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What Are We Teaching in High School Chemistry?

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A dialog among readers and the author began after the publication of "What Should We Teach in High School Chemistry" *(1)* in this *Journal,* which presented results of a survey of college professors asking what students need in high school before entering college-level chemistry. High school teachers began e-mailing the author discussing what they did and did not think was important to include in high school chemistry and their responses to findings from the college professors' survey. This dialog led to the current research study.

Many factors influence what teachers include in their syllabus: national, state, and district standards and tests; textbooks; vertical curriculum; perceived future demands on the students; time and schedule; personal interest of the instructor and students. Have teachers across the nation taken into account all of these factors and formulated a consistent, realistic curriculum? High school teachers were surveyed to investigate the following questions:

- What topics are appropriate for a general high school chemistry course?
- Are the topics thought to be appropriate actually being taught by most teachers, or is the list of "appropriate" topics too large?
- Is there consistency in the topics listed as important among subsets of teachers (e.g., between rural, suburban, and urban school teachers)?
- Do the other levels of chemistry that teachers teach affect how they view high school general chemistry?
- How often are labs and demonstrations used?
- Are teachers using an inquiry approach?
- What other skills are teachers emphasizing?

Summary of the Survey Questions

- City and State
- Type of school: public or private?
- Setting of school: urban, suburban, or rural?
- What type of schedule do you teach on?
- How many years of science are required to graduate?
- Is chemistry required to graduate?
- What chemistry courses do you teach or have you taught?

For each of the topics listed, participants were asked to:

"Please answer based on your first-year general chemistry course (not an honors course). For each topic, please indicate whether you currently cover that topic, you wish that you could cover the topic given more time, or that you feel that topic is not necessary or appropriate for that level (it should be covered in subsequent courses).

- Do you use inquiry labs in your general chemistry classroom? If so, how many per semester?
- Approximately how many labs (of any type) do your general chemistry students do per semester?
- Approximately how many demos do you do for your general chemistry students per semester?
- Do you stress the following in your general chemistry course: Writing skills? Plausibility of answers? Macro–micro connections? Application to life (the "real world")?
- If you had to pick one of these goals, would you rather see a first-year, general chemistry course:
  - Prepare students for college chemistry
  - Interest students in science in their life and world?

Textbox 1. A summary of the survey questions used for this research. See the Supplemental Material[W] for a copy of the actual survey. Note: For the purpose of this survey, inquiry labs are being defined as students designing their own procedures—the problem or purpose may be given to them or may not.

Literature Review

In the recent science education literature, no survey studying which topics high school chemistry teachers cover could be found. One survey asked teachers how they felt about teaching in general and teaching science in particular, comparing different age groups of teachers *(2).* Although this previous survey did not ask about specific chemistry topics, the authors did find that while the teachers were using hands-on methods, they still felt the need to teach more basic concepts and knowledge to prepare their students for the future. Several surveys compared what high school and college instructors thought should be included in high school chemistry *(3–5).* These surveys showed that while the high school teachers focused on content and knowledge, the college professors tended to focus on personality traits, higher-order thinking skills, study skills, and interest. Recommendations of broad topics to be included in the high school course were made in an article that compared four sources of standards to find overlap for recommendations for eighth- and twelfth-year students *(6).* Although several discussions of what *should* be in the course have occurred, no study has been completed on what teachers are *actually* teaching.

Method

An Internet survey was created for high school teachers (the complete survey instrument can be found in the Supplemental Material[W]). The survey included demographic questions, a list of chemistry topics often included in the high school curriculum, questions about laboratory and demonstration use, as well as other areas of emphasis throughout the curriculum (see Textbox 1). Participants were instructed to answer the survey based on their experiences teaching a general, first-year, high school chemistry course—not an honors, Advanced Placement (AP), or college-level course.

High school teacher e-mail addresses were located on high school Web sites throughout the country and e-mail messages were sent directly to the teachers to solicit responses to the survey. Two chemistry teacher support groups that the author is aware of—California Chemistry Teacher Support Group *(7)* and Associated Chemistry Teachers of Texas (ACT_2) *(8)*—encouraged participation in the survey through their e-mail discussion groups. Flinn Scientific also published a summary of the college professor survey results in a FlinnFax newsletter *(9)*, along with a Web link to the new high school survey. A link to the survey was also placed on the Web site of *JCE*'s High School Chemed Learning Information Center (HS CLIC) *(10)*.

Results

The survey received 571 unique submissions, representing all 50 states. See Figure 1 for demographics of the survey participants.

Data were analyzed with one of two methods. Quantitative data (e.g., number of labs used per semester) were compared using ANOVA and post hoc testing. Categorical data (e.g., are writing skills emphasized? yes or no) were analyzed with a χ^2 test. Data were analyzed using the whole population as well as subpopulations for specific questions (public vs private, block schedule vs traditional schedule, etc.) Both types of data analysis used a significance level of 0.05 or below.

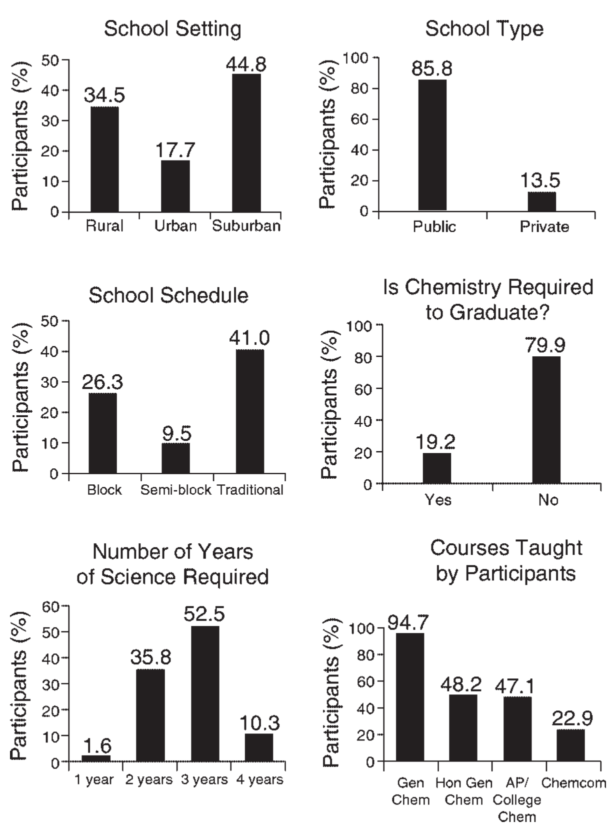

Figure 1. Distribution of the survey participants (N = 571) by school and teaching variables. Note that non-response to questions results in <100% total response; participants teaching more than one level of chemistry results in >100% total response.

Chemistry Topics High School Teachers Think Are Appropriate

Chemistry topics were rated by participants as: (A) a topic they taught, (B) a topic they wished they taught, or (C) a topic they felt is not necessary for high school general chemistry. Topics that were rated as either (A) or (B) were grouped together as topics that the instructor thought were appropriate for the course. These topics were then compared with topics instructors thought were inappropriate (C). Table 1 shows the results of these ratings.

Topics were considered appropriate for the course by at least 93.3% of the teachers with the following exceptions: enthalpy (69.2%), acid–base complex problems (42.9%), kinetics (qualitative) (68.0%), kinetics (quantitative) (34.0%), equilibrium (qualitative) (71.1%), and equilibrium (quantitative) (41.0%).

Although there is a statistically significant difference between many of the topic ratings, the author believes that there is not a practical difference in the ratings. For example, "basic skills" was rated as appropriate for the course by 99.1% of the teachers, and "types of reactions" was rated as appropriate by 97.5% of teachers. These two ratings produced a statistically significant difference using a χ^2 test with $\alpha = 0.05$. However, from a practical point of view, an agreement of 97.5% is significantly high to deem a topic appropriate for the course.

There were no significant differences among subpopulations of teachers. For example, teachers in private school did not differ from public school teachers in which topics were "appropriate" for the course.

What Topics Are Taught in High School Chemistry?

Teachers are teaching a statistically significant lower number of topics than they feel is appropriate for the course. Teachers rated an average of 20.8 (SD 2.92) topics as appropriate for the course, while they actually taught only 18.1 topics (SD 2.99). This discrepancy can been seen in three topics that had a significantly lower percentage of teachers actually teaching the topic: acid–base (pH, strength, titrations) (93.3% appropriate, 69.9% actually teaching); scientific process skills (94.7% appropriate, 77.8% actually teaching); solutions and concentrations (96.3% appropriate, 83.0% actually teaching).

Figure 2 is a histogram representation of the number of topics teachers thought are appropriate versus the number of topics they actually teach in their course. The difference in the teachers' ideal versus the reality is evident in this figure.

Only the 18 topics that teachers considered appropriate for the course (see above) were used for between-population analysis. Differences were found among subpopulations of teachers concerning which topics teachers actually taught (see Table 2). Teachers at rural schools taught fewer topics than teachers at suburban and urban schools. More teachers at suburban schools taught "gases" and "solutions and

Table 1. Chemistry Topics Ranked by Teachers Assessing Whether the Topics Are Appropriate for High School Chemistry

Topics Categorized by Responding Teachers (*N* = 571)	Currently Taught (%)	Appropriate for This Level (%)	Not Necessary at This Level (%)
Topics Thought Appropriate by > 90% of Teachers and Taught by Most			
Balancing reactions	99.1	99.5	0.2
Naming and writing formulas	98.8	99.3	0.2
Moles (molar mass)	98.4	99.3	0.2
Basic skills (units, significant figures, graphing, etc.)	98.4	99.1	0.5
Atomic structure (parts of an atom, electron configuration)	98.1	98.6	0.5
Periodic table and periodicity	96.7	98.5	1.1
Classification of matter and energy, physical/chemical properties/changes	97.9	98.3	0.9
Stoichiometry	95.3	98.3	1.1
Bonding (types and characteristics)	92.6	97.9	1.6
Dimensional analysis (factor label method)	96.1	97.9	1.8
Types of reactions	95.6	97.5	1.8
Basic lab skills[a]	89.3	97.5	1.2
Solutions and concentrations	83.0	96.3	2.5
Gases (kinetic molecular theory, gas laws)	88.1	96.0	3.0
Topics Thought Appropriate by > 90% of Teachers and Taught by Fewer			
Scientific process skills (design of experiments, data analysis, etc.)	77.8	94.8	3.0
History of atomic theory	90.4	94.1	5.1
Lewis dot structures	88.4	93.5	4.6
Acid–base (pH, strength, titrations)	69.9	93.4	4.4
Topics Thought Appropriate by < 90% of Teachers			
Equilibrium (qualitative approach)	41.7	71.1	23.6
Enthalpy (Hess's law, heats of formation, fusion, vaporization, calorimetry)	38.7	69.2	27.8
Kinetics (qualitative approach)	37.5	68.0	27.5
Acid–base (buffers, complex titration problems)	12.3	42.9	50.4
Equilibrium (quantitative approach)	14.9	41.0	52.5
Kinetics (quantitative approach)	8.6	34.0	58.3

[a]Filtering, drying, micro scale, titration, gas collection, heating, measurement, use of glassware

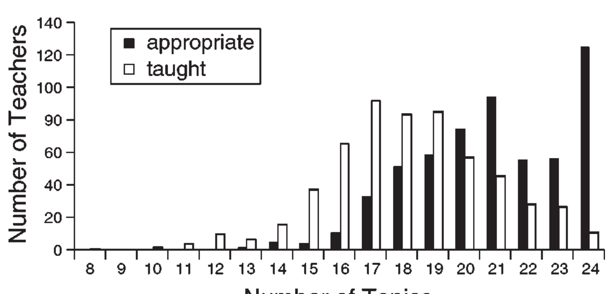

Figure 2. Number of topics rated as appropriate versus number of topics actually taught. Histogram comparison shows that teachers felt more topics are appropriate than they are actually teaching. The solid bars represent the number of teachers who rated that number of topics as appropriate. The white bars represent the number of teachers actually covering that number of topics. For both totals of teachers, *N* = 571.

concentrations" than teachers in either rural or urban schools. Teachers at suburban schools also taught "acid–base (pH, strength, titrations)" more often than teachers at rural schools. Teachers who also teach *Chemistry in the Community* (*ChemCom*, a curriculum written by the American Chemical Society that uses need-to-know instruction and application to industrial and environmental concerns) taught "scientific process skills" in their general chemistry courses more often than teachers who do not teach a *ChemCom* course.

How Many Teachers Use Inquiry Labs, and How Often?

For this survey, an "inquiry lab" was defined as one in which students design the procedure (regardless of where the purpose, problem, or question originated). Of the 571 participants, 55.5% indicated using inquiry in their courses. Teachers reported an average of 3.3 inquiry labs per semester (SD 2.9).

There were no statistically significant differences among subsets of teachers in the percentage who use inquiry methods, or the number of inquiry labs they offer per semester.

How Often Are Teachers Using Labs and Demos?

Teachers use student labs of any kind (inquiry, cookbook, and everything in between) more times per semester than teacher demonstrations. Courses average 13.7 student labs (SD 7.31) and 11.9 teacher demonstrations (SD 10.9) per semester. Figure 3 shows a histogram comparison of the frequency of inquiry labs versus the frequency of labs of any type in a semester. This figure illustrates the large difference in the frequency of use of these two teaching methods.

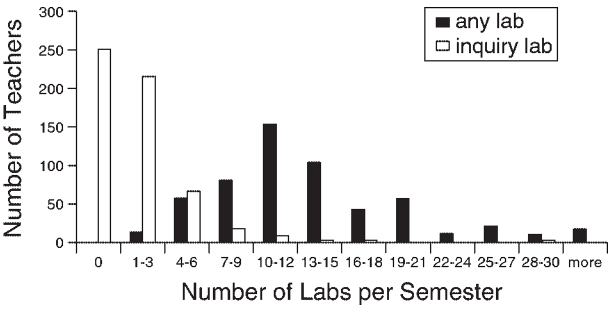

Figure 3. Distribution of labs for teachers responding to the survey (N = 571). Histogram comparison shows frequency of inquiry labs per semester as compared to frequency of any type of lab per semester.

Differences were found in lab use among subsets of teachers (see Table 2). Teachers at schools with a block schedule offered more labs per semester than teachers at schools on a traditional schedule. Those who teach required chemistry courses offered more labs per semester than those who teach courses not required for graduation. No statistical differences in demonstration use were found among subsets of teachers.

Table 2. Differences in Responses by Subsets of Teachers

Subsets of Teachers by Categories	Nature of the Differences among Subsets of Teachers
School Type: Private vs Public Schools	No differences on any question
School Type: Rural vs Suburban vs Urban	Teachers at rural schools teach a significantly lower number of topics (average 17.5, SD 2.7) than teachers at suburban schools (average 18.6, SD 2.51) and urban schools (average 18.2, SD 2.87)
	More teachers at suburban schools actually teach gases (88.7%) than teachers at urban schools (80.2%) and rural schools (75.6%)
	More teachers at suburban schools actually teach solutions and concentrations (95.3%) than teachers at urban schools (85.1%) and rural schools (79.7%)
	More teachers at suburban schools actually teach acid–base (pH, strength, and titrations) (76.6%) than teachers at rural schools (60.4%)
	Teachers at rural schools stress college preparation (54.7%) over student interest in real-life science more than teachers at suburban schools (40.0%) and urban schools (38.0%).
Schedule Type: Block vs Traditional	Teachers at schools using block schedules do more labs per semester (average 14.9, SD 8.5) than teachers at schools using a traditional schedule (average 12.8, SD 7.0)
Graduation Requirement: Chemistry Is Required vs Not Required	Teachers of required courses do more labs per semester (average 15.2, SD 9.7) than teachers of non-required courses (average 13.3, SD 6.6)
Teaching Assignments: Teachers Also Teach AP/College vs Those Who Do Not	No differences on any questions
Teaching Assignments: Teachers Also Teach ChemCom vs Those Who Do Not	More teachers using *ChemCom* cover scientific process skills (84.0%) than teachers not using *ChemCom* (75.9%)

What Other Skills Are Teachers Emphasizing in Class?

Participants were asked whether they stressed general skills in their course: writing skills, recognizing plausibility of answers, making macro–micro connections, and identifying applications to the "real world". Application was stressed by 91.5% of teachers and plausibility of answers by 90.3%. These two skills were stressed significantly more than writing skills (72.1%) and macro–micro connections (50.4%). No statistical differences were found among subsets of teachers.

What Is the Primary Focus of a High School General Chemistry Course

Participants were asked to designate their priority for the course as either being a course to prepare students for college-level chemistry, or a course to interest students further in science in relation to the world around them. Although these need not be mutually exclusive, participants were asked to choose one or the other. Interest in science was the priority for 54.9% of teachers. Those teachers whose priority was to prepare for college indicated that more topics were appropriate for the course (mean 21.1, SD 2.43) than those whose priority is interest (mean 20.6, SD 2.55). Teachers whose priority was to prepare students for college also taught a statistically significantly higher number of topics (mean 18.4, SD 2.78) than those with interest as their top goal (mean 17.9, SD 2.60).

Teachers at rural schools were statistically different from teachers at suburban and urban schools in course priority (see Table 2). Teachers at rural schools favored preparing students for college-level science as their priority while teachers at suburban and urban schools rated increasing student interest in the science of their world as a higher priority.

Table 3. Distribution of Comments by Survey Participants

Synopsis of Teachers' Comments	Frequency[a]
College Professor/High School Interface	
I want to know what colleges need us to teach and it will impact what I include in my course	59
Curriculum Standards	
My state standards have many indicators, but the "basic skills" are not included	2
Depth versus Breadth	
I would rather have depth, not breadth	4
We cover an incredible amount of material, but how much are they really learning?	2
Outside Forces That Affect Curriculum Decisions	
On block schedule, we have less time and therefore cover less material	4
Changes in graduation/admission requirements increase the diversity in the course population, making it difficult to teach to all levels of students	2
Administrators are pushing for more breadth and watered-down curriculum to service all students	2
"Accountability" and testing, etc., is wasting class time	2
My classroom is not conducive to labs/activities, so we don't do them much	2
Topics That Were Missing from This Survey	
I also include organic chemistry in my course	8
I also include nuclear chemistry in my course	3
What Should the Priority of the Course Be?	
We only have one course, so I have to both "prepare for college" and "interest students"	5
The dichotomy of purposes for high school chemistry is the most important problem we face	3
We're trying to teach too many students "college prep" that don't need it and not prepping the students that do need it enough by having only one course	3
What Are Students Missing before They Get to High School Chemistry?	
My students need more mathematics preparation	4
My students are too dependent on their calculators—they can't recognize implausible answers	2

[a]Responses are given in decreasing order; N = 169

Other Comments from High School Teachers

Not all participants included comments on their survey, although many did, as shown in Table 3. Common comments included great interest in knowing what college professors want high school teachers to cover to prepare students; difficulty in balancing the need to prepare students for college with the need to interest them in science; common frustrations with outside forces (accountability and testing, administrators, lack of lab space, classroom interruption, students who are ill-prepared for their course); and struggles with the issue of depth versus breadth in teaching chemistry concepts.

Limitations of the Study

Teachers were fairly consistent throughout the survey. However, this survey did not go in-depth into what exactly was taught within each topic, nor did it attempt to ascertain what expectations the students were held to with respect to depth, mathematics emphasis, difficulty of exams, and so forth. These differences can often be seen between chemistry teachers in the same building, let alone across the nation. The consistency is not characterized by students having the same knowledge and skill level upon completion as a standardized test would show; rather that students are being exposed to roughly similar experiences as described by the teachers. A more detailed picture could be obtained from a survey that broke the topics down into greater detail, although the length of such a survey might prevent large participation.

Implications of the Findings

The results show remarkable agreement among teachers concerning which topics they would like to teach in their courses. Is this list of 18 topics too large, however, for teachers to teach well in one school year? If 75% of the teachers participating in the survey are not teaching all of the topics they think are appropriate, the list is probably too long. The chemistry education community as a whole will need to realize that it is impractical to include all these topics in a single introductory high school chemistry course, as evidenced by the fact that the majority of teachers are not currently able to teach all the topics they find appropriate for the course.

While a statistically significant portion of the teachers are using inquiry teaching methods, this means that 44.5% of the teachers responding to this survey are not incorporating inquiry in their teaching. Learning science content through inquiry is a standard in both the National Science Education Standards *(12)* and the Project 2061 Benchmarks for Science Literacy *(13)* and should be included in more classrooms. Additional research should be conducted to determine what prevents teachers from using inquiry methods; intervention strategies should be put into place based on the findings of such research.

Results of the question concerning the main goal of the general high school chemistry course (interest students in science or prepare them for college-level chemistry) show a statistically significant finding—that student interest in science was the priority, with the exception of teachers in rural schools. Practically speaking, the teachers are roughly split in half on the question. The two purposes are not mutually exclusive and can be accomplished within the same course simultaneously. Several participants commented that they do provide for both priorities in one course. However, those that cited college preparation as the main goal thought more topics were appropriate and taught more topics in their course. Further studies could be done to ascertain whether this increased focus on content diminishes the effectiveness of the other goal (to increase student interest in science in their world), and whether the two goals truly are effectively addressed simultaneously in courses.

Commentary

Of the specific knowledge that is learned in a science class, 70% is forgotten within one year of completing the course *(11).* If this is true, then why do teachers feel such a need to introduce all the topics that students will see in the next level? Would it not be more appropriate to stress process skills, interest, and appreciation for the sciences? This position does not mean that increasing process skills and interest cannot be accomplished while introducing students to chemistry topics; rather, the focus should shift from the concept itself to the thinking skills needed to connect multiple concepts or the ability to connect microscale concepts to macroscale properties. The perceived need to teach all of the topics should be replaced by a focus on teaching fewer topics and teaching them well.

A 1994 survey of coordinators of college chemistry courses *(14)* recommended that although high school chemistry should prepare students for college, it should not be a miniature version of the college course. The article recommended that high school chemistry should be more descriptive, fun, and "not scary"—that it provide students with the basics for coping and functioning in the college course. In a discussion of teacher obsession with content, Gold *(15)* stated:

> The students who do not take college chemistry will forget almost all the content. Those who take some college chemistry will begin to forget it unless it is applied in their own careers. Who needs to know a lot of content? Practicing chemists, that's who, and they will learn the content as they continue on in upper-level courses and in the day to day practice of their professions.

How many students does a high school teacher have each year that will go on to have a career in chemistry, or a field highly related to chemistry? Probably not very many, and as Gold stated in the above quote, there will be plenty of time for them to learn content later in their education. Perhaps if high school chemistry focused a little less on content and a little more on interest, a teacher might increase the number of his or her students that do go on to science-related fields. Studies based on Piaget's work show that less than half of high school seniors can reason at the formal level needed for chemistry's abstract concepts and mathematical application *(16).* If these studies *(16)* are correct and more than half of seniors (and the majority of students taking high school chemistry are taking it earlier than their senior year) do not have the logic skills for abstract concepts (such as atomic theory), then that is an even more convincing argument to leave some topics for later in their education.

Since many surveys of college professors indicate that they believe content is less important than process skills, study skills, interest, and lack of fear in the subject, then high school teachers would do better to prepare their students by setting these as their goals and using content as the avenue through which to meet these goals *(1, 17–19).* Of course, taking the time to increase these other skills will leave less time for content, yet it does not seem to matter to those who teach the next level.

If students take high school chemistry in the sophomore or junior year, how much content is retained by their freshman or sophomore year of college (a span of four or five years) in order to prepare them for college chemistry? The content retained is probably not as important as the attitudes towards science as a whole that the students may hold. Therefore, by interesting our students in the science of their world, we will also be preparing them for college chemistry. Unfortunately, in order to shift the focus, we must first convince textbook and standards authors and publishers, administrators, parents, students, and countless teachers that less is more, which seems a daunting task at best.

[W]Supplemental Material

A copy of the survey instrument is available in this issue of *JCE Online.*

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