

Student Success in Recognizing Definitions of Eight Terms Found in Fourth Grade Science Textbooks

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Abstract

Continued Professional Development (PD) efforts for science teachers in Iowa have occurred over the 1982 – 2004 years. Teachers have comprised over half of the staff in the PD program while also being partners with action research projects. This is a study of student recognition of key terms across 4th, 8th, and 12th grades for classes taught by a team of the teachers at five year intervals over the 1985 through 2000 academic years. Results indicate that there is no increasing success with such recognition over the grade levels sampled or any major changes over time. But, interestingly more use of the NSES and more focus on real world contexts for science study did not result in any less recognition of the science vocabulary words selected.

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A major research project supported by the National Science Foundation and conducted at the University of Northern Illinois was concerned with factors affecting an “attentive public” regarding science and technology. The research was headed by Jon Miller, a political scientist, and assisted by a sociologist and a science educator (Miller, Suchner & Voelker, 1980). Science attentive persons were defined as persons exhibiting 1) interest in science, 2) knowledge of science, and 3) the ability to increase both. To assess the knowledge dimension the researchers chose four science terms for use with a large national sample of 3000 secondary school students (grades 10-12). The terms selected were molecule, amoeba, DNA, and organic chemical. A striking finding was the fact that secondary students showed no growth across high school grade levels in defining the selected terms (Voelker, 1982). Further, the percent of students who were able to demonstrate mastery was unexpectedly low. For example, only 40% of the students could demonstrate knowing and understanding “amoeba” and “DNA”; 25% could demonstrate knowing the term “molecule”; and only 20% could demonstrate understanding the term “organic chemical”.

Past research has focused upon excessive use of words and terminology in science teaching as well as using them as indicators of student learning (Hurd, Robinson, McConnel & Ross, 1981; Yager, 1983; Yager & Yager, 1985). Often science classes have been places where new (and strange) words are taught as the major outcomes of instruction and used as major indicators of student achievement and as evidence of teacher success. Teachers and other leaders often start their planning with the assumption that learners first need the technical vocabulary before they can do science! Interestingly, the focus on new and technical words in science classes surpasses the introduction of new vocabulary in foreign language classes. Often examinations in science stress the mastery of specific terms (Stake & Easley, 1978). The Project Synthesis research reported that 90% of all K-12 science teachers emphasize only mastery of science content (largely by remembering terms) in excess of 90% of instructional time (Harms & Yager, 1981).

K-12 science curricula remain mainly focused on conceptual and factual information. Most teachers and students view science as a body of facts, a collection of formulas, and directed problem-solving methods, all disconnected from the daily lives of students. Evidence of learning is too often based on memorization (NRC, 2007; Seymour & Hewitt, 1994; Trumbull & Kerr, 1993). Most of the typical achievement measures in science during the 80s depended on a special and/or technical vocabulary; there was also great focus in science textbooks upon science terminology and italicized words. At times learning seemed wholly dependent upon mastery of such special science terms. And yet, linguists concerned with vocabulary per se insist that terms are meaningless unless there is first meaning and use established for them (Dale, 1962).

Terminology is best learned when there is a need – often to explain some complex structure or phenomenon. A recent National Research Council report indicates that current approaches for science instruction for young and novice learners may actually be counterproductive (NRC, 1996, p 13). For example, limiting them to learning about discrete science facts without opportunities for discussion, reflection, or direct investigation of the phenomena can lead to a very impoverished understanding of the ideas. Developing expertise in science means developing a rich interconnected set of concepts that move closer and closer to resembling the structure of knowledge in science disciplines found in colleges. Memorizing lists of established scientific facts does not provide the kind of engagement with ideas that will produce rich and interconnected knowledge nor does it help students reason (NRC, 2007, p 338).

Recently Marzano (2004, 2009) has reviewed the research dealing with vocabulary instruction. He maintains that teaching vocabulary improves if a six step process is used. These six are: 1) provide a description, explanation, or example of the new term, 2) ask students to restate the description, explanation, or example in their own words, 3) ask students to construct a picture, pictograph, or symbolic representation of the term, 4) engage students periodically in activities that help them add to their knowledge of the terms in their vocabulary notebooks, 5) periodically ask students to discuss the terms with one another, and 6) involve students periodically in games that enable them to play with terms. Such instructional protocols reach beyond teaching and learning of special vocabulary in isolation.

In many respects the Iowa teachers provided real contexts and classroom practices that were/are the STS features central to Chautauqua, SS&C, and Title IIa projects. These features not unlike the teaching suggested by Marzano include: 1) student identification of problems with local interest and impact, 2) use of local resources (human and material) to locate information that can be used in problem resolution, 3) active involvement of students in seeking information that can be applied to solve real-life problems, 4) extension of learning beyond the class period, the classroom, the school, 5) focus on the impact of science and technology on individual students, 6) viewing science content as more than concepts which exist for students to master on tests, 7) emphasis on process skills which students can use in their own problem resolution, 8) emphasis on career awareness – especially careers related to science and technology, 9) opportunities for students to experience citizenship roles as they attempt to resolve issues they have identified, 10) identification of ways that science and technology are likely to impact the future, and 11) experiencing some autonomy in the learning process (as individual issues are identified). (NSTA, 2008-09, pp. 242-243)

Marzano's work puts a different spin on learning technical terminology. Instead it is how teachers teach and how they involve students in thinking and actions rather than assessing what they are asked to memorize, often by merely recognizing correct definitions. The NSTA view of STS instruction is similar.

Certainly the reform efforts from the 1980s and beyond have focused on other aspects of science, especially on the process skills scientists use to increase understanding of the objects and events in the natural universe. One elementary program, Science – A Process Approach (SAPA), identified 13 skills used by scientists and organized them as the focus for a whole K-8 program (AAAS, 1965). The SAPA program influenced other elementary science curricula and textbook publishers by focusing on general procedures rather than helping students build frameworks of integrated science concepts and processes (NRC, 2007). Students were asked to perform many science activities, making observations and reporting measurements without understanding what they did nor why they did it. Understandingly students often fail to develop meaningful understandings as a result of such programs. Another criticism of SAPA (a process only focus) is that it was based solely on developmental assumptions about student reasoning and learning capacities (Metz, 1995; NRC, 2007).

Generally students enjoyed “learning” the skills – but often their use in any other contexts did not occur. Few attempts to *unite* science concepts with processes were undertaken until the development and release of the National Science Education Standards (NRC, 1996). The NSES reported this “unification” as one of eight facets of science content – and perhaps the most important.

It is clear that the NSES as released in 1996 was much about de-emphasizing special science vocabulary while also providing a rationale for discontinuing the major focus on mastery of basic “discipline-bound” concepts. There also is now a new focus on not considering concepts and/or processes singly and without meaningful contexts. This situation led to the research central to this study. Are there changes in student abilities to

know and understand basic terms over the years following the 1983 and 1985 studies (Metz, 1995; Yager, 1983; Yager & Yager, 1985)?

This study was possible because of the longevity of professional development efforts for PreK-12 teachers in Iowa, beginning in 1983 with the Iowa Chautauqua Program (later merging with the \$4 million Scope, Sequence, and Coordination (SS&C) project which was one of the six state efforts also coordinated by the National Science Teachers Association (NSTA). The Chautauqua program was funded in Iowa following the NSF funding for it through 1998 followed by three Title IIa projects utilizing the same format and focus on instruction. This means data collected from Iowa teachers enrolled in the programs from the first efforts in 1982 to the current efforts in the international arena. One unique facet of the Iowa professional development program is the involvement of teachers as full partners in heading the summer workshops and the annual follow-up short courses (3 day workshops in October and a second in April) – and often over a three-year interim. All staff (and teachers) enrolled are routinely engaged in multiple action research projects. Also of importance is the fact that both Chautauqua and SS&C were assessed and approved by the U.S. Department of Education’s Program Effectiveness Panel (PEP) which was the precursor for funding and dissemination to other states and regions as part of the U.S. Department of Education’s National Diffusion Network (NDN).

The Iowa programs encourage teacher involvement in Action Research. One of these collaborative efforts was a follow-up of the Miller, Suchner, & Voelker (1980) work dealing with mastery of textbook terms. It was common to include the same terms used in the early work. Other features of the Iowa professional development effort included the Science-Technology-Society reforms that utilized the six domains for teaching, learning, and assessment (Yager, 1996). This research has focused on concept and process mastery, creativity and attitude as “enabling” domains, a major focus on application of concepts and skills in new situations – inclusion of technology (the human-made world) as well as pure science, and finally, a focus on the history and nature of science. These are all important and tend to de-emphasize the major focus in most K-16 classrooms as curriculum structures that characterize textbooks and state standards. They also focus less on terminology per se.

This larger context is mentioned to give more reason and a setting for a study looking at concept mastery as related to recognition of accurate definitions of eight terms. Those used by Miller, Suchner, & Voelker (1980) and five others used early in Professional Development projects in Iowa provided the sample of terms used in this study. Actually as many as 50 other terms for varying concepts have been used by groups of teachers over varying time frames. They have produced other results indicating the fate of less focus on such terminology – even when it was not a primary focus of teaching in the Iowa professional development programs. State testing and historical focus for most traditional teaching of science was affected by the “vocabulary first” idea. The use of such terminology in introductions for textbook chapters that define the curriculum seem to continue in spite of the many current reforms efforts.

The eight terms were the ones selected by Teacher Leaders. This study provides a look at changes in student performances over time. Although this study is focused on data collected from PEP reports, NDN experiences, and reports to NSF officials, it is used here to illustrate what has happened over the fifteen year period with respect to recognizing accepted definitions of eight science textbook terms.

Specific Research Questions for this study are:

- 1) How do 4th, 8th, and 12th grade students compare when selecting the most accurate definitions for eight terms found in 4th grade textbooks?
- 2) How does the ability of students to recognize such “correct” definitions change over a 15 year interim?
- 3) How do the findings affect and/or negate the reform agenda indicated in the National Science Education Standards? (As illustrated by less and more emphasis conditions related to teaching, PD, assessment, and content)?

Methodology

The research instrument was developed by selecting eight science terms – 3 from the original Miller, Suchner, and Voelker study in 1980 and also included in a 1985 study involving teachers in one large school district in Iowa where no teachers were enrolled in any long range professional development programs (Yager & Yager, 1985). Teacher teams helped develop the four distractors for the multiple choice items which were selected from a typical fourth grade textbook. The distractor items came largely from students who shared their misconceptions in actual classrooms.

Some teachers used the misconceptions to plan additional learning activities. Some of these efforts were used to define, to improve, and to verify successes with the STS reforms which were described and published in a SUNY Monograph in 1996 (Yager, 1996) and in the current NSTA Position Statement regarding STS (NSTA, 2008-09, p. 242). The information regarding program effects on students all became important data for gaining approval by the U.S. Program Effectiveness Panel (PEP) as well as data for annual reports to NSF and summary reports for each funding period to share with all teachers, administrators, and parents.

The questionnaire consisting of personal information and the 5-choice options for definitions of the eight terms was administered to students randomly selected in homerooms by homeroom teachers in each school where teachers were willing to collaborate. Teachers for 4th graders were permitted to read each item for students when there were reading problems as has been the situation for the samples used by the National Assessment of Educational Progress (NAEP) nationally.

The eight terms selected for the study were selected from 4th grade textbooks with the following definitions:.

Volume – amount of space inside an object;

Organism – any object that is alive;

Motion – a change in position of an object;

Energy – what makes objects in a system interact;

Molecule – smallest unit of material that has the original features of the material;

Cell – small building units of living things;

Enzyme – substances which control all chemical changes in living systems;

Fossil – any evidence of past life.

With the initiation of the Iowa Chautauqua Professional Development Project in 1983 (orchestrated by NSTA and funded by NSF), five centers were typically established each year at sites across the state where enrolled teachers were invited to sample their students at the three grade levels similar to efforts by the National Assessment of Education Progress dealing with concept mastery and their first efforts with a focus in the affective domain (NAEP, 1978). Information was collected prior to direct experiences with the Chautauqua workshops over a summer -- often continuing for three consecutive academic years. Some of these studies looked at differences across grade levels as new teaching strategies were developed and used. Using social issues as organizers was criticized by science educators because of the lack of focus on basic science concepts. There was interest in seeing if such new instructional emphases resulted in less concept mastery and/or less ability to recognize accepted definitions. Of course some could (and do) criticize that the recognition of correct definitions of science terms has little to do with student understanding and ability to use the terms in other situations.

Iowa SS&C, which operated from 1990 through 1997, included all science teachers in 20 Iowa districts where the key teachers helped to convince all teachers and school administrators to be involved in such a national reform effort. Teachers and students were initially selected first from middle schools – the focus for the SS&C project. Many of the central staff members for Iowa SS&C were teachers involved during the Chautauqua Project, 1983-present. It is interesting to note that the focus on science terminology as such diminished radically over the 1985-2006 interim (Kimble, 1999). Data collection continued, however, because of the interest on the part of many teachers concerning results that were initially reported in 1985.

The Chautauqua program, the Iowa SS&C, and the continuing Title IIA workshops were all professional development projects designed to help science teachers develop their own learning processes through inquiry teaching and learning (Dass & Yager, 1999). The programs were designed for in-service science teachers in grades K - 12. However, the participants in the programs were working together in cooperative learning groups to create science inquiry activities that arose from participants' questions, curiosities, and experiences. The programs emphasized learning science content using

inquiry activities that were student-centered (actually proposed, planned, and carried out by students). Moreover, they all focused on a model for inquiry-based science instruction with the teachers inquiring about their own teaching. The primary goal of the professional development was to increase the skills of in-service science teachers of science by indicating needed systemic changes in science instruction in the classrooms of all participating teachers. Basic to all the projects was the idea that teachers need to collaborate with both their students and with each other as well as with school administrators, parents, and community leaders as improvements and changes are planned. A return to a focus on major science terms seemed important to pursue where the teaching approach moved to little or no focus on such terms per se. Learning was defined more basically as evidence for successes on outcomes other than concept mastery. Instead the major focus became ability for students to use their ideas and skills which were too often merely listed in curriculum outlines, textbooks, and state standards. Often research can and has focused on much more important instructional outcomes than defining textbook terms.

This research effort included administering the instrument to students to learn of their successes with selecting correct meanings for the eight terms from randomly selected classrooms by teachers not registered for earlier P.D. Programs in Iowa. The 1985 research was replicated for each of the four years (1985, 1990, 1995, & 2000). New teachers and samples of students from at least one classroom of teachers were selected by Teacher Leaders at sites across Iowa. Table 1 indicates grade levels as well as numbers of teachers and students comprising the sample for this study. Other smaller teacher-generated studies were conducted at the school sites and in other schools in addition to those involved in this study with data collected at five year intervals between 1985 - 2000.

Table 1. Teachers and Students Involved with Choosing Correct Definitions of Science Terms over the 1985-2000 Interim

Year	Grade Level	Number of Teachers	Number of Students
1985	4	50	1480
	8	23	690
	12	21	720
1990	4	37	840
	8	21	643
	12	26	712
1995	4	33	870
	8	24	472
	12	26	486
2000	4	40	911
	8	31	842
	12	28	731

Results

The percentage of the students sampled at each grade level who were able to select the correct meanings for the eight terms is indicated in Table 2. Several findings emerge that are of interest. Perhaps most striking is the fact that there is no consistent growth in student ability to recognize correct definitions of selected terms. Eighth grade students outperformed fourth grade students on three of the terms (Volume, Molecule, and Cell). The differences (that tend to favor eighth graders) were often very small in several instances. Little increase in recognizing definitions of terms occurred for 8th and 12th grade students.

Table 2 indicates that 4th graders performed highest on the term “organism,” and lowest regarding the term “cell” over the 1985-2000 interim. Eighth graders performed highest on the term “volume”, lowest on the term “enzyme” over the 1985-2000 interim. Table 2 also indicates that 12th graders performed highest on the term “motion” in 1985, on the term “volume” in 1990, 1995, and on the term “organism” in 2000. They performed lowest on the term “enzyme” over the 15year interim.

Table II. Percentage of Students Selecting Correct Definitions for Eight Science Terms

Concept	4 th Grade				8 th Grade				12 th Grade			
	1985	1990	1995	2000	1985	1990	1995	2000	1985	1990	1995	2000
Volume	29	28	24	29	75	71	68	70	57	63	72	61
Organism	66	65	59	53	67	65	60	63	61	54	61	66
Motion	41	43	40	36	65	60	63	61	66	58	54	59
Energy	40	38	36	30	54	52	48	52	39	52	49	56
Molecule	25	20	18	12	54	40	50	47	53	47	47	49
Cell	15	18	16	14	46	38	44	40	44	42	48	41
Enzyme	23	20	20	18	24	19	20	19	21	19	24	19
Fossil	36	35	26	30	54	48	48	42	48	46	51	52

Line graphs were developed and included as Figures I through VIII. The graphs allow the reader to note visually the results and to focus on comparisons across the three grade levels for each term. Some general observations can be made.

Figure I indicates that 8th and 12th graders outperformed 4th grade students on the term “volume”. The 8th graders showed highest performance and 4th graders resulted in lowest performance regarding the term “volume” over 1985-2000 interim. During the study, 8th graders performed highest in 1985, and 4th graders performed lowest in 1995.

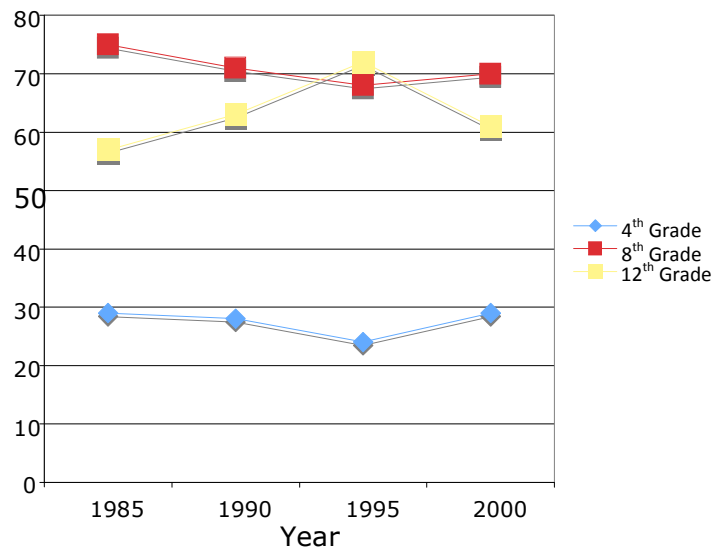


Figure I. Percentage of Students Selecting a Correct Definition for the Term “Volume”

Figure II indicates that 4th graders performed as well as 8th and 12th grade students on the term “organism”. The 4th and 8th graders performed highest in 1985 and lowest in 2000. The 12th graders performed highest in 2000 and lowest in 1990 over the 1985-2000 interim.

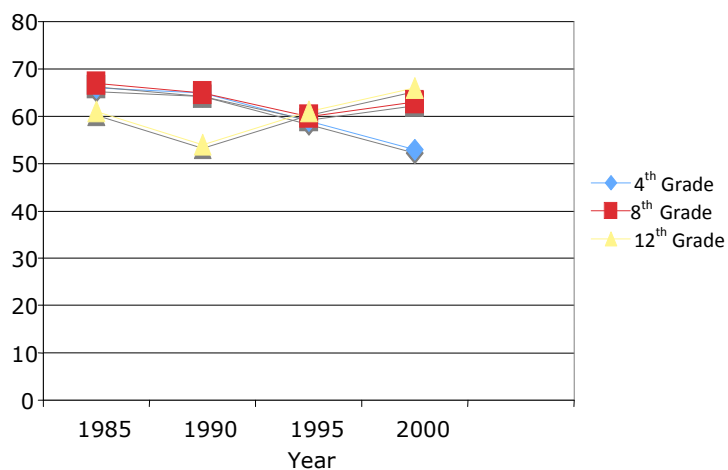


Figure II. Percentage of Students Selecting a Correct Definition for the Term “Organism”

Figure III indicates that 8th and 12th graders outperformed 4th grade students regarding the term “motion”. The 4th graders performed highest in 1990 and lowest in 2000. The 8th graders performed highest in 1985 and lowest in 2000. The 12th graders performed highest in 1985 and lowest in 1995 over the 1985-2000 interim.

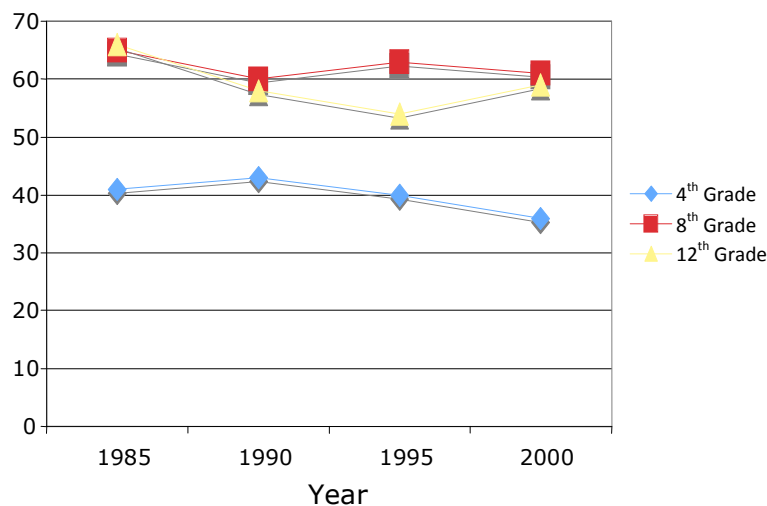


Figure III. Percentage of Students Selecting a Correct Definition for the Term “Motion”

Figure IV indicates that 8th and 12th graders only slightly outperformed 4th grade students with respect to the term “energy”. The 4th graders performed highest in 1985 and lowest in 2000. The 8th graders performed highest in 1985 and lowest in 1995. The 12th graders performed highest in 2000 and lowest in 1985 over the 1985-2000 interim.

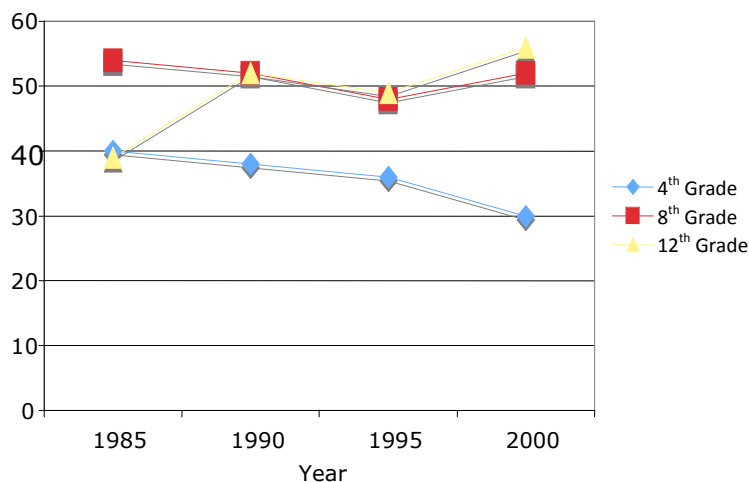


Figure IV. Percentage of Students Selecting a Correct Definition for the Term “Energy”

Figure V indicates that 8th and 12th graders only slightly outperformed 4th grade students regarding the term “molecule”. The 4th graders performed highest in 1985 and lowest in 2000. The 8th graders performed highest in 1985 and lowest in 1990. The 12th graders performed highest in 1985, lowest in 1990 and 1995 over the 1985-2000 interim.

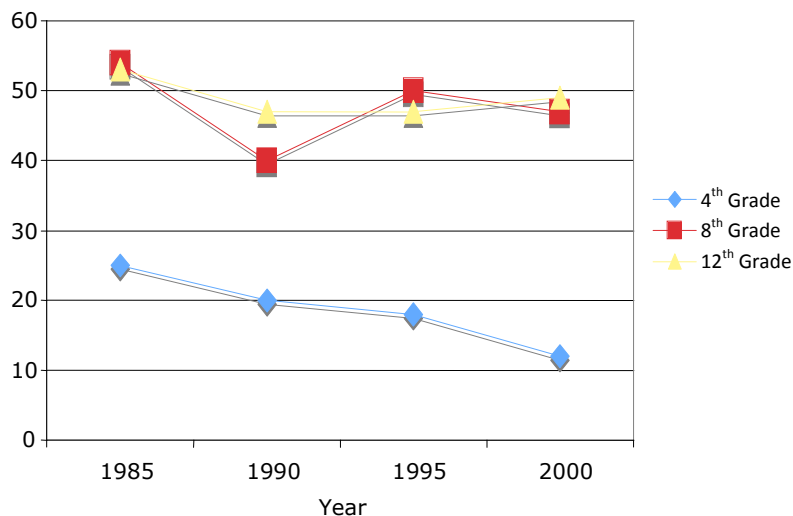


Figure V. Percentage of Students Selecting a Correct Definition for the Term “Molecule”

Figure IV indicates that 8th and 12th graders outperformed 4th grade students regarding the term “cell”. The 4th graders performed highest in 1990 and lowest in 2000. The 8th graders performed highest in 1985 and lowest in 1990. The 12th graders performed highest in 1995 and lowest in 2000 over the 1985-2000 interim.

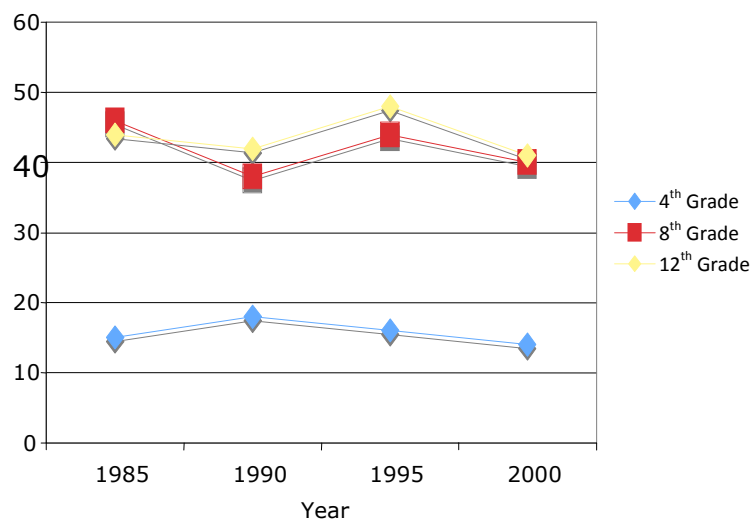


Figure VI. Percentage of Students Selecting a Correct Definition for the Term “Cell”

Figure VII indicates that 4th graders performed as well as 8th and 12th grade students regarding the term “enzyme”. The 4th graders performed highest in 1985 and lowest in 2000. The 8th graders performed highest in 1985 and lowest in 1990 and 2000.

The 12th graders performed highest in 1995 and lowest in 1990 and 2000 over the 1985-2000 interim.

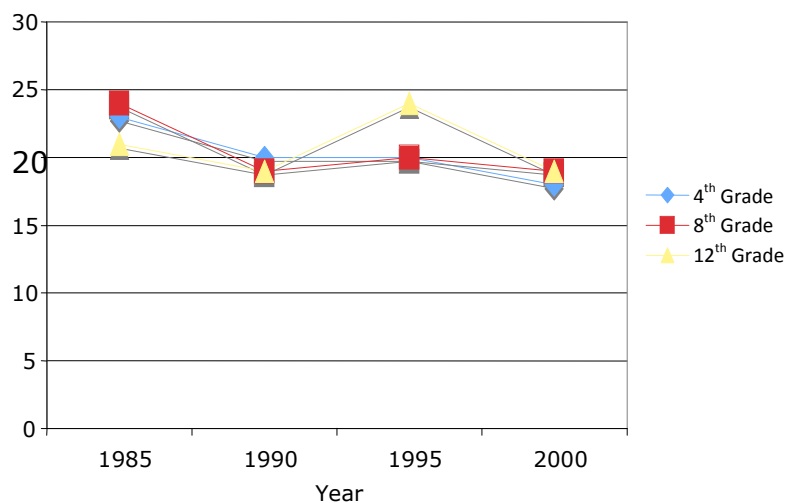


Figure VII. Percentage of Students Selecting a Correct Definition for the Term “Enzyme”

Figure VIII indicates that 4th graders performed as well as 8th and 12th grade students regarding the term “fossil”. The 4th graders performed highest in 1985 and lowest in 1995. The 8th graders performed highest in 1985 and lowest in 2000. The 12th graders performed highest in 2000 and lowest in 1990 over the 1985-2000 interim.

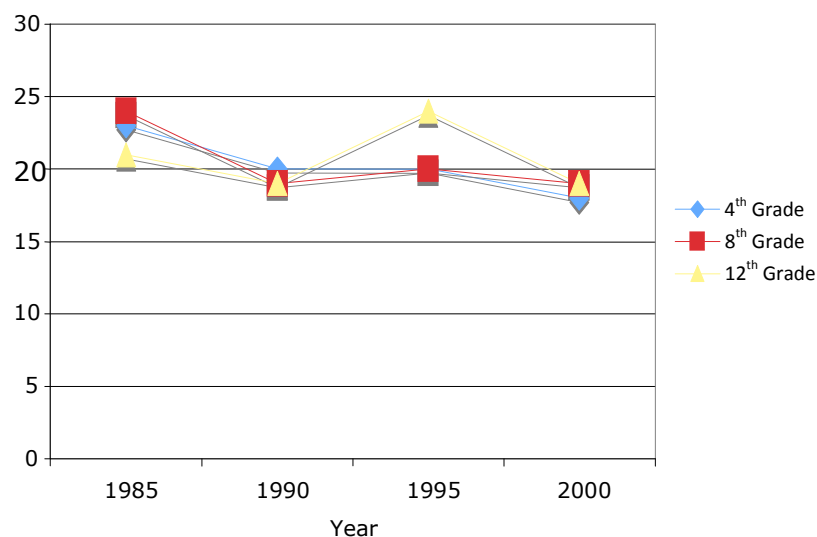


Figure VIII. Percentage of Students Selecting a Correct Definition for the Term “Fossil”

Discussion

Recent reform documents recommend new teaching and learning approaches to science education. The reason is that most teachers use the textbook as the major source for conveying information to students. While textbooks may include basic information about science subjects, they typically overemphasize vocabulary and factual information. Teachers feel pressured to make sure that students “get it all”. They often ask students to memorize specific words and facts (NRC, 1996, AAAS, 1997, p. 8). The results of this study suggest that merely recognizing accurate definitions of words and facts does not increase use of real understanding of the terms. More importantly perhaps is that a focus on local, current, and personal problems does not decrease student ability to recognize the definition of terms.

Overall, the results suggest that an emphasis upon vocabulary development is ineffective and/or misleading in terms of the recent reform objectives of the school science programs. In fact, it can be stated the school science programs for the students and schools studied seem ineffective in increasing real understanding and use of the selected science terms across the four through twelve grades. This experience was the first introduction to current efforts to change instructional focus. More information is needed concerning student ability to use the terms in completely new situations. It would also be of interest if information were not limited solely to textbook definitions and the teaching focus of the teachers as they were newly enrolled in a Chautauqua series.

The results of the study also indicate that help is needed for science teachers to realize the features recommended for improving science education that are set forth in reform documents, especially the National Science Education Standards. Teachers should be involved in helping develop strategies for promoting deeper and more meaningful understanding of science, including science terms. These strategies need to adopt new teaching and learning skills that stress science understanding rather than an over emphasis on rote memorization. They should help students move beyond the level of simple recognition of the meaning of science terms and concepts (NRC, 1996, 2007). Marzano's six points mentioned initially can help with fostering understanding and use of major terms (Marzano, 2009). But, these may not result in the teaching recommended by the NSES (p. 52).

More study is needed regarding varying contexts where teachers focus more than on the terms and their textbook meanings. Perhaps more attention to situations and reasons for use of the terms should be explored by more teachers. Interesting results and many differences among teachers (especially for the long-time teacher leaders) and new teachers involved with the professional development program could provide more insights concerning the data reported in this study. The important finding is that the perceived importance of “vocabulary first” is flawed. Perhaps meaning comes from using and developing the meaning in a variety of settings. Perhaps, too, the use of science concepts and process skills in new contexts may provide the best evidence that real learning has occurred! Certainly real world contexts make it easier to teach with the unification of process skills with science concepts as advocated in the NSES. Use can

provide evidence of real learning as well as the teaching features which encourage it to occur.

Summary and Conclusions

Eight science terms were studied in terms of their stated meanings in textbooks by 4th, 8th, and 12th grade students who were randomly selected from twenty school districts in Iowa. The results indicate that the students do not increase in terms of percentages who master the definition selected for the science terms, especially with respect to the 8th and 12th grades. Regarding the terms “organism”, “enzyme” and “fossil” 4th graders performed as well as 12th grade students. Teaching for such specific and continuing mastery of terminology is questioned by the results. The results diminish the importance for all students to know and be able to use technical language developed and used for convenience among practicing scientists. Students do not increase in their abilities to define the terms over the grade levels – and perhaps more importantly, no evidence has been provided for their use in school nor in life generally – across the grade levels.

In some cases some of the terms were used in studies of what happens in the same schools at the next grade level. Further study is planned regarding issues related to student ability levels, socio-economic levels of students, and gender.

In the last 50 years, there has been little actual reform in American education. Educational policies and programs have recommended significant changes, but classroom practices have not changed. Apparently, the practice and theory of reform do not coincide (Bybee, 1993). Real reforms in science education will occur only if teachers change their ideas about the meaning of science and their views of effective teaching (Yager, 2000). When teacher beliefs are incompatible with the philosophy of science education reform, a gap develops between the intended and the implemented principles of reform (Levitt, 2002).

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