learning outcome	Course Area: General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Application of chemistry	3.30 0.69	3.34 0.71	3.11 0.64	3.40 0.67	3.29 0.69	3,417	0.45	3.23	0.02
Calculation skills	3.53 0.58	2.91 0.87	3.62 0.53	3.41 0.75	3.36 0.75	3,421	0.49	22.24	<0.01
Data presentation and interpretation skills	3.41 0.63	3.06 0.84	3.62 0.63	3.46 0.77	3.37 0.75	3,418	0.53	10.85	<0.01

TABLE 6. Mean, Standard Deviation, and Analysis of Variance of Perceived Importance of Various Learning Outcomes by Institution Type for Items with Significant Differences.

Learning outcome	Institution Type: Public	Private	Overall	Degrees of freedom	m_{se}	F	p
Self-reliance	3.06 0.86	3.25 0.72	3.14 0.81	1,419	0.65	6.01	0.01
Observation skills	3.34 0.79	3.49 0.62	3.40 0.73	1,401	0.53	4.40	0.04
Data presentation and interpretation skills	3.30 0.77	3.48 0.72	3.37 0.75	1,419	0.56	5.87	0.02

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TABLE 7. Mean, Standard Deviation, and Analysis of Variance of Perceived Importance of Various Learning Outcomes by Graduate ProgramType for Items with Significant Differences.

Learning outcome	Department Type Non Graduate	Graduate	Overall	Degrees of freedom	m_{se}	F	p
Communication skills	3.32 0.86	3.16 0.72	3.23 0.81	1,420	0.64	3.79	0.05
Self-reliance	3.23 0.69	3.07 0.89	3.14 0.81	1,419	0.66	4.02	0.05
Data presentation and interpretation skills	3.51 0.70	3.27 0.78	3.37 0.75	1,419	0.55	11.38	<0.01

TABLE 8. Mean, Standard Deviation, and Analysis of Variance of Perceived Importance of Various Learning Outcomes by Course Size for Items with Significant Differences.

Learning outcome	Course Size 1–30	31–50	51–100	>100	Overall	Degrees of freedom	m_{se}	F	p
Scientific Process	3.49 0.69	3.27 0.65	3.26 0.70	3.40 0.68	3.39 0.69	3,413	0.46	3.08	0.03
Calculation skills	3.47 0.68	3.36 0.71	3.06 0.86	3.36 0.78	3.36 0.75	3,421	0.54	5.04	<0.01
Data presentation and interpretation skills	3.55 0.71	3.30 0.79	3.14 0.74	3.26 0.75	3.37 0.75	3,418	0.54	6.77	<0.01

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Perceived Frequency of Measurement of Various Learning Outcomes

Table 9 summarizes the mean perceived *frequency of measurement* of these learning outcomes by the various course areas on a scale of 1 (None) to 4 (Often). Figure 2 shows the two *most frequently measured* learning outcomes are the same across all areas of chemistry: understanding of chemical concepts, and reasoning skills. The third most frequently measured learning outcome in organic chemistry is laboratory skills, while in the other areas of chemistry it is calculation skills. The three *least frequently measured* learning outcomes, across all four areas of chemistry include: social skills, development of positive attitudes, and self reliance. It is interesting to note that there are differences in frequency of measurement on some of these learning outcomes as function of class being taught. For example, there is a trend for increased measurement of communication skills from general chemistry on to physical chemistry.

In terms of frequency of measurement of data presentation and interpretation skills, faculty at private institutions report measuring this learning outcome more frequently (mean = 3.06) than faculty at public institutions (mean = 2.84; $F_{1,410} = 6.61$; $ms_e = 0.75$; $p < 0.01$). Differences in the perceived frequency of measurement of these learning outcomes as a function of graduate program are summarized in Table 10. These different areas include: concepts, communication skills, and data presentation and interpretation skills. The table shows that institutions with graduate programs report measuring concepts more frequently. However, faculty in undergraduate programs report measuring communication skills and data presentation and interpretation skills more frequently than faculty at graduate programs. Table 11 indicates that there is a difference between CCD and non-CCD institutions in frequency of measuring two learning outcomes: social skills and scientific processes. In both cases the CCD respondents reported measuring these outcomes more frequently than do their non-CCD colleagues.

Examination of Table 12 shows that in smaller classes there is a greater frequency of measurement of communication skills, calculation skills, and data and interpretation skills. There are no other detectable differences in frequency of measurement of these learning outcomes as a function of class size.

Perceived Knowledge of Measuring Various Learning Outcomes

Respondents were surveyed on their *knowledge of measuring* these 14 learning

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TABLE 9. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Measurement of Various Learning Outcomes by Area of Chemistry Course.

	Course Area								
Learning outcome	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Basic facts	2.69	2.83	2.65	2.65	2.72	3,412	0.73	0.92	0.43
	0.79	0.87	0.85	0.92	0.85				
Scientific processes	2.61	2.79	2.77	2.75	2.72	3,404	0.73	1.01	0.39
	0.82	0.87	0.86	0.87	0.86				
Concepts	3.49	3.48	3.57	3.38	3.48	3,404	0.41	1.32	0.27
	0.62	0.60	0.60	0.75	0.64				
Laboratory skills	3.10	3.16	3.05	2.80	3.05	3,372	0.88	2.34	0.07
	0.91	0.82	0.91	1.16	0.94				
Communication skills	2.31	2.56	3.11	2.70	2.64	3,412	0.95	11.88	<0.01
	1.04	0.95	0.94	0.95	1.01				
Social skills	1.68	1.72	1.69	1.87	1.73	3,409	0.76	1.02	0.39
	0.90	0.81	0.86	0.94	0.87				
Self-reliance	2.20	2.50	2.32	2.32	2.33	3,407	0.95	1.96	0. 12
	1.01	0.94	0.93	1.01	0.98				
Observation skills	2.88	3.03	2.81	2.85	2.90	3,393	0.80	1.13	0.34
	0.75	0.87	0.98	1.02	0.89				
Reasoning skills	3.37	3.48	3.28	3.30	3.36	3,416	0.54	1.59	0.19
	0.69	0.66	0.79	0.81	0.73				
Development of	1.80	1.86	1.68	2.00	1.83	3,400	0.98	1.58	0.19
positive attitude	0.98	0.98	0.95	1.06	0.99				

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TABLE 9. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Measurement of Various Learning Outcomes by Area of Chemistry Course (continued).

	Course Area								
Learning outcome	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Application of chemistry	2.69 0.84	2.71 0.97	2.38 0.91	2.80 0.87	2.65 0.91	3,407	0.81	3.72	0.01
Calculation skills	3.59 0.57	2.62 0.89	3.70 0.51	3.15 0.78	3.26 0.83	3,414	0.51	52.40	<0.01
Data presentation and interpretation skills	2.86 0.83	2.62 0.92	3.43 0.67	2.93 0.84	2.93 0.87	3,418	0.53	10.85	<0.01

TABLE 10. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Measurement of Various Learning Outcomes by Graduate ProgramType for Items with Significant Differences.

	Department Type						
Learning outcome	Non Graduate	Graduate	Overall	Degrees of freedom	m_{se}	F	p
Concepts	3.41 0.69	3.53 0.60	3.48 0.64	1,405	0.41	3.67	0.06
Communication skills	2.80 0.95	2.53 1.05	2.65 0.81	1,413	1.01	7.66	0.01
Data presentation and interpretation skills	3.10 0.82	2.81 0.89	2.93 0.87	1,410	0.74	10.92	<0.01

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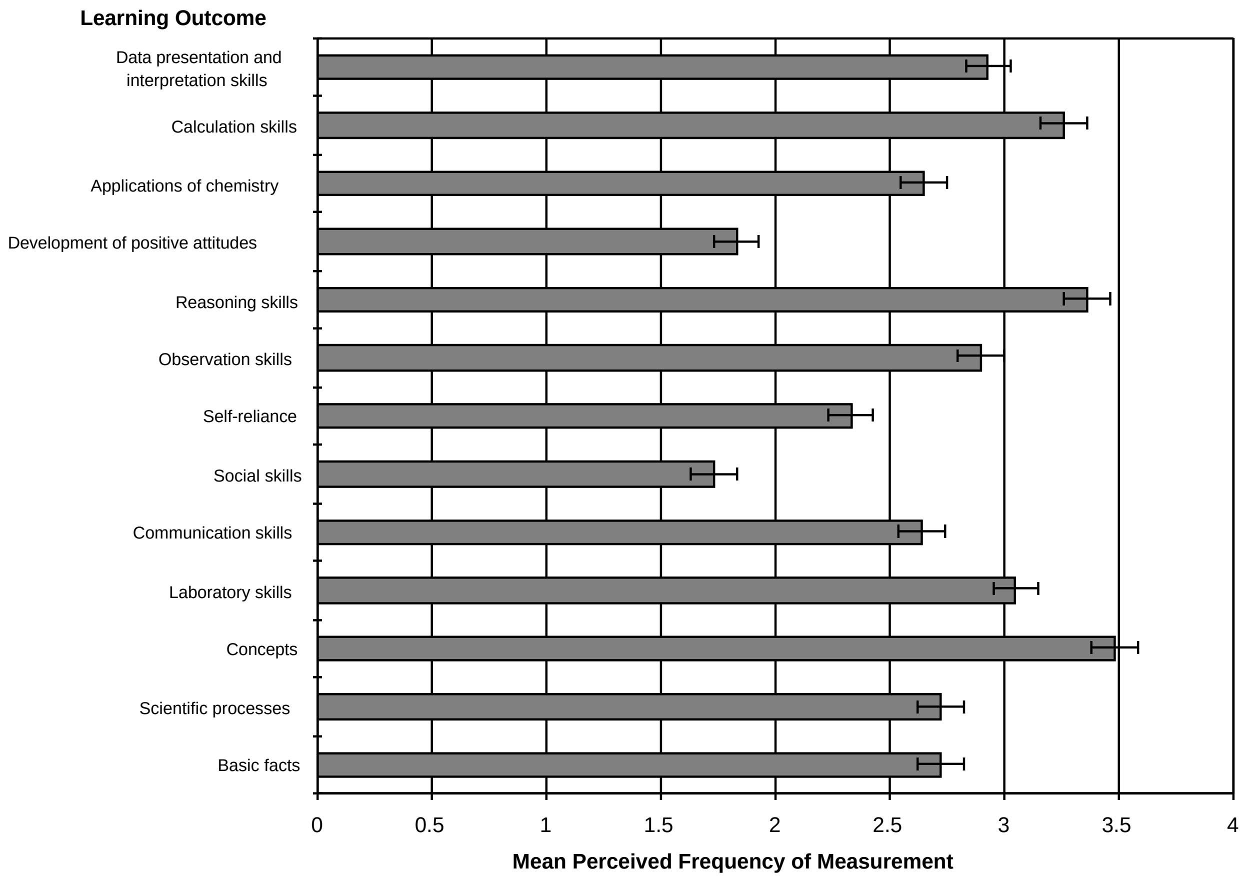

FIGURE 2. MEAN AND 95% CONFIDENCE INTERVAL OF FREQUENCY OF MEASUREMENT OF VARIOUS LEARNING OUTCOMES.

outcomes (see Figure 3). The scale ranged from 1 (Little knowledge of how to measure) to 4 (Much knowledge of how to measure). Table 13 highlights basic facts, concepts, laboratory skills, and calculation skills as the four learning outcomes that faculty believe they have the *most knowledge* of how to measure. Social skills and development of positive attitudes are the two learning outcomes that faculty report having the *least knowledge* of how to measure.

Table 14 summarizes where differences occur between faculty at public and private institutions in knowledge of how to measure these learning outcomes. On each of the four learning outcomes (laboratory skills, communication skills, observation skills, and data presentation and interpretation skills), the faculty at private institutions believe they have more knowledge about how to measure these outcomes. Knowledge of how to measure these outcomes was also examined by graduate/nongraduate program type

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TABLE 11. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Measurement of Various Learning Outcomes by CCD/nonCCD Institutions for Items with Significant Differences.

Learning outcome	Institution Type: Non CCD	Institution Type: CCD	Overall	Degrees of freedom	m_{se}	F	p
Scientific processes	2.70 0.85	2.97 0.85	2.72 0.86	1,406	0.73	3.62	0.06
Social skills	1.70 0.86	2.00 0.99	1.73 0.87	1,411	0.76	3.98	0.05

TABLE 12. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Measurement of Various Learning Outcomes by Course Size for Items with Significant Differences.

Learning outcome	Course Size: 1–30	Course Size: 31–50	Course Size: 51–100	Course Size: >100	Overall	Degrees of freedom	m_{se}	F	p
Communication skills	2.86 0.96	2.64 0.99	2.29 0.96	2.45 1.08	2.64 1.01	3,412	0.98	6.95	<0.01
Calculation skills	3.37 0.75	3.23 0.86	3.06 0.85	3.19 0.92	3.26 0.83	3,414	0.68	2.56	0.05
Data presentation and interpretation skills	3.13 0.82	2.96 0.84	2.62 0.84	2.72 0.93	2.93 0.87	3,409	0.72	8.06	<0.01

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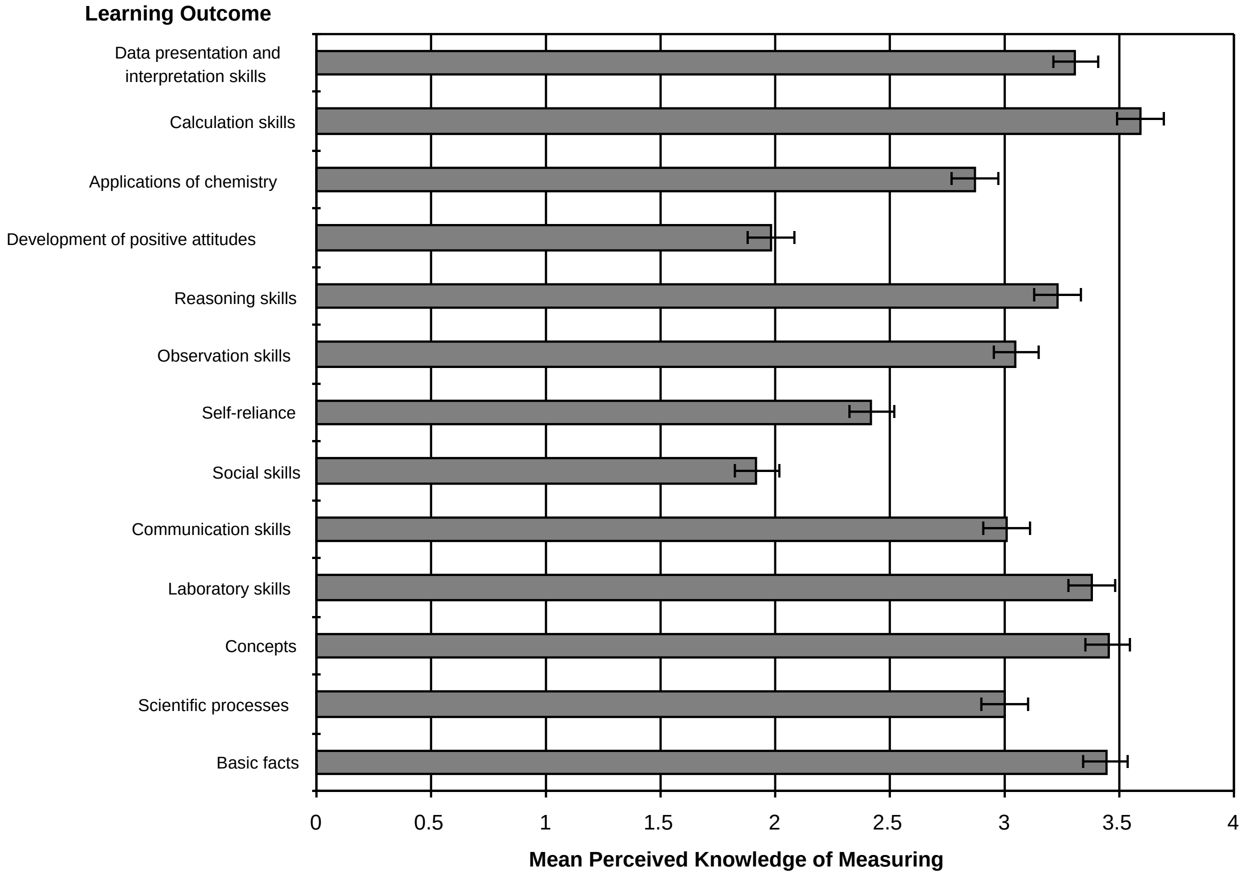

FIGURE 3. MEAN AND 95% CONFIDENCE INTERVAL OF PERCEIVED KNOWLEDGE OF MEASURING VARIOUS LEARNING OUTCOMES.

of institution. Table 15 provides a summary, and shows that faculty at undergraduate institutions believe they have more knowledge of how to measure each of the five learning outcomes for which there are statistically significant differences. There are no significant differences between the CCD and non-CCD respondents in terms of their perceived knowledge of how to measure these learning outcomes.

Table 16 gives information about measuring these learning outcomes as a function of class size. In each case it can be seen that there is a trend in which knowledge of how to measure the learning outcome is highest for small classes, decreases for medium-sized classes, and then increases for larger classes.

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TABLE 13. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Measuring Various Learning Outcomes by Area of Chemistry Course.

	Course Area								
Learning outcome	General	Organic	Physical	Advanced	Overall	Degrees of freedom	MS_e	F	p
Basic facts	3.46 0.77	3.39 0.74	3.56 0.70	3.36 0.72	3.44 0.74	3,407	0.54	1.26	0.29
Scientific processes	2.85 0.91	2.99 0.82	3.07 0.83	3.13 0.80	3.00 0.85	3,401	0.71	2.22	0.09
Concepts	3.44 0.73	3.39 0.73	3.51 0.61	3.48 0.59	3.45 0.68	3,402	0.46	0.62	0.60
Laboratory skills	3.42 0.80	3.33 0.72	3.34 0.79	3.45 0.77	3.38 0.77	3,370	0.59	0.54	0.66
Communication skills	2.88 0.92	2.97 0.86	3.20 0.85	3.06 0.91	3.01 0.89	3,404	0.79	2.46	0.06
Social skills	1.90 0.95	1.91 0.87	1.89 0.90	2.01 0.95	1.92 0.92	3,404	0.85	0.34	0.80
Self-reliance	2.28 0.98	2.52 0.96	2.33 0.90	2.57 1.07	2.42 0.98	3,406	0.95	2.20	0. 09
Observation skills	3.01 0.82	3.14 0.76	3.08 0.77	2.96 0.92	3.05 0.81	3,389	0.66	0.95	0.42
Reasoning skills	3.17 0.78	3.30 0.74	3.20 0.80	3.27 0.76	3.23 0.77	3,410	0.59	0.67	0.57
Development of positive attitude	1.99 0.95	2.00 0.91	1.77 0.85	2.17 1.13	1.98 0.97	3,399	0.92	2.47	0.06
Application of chemistry	2.93 0.83	2.89 0.83	2.68 0.96	2.93 0.84	2.87 0.86	3,406	0.74	1.86	0.13

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TABLE 13. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Measuring Various Learning Outcomes by Area of Chemistry Course. (continued).

Learning outcome	Course Area General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Calculation skills	3.75 0.47	3.34 0.77	3.74 0.46	3.54 0.65	3.59 0.63	3,413	0.36	11.29	<0.01
Data presentation and interpretation skills	3.32 0.75	3.15 0.78	3.49 0.64	3.30 0.71	3.31 0.73	3,407	0.53	3.79	0.01

TABLE 14. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Measuring Various Learning Outcomes by Institution Type for Items Showing Significant Differences.

Learning outcome	Institution Type Public	Private	Overall	Degrees of freedom	MS_e	F	p
Laboratory skills	3.29 0.84	3.49 0.65	3.38 0.77	1,371	0.58	6.60	0.01
Communication skills	2.94 0.92	3.11 0.85	3.01 0.89	1,405	0.80	3.62	0.06
Observation skills	2.98 0.86	3.14 0.74	3.05 0.81	1,390	0.66	3.77	0.05
Data presentation and interpretation skills	3.24 0.77	3.39 0.68	3.30 0.73	1,408	0.54	4.16	0.04

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TABLE 15. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Measuring Various Learning Outcomes by Graduate/non-Graduate Program for Items Showing Significant Differences.

Learning outcome	Department Type: Non Graduate	Graduate	Overall	Degrees of freedom	MS_e	F	p
Basic facts	3.52	3.38	3.44	1,408	0.54	3.76	0.05
	0.65	0.79	0.74				
Laboratory skills	3.51	3.27	3.38	1,371	0.59	8.79	<0.01
	0.69	0.81	0.77				
Communication skills	3.17	2.89	3.01	1,405	0.78	9.95	<0.01
	0.78	0.96	0.89				
Calculation skills	3.68	3.53	3.59	1,414	0.39	5.96	0.02
	0.54	0.68	0.63				
Data presentation and interpretation skills	3.44	3.20	3.30	1,408	0.53	11.84	<0.01
	0.64	0.78	0.73				

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TABLE 16. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Measuring Various Learning Outcomes by Class Size for Items Showing Significant Differences.

Learning outcome	Course Size 1–30	31–50	51–100	>100	Overall	Degrees of freedom	MS_e	F	p
Basic facts	3.52 0.68	3.43 0.67	3.22 0.83	3.46 0.83	3.44 0.74	3,407	0.54	2.67	0.05
Concepts	3.53 0.60	3.46 0.63	3.22 0.79	3.46 0.74	3.45 0.68	3,402	0.45	3.36	0.02
Communication skills	3.17 0.83	3.03 0.84	2.71 0.86	2.89 1.03	3.01 0.89	3,404	0.78	5.07	<0.01
Data presentation and interpretation skills	3.42 0.67	3.36 0.60	3.00 0.89	3.25 0.79	3.31 0.73	3,407	0.52	5.50	<0.01

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Relations Among Perceived Importance, Frequency of Measurement and Knowledge of Measurement of Various Learning Outcomes

Examination of these data highlights the perceptions faculty have about various learning outcomes in chemistry. Across the chemistry course areas there is relative homogeneity of perceived importance of the outcomes, their frequency of measurement, and faculty knowledge about how to measure these same outcomes. But what are relationships among these three different aspects related to the learning outcomes? Table 17 shows the correlations among the overall mean values (importance, frequency of measurement, and knowledge of measuring) across the 14 outcomes listed in the survey. In each case there is a significant and positive correlation between each pair of measures. For example, if a learning outcome is perceived as important (e.g., understanding of concepts), then faculty tend to report having a greater knowledge of how to measure the outcome.

What are faculty perceptions of the accuracy of various assessment techniques, their frequency of measurement using these techniques,and perceived knowledge of how to use such techniques as a function of chemistry course being taught, institution type, and course size?

Perceived Accuracy of Various Assessment Techniques

Faculty were asked to rate the perceived accuracy of 15 different methods of measuring student learning on a four-point scale from 1 to 4 (Not Accurate to Very Accurate). Table 18 summarizes the responses, shows where there are differences in responses among the four chemistry teaching areas, and is depicted graphically in Figure 4. The three measurement-of-student-learning procedures considered *most accurate* are: essay questions, laboratory reports, and research projects (except for organic faculty who viewed performance-based assessments as more accurate). The two measurement procedures considered *least accurate* are questionnaires such as interest inventories and peer/self ratings.

When the perceived accuracy of these same assessment techniques are analyzed in terms of public/private institutions there are no detectable differences. However, there is a detectable difference for one of the assessment procedures when compared in terms of graduate programs. If an institution has a graduate program in chemistry then

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TABLE 17. Correlations Among the Means of Perceived Importance, Frequency of Measurement, and Knowledge of Measuring 14 Learning Outcomes Across all Chemistry Course Areas.

	Perceived Importance of Learning Outcomes	Perceived Knowledge of Measuring Outcomes
Perceived Knowledge of Measuring Outcomes	0.73 ($p < 0.01$)	
Perceived Frequency of Measuring Outcomes	0.90 ($p < 0.01$)	0.92 ($p < 0.01$)

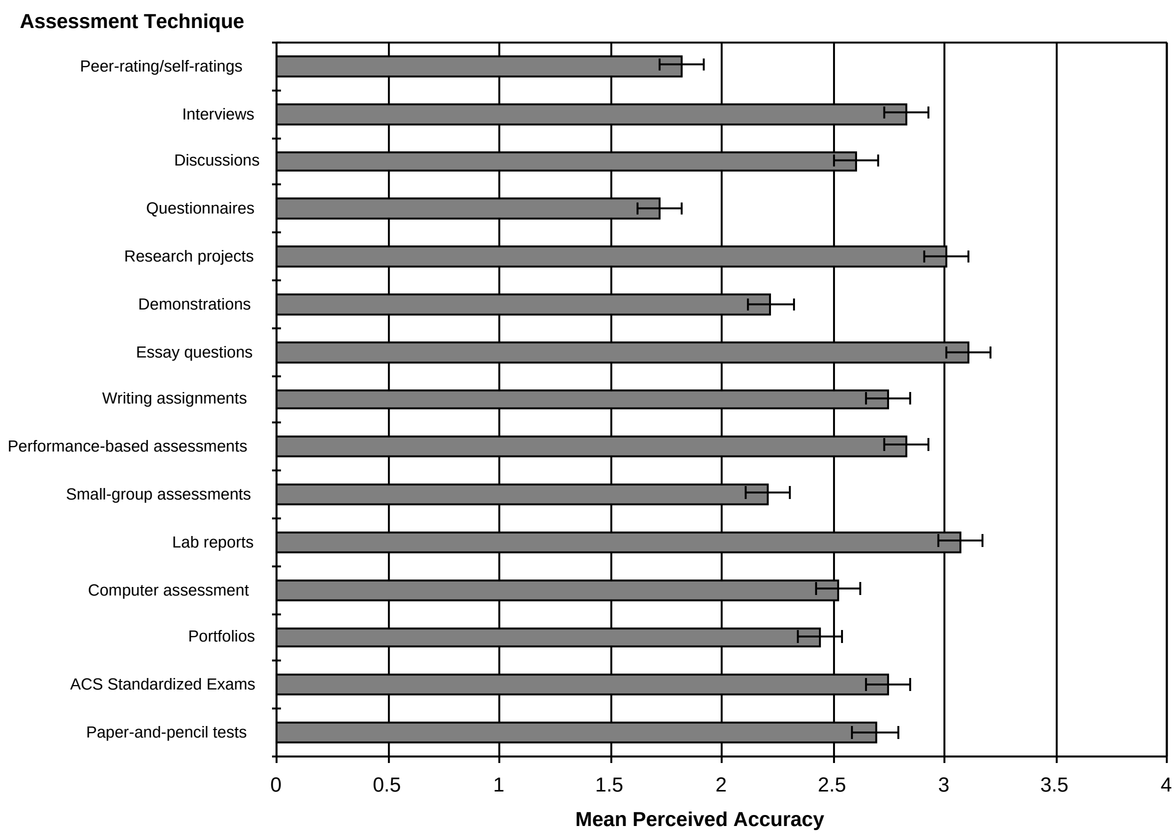

FIGURE 4. MEAN AND 95% CONFIDENCE INTERVAL OF PERCEIVED ACCURACY OF VARIOUS ASSESSMENT TECHNIQUES.

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TABLE 18. Mean, Standard Deviation, and Analysis of Variance of Perceived Accuracy of Various Assessment Techniques by Area of Chemistry Course.

	Course Area								
Assessment technique	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Paper-and-pencil tests	2.86 0.86	2.65 0.86	2.43 0.81	2.73 0.84	2.69 0.86	3,407	0.71	4.63	<0.01
ACS Standardized Exams	2.76 0.74	2.80 0.76	2.67 0.72	2.75 0.71	2.75 0.73	3,383	0.54	0.45	0.72
Portfolios	2.43 0.85	2.40 0.79	2.43 0.95	2.49 0.82	2.44 0.85	3,354	0.73	0.18	0.91
Computer assessment	2.59 0.79	2.57 0.68	2.50 0.72	2.40 0.74	2.52 0.74	3,350	0.54	1.21	0.31
Laboratory reports	2.87 0.68	3.02 0.76	3.29 0.68	3.20 0.79	3.07 0.74	3,378	0.53	6.26	0.00
Small-group assessments	2.33 0.80	2.14 0.76	2.09 0.88	2.24 0.83	2.21 0.81	3,367	0.66	1.64	0.18
Performance-based assessments	2.85 0.75	2.98 0.72	2.63 0.86	2.76 0.81	2.83 0.78	3,359	0.60	3.14	0.03
Writing assignments	2.64 0.84	2.77 0.82	2.78 0.78	2.84 0.77	2.75 0.81	3,391	0.65	1.13	0.34
Essay questions	3.13 0.74	3.09 0.84	3.00 0.88	3.24 0.71	3.11 0.79	3,398	0.63	1.36	0.26
Demonstrations	2.51 0.94	2.04 0.88	1.97 0.87	2.27 0.93	2.22 0.93	3,345	0.82	6.84	0.00
Research projects	2.91 0.82	2.91 0.74	3.06 0.79	3.20 0.70	3.01 0.77	3,376	0.59	2.91	0.03

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TABLE 18. Mean, Standard Deviation, and Analysis of Variance of Perceived Accuracy of Various Assessment Techniques by Area of Chemistry Course (continued).

Assessment techniques	Course Area: General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Questionnaires	1.81 0.78	1.77 0.76	1.57 0.77	1.67 0.75	1.72 0.77	3,346	0.59	1.70	0.17
Discussions	2.63 0.85	2.51 0.84	2.57 0.87	2.71 0.80	2.60 0.84	3,375	0.71	0.90	0.44
Interviews	3.06 0.96	2.65 1.07	2.86 0.96	2.69 0.96	2.83 1.00	3,367	0.98	3.66	0.01
Peer-rating/self-ratings	1.92 0.73	1.79 0.75	1.75 0.75	1.77 0.66	1.82 0.73	3,367	0.53	1.09	0.35

TABLE 19. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Measuring Various Learning Outcomes by Class Size for Items Showing Significant Differences.

Assessment Technique	Course Size: 1–30	31–50	51–100	>100	Overall	Degrees of freedom	m_{se}	F	p
Laboratory reports	3.22 0.73	2.97 0.81	2.89 0.74	2.96 0.65	3.07 0.74	3,378	0.53	4.77	<0.01
Writing assignments	2.82 0.83	2.58 0.84	2.51 0.86	2.96 1.03	2.75 0.89	3,391	0.63	5.46	<0.01
Research projects	3.11 0.74	2.99 0.78	2.78 0.81	2.97 0.78	3.01 0.77	3,376	0.59	2.74	0.04

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discussion is perceived to be a less accurate way to measure student learning ($mean_{grad}$ = 2.51) than judged by faculty teaching in undergraduate programs ($mean_{nongrad}$ = 2.71) by a significant amount ($F_{1, 376} = 5.11$; $ms_e = 0.71$; $p = 0.02$). Analyses of variance indicate no differences between CCD and non-CCD respondents' judgments of perceived accuracy of these various techniques for measuring student learning.

The judgment of perceived accuracy was also examined as a function of class size. Table 19 shows results for the items that differed across class size. The same pattern can be seen in all cases of the measurement techniques for which there were perceived differences (laboratory reports, writing assignments, and research projects). Faculty teaching the smallest classes perceive these techniques as most accurate, and decreases with increasing class size until the class size exceeds 100. At that point, perceived accuracy increases.

Perceived Frequency of Use of Various Assessment Techniques

Respondents were asked to indicate on a four-point scale how often they used these various assessment techniques (from None to Often). From Table 20 it can be seen that the assessment procedures used *most frequently* are: laboratory reports, essay questions, and paper-and-pencil tests (also depicted in Figure 5). The techniques used *least frequently* include: peer/self ratings, questionnaires such as interest inventories, and interviews or oral exams. Table 20 also shows that there are significant differences among the chemistry course areas for the frequency of use of the different measurement techniques. For example, those people teaching physical chemistry report using paper-and-pencil tests less frequently than colleagues in other teaching areas. However, the physical chemistry faculty also indicate that they used laboratory reports as assessment techniques with greater frequency than their colleagues. There is also a steady progression in the frequency of use of essay questions for general through advanced chemistry courses.

When the frequency of use of measurement techniques is examined in terms of institution type, three differences are found and are summarized in Table 21. In each case, the private institution faculty report using the assessment techniques (portfolios, performance-based assessments, and questionnaires) with greater frequency. Some differences on frequency of use of assessment techniques are also found as a function of whether the chemistry department had a graduate program (see Table 22). Faculty

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TABLE 20. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Use of Various Assessment Techniques by Area of Chemistry Course.

	Course Area								
Assessment technique	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Paper-and-pencil tests	2.80 1.22	2.53 1.22	2.08 1.27	2.56 1.20	2.53 1.25	3,412	1.50	5.99	<0.01
ACS Standardized Exams	1.69 0.95	1.87 0.95	1.67 0.89	1.83 1.05	1.76 0.96	3,406	0.92	1.14	0.33
Portfolios	1.37 0.78	1.38 0.77	1.56 1.00	1.41 0.84	1.42 0.85	3,393	0.71	1.06	0.37
Computer assessment	1.42 0.82	1.18 0.83	1.59 0.83	1.49 0.81	1.48 0.83	3,386	0.68	0.66	0.58
Laboratory reports	3.57 0.82	3.56 0.80	3.72 0.66	3.32 0.99	3.53 0.74	3,381	0.68	3.01	0.03
Small-group assessments	1.74 0.93	1.66 0.79	1.57 0.81	1.81 0.93	1.69 0.87	3,397	0.76	1.26	0.29
Performance-based assessments	1.93 0.91	2.68 0.93	1.83 0.90	2.21 1.10	2.18 1.01	3,377	0.91	16.27	<0.01
Writing assignments	1.67 0.88	1.83 0.81	2.08 1.00	2.24 0.89	1.92 0.91	3,404	0.79	1.92	0.91
Essay questions	2.45 0.74	2.55 0.84	2.60 0.88	2.97 0.71	2.62 0.79	3,408	1.13	4.61	<0.01
Demonstrations	1.94 0.97	1.50 0.70	1.51 0.75	1.61 0.69	1.66 0.82	3,369	0.64	7.02	<0.01
Research projects	1.57 0.92	1.94 0.97	2.06 1.02	2.09 1.04	1.89 1.00	3,392	0.97	6.07	<0.01

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TABLE 20. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Use of Various Assessment Techniques by Area of Chemistry Course (continued).

Assessment techniques	Course Area: General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Questionnaires	1.35 0.62	1.34 0.64	1.09 0.29	1.24 0.51	1.27 0.59	3,379	0.30	4.39	<0.01
Discussions	2.15 0.94	2.19 0.97	2.08 0.99	2.50 0.98	2.23 0.97	3,392	0.93	3.23	0.02
Interviews	1.28 0.62	1.22 0.44	1.45 0.78	1.27 0.66	1.30 0.63	3,398	0.39	2.45	0.06
Peer-rating/self-ratings	1.29 0.56	1.27 0.48	1.23 0.50	1.24 0.51	1.26 0.51	3,394	0.27	0.32	0.81

TABLE 21. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Use of Various Assessment Techniques by Institution Type for Items with Significant Differences.

Assessment Techniques	Institution Type: Public	Private	Overall	Degrees of freedom	m_{se}	F	p
Portfolios	1.33 0.73	1.56 0.96	1.42 0.85	1,394	0.70	7.29	0.01
Performance-based assessments	2.02 1.0	2.39 0.99	2.18 1.01	1,378	0.99	12.53	<0.01
Questionnaires	1.20 0.45	1.35 0.67	1.26 0.56	1,380	0.31	6.23	0.01

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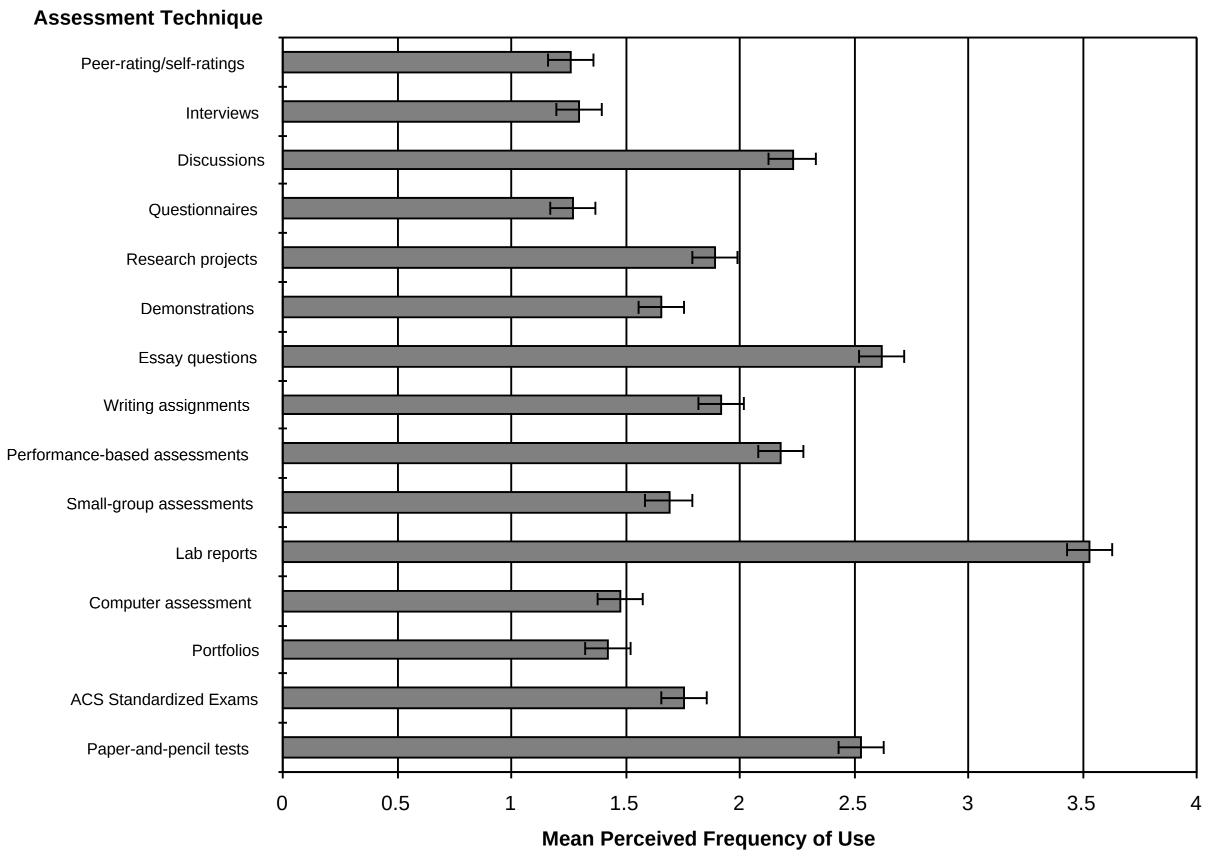

FIGURE 5. MEAN AND 95% CONFIDENCE INTERVAL OF PERCEIVED FREQUENCY OF USE OF VARIOUS ASSESSMENT TECHNIQUES.

teaching in undergraduate departments report using several techniques with greater frequency: portfolios, performance-based assessments, writing assignments, demonstrations, and discussions. Table 23 shows where faculty at CCD and non-CCD institutions differ in terms of frequency of use of various assessment of learning techniques. Faculty at non-CCD institutions use paper-and-pencil exams, and ACS standardized tests more frequently than faculty at CCD institutions. In contrast, CCD faculty reported using small-group assessment and peer/self ratings with greater frequency than colleagues at the non-CCD institutions.

In some cases there are differences in frequency of assessment strategies used as a function of class size (see Table 24). For example, frequency of use of ACS exams increased with class size (until reaching a class size greater than 100). Use of writing assignments, research projects, and class discussion, all decrease with increasing class size.

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TABLE 22. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Use of Various Assessment Techniques by Graduate ProgramType for Items with Significant Differences.

Assessment Techniques	Department Type Non Graduate	Graduate	Overall	Degrees of freedom	m_{se}	F	p
Portfolios	1.54 0.92	1.33 0.77	1.42 0.85	1,394	0.71	6.09	0.01
Performance-based assessments	2.36 0.94	2.04 1.05	2.18 1.01	1,378	1.00	9.16	<0.01
Writing assignments	2.03 0.88	1.84 0.93	1.93 0.91	1,405	0.83	4.34	0.04
Demonstrations	1.76 0.88	1.58 0.75	1.66 0.82	1,371	0.66	4.55	0.03
Discussions	2.35 0.97	2.12 0.97	2.22 0.98	1,393	0.94	5.19	0.02

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TABLE 23. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Use of Various Assessment Techniques by CCD/nonCCD Institutions for Items with Significant Differences.

Assessment Techniques	Institution Type: Non CCD	Institution Type: CCD	Overall	Degrees of freedom	m_{se}	F	p
Paper-and pencil tests	2.56 1.24	2.11 1.28	2.53 1.24	1,414	1.54	4.20	0.04
ACS Standardized Exams	1.79 0.97	1.49 0.84	1.76 0.96	1,408	0.92	3.39	0.07
Small-group assessment	1.67 0.87	1.97 0.80	1.69 0.87	1,399	0.75	3.79	0.05
Peer-rating/self-rating	1.25 0.50	1.42 0.60	1.26 0.51	1,396	0.26	3.64	0.06

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TABLE 24. Mean, Standard Deviation, and Analysis of Variance of Perceived Frequency of Use of Various Assessment Techniques by Class Size for Items with Significant Differences.

	Course Size								
Assessment Technique	1–30	31–50	51–100	>100	Overall	Degrees of freedom	m_{se}	F	p
ACS Standardized Exams	1.75 0.97	1.81 0.94	2.00 1.05	1.56 0.86	1.76 0.96	3,406	0.91	2.71	0.05
Portfolios	1.47 0.90	1.60 0.98	1.45 0.87	1.14 0.41	1.42 0.85	3,393	0.70	4.53	<0.01
Writing assignments	2.15 0.91	1.86 0.95	1.69 0.78	1.70 0.89	1.92 0.91	3,404	0.80	7.10	<0.01
Essay questions	2.80 1.05	2.59 1.03	2.36 1.0	2.49 1.18	2.62 1.07	3,408	1.13	3.50	0.02
Research projects	2.15 1.01	1.72 0.97	1.80 0.96	1.56 0.92	1.89 1.00	3,392	0.95	8.29	<0.01
Discussions	2.34 1.03	2.21 0.90	2.20 0.90	1.97 0.94	2.22 0.97	3,392	0.94	2.51	0.06

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Perceived Knowledge of Use of Various Assessment Techniques

Faculty were surveyed on their self-judged knowledge of using different methods for measuring student learning (see Table 25 or Figure 6). The four-point scale ranged from “Little knowledge of how to use the technique” to “Much knowledge of how to use the technique.” In all four areas, the respondents are most knowledgeable about paper-and-pencil test and laboratory reports. Physical and organic faculty report using small group assessments with less frequency than in general and advanced courses. The faculty teaching organic courses believe they have more knowledge about using performance-based assessments than do those teaching general, physical, and advanced chemistry courses.

Table 26 summarizes that faculty at private institutions report having more knowledge about measurement of learning using portfolios, laboratory reports, and performance-based assessment than faculty at public institutions. Table 27 highlights that undergraduate faculty believe they have more knowledge of measuring learning via laboratory reports, performance-based assessment, writing assessment, and discussions than faculty in departments with graduate programs. Faculty at CCD and non-CCD institutions perceive that they differ in the amounts of knowledge they have for using two measurement-of-learning techniques: small group assessments and questionnaires. In both cases the CCD respondents feel more knowledgeable, as can be see in Table 28. Table 29 summarizes the perceived knowledge of assessment techniques as a function of course size. The table reveals that there are significant differences in knowledge of writing assignments and essay questions among the different course sizes. The faculty teaching the mid-sized courses (from 31 to 100 students) report having less knowledge about using these techniques than the faculty teaching small or large classes.

Relations Among Perceived Accuracy, Frequency of Use, and Knowledge of Use of Various Assessment Techniques

The data in the previous subsections highlight the perceptions faculty have about the accuracy of various assessment techniques. This section reports faculty knowledge about, and use of, such assessment techniques. Across the chemistry course areas there is diversity of perceived accuracy of measurement techniques in 9 of the 15 listed techniques. There are also differences among the chemistry course areas in terms of the

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TABLE 25 Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Use of Various Assessment Techniques by Area of Chemistry Course.

	Course Area								
Assessment technique	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Paper-and-pencil tests	3.47 0.72	3.29 0.74	3.26 0.77	3.3 0.67	3.35 0.73	3,404	0.53	1.93	0.12
ACS Standardized Exams	2.97 1.07	3.14 0.89	2.98 1.03	2.96 0.98	3.02 0.99	3,395	0.99	0.78	0.51
Portfolios	2.06 1.06	2.10 0.98	2.15 1.09	1.93 1.0	2.06 1.03	3,383	1.06	0.74	0.53
Computer assessment	2.32 1.02	2.10 0.94	2.33 0.98	2.05 0.98	2.20 0.98	3,377	0.96	2.01	0.11
Laboratory reports	3.56 0.59	3.60 0.53	3.74 0.47	3.54 0.58	3.61 0.55	3,381	0.68	3.01	0.03
Small-group assessments	2.21 0.94	2.13 0.93	1.93 0.90	2.32 1.02	2.15 0.95	3,388	0.89	2.58	0.05
Performance-based assessments	2.68 0.99	3.29 0.77	2.47 0.96	2.92 1.01	2.86 0.98	3,369	0.87	13.78	<0.01
Writing assignments	2.73 1.00	2.94 0.83	2.93 0.86	3.04 0.77	2.89 0.89	3,395	0.78	2.32	0.07
Essay questions	3.24 0.82	3.24 0.81	3.14 0.95	3.35 0.74	3.24 0.83	3,400	0.69	0.96	0.41
Demonstrations	2.72 1.05	2.39 1.06	2.21 1.03	2.57 1.03	2.49 1.06	3,356	1.09	3.97	<0.01
Research projects	2.85 0.99	3.09 0.86	3.11 0.85	3.12 0.95	3.03 0.92	3,372	0.84	1.96	0.12

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TABLE 25 Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Use of Various Assessment Techniques by Area of Chemistry Course (continued).

	Course Area								
Assessment techniques	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Questionnaires	2.01	1.82	1.77	1.61	1.82	3,365	0.87	2.92	0.03
	1.03	0.94	0.93	0.78	0.95				
Discussions	2.72	2.70	2.65	2.88	2.73	3,388	0.87	1.03	0.38
	0.96	0.91	0.90	0.96	0.93				
Interviews	2.49	2.43	2.67	2.41	2.50	3,372	1.03	1.18	0.32
	1.02	1.03	0.99	1.02	1.02				
Peer-rating/self-ratings	2.02	1.90	1.85	1.93	1.93	3,375	0.92	0.56	0.64
	1.04	0.88	0.94	0.95	0.96				

TABLE 26. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Use of Various Assessment Techniques by Institution Type for Items with Significant Differences.

	Institution Type						
Assessment Techniques	Public	Private	Overall	Degrees of freedom	m_{se}	F	p
Portfolios	1.98	2.18	2.07	1,384	1.05	3.58	0.06
	1.01	1.04	1.03				
Laboratory reports	3.54	3.69	3.61	1,373	0.30	6.91	0.01
	0.56	0.53	0.55				
Performance-based assessments	2.74	3.01	2.86	1,370	0.94	7.15	0.01
	0.99	0.95	0.98				

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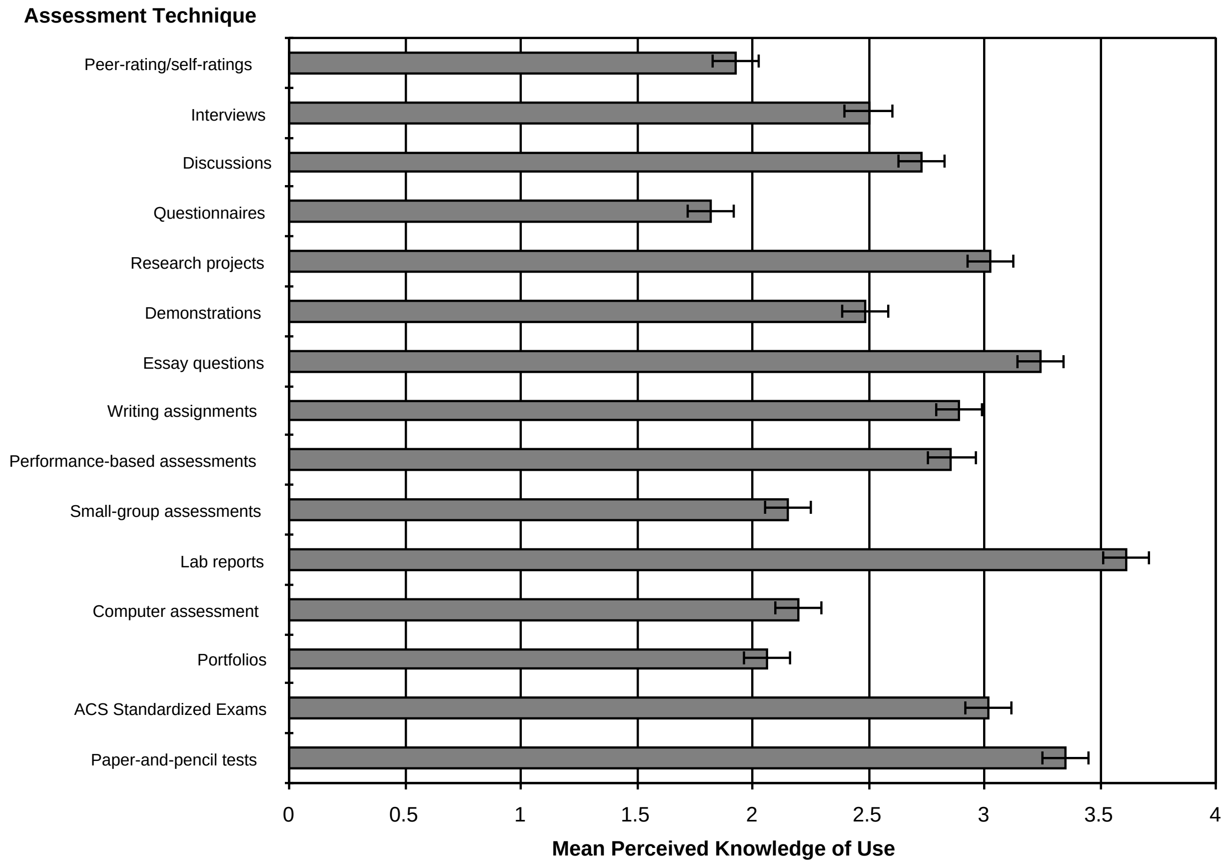

FIGURE 6. MEAN AND 95% CONFIDENCE INTERVAL OF PERCEIVED KNOWLEDGE OF USE OF VARIOUS ASSESSMENT TECHNIQUES.

frequency of use, and faculty knowledge about how to use the various assessment techniques. But what are the relationships among these three different aspects related to the learning outcomes? Because perceived accuracy, frequency of use, and knowledge of use were related to courses being taught, correlations among these three dimensions were done across all four course areas. For example, the mean perceived accuracy of the 15 assessment techniques for faculty teaching *general chemistry* were correlated with their mean perceived frequency of use of the same techniques. Table 30 shows the correlations among the mean values (perceived accuracy, frequency of use, and knowledge of use) across the 15 assessment techniques listed in the survey. In each case there is a significant and positive correlation between each pair of measures. For example, if a technique outcome is perceived as accurate (e.g., essay questions), then faculty tend to report having a greater knowledge of how to use the technique.

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TABLE 27. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Use of Various Assessment Techniques by Graduate ProgramType for Items with Significant Differences.

Assessment Techniques	Department Type Non Graduate	 Graduate	 Overall	Degrees of freedom	m_{se}	F	p
Laboratory reports	3.71 0.49	3.52 0.58	3.61 0.55	1,373	0.30	10.72	<0.01
Performance-based assessments	3.09 0.85	2.68 1.03	2.86 0.9788	1,370	0.92	16.34	<0.01
Writing assignments	2.99 0.79	2.82 0.95	2.89 0.89	1,396	0.78	4.01	0.05
Discussions	2.84 0.87	2.66 0.97	2.73 0.93	1,389	0.86	3.68	0.06

TABLE 28 Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Use of Various Assessment Techniques by CCD/nonCCD Institutions for Items with Significant Differences.

Assessment Techniques	Institution Type Non CCD	 CCD	 Overall	Degrees of freedom	m_{se}	F	p
Small-group assessment	2.12 0.95	2.48 0.94	2.15 0.95	1,390	0.90	4.57	0.03
Questionaires	1.78 0.93	2.13 0.98	1.82 0.94	1,367	0.88	3.82	0.05

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TABLE 29. Mean, Standard Deviation, and Analysis of Variance of Perceived Knowledge of Use of Various Assessment Techniques by Class Size for Items with Significant Differences.

	Course Size								
Assessment Technique	1–30	31–50	51–100	>100	Overall	Degrees of freedom	m_{se}	F	p
Writing assignments	2.99 0.79	2.84 0.91	2.65 0.96	2.94 0.98	2.89 0.89	3,395	0.78	2.57	0.05
Essay questions	3.29 0.82	3.08 0.84	3.12 0.88	3.39 0.77	3.24 0.83	3,400	0.68	2.56	0.05

TABLE 30. Correlations Among the Means of Perceived Accuracy, Frequency of Use of Technique, and Knowledge of Using the Technique Across by Chemistry Course Areas.

Dimensions Correlated	General	Organic	Physical	Advanced
Perceived Accuracy with Frequency of Use	0.46 ($p = 0.09$)	0.69 ($p < 0.01$)	0.76 ($p < 0.01$)	0.77 ($p < 0.01$)
Perceived Accuracy with Knowledge of Use	0.74 ($p < 0.01$)	0.87 ($p < 0.01$)	0.87 ($p < 0.01$)	0.88 ($p < 0.01$)
Knowledge of Use with Frequency of Use	0.86 ($p < 0.01$)	0.86 ($p < 0.01$)	0.85 ($p < 0.01$)	0.89 ($p < 0.01$)

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What are various administrative characteristics of assessing student learning as a function of chemistry course being taught, institution type, and course size?

Class and Laboratory Time Used for Assessing Learning

Faculty were asked about administrative aspects of assessing student learning such as the amount of class and laboratory time used for assessment, and the amount of time taken to develop assessment activities. Although Table 31 shows no difference across all areas of chemistry instruction, 53% of the respondents indicate that measurement of learning takes between 10% or less of their class and laboratory time.

When the distribution of time spent assessing learning is examined by the other variables, it is found that there are no detectable differences between public and private institutions ($\chi^2 = 0.86$; df = 3; $p < 0.83$) or between graduate and nongraduate programs ($\chi^2 = 2.48$; df = 9; $p < 0.06$). There are slight differences between the CCD and non-CCD funded institutions ($\chi^2 = 7.20$; df = 3; $p = 0.06$). Almost 48% of the faculty in CCD institutions report spending more than 20% of class and laboratory time on assessment in comparison to only 32% of their non-CCD colleagues.

A marginally significant difference ($\chi^2 = 16.46$; df = 9; $p = 0.06$) is seen when class size is examined. Almost 50% of the respondents teaching courses in the 31–50 student range report spending 11–20% of class and laboratory time measuring learning (in contrast to the other three class sizes in which only 34% of the respondents spend that much time measuring learning).

Time Used for Developing Test and Quizzes, and Other Assessment Techniques

Amount of time creating tests and quizzes is another administrative aspect that was analyzed. Table 32 shows that 50% or more of the respondents teaching general or organic chemistry report spending 2 or more hours each week creating tests and quizzes. This is significantly different (and greater) from their colleagues teaching physical chemistry and other advanced courses ($\chi^2 = 31.33$; df = 9; $p < 0.01$).

Although there are differences in time spent creating tests and quizzes by course type, there are no differences for the public/private dichotomy ($\chi^2 = 1.01$; df = 3; $p = 0.80$)

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TABLE 31. Perceived Frequency of Percent of Class and Laboratory Time Used Measuring Student Learning by Area of Chemistry Course.

	Course Area				
% of Time Used for Assessment	General	Organic	Physical	Advanced	Overall
Less than 5%	9.8	6.2	4.3	5.4	6.7
5–10%	44.7	40.7	53.8	51.1	47.0
11–20%	38.2	38.9	32.3	34.8	36.3
More than 20%	7.3	14.2	9.7	8.7	10.0
	$\chi^2 = 8.94$	df = 9	$p = 0.44$		

TABLE 32. Perceived Frequency of Percent of Time Devoted Each Week to Creating Tests and Quizzes by Area of Chemistry Course.

	Course Area				
Hours each week	General	Organic	Physical	Advanced	Overall
0	2.4	0.0	1.1	1.1	1.1
< 2	47.6	43.0	65.9	70.5	55.4
2–5	46.0	50.0	31.9	28.4	40.1
> 5	4.0	7.0	1.1	0.0	3.3
	$\chi^2 = 31.33$	df = 9	$p < 0.01$		

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or for graduate/nongraduate programs (χ^2 = 5.78; df = 3; p = 0.12). However, a greater percentage of the CCD faculty (52% compared with 42% in non-CCD) report spending more than two hours each week preparing tests and quizzes (χ^2 = 18.92; df = 3; $p < 0.01$).

Course size also appears to be significantly related to the amount of time spent creating tests and quizzes (χ^2 = 25.94; df = 9; $p < 0.01$). For small classes (1–30 students), only 30% of the respondents report spending 2–5 hours each week constructing tests and quizzes. In larger classes, almost 50% of the faculty state that they spend 2–5 hours each week constructing tests and quizzes.

The respondents were asked how much time they spend developing other means of measuring learning (portfolios, interviews, etc.). As can be seen in Table 33, there are no detectable differences in the distribution of time spent in these activities across the four teaching areas (χ^2 = 9.56; df = 9; $p < 0.39$). Only about 30% of the faculty report spending more than 2 hours each week developing other means of measuring student learning (compared with about 45% of the faculty reporting spending this amount of time creating tests and quizzes).

Chi-square analyses of the distributions of time developing other means of measuring student learning show no relation to the public or private nature of the institution (χ^2 = 1.33; df = 3; $p < 0.72$). However, there is a significant difference between the distributions of time spent developing other means of assessing student learning as a function of graduate/nongraduate programs (χ^2 = 9.12; df = 3; $p < 0.03$). While 45% of the faculty in graduate programs report spending 0–2 hours each week developing other means of measuring learning, more faculty at undergraduate institutions report spending this amount of time (56%).

No differences were seen among the distributions of time developing other means of measuring student learning as a function of class size (χ^2 = 8.21; df = 9; $p < 0.51$).

What are perceptions of changing assessment practices as a function of chemistry course being taught, institution type, and course size?
The final section of the survey asked about changing assessment practices. Respondents were asked to rate how supportive various groups were to changing ways of measuring student learning on a five-point scale (from opposed to supportive). Over

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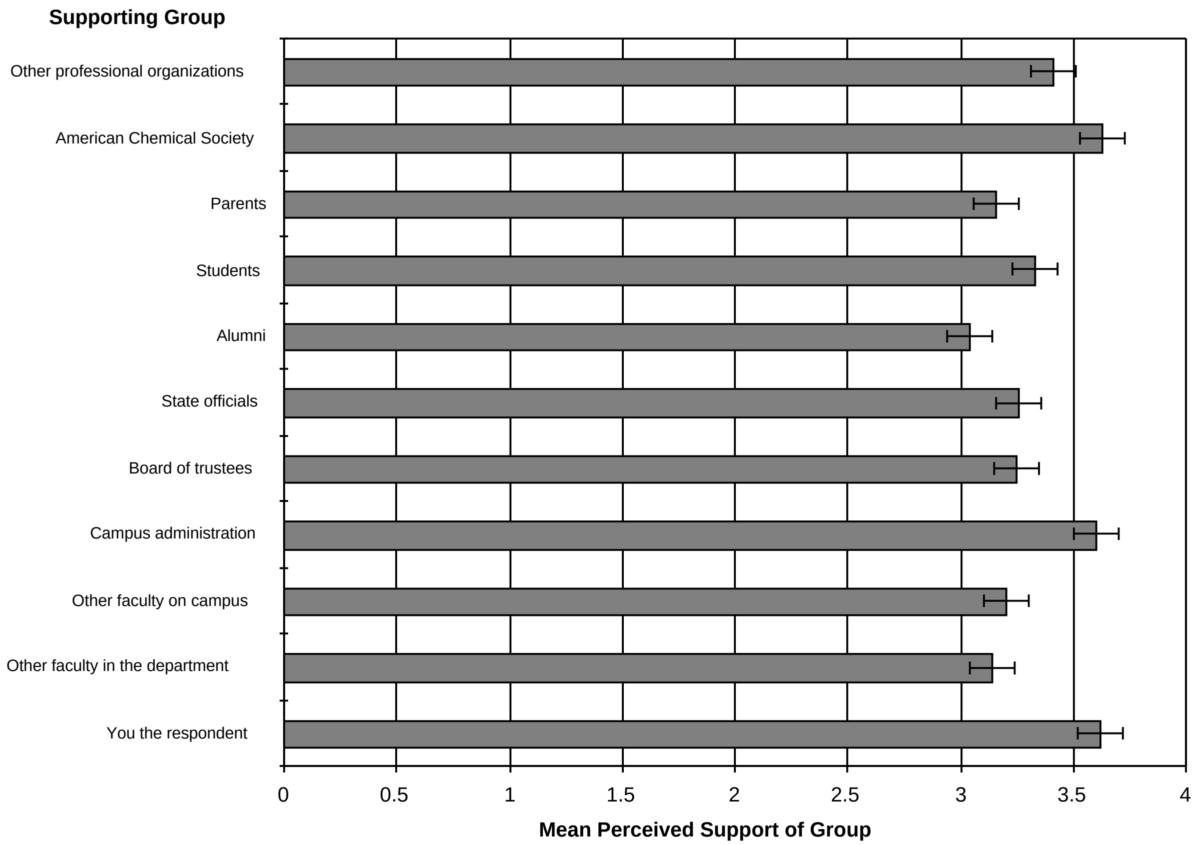

FIGURE 7. MEAN AND 95% CONFIDENCE INTERVAL OF PERCEIVED SUPPORTERS OF CHANGING ASSESSMENT PRACTICES IN CHEMISTRY.

all four areas of chemistry teaching, the faculty perceive the *biggest supporters* of changing assessment practices to be the American Chemical Society, the respondents themselves, and campus administrators (see Table 34 or Figure 7. The groups perceived as *least supportive* include alumni, parents, and other faculty in the department. It should be noted that there is a significant difference on the “You the respondent” item as a function of course taught. Although homogeneous across all other supporting groups, faculty respondents teaching general chemistry perceive themselves as more supportive of changing measurement learning practices than faculty teaching other courses perceive themselves.

Differences were also detected for some of the support groups as a function of the other demographic variables. Faculty at public institutions believe other faculty in their department are less supportive for changing assessment practices (mean = 3.02) than

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TABLE 33 Perceived Frequency of Percent of Time Devoted Each Week to Creating Other Means of Measuring Learning by Area of Chemistry Course.

	Course Area				
Hours each week	General	Organic	Physical	Advanced	Overall
0	21.0	24.3	18.6	18.1	20.6
< 2	53.2	44.7	45.3	55.3	49.9
2–5	21.8	21.4	27.9	16.0	21.6
> 5	4.0	9.7	8.1	10.6	7.9
	$\chi^2 = 9.56$	df = 9	$p < 0.39$		

TABLE 34. Mean, Standard Deviation, and Analysis of Variance of Perceived Supporters of Changing Assessment Practices by Area of Chemistry Course.

	Course Area								
Supporting group	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
You the respondent	3.85 1.12	3.43 1.06	3.59 0.93	3.55 0.93	3.62 1.03	3,412	1.05	3.45	0.02
Other faculty in the department	3.10 1.13	3.14 1.07	3.23 0.83	3.07 0.86	3.14 1.00	3,394	1.00	0.41	0.75
Other faculty on campus	3.19 0.97	3.28 0.86	3.14 0.71	3.20 0.78	3.20 0.84	3,373	0.71	0.44	0.72

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TABLE 34. Mean, Standard Deviation, and Analysis of Variance of Perceived Supporters of Changing Assessment Practices by Area of Chemistry Course (continued).

	Course Area								
Assessment technique	General	Organic	Physical	Advanced	Overall	Degrees of freedom	m_{se}	F	p
Campus administration	3.66 0.89	3.63 0.93	3.62 0.78	3.42 0.85	3.60 0.87	3,370	0.76	1.30	0.27
Board of trustees	3.23 0.78	3.28 0.86	3.27 0.78	3.22 0.76	3.25 0.79	3,324	0.64	0.11	0.95
State officials	3.22 0.84	3.31 0.86	3.35 0.85	3.15 0.88	3.26 0.86	3,294	0.73	0.77	0.51
Alumni	2.99 0.77	3.10 0.88	3.04 0.77	3.04 0.63	3.04 0.76	3,327	0.58	0.32	0.81
Students	3.35 1.05	3.46 1.01	3.20 0.86	3.28 0.90	3.33 0.97	3,380	0.94	1.29	0.28
Parents	3.07 0.87	3.30 0.90	3.18 0.66	3.06 0.80	3.16 0.82	3,332	0.67	1.69	0.17
American Chemical Society	3.65 0.95	3.73 0.87	3.48 0.93	3.64 0.92	3.63 0.92	3,354	0.85	1.21	0.31
Other professional organizations	3.41 0.91	3.49 0.78	3.37 0.84	3.38 0.78	3.41 0.83	3,276	0.69	0.29	0.83

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the faculty at private institutions (mean = 3.31; $F_{1,395} = 8.39$; $ms_e = 0.98$; $p < 0.01$). Table 35 shows the differences in perceived support as a function of graduate/nongraduate program. Faculty teaching in undergraduate institutions perceive their departmental colleagues and campus administration as larger supporters than their colleagues who are in graduate departments. In contrast, faculty teaching in graduate programs believe students are a bigger supporter of changing assessment practices than their colleagues at undergraduate institutions. Faculty in CCD institutions also differ on perception of some support groups from their non-CCD counterparts (see Table 36). Faculty at CCD institutions believed they are more supportive of changing assessment practices than the faculty respondents from the non-CCD institutions. However, CCD faculty felt that other faculty on campus, and the ACS, are less supportive of changing assessment practices than the non-CCD faculty.

The responses were also the same across all class sizes except on one supporting group ("other faculty in the department"). Faculty teaching smaller classes perceive the support of other faculty in the department to be higher ($F_{3,\,395} = 2.91$; $ms_e = 0.98$; $p = 0.03$).

Obtaining Information on New Means of Assessing Student Learning

Faculty were also asked about where they receive information about new means of measuring student learning. There are no differences ($\chi^2 = 6.81$; df = 6; $p = 0.34$) in the distributions of responses (as a function of course taught) to the question: Have you attended any on-campus workshops addressing assessment of student learning? About 45% responded they had attended such a workshop, and about 14% indicated they would if it were available. There are no differences in distributions of responses to this question when examined by the other variables (public/private, graduate/nongraduate, CCD/non-CCD institution, or class size).

Faculty also responded to the question: Have you attended presentations on assessment at regional or national conferences? Again, there are no differences among the distributions of responses as a function of course taught ($\chi^2 = 9.15$; df = 6; $p = 0.17$). About 33% of the faculty responded "yes" to the question, and about 6% believed they would if such a session were available. No difference between responses can be detected for the other variables except for CCD/non-CCD institutions. Faculty at CCD

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TABLE 35. Mean, Standard Deviation, and Analysis of Variance of Perceived Supporters of Changing Assessment Practices by Graduate ProgramType for Items with Significant Differences.

Learning outcome	Department Type: Non Graduate	Department Type: Graduate	Overall	Degrees of freedom	m_{se}	F	p
Other faculty in the department	3.29 0.96	3.02 1.02	3.14 1.00	1,395	0.99	7.54	0.01
Campus administration	3.70 0.89	3.52 0.86	3.60 0.87	1,371	0.76	3.58	0.06
Students	3.22 0.96	3.41 0.97	3.33 0.97	1,381	0.93	3.67	0.06

TABLE 36. Mean, Standard Deviation, and Analysis of Variance of Perceived Supporters of Changing Assessment Practices by CCD/nonCCD Institutions for Items with Significant Differences.

Learning outcome	Institution Type: Non CCD	Institution Type: CCD	Overall	Degrees of freedom	m_{se}	F	p
You the respondent	3.58 1.03	3.97 1.03	3.62 1.03	1,414	1.06	5.06	0.03
Other faculty on campus	3.23 0.84	2.94 0.86	3.20 0.84	1,375	0.71	3.59	0.06
American Chemical Society	3.67 0.89	3.27 1.15	3.63 0.92	1,356	0.83	5.70	0.02
Other professional organizations	3.45 0.93	3.03 0.98	3.41 0.94	1,278	0.68	5.99	0.02

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institutions are significantly more likely ($\chi^2 = 6.33$; df = 2; p = 0.04) to have attended a session (45%) than their non-CCD peers (32%).

Journal articles are another way to learn about broader means of measuring student learning. Faculty were asked if they had read articles discussing assessment of student learning. Table 37 summarizes their responses and shows that there are slight significant differences ($\chi^2 = 12.66$; df = 6; p = 0.05) among the different courses being taught. A greater percentage of general chemistry and physical chemistry faculty report having read articles on assessing student learning. No differences in responses are detected when examining responses by institution type or class size. However, there are differences for the CCD/non-CCD institutions. More faculty at CCD-supported institutions (93%) reported having read articles on assessing student learning than the 76% of their non-CCD peers ($\chi^2 = 12.66$; df = 6; p = 0.05).

Summary of Results

Based on the data collected and analyzed, a number of summary statements can be made about practices for assessing student chemistry learning in terms of learning outcomes being measured, assessment techniques, administrative aspects of assessment, and support for changing assessment practices. In terms of learning outcomes:

- Faculty across all chemistry course areas believe that conceptual understanding and reasoning skills are the most valued outcomes of chemical education. They also believe social skills and the development of positive attitudes are the least important.

- There is a positive relationship between the perceived importance of an outcome and how frequently the outcome is measured, between the importance of the outcome and a faculty member’s reported knowledge of how to measure the outcome, and between the frequency of measurement of the outcome and a faculty member’s reported knowledge of how to measure it.

Overall, except for a few differences among certain learning outcomes, most of the faculty teaching in different chemistry courses, institutions, and class sizes, have similar beliefs about the relative importance of various learning outcomes.

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TABLE 37. Percent Responses to: "Have you read any articles dealing with assessment of student learning?" by Area of Chemistry Course.

	Course Area				
Response	General	Organic	Physical	Advanced	Overall
Yes	85.2	72.2	80.0	69.5	77.1
No	13.3	22.6	18.9	27.2	19.4
Would if available	1.6%	5.2	1.1	6.3	3.5
	$\chi^2 = 12.66$	df = 6	$p = 0.05$		

However, there seems to be more diversity in perceptions related to the techniques chemistry faculty believe are accurate, and use, for measuring learning. The results can be summarized as follows:

- Faculty perceive open-ended assessments (e.g., essay questions, laboratory reports) to be the most accurate means of measuring student learning. Student-reported data are perceived as least accurate measures of student learning.
- There are positive correlations among the faculty perceptions of the accuracy, frequency of use, and knowledge of use of various assessment techniques.
- There is a decrease in the use of labor-intensive assessment techniques (e.g., writing assignments or research projects) as class size increases. However, for classes larger than 100 students, there appears to be an increase in the use of these techniques—possibly due to additional instructional resources such as teaching assistants.

Administrative aspects are a component of decision-making about the use of different assessment of student learning practices. However, for the most part there is a homogeneity of responses concerning time spent on assessment.

- The majority of faculty across all course areas and institution types use 10% or less of lecture and laboratory time for assessing learning

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However, there are differences in terms of time taken to prepare assessment tasks:

- General and organic faculty report spending more time preparing quizzes and exams than do their colleagues in more advanced courses.
- Faculty teaching larger classes state they spend more time preparing quizzes and tests.

But in terms of developing other means of assessing learning there appears to be few differences. Only about 30% of the faculty report spending more than 2 hours each week developing new means of assessing learning.

Finally, there is also a homogeneity of faculty perceptions of some aspects of changing assessment practices in terms of perceived supporters or where they get information regarding changes.

- Respondents across all course areas viewed themselves, the ACS, and campus administrators as the biggest supporters of changing assessment practices.
- Almost half of the respondents have attended a workshop on assessing learning, and almost three-quarters reported reading articles about assessing student learning.

Discussion

Prior to discussing these results, at least three issues should be considered: self-selection of the respondents, the large sample size and descriptive nature of the data, and the self-reporting nature of the data.

First, the self-selecting nature of the respondents needs consideration. Although a random sample of institutions was selected, and a fairly good response rate was obtained, it is probably the case that respondents were people with an interest in assessment practices. This is supported by the data on perceived supporters for changing assessment practices because the respondents perceived themselves as bigger supporters of change than other faculty in their department. This self-selection will probably lead to an overestimate of the perceived accuracy, frequency of use, and knowledge of using less traditional assessment techniques. However, in terms of

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relative ordering of learning outcomes and their measurement, there should not be a very large difference. Additional research will address this point.

A second issue to consider is the large sample sizes and the descriptive nature of the data. Because of the fairly large sample sizes, the standard errors of the calculated means are quite small. In turn, with these large samples it is possible to see small, and yet unimportant, differences between measures. However, these small differences do allow results to be ordered with confidence (e.g., conceptual understanding is valued more as a learning outcome than are social skills). But these data are descriptive in nature rather than experimental. From these results we can state observed relations (e.g., perceived value of an outcome is positively related to its frequency of measurement), but causal inferences should not be drawn. Experimental work needs to be done to determine the directions of causality in such relations.

A final issue to consider is the self-reported nature of the data. For example, observations were not made to see how much time was used in classes and laboratories for assessment. Nor were faculty actually tested to determine their knowledge of various assessment techniques. However, while faculty may not know their absolute knowledge of how to measure a particular learning outcome, they are probably good judges of their relative knowledge of how to measure different learning outcomes (e.g., reasoning skills versus social skills). This relative information can still be used to examine relations among different aspects of assessment. Future work, however, should involve trying to triangulate these self-reports with observations of assessment practices the respondents use.

Some Implications and Charges to the Chemistry Education Teaching Community

The data and results obtained through this study paint a broad picture of what is happening in terms of assessing student learning in chemistry at the college level. There are a number of implications that could be drawn from this work. We will focus on two.

Valued Learning Outcomes and Cooperative Learning

On one hand, the homogeneity of valued learning outcomes across all chemistry course areas is a positive situation because it indicates the chemistry teaching community has reached a mature point of consensus. At the same time, the chemical industry and other

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chemistry-related employers indicate agreement about what they value in employees [10]. The largest discrepancy in terms of value of various learning outcomes between the chemistry teaching community and the chemistry employment community involves issues related to communication and working effectively in groups. As part of our work in the chemistry teaching community, we need to develop communication and group-related skills in our students.

Many faculty in the chemistry teaching community are starting to look toward cooperative learning as a way to enhance learning [11–13]. However, examination of these efforts indicates that the primary reason the community is using cooperative learning strategies is to enhance cognitive understanding in chemistry (see [14] for example). For the most part the chemistry teaching community has ignored trying to teach group skills (e.g., role-taking, planning, running meetings, dealing with group conflict) and do not value them as learning outcomes. This must change if we are to produce quality people who can think about chemistry and operate in group-based environments. But how can this be accomplished?

Professional Development in the Area of Assessment of Student Learning

Although there are resources available for learning about broader means of assessing student learning at the college level [15], they do not tend to address chemistry-specific issues. Assessment of learning is a technical process that ranges from task design, to collection and examination of statistical evidence of reliability and validity of the obtained measures. These technical aspects can be learned in several ways. We suggest:

- That journals such as *The Chemical Educator* or the *Journal of Chemical Education* actively solicit and publish manuscripts dealing with assessment of learning.

- That funding sources of curriculum-reform projects require that a component of the project examine how assessment of student learning should change to be congruent with content and instructional changes.

- That the ACS and the National Science Foundation sponsor short courses at national meetings, or summer faculty-enhancement workshops, that focus on

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technical aspects of assessment including means of measuring social and communication outcomes.

Without additional research we will not be able to determine the direction of causality between faculty members' perceived value of learning outcomes, their knowledge of how to measure these outcomes, and their frequency of doing so. It seems that if faculty were educated about how to measure outcomes such as group skills, then they might be valued more and assessed appropriately. If we do not assess the outcome, the students will not orient themselves to learn it.

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