Chemistry Education, Kindergarten through College: Should We Be Changing the Direction of Where It Is Going?

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Abstract

This article is based on the plenary lecture given at the IV International Conference on Pre-University and University Chemistry Teaching held in Merida, Mexico, in November 2005. It will differ slightly from the lecture because of the interactive nature of the original presentation.

Introduction

In the 1980s I assisted in directing a summer six-week workshop at the University of Maryland for high school chemistry instructors on the teaching of chemistry. A young woman, who had recently graduated from the University, was the workshop secretary/assistant. She had been selected for the job, not only because of her nice personality and skills, but because of her chemistry background. She had obtained the highest average in the introductory chemistry class of about 500 students at the University of Maryland.

When I asked this young woman why she had taken this introductory course after she already had her undergraduate degree, she said that she wanted to become a veterinarian, and that college chemistry was a prerequisite. She also said that she took high school chemistry and got an "A"in the course but that she "didn't understand a thing!"

She explained that when she went to register for classes at the University as a freshman, she decided to go to the bookstore to examine the textbooks because she thought that she would major in an area that she could understand the subject by reading the textbooks. From this experience, she decided to major in psychology. However, after completing her undergraduate degree, she decided that she really wanted to become a veterinarian, and hence enrolled in the chemistry course. At 22, this young woman understood chemistry so well, that she was at the top of the class!

This true story says a lot to us about what is happening to students who do not understand chemistry in high school, but actually get good grades because they excel at memorization. From their experience, many students from grade school through high school probably think that they are not capable of understanding it, and hence rule out the many careers for which chemistry is a requirement. The cause of this may be because many complex aspects of chemistry are presented to students at too early an age, the content doesn't relate to anything in everyday life, or there is just too much to understand so students memorize it for the test!

Learning in chemistry can be very interesting at all ages if it is related to everyday life, and students are given opportunities to discuss it with one another as suggested by the social-constructivist model of learning. One way of doing this is to have students participate in ConcepTests. The following is an example of a ConcepTest that is appropriate for persons of over 5 years of age.

Demonstration: Margarine and Water:

Question #1: Predict what will happen when I take a slice of margarine from the end of the stick of margarine, and carefully place it in the glass of room temperature water?

You will have three choices:

A. It will float.
B. I don't know what it will do.
C. It will sink.

Before I do anything, I want everyone in the room to participate simultaneously by predicting what you think will happen by

A. Raising a blue paper if the answer is A
B. Raising a white paper if the answer is B
C. Raising a red paper if the answer is C

Now let's repeat the experiment using another glass of tap water. This time I will place the remaining stick of margarine in an identical glass filled with the same volume of room temperature water.

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Question #2: Predict what will happen when I take the rest of the stick of margarine, and carefully place it in another glass of the same volume of room temperature water as before?

You will have the same three choices:
A. It will float.
B. I don't know what it will do.
C. It will sink.

Before you do anything, I want everyone in the room to participate simultaneously by

A. Raising a blue paper if the answer is A
B. Raising a white paper if the answer is B
C. Raising a red paper if the answer is C

Now I want you to take a few minutes to discuss the results with the person sitting on either side of you. Can you give an explanation of what is occurring?

ConcepTests for use in science teaching are really not tests that are used for assigning grades to students, but used to assess the knowledge that students have before a concept is introduced by the instructor. They help guide instruction, and also may interest students in the concepts to be studied. ConcepTests were formally introduced in print to teachers of physics by Eric Mazur (1997) and to chemistry teachers by Landis *et al.* (2001).Teachers of science at all levels can create their own Concep Test questions to determine where to begin instruction. Some universities have had electronic systems installed in large lecture halls so that they can get this information almost immediately from students by having them press a button at their seats and then display the results to the class.

A ConceptTest on sinking and floating could be used with young children when they are introduced to the concept, but the instruction would be different because the lesson would be an experiential one in which children would test what kinds of things sink or float. In other words, children in first grade would not be expected to give an elaborate answer involving density, nor would children at the middle school level.

My experience in using this sinking and floating demonstration with large groups of middle school or high school science teachers, has consistently shown that even some experienced science teachers do not answer the question correctly. Yet, if these teachers had been asked to compare the behavior of ice in a glass of water to the behavior of an iceberg in the ocean, everyone would predict that they both float. Teachers know this because they have seen ice cubes float in water and have seen pictures icebergs sticking out of the water in the ocean! In addition, almost every teacher would be able to explain the answer in terms of density or forces because these are common topics taught in high school chemistry and physics!

The Reform of Science Education

The current reform of science teaching in the United States is different from the reform of the sixties particularly at the elementary level that focused on the science process skills such as making observations, controlling variables, doing experiments, etc. One of the major changes made by the National Research Council, that formulated the US Standards, is that the focus of instruction should be on giving explanations.

As Alex Johnstone (1990, 1993) has pointed out, chemistry (and other sciences as well) can be understood, and hence taught, on three different levels: the macroscopic, particle, and symbolic levels. Johnstone depicts these levels at the vertices of an equilateral triangle with the macroscopic at the top of the triangle, the particle level on the left, and the symbolic level on the right. It follows that explanations can also be given on these three levels. In the case of sinking and floating, the following are some of the explanations that could be given each level.

Macroscopic Explanation: In each experiment you have the same materials. When the materials are the same, it doesn't matter how much you have of them. It will always do the same thing-sink or float.

Particle Explanation: The molecules in the different size pieces ice are identical. They aren't compressed more in one than the other. So they will react in the same way in sinking and floating. If it was two different materials, the particles making up one substance may be heavier than another substance and then it might not have floated.

Symbolic Explanation: The density of each piece is the same, and sinking and floating depends on density of the object floating in relationship to the density of the liquid. Density equals the mass divided by volume, $D = M/V$. As the mass increases, the volume increases proportionately, so the density will be the same. From the standpoint of physics, an explanation using forces could also be given.

In teaching chemistry, teachers need to be aware of the appropriate level for the group being taught. He or she might think that when students enroll in the chemistry course at the college level, they have had chemistry in high school, middle school and even in elementary school, so instruction can begin at the symbolic level. This is not the case. Because students "have had" a topic, does not mean that it was understood or remembered.

For example, suppose you were shown you a picture of a Chinese symbol, and asked what it represented. Unless you were Chinese or studied the Chinese language, it would have no meaning. If the letters "b a n a n a" were written on a piece of paper and you spoke or read no English, it would have no meaning. If you were shown a black and white picture of a banana, you would probably recognize it by its shape, but you wouldn't know whether the banana was ripe or not. However, if you could actually see, feel and smell the banana, (observe it on the macroscopic level), you would know more than you could determine from a black and white picture/photo, and much more than from the symbolic representation of it in an unfamiliar language.

The same is true in chemistry. It can be taught on the macroscopic, particle, and symbolic levels. The symbolic level is not very meaningful unless one understands the macroscopic or particle levels. Unfortunately many teachers at the high school and college levels frequently forget about making links to the macroscopic level or the particle level, and base most of their instruction on the symbolic level. This lack of integration of the three modes of representing phenomena results in the fragmentation of concepts in long-term memory, and is an impediment to meaningful learning. A probable result of this is that students memorize content for a test, and then rapidly forget it soon thereafter.

What are the implications of this for teaching? Does the direction of chemistry education need to change? This is dependent on the level of the state standards, on particular textbooks in use, on teacher preparation, and on testing.

How People Learn

Two theories of how people learn have implications for teaching. These are the Information Processing Model on how information is processed in the brain, and the Social Constructivist Model on how the social interaction with teachers and other students assists a person in understanding.

In the Information ***Processing Model*** as noted by Baddeley (1991), events, observations, and instructions are first perceived by the senses (sight, hearing, smell, taste, and touch) and pass into short-term memory for a short period of time where they are interpreted, rearranged, compared with other concepts, and prepared for storage in long-term memory. They are then stored in long-term memory either connected to other concepts to which they are related (sometimes branched, sometimes in separate fragments), or as a single entity. They can be retrieved as single entities or in their branched state. Novices have under-developed groupings of concepts whereas experts have complex groupings. These can be thought of as ConceptMaps. Experts are thought to have complex ConceptMaps whereas novices' ConceptMaps contain fewer related concepts. As additional concepts are presented to a person, these new concepts can enhance an existing cluster of concepts stored in long-term memory making it more complex, or can exist independently.

An expert in chemistry can more readily make connections between matter observed on the macroscopic level with matter as it exists on the particle level, and can also represent that matter on a symbolic level than a novice. If an expert observes water, he/she may think of it in its three states: a clear or cloudy ice cube or block, a colorless liquid, and a non-visible vapor on the macroscopic level. Simultaneously he/she will think of molecules composed of hydrogen and oxygen atoms in a ratio of two hydrogen bonded to one oxygen at an angle of 104.5° on the particle level, and represented by the formula, H_2O on the symbolic level. In addition, he/she will be able to think about the uses of water, the percentage of water in the universe, the decomposition of water, etc. At the other extreme, a young child will think of it as a colorless liquid that is safe to drink. As the child ages and becomes more educated, he or she will eventually will become more like the expert in terms of the clusters of concepts that are organized in long-term memory in the brain about water.

ConceptMaps have an important place in curriculum development in the United States. The American Association for the Advancement of Science in collaboration with the National Science Teachers' Association published a book in 2001 entitled *Atlas of Scientific Literacy (2001)*. It contains numerous ConceptMaps that are useful in curriculum development.

The ***Social Constructivist Model of Learning*** addresses how social interaction of students with teachers and with other students enhances learning, that is, facilitates the formation of these clusters of concepts in the brain. The model consists of four main parts as outlined by Krajcik(1991):

1) Students describe their own understanding.
2) Students modify their own understanding in one of three ways:
   a) Students and teachers exchange and clarify understanding,
   b) Students are exposed to conflict situations through discrepant events.
   c) Students construct new understanding.
3) Students apply the new understanding.
   a) Students construct new linkages between concepts.
4) Students compare new understanding with pre - vious understanding (shown as #1 above).

Earlier in this article, a demonstration of the sinking/floating of different size pieces of margarine when placed in identical glasses of water was described. This demonstration in which the audience was involved, was deliberately placed at the beginning of the lecture on which this paper is based, because it illustrates so well, what is involved in learning. First, it illustrates a ***Social Constructivist View of Learning*** by having participants interacting with one another, and second, ***The Information Processing Model*** of storing the information in long-term memory.

Learning involves active participation. In the case of the sinking and floating of margarine, persons attending the lecture were asked to discuss what they thought was going to happen with the person sitting next to them when the small pat of margarine was placed in the water. They then noted what happened. Fol - lowing this, persons were asked to predict what would happen if a large piece was placed in the water. They also discussed this with a small group of people. Many people thought that the large piece of margarine would sink. After the demonstration when they noted that it floated, they were asked to explain why the result was the same. Persons again inter - acted with the persons sitting around them in provid - ing an explanation. Learning occurred through so - cial interaction.

Hopefully, the information that was acquired through the social interaction of others resulted in the finding being stored in long term memory. If a similar experiment was done by the participants with large and small paper clips, and participants were asked about sinking and floating behavior, they should give a correct answer. Most everyone's long-term memory would now contain the appropriate linkages so that he or she would know that neither the size of the paper clips, nor the number you had, if they were all made from the same material would act the same way. They would all either sink or float when placed in a container of water, and they would be able to explain this without having to do the activity!

Basing Instruction on Learning Theory

In teaching science or any other subject it is impor - tant to structure to instruction on what is known about learning. At Indiana University a three credit-hour general science course for prospective elementary teachers. It is entitled *Introduction to Scientific Inquiry*), and was created and modified over time to take into account how people learn. About 300 students initially enroll in the course, with about 5 to 10% testing-out each semester through a test-out system.

One of objectives for teaching this course for prospective elementary teachers is not only to increase these students knowledge of chemistry, but to model how science should be taught, (particularly chemistry) to children. The teaching techniques used in this course are interactive and appropriate for teaching science at the middle school, high school, and college levels.

Students sit in groups of four at six lab tables. Each new concept is introduced using a ConcepTest using the schema introduced earlier. These are not graded, but are used to inform students immediately about how well they already understand a given concept. This same information is given to the in - structor who can modify instruction accordingly. After a brief orientation to the topic, students work in their group of four, with each student serving a different role, as is common in cooperative learning. These are: facilitator, recorder, spokesperson, and technician/equipment manager.

The course utilizes two texts developed by the author. One is entitled *Introductory Science Skills (1993)* published by Waveland Press, Inc., and the other, *Active Learning Strategies: Science Process Skills, Inquiry and the Nature of Matter (2005)* published locally by Tichenor. The latter is chemistry-oriented, because even though students must have obtained a "C" or higher in high school chemistry as a pre-req - uisite for admission into Indiana University, most students do not pass the chemistry pre-test for the course.

The Active Learning Strategies text contains 15 ConcepTests relating to chemistry. These include: Observation, Inference and Prediction, Length and Area, Surface Area and Volume, Accuracy and Precision, Variables and Operational Definitions, Graphing, Scientific Notation, Direct Proportion and Slope, Direct proportion, Inverse Proportion, States of Matter, Substances, Changes of State, Mixtures, and Chemical/Physical Changes.

This same book contains ten experiments that are called CAps, Chemical Applications. The format used is very open-ended and is designed for students to work in groups of four. A question is proposed and equipment is listed. Then students respond to four questions: **1.** What do you think? **2.** What does your group think? **3.** What does the group observe? **4.** How does the group interpret the results?

Titles of the Chemical Applications are: Sinking and Floating; What Processes Occurred?; Classifying Materials; Viscosity and Density; Burning a Candle Under a Jar; Estimating Particles; Increasing the Rate of Dissolving; Explaining Floating and Sinking; Mixtures or Substances; and Factors Affecting the Evaporation Rate. The last activity is done individually at the student's place of residence over a five week period, and presented to the class at the end of the semester. It is used as part of the final exam for the course.

The final section of the book focuses on the students' construction of models using Play-Doh to provide explanations of chemical phenomena and changes matter undergoes. Students then record their models as two-dimensional particle pictures. Students make models to explain: States of Matter, Separation of Liquids, Burning, Solutions, Density, Chemical Decomposition, Mixtures, Balancing Equations, and Predicting Evaporation Rate.

During the entire course students are actively working with one another and involved in their own learning. The course focus is on the macroscopic and particle levels, although toward the end of the course, particles are represented symbolically and students learn to write formulas and balance equations by going from the particle representation to the symbolic representation.

If students came to the University having a good background in chemistry, such a course would not be needed, and it could possibly be phased out. However, at this time, this does not appear to be the case. Even if students did know all of the chemistry that is included in the course, the course serves the additional purpose of modeling teaching techniques that prospective teachers can use in their own elementary, middle school and high school classrooms. At Indiana University, we try to help students understand the chemistry needed for teaching science at the elementary level, while simultaneously modeling the interactive techniques that they should be using as an elementary school science teacher.

The Influence of Textbook Publishers onTeaching

One of the major problems in the implementation of the current National Science Education Standards in the United States is that the Standards are written to be minimal. This is interpreted by most states to mean that instruction must go beyond the minimum that is included in the National Standards so that students in the US will excel in science. This is particularly true in states of large population such as California and Texas that have a great influence on textbook publishers because of large number of textbooks purchased in their states. In addition, it appears that many textbook authors of elementary, middle school and high school science books are college professors who appear to be unaware of what the average child is capable of learning in the limited amount of time allotted to school science.

Hence, textbooks sometimes include advanced topics that are not included in the National Standards, but are included in the State Standards.

For example, in a presentation given by a college professor at a session on teaching chemistry to children at a recent national conference on chemical education, the speaker indicated that the "particle nature of matter" was appropriate content for fourth graders. Although some children at this age level might understand the particle nature of matter, one needs to consider whether teaching it to the whole class is appropriate.

If the majority of students do not understand a given topic, or if a topic takes an inordinate amount of time to teach, the topic should probably not be included in curriculum at that grade level. If it takes a month to teach a general science class of ninth graders to learn to write correctly balanced chemical equations when given the names of the reactants and products, then this topic is not appropriate for this grade level. Otherwise many students will develop a negative attitude toward chemistry because they think that they are not smart enough to learn it! In addition, there are so many interesting things in chemistry on the macroscopic level that all children can enjoy learning, why not spend the science instructional time on these?

The National Standards in the US for chemistry were developed by the American Chemical Society that sought the advice of persons across the US, and are very appropriate for the US population. Hopefully, the Standards for the elementary grades in Mexico are also appropriate. If pictures of the electron-cloud model of the atom appear in a fourth-grade textbook in Mexico, such as can be found in one textbook series in the US, you can conclude that the direction of science education needs to change!

Elementary School Science Programs

In the US, there are least two excellent programs in science education at the elementary level (grades 1-6). The production of each was partially supported by the National Science Foundation. They are FOSS, the Full Option Science System, and STC, Science andTechnology for Children. Both programs engage children by using a hands-on-approach, and are developmentally appropriate. Both are currently published by Delta Education.

There are many other elementary textbooks on the market. Many of these are accompanied by kits that children can use to do a variety of experiments. Unfortunately teaching science by having children read and memorize the textbook is not uncommon in many elementary schools in the US. Much work still needs to be done at the elementary level to give children positive experiences that continue to foster their enthusiasm to learn about the world around them.

Middle School Chemistry Programs

At the middle school level, STC also has an excellent program for children in grades 6-8. It stresses the macroscopic properties of matter and changes that matter undergoes and carefully introduces symbols but does not focus on the particle and symbolic levels of chemistry. FOSS is in the process of creating a middle school program with a unit on chemistry. My initial review of the textbook was that it goes beyond the National Science Standards in representing the particle nature of matter, and symbolic representation of chemical change having students predict products of chemical reactions and write balanced chemical equations for the reactions. This is generally thought to be even too complex for most ninth grade students! Hopefully the book has been modified before going to press!

High School Chemistry Programs

At the high school level, the American Chemical Society has just completed the development of the fifth edition of ***ChemCom, Chemistry in the Community.*** Previous editions have been very appropriate for the majority of high school chemistry students in the US. The textbook balances content with applications and shows the importance of chemistry in everyday life.

Many high school chemistry teachers reject the book because they do not view it as suitable for high school students who will go to college. This author's view is that, little do these high school teachers realize, that they are actually discouraging most students that enroll in high school chemistry from ever taking a college chemistry course. This occurs because students do not understand much of the chemistry presented to them in the traditional textbooks now on the market. Consequently they memorize the material for a test, and then quickly forget it, thus limiting their career choices to those not requiring knowledge of chemistry

One of this author's hobbies has been to interview persons with whom she sits when traveling alone by airplane to meetings, etc. about their high school chemistry experience. Only one out of about ten persons that has been asked if they took high school chemistry, and liked it, has ever given an affirmative response!

The major change in the reform of the 90's from the reform of science education in the 60's, is that students should be able to give explanations of the phenomena that are observed. Giving explanations is linked to understanding, which probably does not occur in an overloaded curriculum!

Expansion of Knowledge of Chemistry

The history of chemistry has much to tell us about the textbook situation that we are in today. During a span of only 37 years, many scientific "discoveries" have been made in chemistry. These include:

- 1766 Cavendish: Discovery of hydrogen by determining its density (1/4 that of air).
- 1780 "Phlogiston theory".
- 1789 Lavoiser: Elements of chemistry "33" elements.
- 1803 Dalton: Law of Multiple Proportions, OO and OOO.

Today scientific discoveries are occurring at even a faster rate than in the past. The questions is, “How much content can a student learn in one academic year and not be turned off to chemistry?

A few years ago, this author (a co-author of a very popular high school chemistry text over which the publisher had full control of the topic order, etc.) made a comparison given below of two high school textbooks . The content of the textbook used in her high school chemistry course that “she didn’t understand very much” and the content of a textbook of which she was a co-author. They were published 45 years apart.

The table below speaks for itself. How can we expect high school students to learn all of this chemistry in high school today when the content has about doubled and the time students spend in high school chemistry classes has decreased significantly. In the 1950s, it was common for students in most high schools to spend 300 minutes per week in class studying chemistry. They had three 42 minute periods of “lecture” plus two double periods of 87 minutes in the laboratory. At the present time, most students spend five 50 minute periods per week (250 minutes) in their chemistry class including lab. It seems quite unreasonable to expect that students today will learn twice as much chemistry in about 83% of the time as students taking chemistry a half century ago! It even may be more of a problem today, because the high school textbooks probably contain more information than they did fourteen years ago!

Comparison of Chemistry: A Course for High Schools, NY: Van Nostrand, 2nded., 1947 with *Chemistry:* The Study of Matter, *Englewood Cliffs, NJ:Prentice Hall, 4thed., 1992*

	Text (1947)	Text (1992)	Ratio (1992/1947)
No. of Pages	555	816	1.47
Area/Page	340 cm^2	500 cm^2	1.47
Information			2.16[1]
Glossary Terms	162	580	3.58[2]
Space/Term			0.60[3]

[1] Considering the space in the textbook, there is 2.16 times more information in the 1992 textbook as compared to the information in the 1947 textbook.
[2] Considering the terms in the glossary, there are 3.58 more terms in the 1992 textbook as compared to the number of terms in the 1947 textbook.
[3] Considering the amount of space per term available in the textbook. Students will learn /understand the content in 0.6 of the time allotted to learning only 45 years ago.

College Chemistry Programs

At the present time, there are numerous college chemistry textbooks on the market for use in introductory chemistry courses. They also have become increasingly complex. Recognizing that this was the case, and that not all students who enroll in an introductory college course will major in chemistry, or pursue a major that requires a deep understanding of chemistry, the American Chemical Society supported the publication of a college chemistry textbook entitled: **Chemistry in Context: Applying Chemistry to Society**. It is published by Wm. C. Brown, 1994.

This textbook contains thirteen chapters that relate chemistry to the real world. It is an off- spring of Chemistry in the Community, and is intended for non-science majors to promote chemistry literacy. As indicated in the Preface, the text presents information as it is needed to inform the reader about issues that are chemistry-related in everyday life. Chapters include: “The Air We Breathe, Protecting the Ozone Layer, The Chemistry of Global Warming, Energy, Chemistry, and Society, TheWonder ofWater, Neutralizing the Threat of Acid Rain, Onondaga Lake: A Case Study, The Fires of Nuclear Fission, Solar Energy: Fuel for the Future, The World of Plastics and Polymers, Designing Drugs and Manipulating Molecules, Nutrition: Food for Thought, and The Chemistry of Tomorrow. The text is contains about 404 pages with 183 terms in the glossary. Other chemistry textbooks for this same audience have been published. For example, ***World of Chemistry***, published by Saunders College Chemistry, 1991, has 759 pages, contains 22 chapters, and has no glossary.

Because it appeared that a comparison of college chemistry textbooks over a 50 year span might be an indicator of how college chemistry instruction is changing over time, five textbooks with copyrights from 1945 to 1959 were compared to five textbooks from the mid- to late 1990s to 2005. All the textbooks of a given era were approximately the same length and width. They varied significantly in their weight, and number of pages. No comparisons could be made about the glossaries because none of the course textbooks in the 40’s and 50’s that were compared contained glossaries.

The ratio of the increase in content of the book over a 50 year span can be estimated by the ratio of product of the surface area and the number of pages in the text (1.66) or perhaps by comparing the mass/book appears (1.85). Neither estimate takes into account the additional space that is used for photos, charts, and graphics that are more plentiful in later editions.

Although this short study was not scientifically conducted by random selection from all textbooks published during each time frame, but from a limited number of textbooks available from the Indiana University library, results may not represent the true picture. It is interesting, none the less, to note similarities between the comparison of the above table with the table presented earlier for high school chemistry textbooks. Both studies show that there is a considerable increase of content contained in the texts over the fifty year period. One wonders how this will progress over the next 50 years, and if so, how chemistry instruction might be re-configured so that it remains within reach for the ordinary student!

The focus of most of the reform in chemistry education at the college level over the past 10 years is not in the creation of textbooks containing more content, but in modifying how chemistry is taught. In addition to the greater use of technology in teaching and compact discs, Dvds, videotapes, etc, there has been a concerted effort by the chemistry community to reform how chemistry is taught by making it more interactive. The most comprehensive reform has occurred with NSF funding in the mid -1990s with the funding of the Multi-Initiative Dissemination (MID) Project of innovations in chemistry instruction. This program created a variety of ways to help students (1) learn to reason through problems rather than relying on algorithms, (2) make connections between chemistry concepts and the real world, (3) get actively involved in discovery and inquiry about chemistry, and (4) engage in the process of doing science. Four main programs are involved: New Traditions, Peer-LedTeam Learning, Chem Connections, and Molecular Science. More information can be obtained from www.cchem.berkeley.edu/~midp/

In conclusion, the title of this paper is: ***Chemistry Education, Kindergarten through College: ShouldWe Be Changing the Direction of Where It Is Going?*** This question can be answered in the affirmative for teachers who are expecting too much of their students, and try to "cover the textbook". Many teachers have begun to change science education in the United States in a positive way. What needs to happen is that more teachers at every level modify their instruction making it more active, selecting topics related to the real world and to interests of students, and to their students' developmental level.

Comparison of College Chemistry Textbooks in the Mid 1950s and 2000

	(1945-1959)	(1995 - 2005)	Ratio
Average			
Length/page	24.0 cm	26 cm	
Width/page	18.5 cm	21 cm	
Surface Area	445 cm^2	546 cm^2	1.23
Mass /book	5.7 kg	10.9 kg	1.85
Pages/book	676 /book	914	1.35
Pages $\times$ SA	300,820	488,044	1.66

Problems still exist with the large quantity of chemistry knowledge that teachers present to students. With the large influx of knowledge, it may be that students will need to specialize in a given area of chemistry earlier. Chemistry educators need to continue to think of creative ways to enhance learning. The last thing that we want to do is to promote the image of school shown in a cartoon in which one student says to another "one thing school is good for, ruling out possible careers! Last week it was math, today it's science."

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