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ABSTRACT

This project studied the effects of an inquiry-based, integrated science course on student science literacy. The course was aligned to state and national science standards. The target population consisted of sophomore, junior, and senior high-school students in an upper-middle class suburb of a major Midwestern city. Questionnaires, tests, and anecdotal information documented the problem of poor science literacy. Analysis of probable cause data showed students lack an ability to explain main ideas, develop main ideas with valid supporting statements, and critically read and analyze articles written for the general reader. Faculty reported that students were generally unaware of or misinformed about scientific issues and that they did not use critical thinking skills to analyze information and come to reasonable conclusions. Based on a review of current literature, using an inquiry-based, coherent, integrated approach to teaching science would help students see science as a discipline with connections among biology, chemistry, physics, and earth science. An inquiry-based approach would give students an opportunity to be apprentice sciences and practice the kind of thinking necessary for scientific inquiry. Analyzing science from the popular media-magazine articles and TV and radio programs would help foster an interest in real world problems and develop abilities to be scientifically literate citizens. Post intervention data indicated an increased awareness of scientific issues. Students improved their ability to explain and develop main ideas. They were able to read a science article more critically, identifying main points, explaining evidence, stating conclusions, and discussing their agreement or lack thereof with the conclusions. Students improved the quality of other questions they wished to answer about the issue and what officials might do to address the issue. (Contains 40 references.) (Author/SAH)

IMPROVING STUDENT SCIENCE LITERACY THROUGH AN INQUIRY-BASED, INTEGRATED SCIENCE CURRICULUM AND REVIEW OF SCIENCE MEDIA

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An Action Research Project Submitted to the Graduate Faculty of the School of Education in Partial Fulfillment of the Requirements for the Degree of Masters of Arts in Teaching and Leadership

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Post intervention data indicated an increased awareness of scientific issues. Students improved their ability to explain and develop main ideas. They were able to read a science article more critically, identifying main points, explaining evidence, stating conclusions, and discussing their agreement or lack thereof with the conclusions. Students improved the quality of other questions they wished to answer about the issue and what officials might do to address the issue.

To My Parents

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CHAPTER 1

PROBLEM STATEMENT AND CONTEXT

General Statement of Problem

Many students in the regular level science classes exhibit a poor attitude toward science, low achievement in science, a lack of personal and social awareness of the importance of science, and an inability to solve problems using the science process. Evidence demonstrating the exhistance of these issues includes surveys, tests, and anecdotal information.

Immediate Problem Context

The target site is a high school district serving two communities located in a western suburb of a major Midwestern city. This single-school district has an enrollment of 2698 students in grades nine to twelve. The school enrollment is 61.4% White, 30.5% Black, 4.6% Asian/Pacific Islander, 4.2% Hispanic, and 0.1% Native American. The population includes 12.6% low-income students who are receiving public aid, living in institutions for neglected or delinquent children, living in foster care, or eligible to receive free or reduced priced lunches. 0.6% of the students, with limited English proficiency, are eligible for bilingual education. The drop out rate is 2.0%, the attendance rate is 93.3%, student mobility is 12.2%, chronic truancy is 7.4%, and the graduation rate is 90.5% (School Report Card, 1998).

The college-sending rate in the 1997-98 school year was 90% of the population featuring 23 national merit semifinalists. Of the student population, 20% participated in Advanced Placement exams with 85% earning a grade of 3-5, 71.4% took the ACT exam earning an average score of 23.7 while those taking the SAT exam averaged a score of 1202. The Illinois Goal Assessment Program (IGAP) tested 10^{th} grade students in reading, mathematics and writing and 11^{th} grade students in science and social studies. School scores differ significantly because the state scores fall completely below the school bands. Scores were from 15% to 18% higher than the state average in reading, mathematics and social studies but only 8% higher in science and writing. The results of students meeting state goals are given in Table 1 (School Report Card, 1998).

Table 1

School IGAP Results Compared to State Averages

	Reading		Mathematics		Writing	
	Score	Band	Score	Band	Score	Band
School	269	259-279	304	296-312	28.3	28.1-28.5
State	228		264		26.2	

	Science		Social Studies	
	Score	Band	Score	Band
School	284	276-292	289	279-299
State	263		249	

There are 201 certified faculty members and 222 noncertified staff members. Of the certified faculty, 189 are full-time teachers, and 12 are part-time teachers totaling 153 full-time equivalents. The faculty are 83.3% White, 7.9% Black, 3.1% Hispanic, and 0.8% Asian/Pacific Islander with 54.7% Female and 45.3% Male. The faculty's average teaching experience is 17.1 years with 14.9% of the faculty having bachelor's degrees and 85.1% having master's degrees and above. The faculty is organized in eight different divisions each with a division head and secretary. There are 12 dean counselors who support about 230 students each. The school has a single superintendent/principal and seven other central office administrators. The superintendent/principal salary is $127,000, the average administrator salary is $91,220, and the average teacher salary is $63,243. The average class size is 23.7 students. The pupil-teacher ratio is 20.9 to 1, the pupil-certified staff ratio is 14.2 to 1 and the pupil-administrator ratio is 132.8 to 1. The instructional expenditure per pupil is $7,261, and the operational expenditure is $11,834 while the total school tax rate is $3.23 per $100 (School Report Card, 1998).

The campus is centrally located in the community on four and a half city blocks with the building covering two city blocks. While the school has a history of 127 years of education, the current building was constructed in 1905 with multiple additions in the 1920s, 1950s, and 1960s. Today's building is a four-story brick structure, which includes a field house, gymnasiums, and two swimming pools. The school has no parking lot and does not provide general busing for students. The majority of special education students are served within the building using special facilities and programs. There are two student cafeterias on the first floor and a staff cafeteria on the second floor. The library is located on the second and third floor with extensive computer access available. In addition to the main auditorium there is a small theater and a TV studio that supports a student operated cable news program. There are eight computer labs with both Mac and PC platforms that are available to students, faculty, and staff.

After several years of dialogue between members of the school and the community, the staff developed several programs to better meet needs of all students. A peer mediation program helps students solve problems without negative behaviors. A community volunteer program assists staff and faculty in many areas bringing people from the community into the building. A freshmen seminar program helps incoming students make the transition from middle school to high school. The freshmen have exclusive use of one of the cafeterias, are restricted to the school campus during the day, and are provided instruction and assistance in the school community as well as in academic and social areas. An extensive academy assists students in all academic areas using a variety of techniques including a reading center, tutorial center, a co-teaching program, a school to career program, a behavior management program, and a general resource center.

Many building improvements have been made over the last several years including locker room renovations, science lab upgrades, and a new welcoming center. In addition to the computer labs, eleven classrooms have been outfitted with student computers, and every staff member has his or her own computer. All classrooms have access to an internal computer network and external access to the Internet. All staff members have access to technology training programs from basic to advanced levels. An up-to-date security system incorporates cameras, alarms, key card entry, and additional security personnel throughout the building. In addition, asbestos has been removed in the student center and adjacent hallways.

The science division has 17 teachers and 1 lab aide. There are 15 lab rooms and 5 classrooms in the science area. Five of the labrooms were remodeled 2 years ago and equipped with computers. Other labrooms share three additional sets of computers. Teachers were trained to use the equipment and software purchased to conduct computerized labs. The school offers four field-based programs during the summer whereby students are able to travel to unique environments, such as the Costa Rican rain forest, to study the environmental, biological, and geological sciences. Teachers are encouraged to expand current programs and develop new programs to meet the needs and interests of the students. Students are required to take only one science course but are encouraged to take two or three courses to meet college entrance requirements. Instructors teach five classes with a total of about 125 students. Courses include biology, chemistry physics, earth science, and environmental science. In addition to the honors and regular levels offered to most students, there is a special biology course for students with reading difficulties and a few biology and earth science classes that are team-taught with the special education department. There are a few special interest electives offered in addition to an Advanced Placement program.

The Surrounding Community

The high school serves two distinct communities located just west of a large urban area. The larger community in which the school is actually located was settled in the 1840s and incorporated in 1902. This community celebrates the diversity of its population with an urban/suburban lifestyle and has a population of 53,648 in a 4.5 square mile area. According to the community profile of 1999 the ethnic make up of the community is 74.8% White, 18.0% Black, and 7.2% other races with a median age of 33.8 years of which 23.6% are under 18 years. The median family income is $51,737. The median home value is $184,000, the median condominium value is $93,500, and rental rates range from $450 - $1300. Of the approximately 23,000 housing units about half of them are single family dwellings and half are multi-family dwellings where about half are rented and half are owned. The community tax rate is 12.747%. The local government consists of a president, six trustees, a clerk, and a manager. There are eight financial institutions, three fire stations, two hospitals, one main library with two branches, 53 places of worship, and 16 parks including a conservatory, two swimming pools and an indoor ice rink. In addition to the main police station, there are seven resident beat officers and several satellite stations. In addition to the high school district in this study, there is a single community elementary district and several private schools. The community has access to two rapid transit lines, one commuter rail line, and several bus routes. The community has a rich cultural history with many historic landmarks.

The second community was settled in the 1830s and was incorporated in 1880. It is an affluent community that is primarily a residential area with several large religious and educational institutions. It has a population of 11,329 in a 2.5 square mile area. The ethnic make up of the community is 94.6% White, 3.0% Asian/Pacific Islander, 1.5% Black, and 0.9% Others with the median age of 37 years of which 22.0% is under 18 years. The median family income is $96,038. The median home value is $359,035 with approximately 4,000 housing units and a community tax rate of 10.644%. The local government consists of a president, six trustees, a clerk and an administrator. There are five financial institutions, one fire station, one police station, one library, eight places of worship, and seven parks including a tennis complex and pool. There is a single community elementary district, two universities, a nearby community college and several private schools. The community has access to one rapid transit line, one commuter rail line, and several bus routes.

In addition to the five active parent organizations in the school, the citizens in the communities are also very involved in school issues. The Youth Township in cooperation with the high school helps to meet the needs of our students with many programs ranging from intramural sports to music. There are also many special programs providing assistance, counseling and alternatives for troubled, low-income, and neglected children.

National Context of the Problem

Today's society is confronted daily with scientific issues that are important to the rapidly changing times. Whether it concerns genetically altered produce, medical breakthroughs, the depletion of the ozone layer, or space exploration, citizens today are faced with making choices about subjects that they may know little about. The public needs to be scientifically literate so that appropriate understanding of issues and decisions can be made (National Research Council, 1996, p.1). By understanding the science process, people can use problem solving and critical thinking to make informed choices.

Unfortunately various studies indicate that less that 10% of Americans and less than 25% of college graduates are scientifically literate (Hazen & Trefil, 1990, p. xv). Even when American students are compared to international students, they are well below average in problem solving (Rutherford & Ahlgren, 1990, p. vii).

One reason for low interest and achievement in science is the attitude that people have about science. Many people have negative feelings and attitudes towards learning science, causing them not to pursue further knowledge in science (Gogolin & Swartz, 1992, p. 488). In one study of high school students, over half did not enjoy science, thought it was dull, and overall did not have a positive attitude toward science (Ebenezer & Zoller, 1993, p. 181).

CHAPTER 2

PROBLEM DOCUMENTATION

Problem Evidence

During the first four weeks of the fall semester, 1999 students completed three activities to assess scientific literacy. They identified where they got information about science, listed current science issues, selected one issue to describe in more detail and analyzed an article about a scientific issue. The three Integrated Laboratory Science I were composed of freshmen and sophomore students of predominately average level. A total of 24 students, 8 students randomly selected from each class, was included in the study. Because teaching assignments changed in the second semester, it was not possible to complete the intervention and retest these students. However, the evidence gathered from the pre assessment strongly indicate that the research should be completed. During the first week of the school year 2000-2001, a second group of students completed the same activities. Students, sophomores, juniors and seniors generally unmotivated and predominately low-average, were in three sections of ChemCom, a regular level chemistry class.

Because the activities were repeated but the intervention and post assessment was completed for only the second group of students, the baseline data is reported in separate graphs. The first two activities looked at how aware students were of science in the world around them by asking them to identify and describe current science-technology related issues and where they got information about science and technology (Appendix A). The results shown in Figures 1-9 indicate that students listed an average of 5.5 science issues with 47% of the issues mentioned related to computers and electronics. Most students got their information from three sources, half of which were the electronic media, including television and the Internet. Results in Figures 2-10 indicate that the ChemCom students of school year 2000-2001 listed an average of 6 science issues with 48% of the issues related to computers and electronics. One-third of the students learned their information from three sources while 80% listed from two to four sources. Television and school were the most frequently cited. These data show that students were able to identify some current issues in which science was a cause and/or solution. While five or six issues may seem reasonable for this age group, the quality of the answers suggest a naïve understanding. For example, one student described the issue of cell phone use while driving in the context of improving cell phones rather than in the context of traffic safety. Another student mentioned cloning animals as a way to study embryo development but did not mention the moral issue of cloning humans.

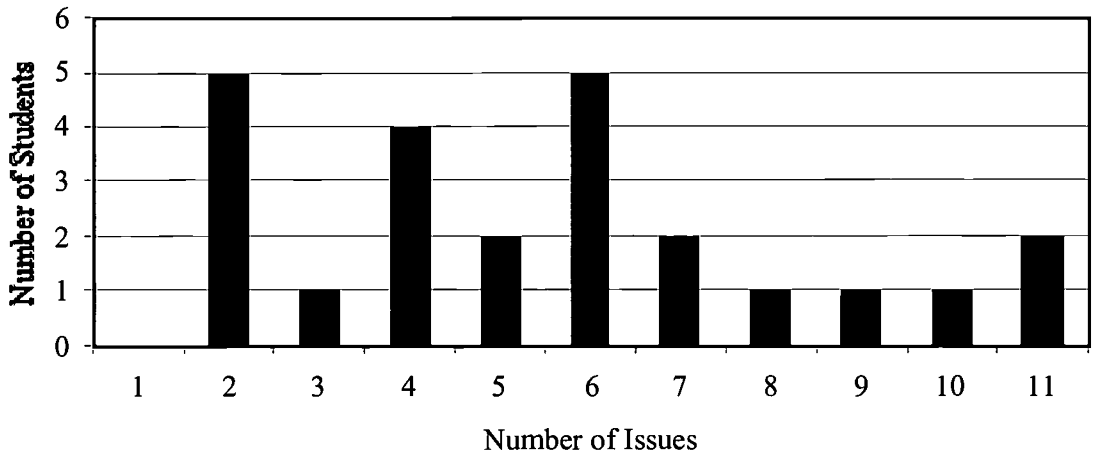

Figure 1. Total number of science issues listed by each student

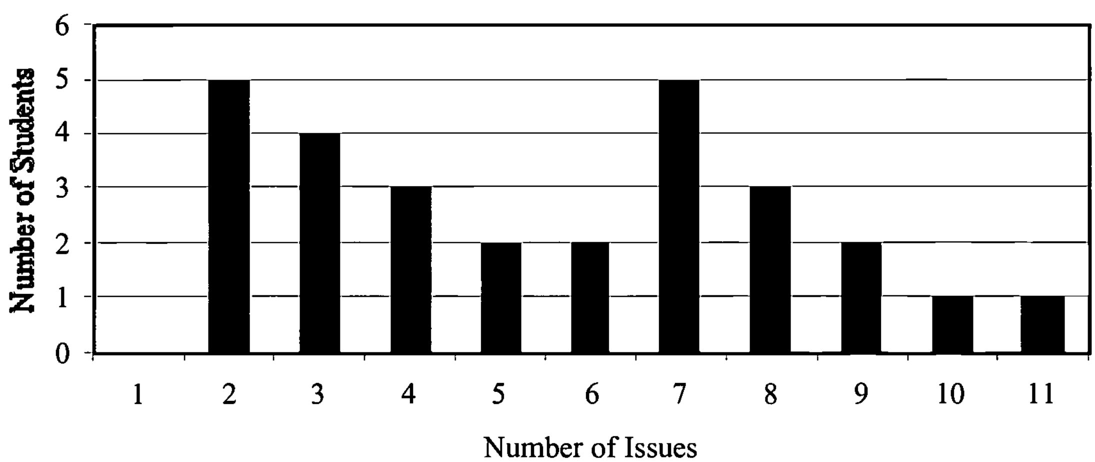

Figure 2. Total number of science issues listed by each student - 9/00

Figures 1 and 2 show that while eleven was the maximum number of issues listed, over two-thirds of the students listed between two and six issues.

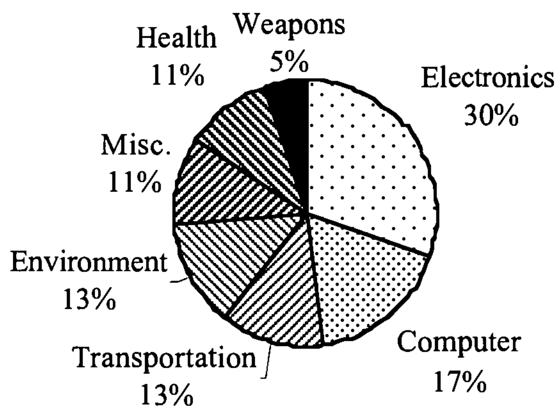

Figure 3. Issues mentioned by students

Figure 3 shows that in 1999 30% of the issues mentioned were about electronics, 17% were related to computers, 13% were about modes of transportation, 13% were about environmental issues, 11% were about health-related issues, and 5% were about weapons. In 2000 36% of the issues were about electronics, 12% were related to computers, 12% were about modes of transportation, 18% were about environmental issues, 10% were about health -elated issues, and 3% were about weapons.

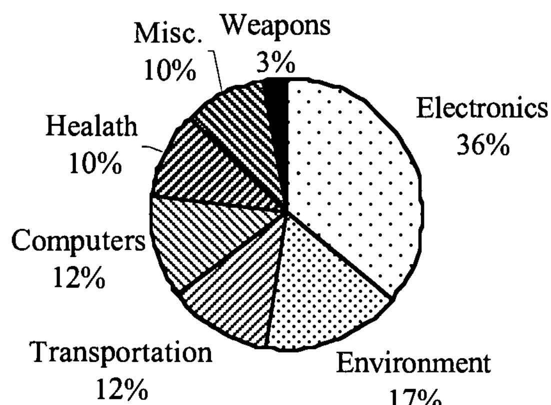

Figure 4. Issues mentioned by students - 9/00

While the percentages are similar for both groups, the older students listed more concerns about the environment while the younger students were more aware of issues related to computers. These data suggest, as one might expect, that students are pretty familiar with some issues related to the electronic gadgets and computers and cars which are a big part of their world. The environment and health are other areas with which students are likely to be familiar, perhaps because they are included in the school curriculum and the media, particularly television, covers them regularly.

The students selected one issue, and two open-ended questions asked where they learned about this issue—the most important source of information and additional sources. Students listed various forms of the media, people, books, and school. The data show how many sources of information the students use.

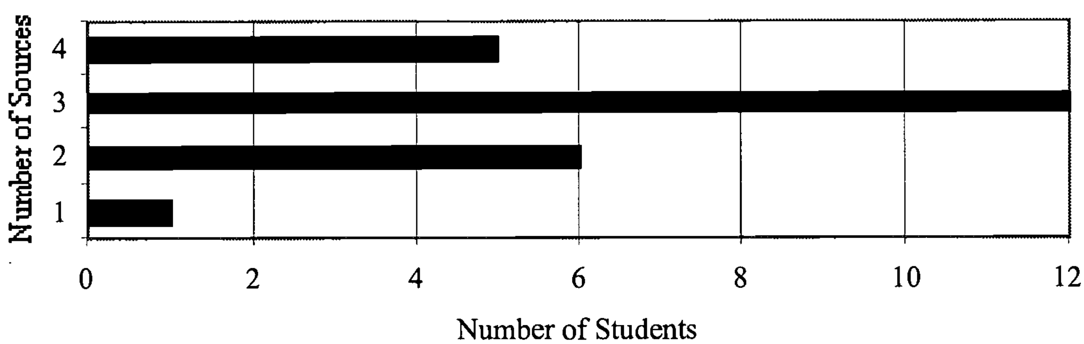

Figure 5. Number of sources students get information from

Figure 5 shows that half of the students got their information from three sources, a quarter of the students used only two sources and a fifth of the students used four sources.

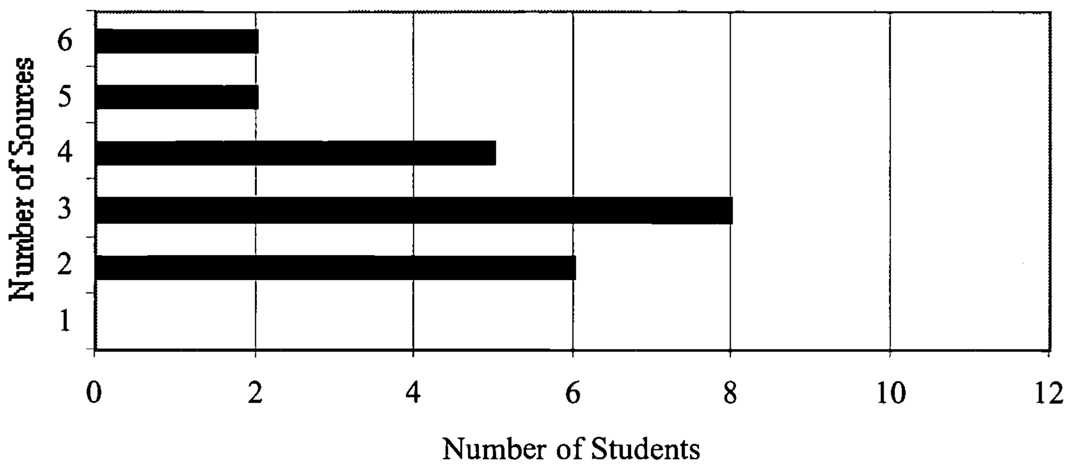

Figure 6. Number of sources students get information from - 9/00

Figure 6 shows that generally the ChemCom students got information from more sources. While three remained the most common number of sources, only eight students reported this level. Nine students reported using more than three sources, and six reported less than three sources. The data show that students did get information from more than one source which allowed them an opportunity to study the issue from different perspectives.

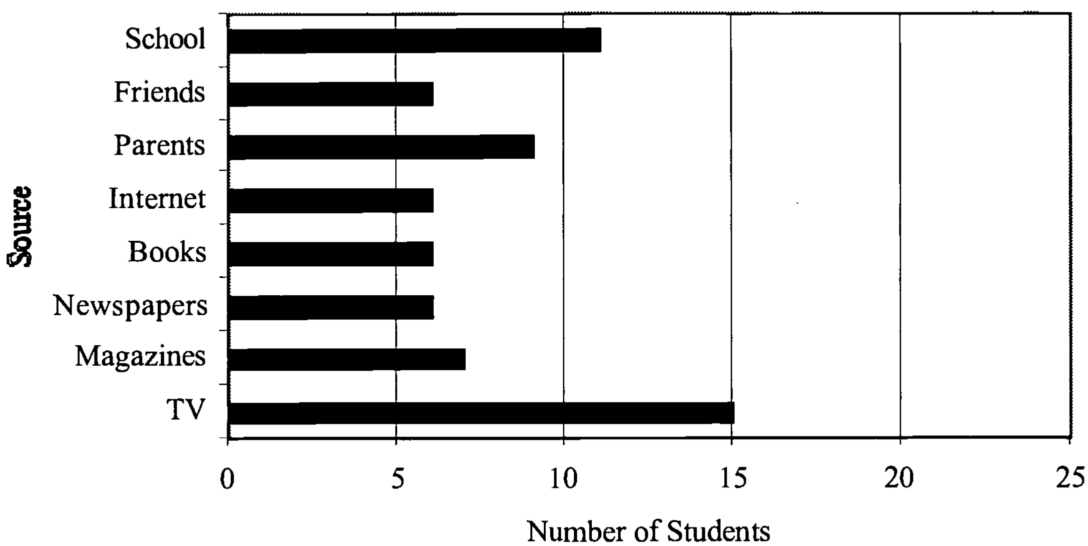

Figure 7. All sources used by students for information

The data also show where students got their information. Figure 7 shows that over 60% of the 24 students got information from television, 46% learned about the issue in school, 38% talked with their parents, 29% read magazines, and 25% got information from each of the following: friends, the internet, books, and newspapers.

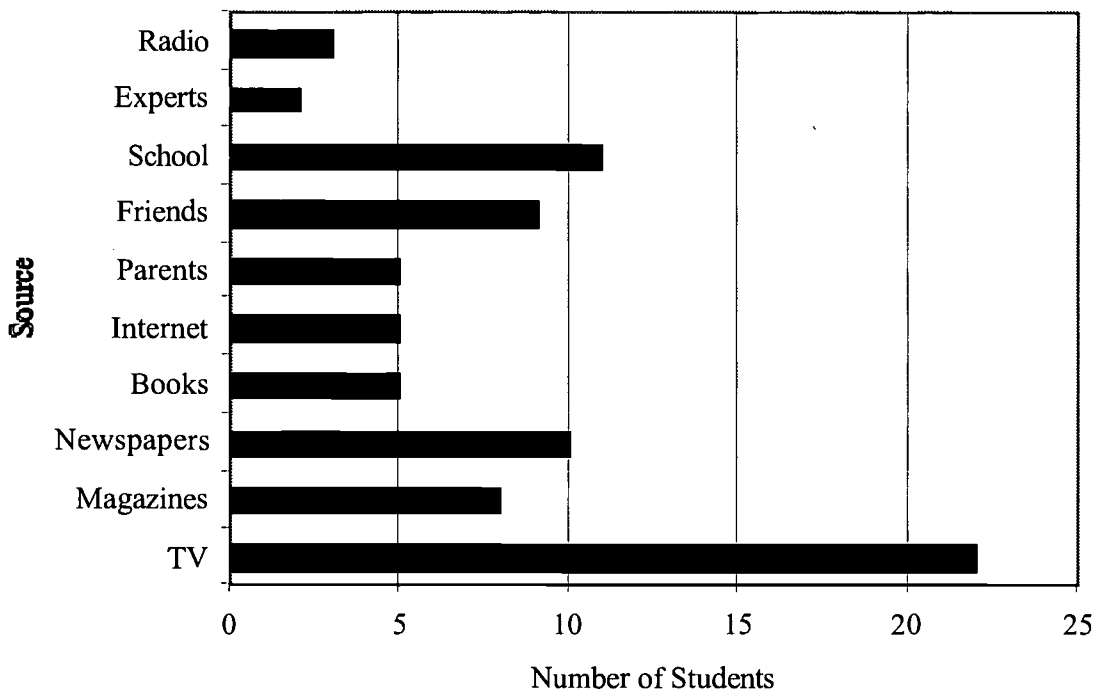

Figure 8. All sources used by students for information - 9/00

The data for the ChemCom students are similar. However, they reported two more sources, experts and the radio, and there was a significantly higher number of students reporting television as a source of information. Television remained the most popular source with school second. Newspapers replaced parents as the third most common source. Printed materials were more popular with the younger students.

These data and those that follow suggest that instruction should provide a variety of issue-related materials for students to use in class to balance the amount of information they get from television. More research could break down school as a source of information so that instruction could include group work, with research in the library or on the Internet, presentations from experts, etc. in the right proportions to bring balance to sources of information.

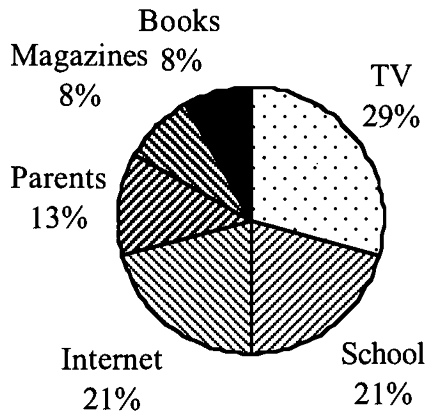

Figure 9. Source the students get the most information from

Figure 9 shows that 29% of the students got most of their information from television, 21% used from the Internet, 21% learned at school, 13% learned from their parents, 8% read magazines, and 8% read books.

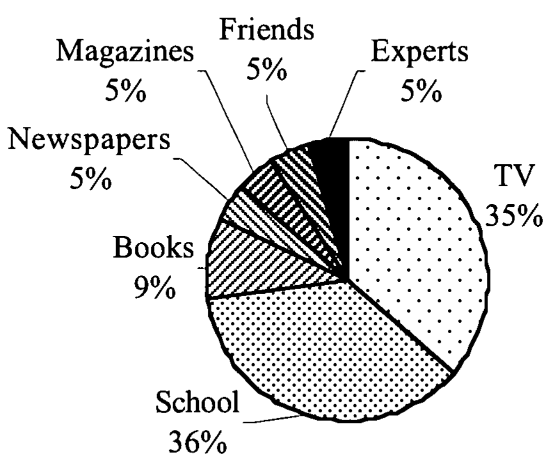

Figure 10. Source the students get most information from 9/00

In Figure 10 there are two new categories, experts and radio. Over 70% of the students got most of their information either from television or school. Surprisingly, the ChemCom students did not use the Internet. Books were mentioned by 9% of the students. Other sources—magazines, newspapers, radio and experts—were selected by 5% of the students.

Students had an opportunity to discuss their issue of choice, stating the main idea and listing as many things as they could about the topic including cause, effect, and solution. The main idea statement was scored on a four-point scale. Students earned the highest score, master, if they included all aspects of the main idea. They earned the second score, expert, if they explained most, but not all of the idea. They earned the third score, intermediate, if they explained part of the idea but included incorrect information. They earned the lowest score, novice, if they tried to answer the question but did not state the main idea. Figures 2.6 and 2.7 indicate that about two-thirds of the students were at an intermediate level and most students gave between zero and two correct statements about the issue.

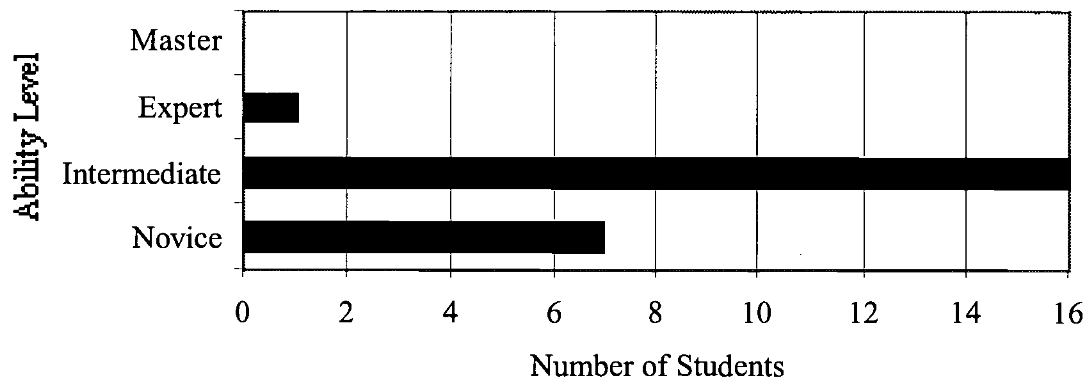

Figure 11. Students' ability to explain the main idea

Figure 11 shows that no student achieved mastery, only 1 student was an expert, 16 students were at an intermediate level, and 7 students were novices.

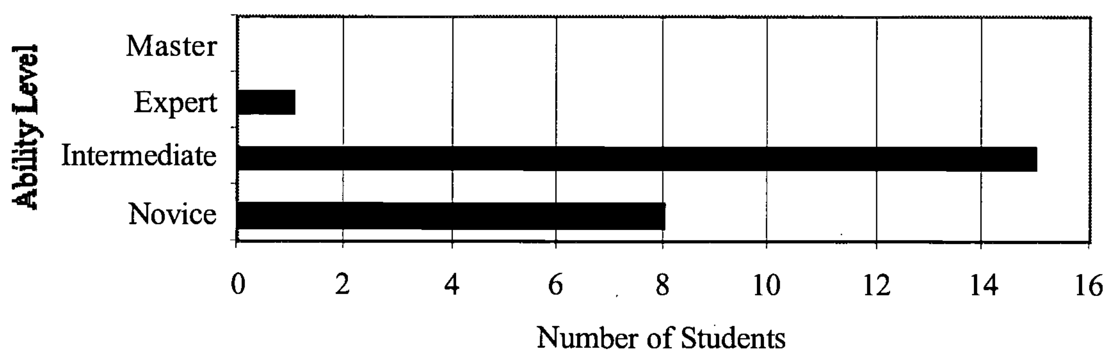

Figure 12. Students' ability to explain the main idea - 9/00

Figure 12 shows results for the ChemCom students were similar in 2000. Students had difficulty explaining the main idea on issues related to electronics and computers. This may have been caused in part because the example in the survey led them to make statements of the kind, "We would not have cars if they had not invented the engine." Other students focused on the impact of technology without developing the issue.

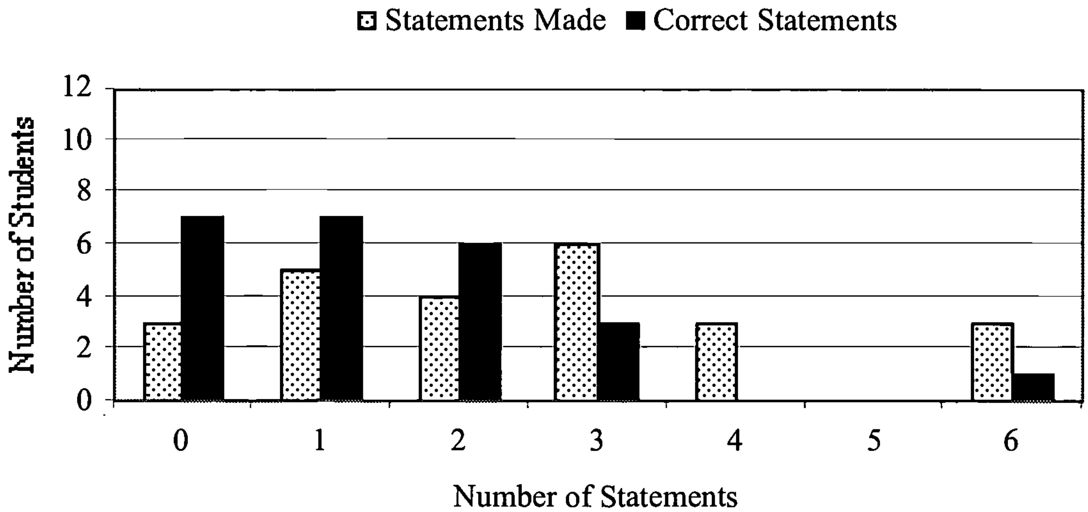

Figure 13. The number of statements made about the main idea

Figure 13 that students made 61 statements overall, 34 or 56% of which were valid. Six students made either 4 or 6 statements about the issue, six students made 3 statements, four students made 2 statements and eight students made 1 or none. The figure also shows that only one student made 6 valid statements, nine students made either 1 or 3 valid statements, and 14 students made one or none.

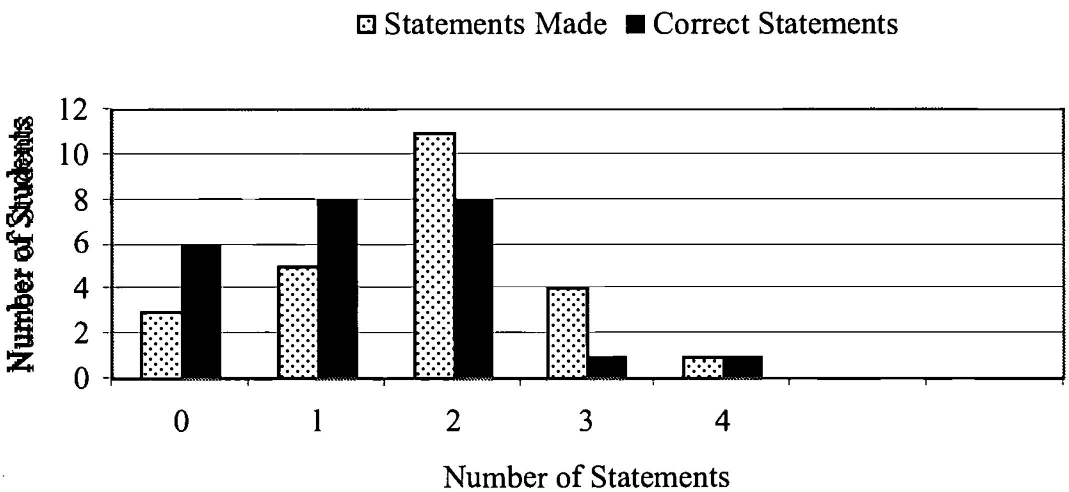

Figure 14. The number of statements made about the main idea - 9/00

Figure 14 shows that while the ChemCom students made fewer statements, but a larger percentage were correct. Of 43 statements, 31 or 72%, were valid. One student made 4 statements, and they were all valid. Three students who made either 3 or 2 statements, made incorrect statements reducing their totals accordingly. One student made 3 valid statements; eight made 2 valid statements and eight made 1 valid statement. Six students made no valid statements.

In the final activity, students read a scientific article, "Do offshore wells fight natural pollution?" about drilling in the Santa Barbara channel. The article interviewed two scientists with opposing views. Students answered a series of questions based on the article (Appendix B). The first five questions that looked at the student's ability to interpret the article were graded on the four-point scale used before: novice, intermediate, expert, and master. Results reported in Figures 2.8-2.13 and in Figures 2.8.a-2.13.a show that overall the students fall in the novice and intermediate levels. They were unable to correctly answer the questions or gave minimal answers.

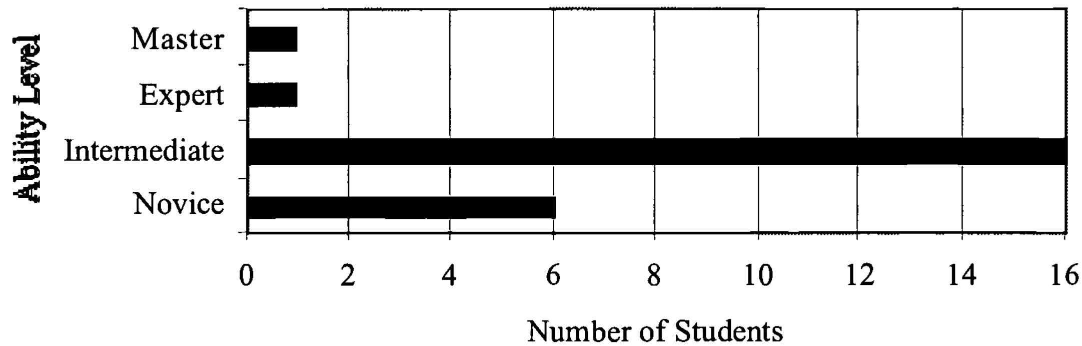

Figure 15. State the main point of the article

Figure 15 shows that two-thirds of the students were at an intermediate level at stating the main idea of the article, one-third were novices, one student was an expert and one a master, giving a complete description of the main idea.

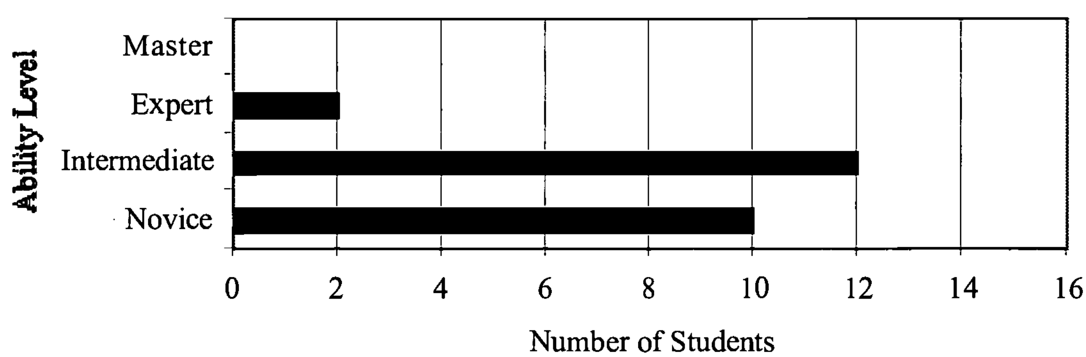

Figure 16. State the main point of the article - 9/00

Half of the ChemCom students were at an intermediate level, two-fifths were novices, and two students were experts as shown in Figure 16.

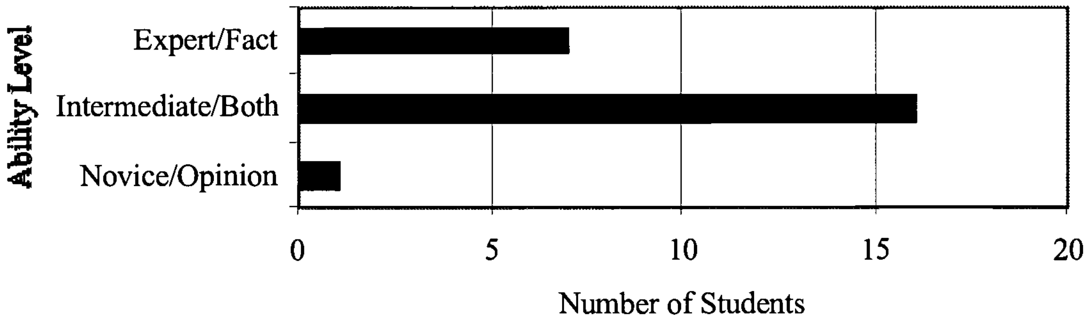

Figure 17. Fact vs Opinion

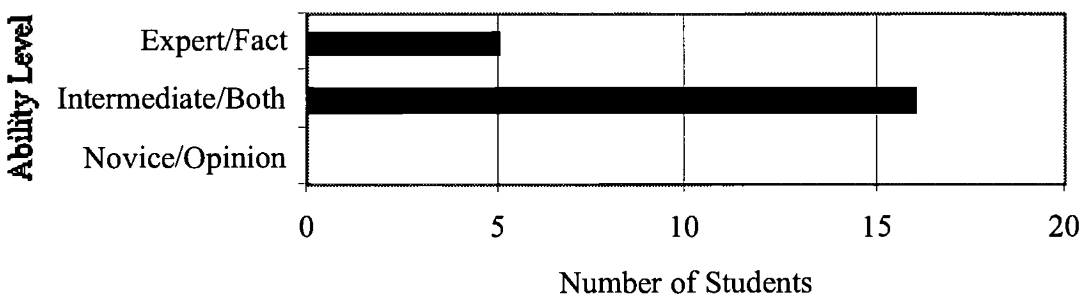

Figure 18. Fact vs Opinion - 9/00

Figure 17 shows that out of a total of 24 students one-third of the students correctly indicated that the article gave facts, two-thirds also thought both opinions and facts were given, and one student indicated that only opinions were given. Figure 18 shows similar results. One of the problems students have when analyzing scientific articles is identifying the facts and data that support conclusions. They also have difficulty citing data or facts to support their own conclusions. These data show that an inability to separate fact and opinion may be one of the reasons for this difficulty. If teachers relied less on textbooks and more on news articles as sources of information, students could practice fact identification in the media.

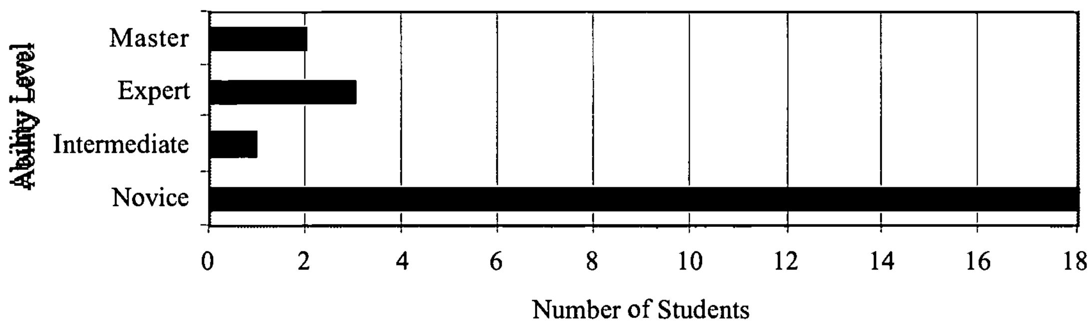

Figure 19. Stating the Conclusion

Figure 19 shows that out of a total of 24 students 75% of the students were unable to determine the conclusions expressed in the article. Two students were masters, three were experts, and one was at an intermediate level.

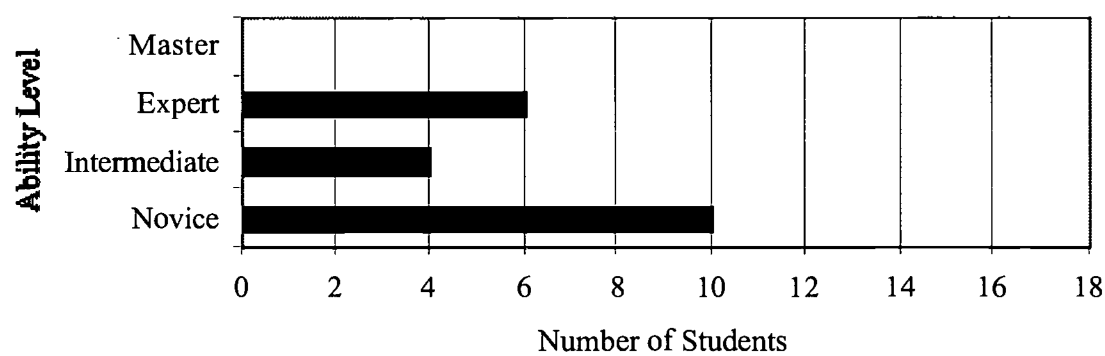

Figure 20. Stating the Conclusion - 9/00

Figure 20 shows that of 24 students responding 40% of the ChemCom students were unable to determine the conclusion, 16% were intermediates and 25% were experts. These data suggest that students need help analyzing their work, discussing results and facts describing the point of the experiment and what their work showed. Time for reflection either in small groups or individually is often omitted in order to complete the work before the bell rings.

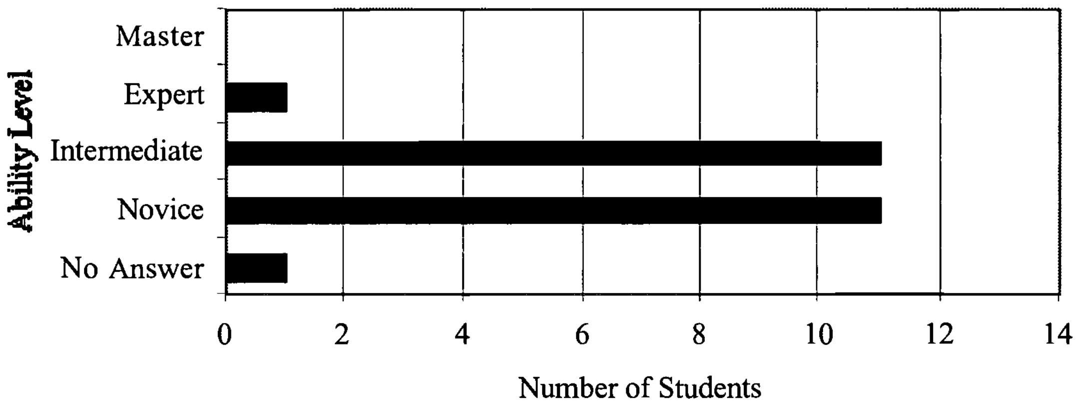

Figure 21. Explaining the Evidence

Figure 21 shows that about half of the students were novices, unable to find any evidence presented in the article to support the authors' conclusions, and half, intermediates, found one fact as supporting evidence. One student found two main facts, and one did not answer the question.

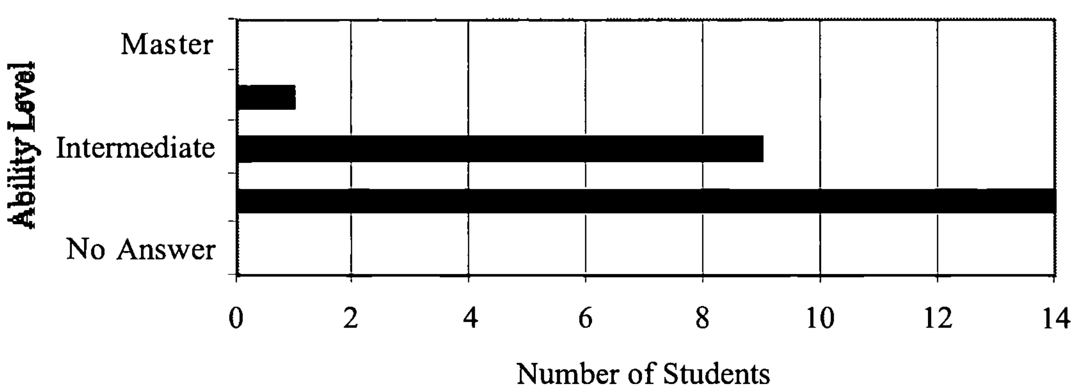

Figure 22. Explaining the Evidence - 9/00

Figure 22 shows out of total of 24 students 58% of the ChemCom students as novices, 38% as intermediates, and one at a masters level, identifying two facts as supporting evidence.

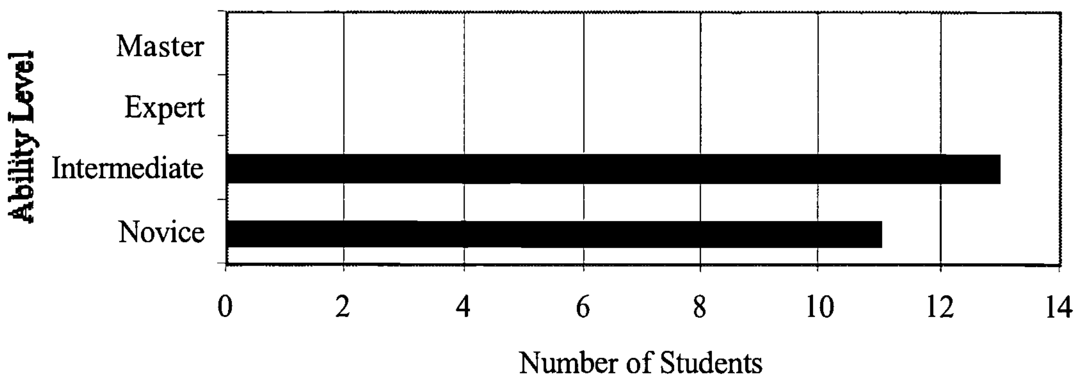

Figure 23. Conclusion Agreement

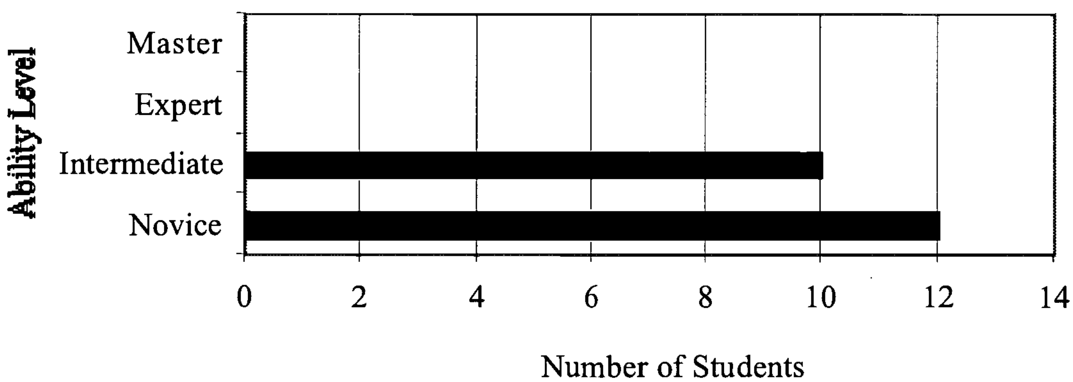

Figure 24. Conclusion Agreement - 9/00

Students were asked with which conclusion, if either, they agreed. Figures 23 and 24 show that the classes split pretty evenly. Around half of the students gave a basic explanation of their choice. The response of the other half of the students, novices, either did not choose or did not support their choice. These data show that students are not comfortable selecting one argument with which they agree and stating evidence that supports their conclusion. This is undoubtedly tied into their inability to identify facts and explain evidence.

The total scores of the first five questions were added together for an overall score on analyzing the article. The novice scored 5 points for trying to answer all five questions, the highest possible score was 20 points for a master level on all questions.

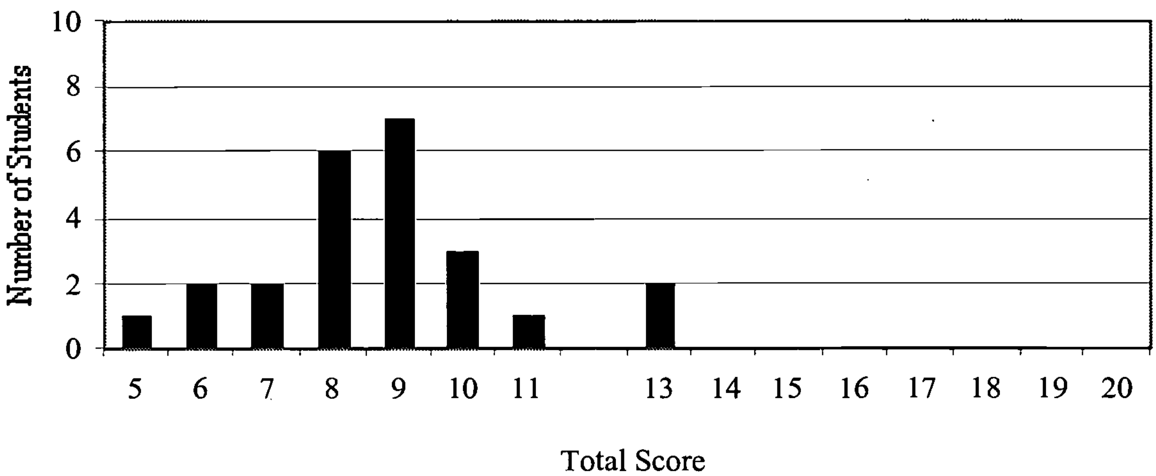

Figure 25. Total Score Questions 1-5

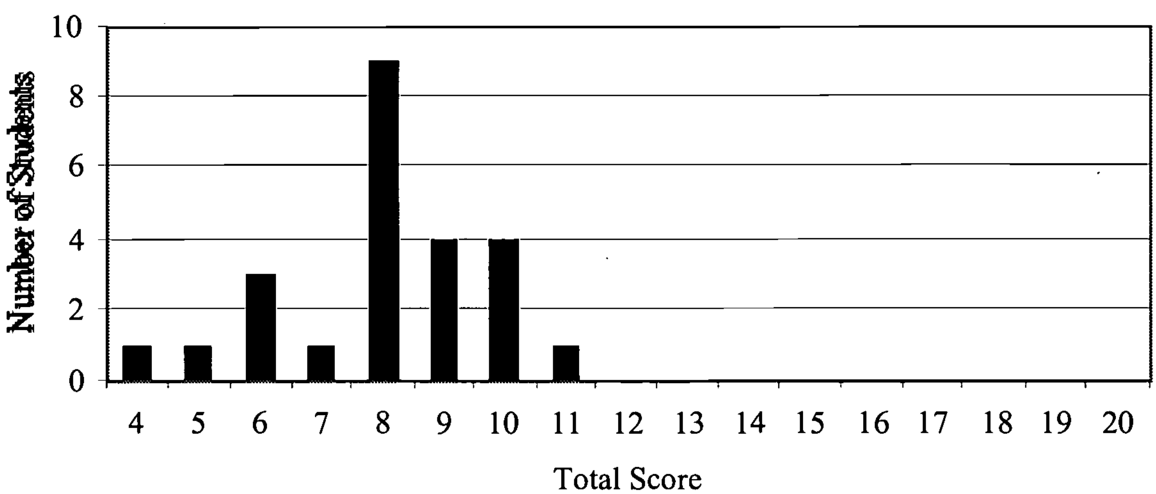

Figure 26. Total Score Questions 1-5 - 9/00

Figures 25 and 26 show that most students scored between 5 and 11 points, with the about two-thirds of the students scoring 8 to 10 points. Only two scores were higher than the midpoint.

In the last two questions students were asked what else they would like to know and if they lived in Santa Barbara what they would want officials to do. Although the students are not at a mastery level, they were better at listing what they needed to know than they were at deciding what should be done.

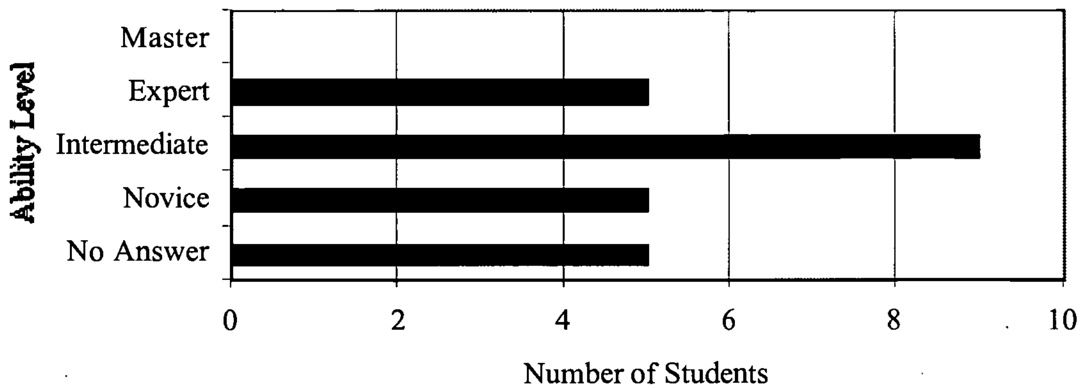

Figure 27. Quality of questions students want to know

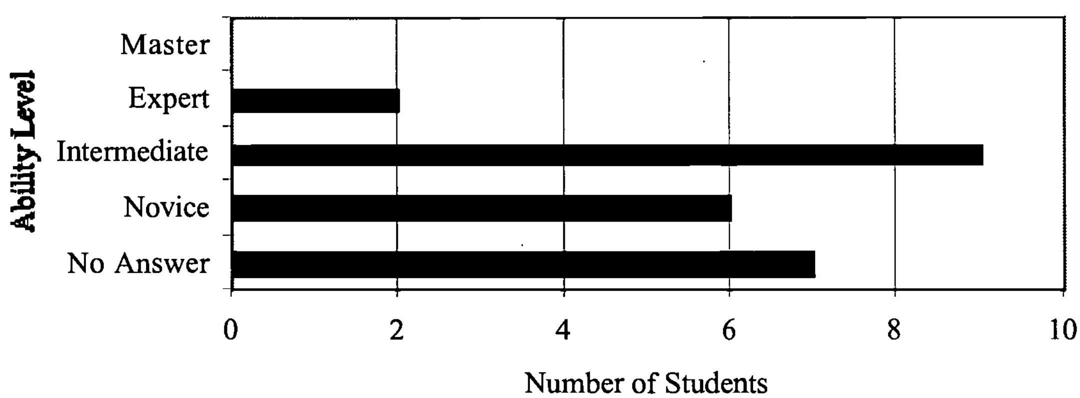

Figure 28. Quality of questions students want to know - 9/00

Figures 27 and 28.a show that five or seven students did not answer. Of those who answered, 40% were at an intermediate level and 20% were novices. Five or two were experts.

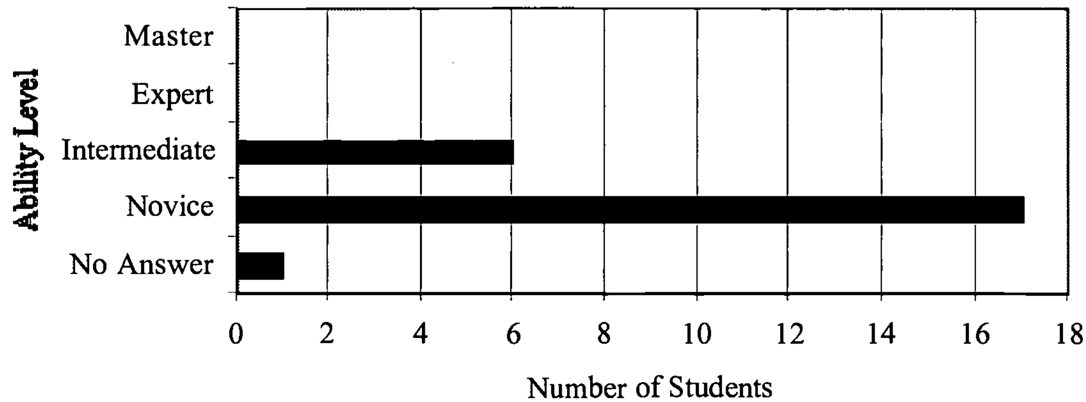

Figure 29. Quality of what students want officials to do

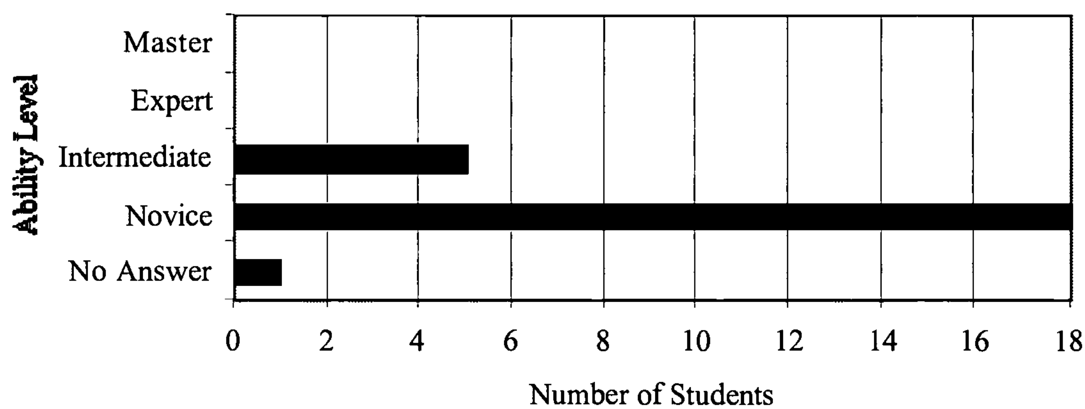

Figure 30. Quality of what students want officials to do - 9/00

Figures 29 and 30 show that over 70% of the students could not think of anything for the officials to do and scored at a novice level. Six of the remaining students were at an intermediate level and one student did not answer the question.

The results of these activities show that students do get information about science and technology from a variety of sources, however, they are not able to process that information very effectively. Further, they are not very good at identifying or discussing current issues that may be caused by science and technology or have a scientific or technological solution. For example, this summer metropolitan newspapers were full of articles and reports on mercury spills caused when the gas company replaced residential gas meters. Ordinary people needed to know if they were at risk. Was their house one of the thousands impacted. What was the nature of the health-threat from mercury. What levels were dangerous, over what period of time, in what concentration. What type of exposure was a problem, etc. None of the students mentioned this issue in the fall.

Neither can they read a scientific article written for the public and make much sense of it. On average, they cannot identify the main points and conclusions, separate facts and opinions, state evidence supporting conclusions or choose and defend their own conclusions. They do a better job of recognizing what else they need to know than they do of suggesting actions people might take to mediate a problem or implement a recommended solution. All of these abilities are ones that are part of the responsibilities of informed citizens.

Citizens are asked to make choices all the time that have an impact on the quality of their lives and for which science has evidence to help decide the course of action. High school students do not demonstrate these skills and need to develop them as that as adults they can make informed decisions. Activities in science classes that promote skill development in these areas include those that increase awareness of current scientific issues and develop students' ability to critically analyze scientific information and assess the quality of scientific experiments.

Probable Causes

The world is in a time of unprecedented change, largely driven by science and technology. While the dashboards of today's automobiles contain more computer power than the Apollo 13 spacecraft, the science classrooms of today all too often appear and function as they did 100 years ago. In 1894 a prestigious national commission, The Committee of Ten, determined the high school science curriculum—biology, chemistry and physics. Then, and now, most course content and pedagogy is based on what teachers perceive students need to know and be able to do to prepare for college-level courses that focus on training future scientists and engineers. However, the vast majority of students will not become scientists or engineers, and denying any students the academic keys to the 21st century is not in the best interests of the nation. According to the ARISE Report, 1998 the 21st century requires that all citizens be scientifically literate and savvy. Among other things this means that they must:

- Be responsive to accelerating change driven by new technologies.
- Work together to find measured yet creative solutions to problems, which are today unimaginable.
- Anticipate the impacts of their actions.
- Communicate effectively about science and technology.
- Maintain the balance among society, economic growth and the environment.

Therefore, the goal of science education has changed. It is not clear if the new goal is well understood by the educators responsible for developing K-12 science education programs. Koballa, Kemp, and Evans (1997) suggest that current science reform efforts are based on achieving scientific literacy, but teachers do not agree on a definition. This is due in part to its complex and dynamic nature. At the same time the interpretation of scientific literacy has changed over time.

Simpson and Anderson (1992) comment that scientific literacy is being discussed now more than ever. We hear about the need to educate students in the broad sweep of science. Most students who will not become scientists need to understand the impact of science and technology to society rather than all the details. We must teach science as a process as well as a product so that students will understand that the world is full of unanswered and hard-to-solve, complex questions. Sousa (1996) asks if we are teaching high school science backwards. Scientific literacy for all students does not mean that they should be able to do what scientists do but that they are able to use science to make appropriate decisions.

Hazen and Trefil (1991) support this view and contend that scientists and educators have not provided the general public with background knowledge needed to cope with the future world. What is missing is knowledge needed to understand public issues, that is "a mix of facts, vocabulary concepts, history and philosophy." It is the more general knowledge used in political discussions. It is the knowledge that allows individuals to read the newspaper articles or listen to the news about science in the same way that they process information about other topics.

The evidence supports these comments. While "the good news is that scientific literacy among U.S. adults is declining, the bad news is that they still do not know about such things as DNA, radioactivity or whether the Earth revolves around the sun once a year." A recent survey confirms results from previous surveys and shows that only 9% of American adults know what a molecule is and only 27% can define DNA. Fifty-three percent do not know that the Earth revolves around the sun in a year. We need to do a better job at the high school level so that students learn these things, says Miller (1997).

The report on The High Stakes of High School Science (1991) states that science education is simply not working for the majority of students. Students who enter the workforce directly upon high school graduation and students traditionally underrepresented in science are in that majority. The report states that two-thirds of the students typically do not choose to take science courses beyond the requirements or achieve well in the courses they do take. At the same time the college-bound students are under-served because of the dominance of the college science curriculum on the high school curriculum. The report states that this brief description of the problem is consistent with the results of over 300 studies issued during the 1980's. The report from industry is the same. Jacobs (1996) reports what industry leaders tell educators based on their observations of abilities of high school graduates. They have an overall perception that schools are not teaching necessary science skills. Students need basic understanding of science and how it relates to their lives. To achieve this leaders recommend science courses emphasize more hands-on activities, communication skills and principles of biology, chemistry and physics be taught to all students.

Dulski, Dulski, and Raven (1995) acknowledge the widespread problem of scientific literacy of a general public that may base their support on major science-related public policy issues on generally emotional or nonfactual grounds. Evidence from recently complied research studies shows mixed results concerning attainment of STS goals related to public decisionmaking. The authors conducted a study of high school student attitudes toward several science-related topical areas such as nuclear energy, environmental issues and space exploration. Their study adds insight into individuals' attitudes that exist within an interrelated network of web. Educators need to consider a pedagogical approach that takes into account these attitudinal interrelationships in order to affect behavior.

Bingle and Gaskell (1994) build on the thesis that while scientific literacy has many characteristics of an educational slogan where the term means different things to different people.

there is substantial agreement that the most important aspects of scientific literacy are those that develop knowledge and skills to make decisions and solve problems where science and society come together. However, there are some issues such as nuclear energy and global warming where there is disagreement among scientists as well as among citizens. Although citizens have an interest in how the issues are resolved, the information on which to make an informed decision is complex, based on many sources and often inconclusive. Bingle and Gaskell explore two ways of critically examining scientific knowledge. Using the context of NASA's Galileo Mission to Jupiter, they discuss the reliance on constitutive values normally inaccessible to ordinary citizens on the one hand and the importance of contextual values that are accessible on the other. Implications for teaching include including a synthesis in which social issues are seen as a vehicle for studying the social studies of science and the social issues are seen as a way of making sense of social aspects of science.

Coburn, Gibson, and Underwood (1995) find that students seem to separate knowledge and skills gained in school from their world outside the classroom. Simpson and Anderson (1992) comment that we must teach science as a process as well as a product so that students will understand that the world is full of unanswered and hard-to-solve, complex questions.

How do we educate students to become scientifically literate? What is the magnitude of the change needed to reform science education? Fort (1993) suggests that most Americans grow up in "science-shy families in science-shy communities and attend science-shy schools, where they study science –shy curricula, taught by science-shy teachers, who use science-shy approaches (lectures and textbooks) and are governed by science-shy administrators."

<u>The National Standards and the Science Curriculum</u> (1996) includes an important article by Goldsmith who outlines the challenges inherent in trying to reform science education. They

touch all aspects of education "from the training of teachers to the practices of the classroom to the processes by which results are assessed." Teachers need to develop an understanding, an ownership of the reforms that are needed, and the initiative for this must come from the teachers. Challenges to overcome include what it means to educate all students, the influence of "local control" and the fear some have of public education, public perceptions about the quality of science learning, and college and university practices that are so different from the new standards.

While the most desirable presentation of science depends on the interweaving and integration of important science themes, many structural conditions mitigate against achieving this form of instruction in the near term, including:

- The absence of a cadre of teachers prepared in the content and skills to teach in this way.
- The absence of materials appropriate to the high school level designed to support this type of instruction.
- The concerns of parents and policymakers about the acceptance of courses other than the standard ones in the college admission process.
- The lack of assessments geared for other than "standard" courses. (ARISE Report, 1998)

Somewhat ironically, national reform efforts recommend that science be taught to *all* students the way science is done. However, the vast majority of science and mathematics teachers have never had an opportunity to actually 'do' science or mathematics in a real-world setting. This situation perpetuates certain myths about the nature of science and mathematics because most teachers have no practical experience in the fields they are teaching.

The National Science Education Standards (1995) envision change throughout the system with changes in emphases. The following chart from the Standards recommends changing the emphasis in science teaching and learning (p.52). The left-hand column gives us a picture of what science education has been like. The right-hand column describes the future contained in the Standards.

CHANGING EMPHASES	
LESS EMPHASIS ON	MORE EMPHASIS ON
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry.
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives and history and nature of science
Separating science knowledge and process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities and ideas to be learned

Making changes of this kind require support for professional growth and development, but schools rarely devote sufficient resources for the sustained level for this type of systemic change. The Standards state that "teachers can be effective guides for students learning science only if they have the opportunity to examine their own beliefs (about science, learning and teaching), as well as to develop an understanding of the tenets on which the Standards are based" (Standards, 1995). Koballa, Kemp and Evans (1997) suggest that teachers will not understand scientific literacy without reading a great deal and reflecting on what they have read.

Illinois educators have taken a yearlong look at the professional development needs of teachers of problem-based learning. Findings show that teachers new to inquiry need clear and thorough information, including examples of well-designed problems and of effective coaching. Newer practitioners need formal training and informal mentoring. Experienced practitioners benefit from communication and support with other experienced colleagues. Building capacity requires long-term follow-up and networking.

Schools are faced with a science education program that looks little different than the one of 100 years ago that is trying to educate all students for the 21st century. The primary problem is changing the goal of education from one of training scientists and engineers to developing knowledge and skills for a scientifically literate society. This change requires changes in curriculum and instruction that have implications throughout the system. Most important is providing sustained professional development that allows teachers to examine their own beliefs about science, scientific literacy and science education.

CHAPTER 3

THE SOLUTION STRATEGY

Literature Review

Science for All Americans (1989) and the National Science Education Standards (1995) contain recommendations on what all students should know and be able to do in order to be scientifically literate. The Standards discuss how science should be taught with changing emphases for teaching that include more emphasis on understanding and responding to individual student needs, selecting and adapting curriculum, focusing on student understanding and use of scientific knowledge, guiding students in active and extended inquiry, providing opportunities for discussion and debate, continually assessing student achievement, sharing responsibility for learning with students, supporting a community of learners and working with other teachers to enhance the science program.

In the October 1999 issue of Scientific American six experts in science education outlined feasible, proven ways to improve science education. They included: replace memorization with exploration and invention; focus the high school curriculum; select math textbooks for the right reasons; eliminate low academic tracks; assess performance, not regurgitation; and build on students' preconceptions about science.

These ideas can be summarized by four main challenges to make science teaching more reflective of science itself—make inquiry the basis of science learning, teach fewer topics in more depth, connect classroom science with the students' real world, and involve students in the scientific community.

Making Inquiry the Basis of Science Teaching

Making inquiry the basis of science teaching means making teaching and learning collaborative and student-driven. Considerable literature supports the position that students should be investigators responsible for their own learning, constructing their own knowledge. Teachers facilitate this process by create learning environments that provide students with opportunities for an in-depth engagement in science. In an open, friendly and flexible environment, teachers provide opportunities and guidance for students to participate in a variety of learning activities. Teaching strategies emulate, closely, the way scientists build knowledge through inquiry. Effective and efficient student assessment measures learning in a variety of ways, including methods such as performance-based assessment self-assessment and peer assessment in addition to traditional methods.

Making inquiry the basis of science teaching means helping students as problem solvers develop higher-level thinking skills by taking ownership for their learning. This can be encouraged in many ways, such as engaging students in choosing and planning study projects and structuring classroom environments. Both group and individual study are important. Group work encourages the need for cooperation among students, among teachers and among students and teachers while individual activities encourage self-confidence and a sense of accomplishment.

Making inquiry the basis of science teaching means making the school a community of learners reaching beyond classroom walls into the community. The curriculum is coherent throughout the various fields of science, integrated with other disciplines and connected to real issues in everyday life. Learning to conduct scientific inquiry requires a wide range of equipment, materials and technology as well as interaction with scientists, engineers and technicians. In the best situations, students develop scientific knowledge and habits of mind by working alongside scientists to make sense of the world using real experimental data.

The National Standards state that at all stages of inquiry teachers guide, focus challenge and encourage student learning. A new publication, Inquiry and the National Science Education Standards, provides valuable insights into the ways teachers might sustain the natural curiosity of students and help them develop the sets of abilities associated with scientific inquiry.

Students must acquire more than scientific knowledge and appreciation of science. They need a can-do attitude and effective problem-solving skills. They need to be able to apply them in their everyday lives. These attitudes and skills require inquiry experiences at all grade levels. Students must have control over their own learning with teachers facilitating that learning (Wright & Wright, 1998).

Many educators give examples of use inquiry in the classroom from their own experience. On his Website, Doug Duncan, University of Chicago, discusses a new way to teach introductory astronomy where "significant and lasting learning" take place when students are actively engaged. For example, they take a new concept and relate it to something they already know. They try to apply it to solve a problem or explain it to someone else. This is much more effective that the traditional lecture that fails to achieve the same results. Nelson (1996) found a constructivist approach an effective way to help a diverse student body work together.

Questioning strategies are an important component of inquiry. Penick, Crow and Bonnstetter (1996) present a logical strategy for any topic. The strategy is designed to provide teachers with one more tool for thinking about questions and their use in classroom scientific inquiry. *H R A S E* stands for history, relationships, application, speculation and explanation, the logical order for categories of questions. Rita (1998) describes constructivist strategies she uses in her classes including students pursuing their own questions, using open-ended questions, increasing wait-time, accepting student responses with a neutral "okay," and starting units with student input and hands-on activity.

Simpson (1991) reports several themes rooted in research and effective practice have emerged from the dialogue about reforming science education. Among them are construction—students need to construct their own knowledge through engagement in science (p. 30).

Teaching Fewer Topics in More Depth

In order to promote inquiry students need to spend more time on a given subject. Investigations over an extended period of time allow students time to investigate and analyze questions, to analyze and synthesize data, to apply results to explanations, to use evidence to revise explanations, and to communicate ideas. The more investigations students perform, the better will be their understanding of the value of inquiry and their knowledge of science. Thus, educators argue that the science curriculum should cover fewer topics in more depth. Carlson (2000) states that all students benefit from a curriculum that emphasizes the teaching of concepts in depth and that focuses on process and critical thinking skills. Maienschein (1998) describes two prevailing but different approaches to scientific literacy that have different implications for education. Promoting scientific literacy requires a new way of teaching that stresses "long-term process over short-term product" and questions over answers. The student may have less overall knowledge but has developed skills for adapting to the challenges of a rapidly changing world.

Connecting Classroom Science with the Students' Real World

One teaching strategy was outlined by Morvillo and Brooks (1995) who use popular news stories to spark student interest in science. These teachers have a vast collection of newspaper and magazine articles dating back for several years. Completed up-to-date articles are kept on a bulletin board and new headlines are shared on the overhead. The headlines serve as starting points for class discussion. Students break into small groups for further research. Students ask critical questions and look for relationships between textbook topics and current issues and see the scientific process in action. This approach allows teachers to integrate several units of study as they apply particular issues.

Simpson (1991) reports that several themes rooted in research and effective practice have emerged from the dialogue about reforming science education. Among them are connections—students need to make connections between science and other things they value (p. 30).

A central strategy for teaching science is investigating authentic questions generated from student experiences. Steen (1991) reports that students thrive in vigorous learning communities that help them make connections with issues of importance to them. Hurd (1997) contends that a curriculum that can be lived and that students can relate to helps develop scientifically literate students.

Bybee (1995) discusses implications of scientific literacy for curriculum and instruction. Students should develop perspectives of science and technology that include the roles of science and technology in personal life and society as well as the history and nature of science and technology.

Students will learn how different science fields are interrelated if teachers follow the recommendations of the National Academy of Science in the new science standards. Dahir (1995) in his Time Magazine article notes that this approach more closely reflects how science can be used to deal with common problems such as the biological and physiological effects of pollution.

Nelson (1999) discusses classroom implications for achieving scientific literacy. "Research tells us that students come to school with their own ideas—some correct and some not." (p. 14) Teachers must begin by identifying students' preconceptions and address those that reflect faulty thinking. Next the teacher engages the students with the subject matter preferably in the context of areas of student interest.

Involving Students in the Scientific Community

Simpson (1991) discusses the gap between society's need for scientific literacy and the ability of our schools and colleges to provide it. One major problem is that teachers teach science the way they learned it in college. Several themes rooted in research and effective practice have emerged from the dialogue about reforming science education. Among them are community—students learn best when they are socialized into the scientific community as they struggle to learn methods and results; continuity—students need to experience mathematics and science as a "seamless fabric of learning" from pre-school through graduate schools (p. 30).

Science has a value dimension that lies largely outside education. Koballa, Kemp and Evans (1997) state that although students begin a study of science in school, teachers must provide students with the knowledge and skills for a life-long pursuit of scientific literacy. They must help motivate students to value science knowledge and skills for the long term. Today scientists recognize that their community is not limited to practitioners but includes public and private funding agencies, policy and decision makers and voters. Preparing students to assume these roles responsibly can bring these students actively into the research community.

Project Objectives and Processes

As a result of article reviews and content integration and discussions during the 1999-2000 school year the freshmen and sophomore integrated science students will increase their awareness of the wide variety of current scientific issues as measured by a pre-/post- response journal question.

As a result in-depth analyzing of selected popular media coverage of science issues during the 1999-2000 school year the freshmen and sophomore integrated science students will increase their ability to critically analyze popular scientific information as measured by their ability to analyze articles.

As a result of conduction inquiry-based investigations during the 1999-2000 school year the freshmen and sophomore integrated science students will increase their ability to assess the quality of scientific experiments as measured by their response to a pre- post-test analyzing experimental procedures for characteristics of scientific methodology.

In order to accomplish the project objective, the following processes are necessary:

- Articles from a variety of resources will be gathered for assessment.
- Materials and topics that integrate the sciences and look at real world application need to be developed.
- Activities using good science process and thinking need to be developed.
- Reflective journal responses and discussions about scientific processes need to be

incorporated into the curriculum.

Project Action Plan

The researcher will design and give three baseline assessments to determine the level of student science literacy prior to the second semester. Assessments will include a free-response journal entry, a written analysis of an article from the popular press and an essay test.

Interventions include offering an inquiry-based integrated science course which includes extensive reliance on real world issues. The objective is to build knowledge of science following the hierarchical nature of science as it has unfolded over the past century. The curriculum blends the concepts that cross and connect disciplines with the concepts that repeat and extend disciplines. The curriculum during the second semester is about the atmosphere. Topics covered will include: physical properties of gases, atmospheric heating, weather, chemical properties of gases, and life cycles of gases. The curriculum will also examine the process of science including the nature of theory, how do we learn, false roads in science, the crucial role of skepticism etc.

The curriculum will be targeted as inquiry in which students, with guidance from the teacher, become apprentice scientists asking questions and developing ways of finding answers to those questions. Through this experience students will learn the scientific way of thinking. The curriculum will introduce real-world interdisciplinary problems. Popular media coverage of science will supplement standard textbooks and laboratory materials. Students will help select study topics by bringing in article and topics that interest them.

Teaching strategies will include individual and group work. Class discussions will be facilitated by techniques such as think-pair-share.

Methods of Assessment

In order to assess the effects of the intervention, students will be given three post-tests. They will list and discuss their knowledge of science in the real world. They will read an article and answer questions. Their success will be evaluated using a rubric. They will assess different experiments about the science processes used. Journal responses and article reviews throughout the year will also be assessed for improvement.

CHAPTER 4

PROJECT RESULTS

Historical Description of the Intervention

The objective of this project was to improve student scientific literacy, increasing students' awareness of current scientific issues, their ability to critically analyze scientific information, and their ability to assess the quality of scientific experiments. In order to effect these changes several strategies were used. The integrated curriculum incorporated chemistry, biology and earth science topics, using real-world issues of local, national and world interest and inquiry-based activities.

In order to increase the students' awareness of scientific impact on their lives, students began the year with a four-week project about personal water use. During the second week of school students gathered data at home about their families use of water. In the third week they analyzed this data and discussed how their families used water. By the fourth week working in cooperative groups, students researched methods of water conservation looking for practical ways to reduce their home water use. In the fifth week groups reported their proposals for saving water in the home to the class.

In order to develop the students' ability to conduct and assess scientific experiments, students conducted experiments and analyzed demonstrations. Students participated in several experiments studying what is in water and how water can be purified. During the third week students devised and implemented a method for cleaning a sample of dirty river water. During the fifth and sixth weeks students explored experimental techniques to test for various contaminants in water including solids, colloidal material, and ions. They tested samples provided as well as water samples brought from home. During the seventh week students tested the solubility of various materials in water. In the final week students explored the effects of hard water and methods of softening the water.

Throughout the intervention period, students observed and discussed demonstrations performed by the instructor. First, students recorded their observations individually. In pairs students compared their observations and came up with possible explanations for what they observed. In larger groups students compared the possible explanations and developed experiments that could prove or disprove their theories. The class attempted some of the experiments and discussed the results.

In order to develop the students' ability to critically analyze scientific information and to increase the students' awareness of real-world issues, students read articles and watched television programs. Starting in the second week and every week thereafter, students read, analyzed and discussed articles selected by the instructor. Topics included local concerns about mercury in homes, a fish kill in a river, arsenic contaminated wells in India, cyanide contamination from mining in Argentina, and beach contamination in Europe. First students read the article, stating the main idea and listing facts in the article. Students were paired to discuss the main idea and compare their lists of facts. The pairs wrote what they thought about the article and came up with questions they had about the information in the article. In larger groups or as a class, students discussed the articles and questions, and the class developed a list of actions that could be taken regarding the issue.

In addition to the articles, students also watched short segments from television programs about water issues throughout the world. These included parasites in Milwaukee drinking water, the conflict between farm and city use of water in California, the severe shortage of water in Mexico city, the problem of safe drinking water in India, and the overuse of the Australian aquifer. After watching each segment students summarized the program, generated questions about the issue, and developed a list of possible actions that could be taken.

Presentation and Analysis of Results

In order to assess the growth of students' level of scientific literacy, students repeated the three activities they completed at the first week of school in the last week of October The first two activities looked at how aware students were of science in the world around them by asking them to identify and describe current science-technology related issues and where they got information about science and technology (Appendix A). The results shown in Figures 31-35 indicate that students listed an average of 9.5 science issues, 150% of the pre-intervention score. The number of issued mentioned related to computers and electronics dropped from 47% to 33%. Most students generally got their information from three or four sources, with the most popular sources being television and school.

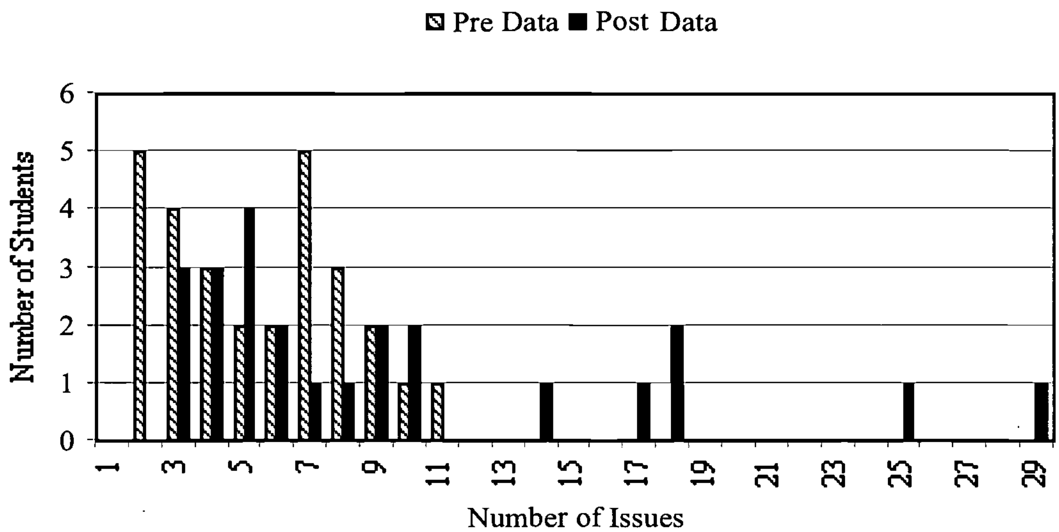

Figure 31. Total number of science issues listed by each student

Figure 31 shows that while 29 was the maximum number of issues listed after the intervention, 75% of the students listed between 3 and 10 issues. Before the intervention most students listed between two and six issues. Six students, 25% of those answering in October, developed much longer lists of issues. Most these tended to be listed with electronic gadgets in a repetitive way rather than focusing on a variety of issues including those studied in class or in the news.

Figure 32 shows that post intervention 27% of the issues mentioned were about electronics, 14% were environmental issues, 13% were modes of transportation, 10% were health related issues, 6% were related to computers, 3% were about weapons and 27% were in miscellaneous areas. Compared with earlier results, issues in the electronics area still were most common, however, computer-related issues dropped from 17% to 6%. There was a large increase in miscellaneous issues stemming from the pattern that several students followed to generate a list of related items. Most of them were electronic but includes items related to household safety, foods, and amusement parks to name a few. Some of the cause for this form of reporting may have been the example included in the activity that indicated one needed a laser to have a CD player.

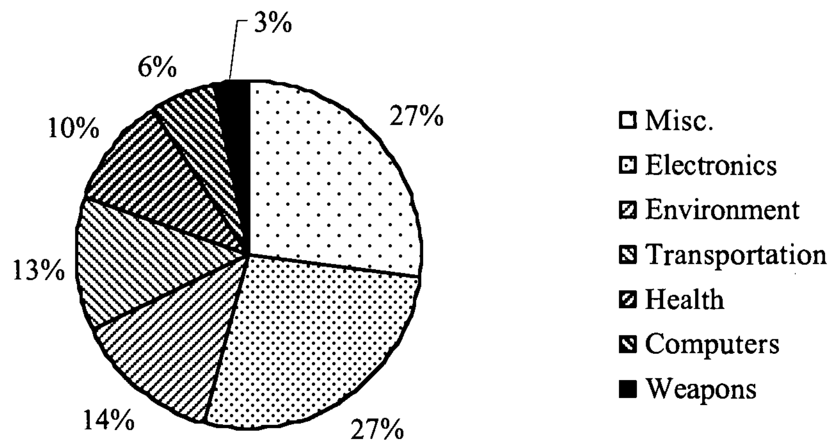

Figure 32. Issues mentioned by students - post

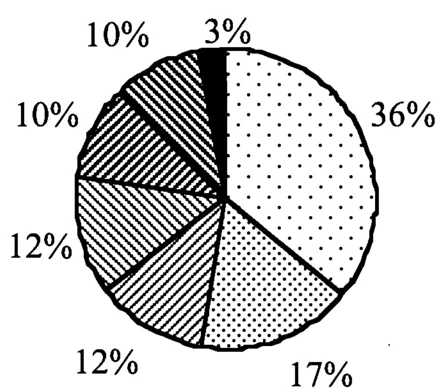

Figure 33. Issues mentioned by students - pre

Figure 34 shows that after the intervention out of a total of 24 students two-thirds got most of their information from three or four different sources, 21% of the students used one or two sources and 13% of the students used five or six sources. There is little change compared with the pre-intervention results. These results are not surprising considering the fact that the work in class did not emphasize using new or different sources of information but focused on doing a better job of analyzing information from sources already identified. The fact that some students identified more sources may reflect more awareness of different sources. In the case of issues like those discussed in class, more awareness of the issue may have lead to more awareness when the issue was reported in various media.

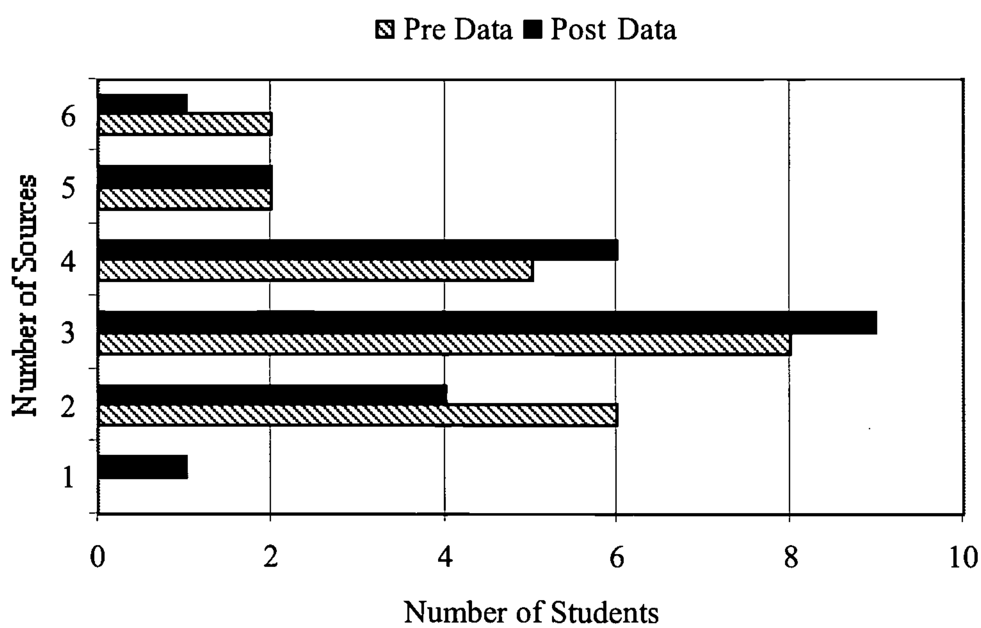

Figure 34. Number of sources students get information from

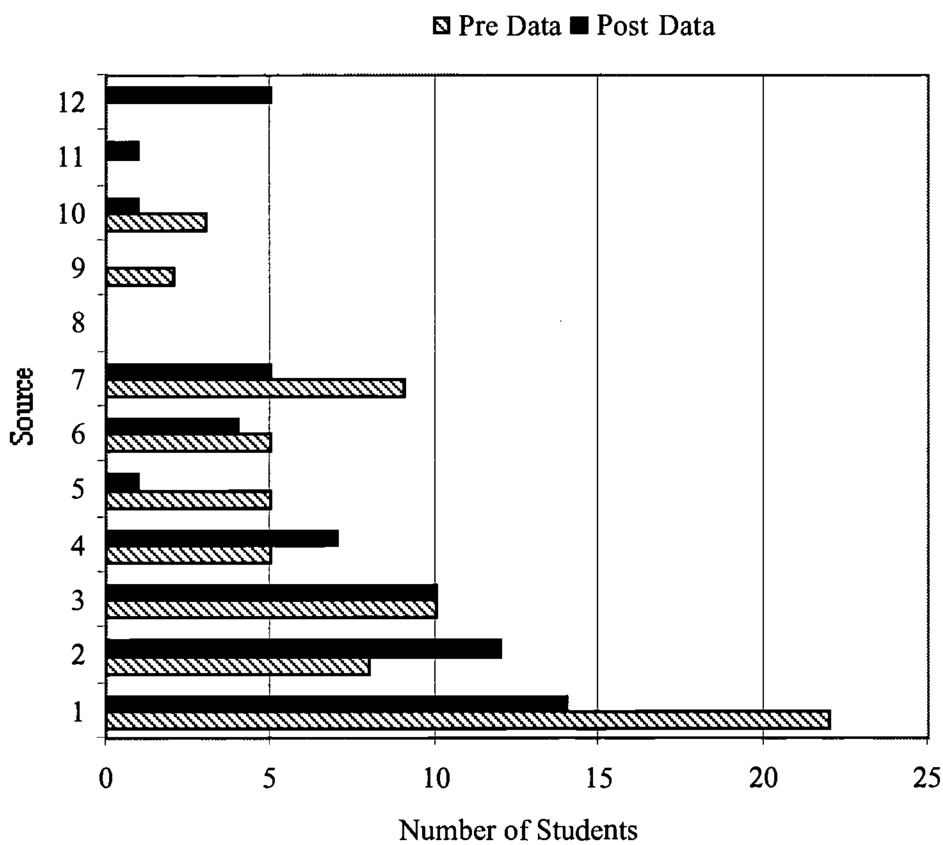

Figure 35. All sources used by students for information

Figure 35 shows that after the intervention out of a total of 24 students 17% learned information in school, 14% learned from television, 22% learned from newspapers and magazines, 7% learned from books and 40% learned from each of the following, parents, friends, tinkering and life experiences, the Internet and the radio. These data suggest that when students study issues in school, they became more aware of science coverage in the media. Also, some students mentioned issues discussed in class and would naturally include school, television and print media as sources of information. Students reported people less often as information sources after the intervention. However, some of them reported learning about issues from personal experience. One interesting response came from a student who specifically noted that taking apart and repairing an item led to his issue and concern. Older scientists often talk about tinkering as an important reason for studying science, but children have little opportunity to tinker today. Taking apart a digital clock is not the same as taking apart an analog clock.

Figure 36 shows that post intervention out of a total of 24 students 39% learned most of their information from television, 24% learned in school, 17% learned from life experiences, 17% learned from books, newspapers and magazines and 3% learned from their parents. The changes in the major sources of information is little changed from the pre intervention. As noted above an interesting change is the students who reported their own experiences as a source of information.

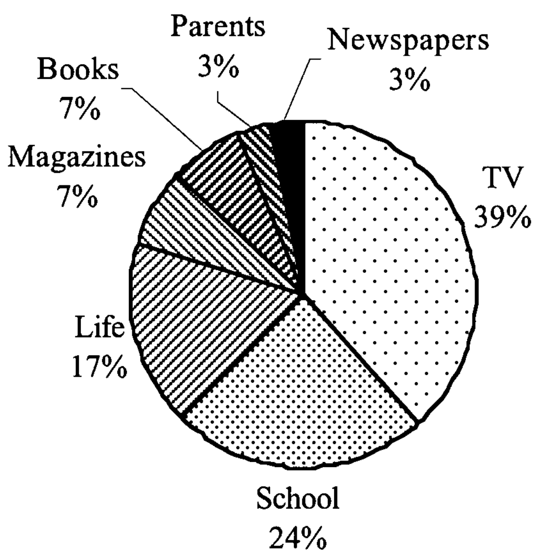

Figure 36. Source the students get most information from - post

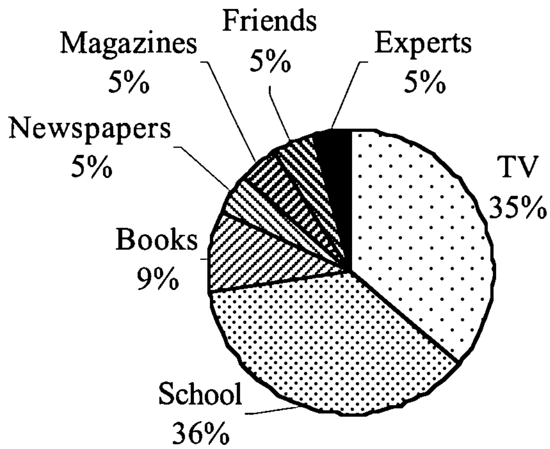

Figure 37. Source the students get most information from - pre

Students had an opportunity to discuss an issue of their choice, stating the main idea and listing as many things as they could about the topic including cause, effect, and solution. The main idea statement was scored on a four-point scale. Students earned the highest score, master, if they included all aspects of the main point. They earned the second score, expert, if they had most, but not all, of the idea explained. They earned the third score, intermediate, if they had part of the idea explained but also included incorrect information. They earned the lowest score, novice, if they tried to answer the question but did not state the main idea at all. Figures 38 and 39 indicate that about two-thirds of the students remained at an intermediate level, but fewer students were novices and more were experts. The trend is in the right direction. Most students gave between zero and two correct statements about the issue.

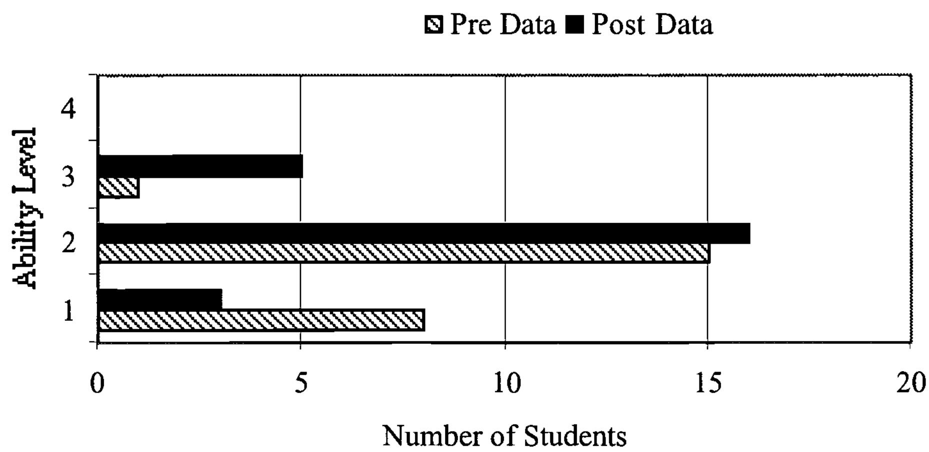

Figure 38. Students' ability to explain the main idea

Figure 38 shows that, while no student achieved mastery, five students were experts, sixteen students were at an intermediate level, and three students were novices. These results indicate that the students are becoming more effective in identifying the main point. While most students remained at the intermediate level, about 20% became experts. In class students had read and discussed seven articles. With more practice one would expect to see improvement in this area.

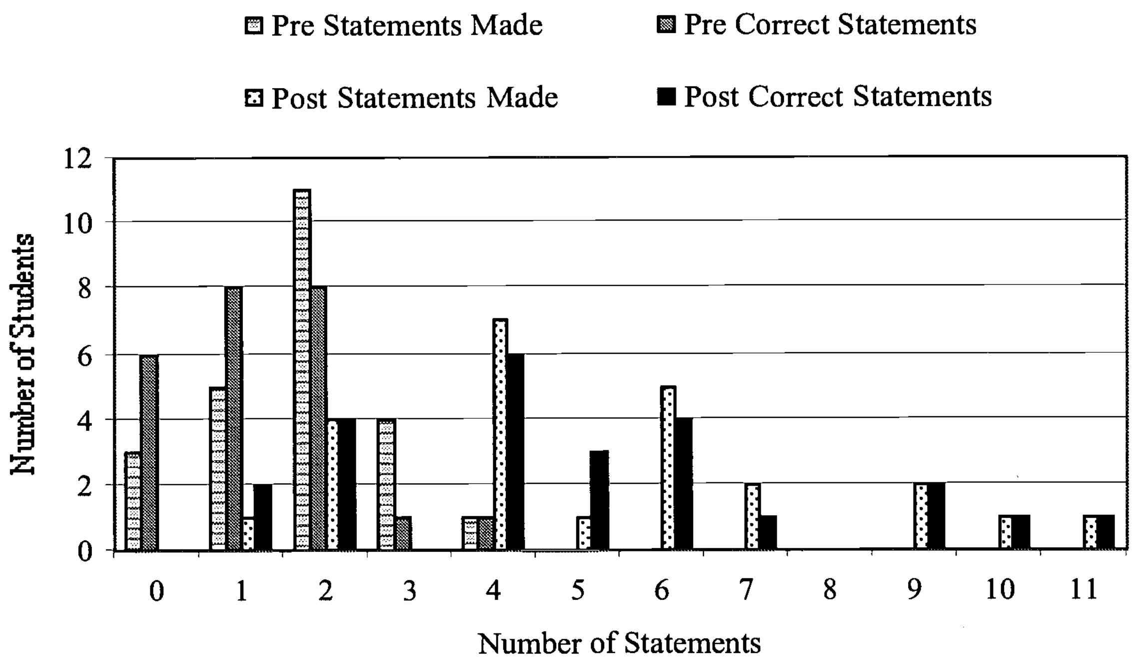

Figure 39. The number of statements made about the main idea

Figure 39 shows that after intervention half of the 24 students made between 4 and 6 statements about the issue, one-fifth of the students made one or two statements, and one-fourth made between 7 and 11. The total number of statements made, 125, is almost three times as many statements as the students made pre intervention. One hundred nineteen or 95% of the statement were valid compared with 72% in September. Five students made between 7 and 11 valid statements, thirteen students made between 4 and 6 valid statements, and six students made 1 or 2 valid statements. In both assessments students who made the most statements were also the most accurate. The statements of three students were all valid in October compared with one student in September. This suggests that the more able students were not only able to get more out of the article, but also they were more careful or understanding in their answers. In both assessments some students made several incorrect statements, dropping their scores.

In the final activity, students read a scientific article, "Do offshore wells fight natural pollution?" about drilling in the Santa Barbara channel. The article interviewed two scientists with opposing views. Students answered a series of questions based on the article (Appendix B). The first five questions that looked at the student's ability to interpret the article were graded on the four-point scale used before: novice, intermediate, expert, and master. Results reported in Figures 40-45 show that most of the students fall in the intermediate level. Results for expert and master levels ranged from 25% on students' ability to identify scientific evidence to 58% on students' ability to identify scientific conclusions. This shows significant improvement, demonstrating that practice does help develop these skills. Working individually and in small groups checking one another's work, participating in class discussions all helped students become more critical readers. The data in the following figures demonstrate the movement of the students from novice and intermediate to expert and master on five tasks, stating the main point, identifying conclusions, explaining the evidence and choosing and defending a conclusion. The only area in which students did not improve was identifying fact and opinion.

Figure 40 shows that out of a total of 24 students 45% were at an intermediate level at stating the main idea of the article, one student was a novice, seven students were experts and five students were masters, giving a complete description of the main idea. These data suggest that with practice students significantly improved their ability to state the main point of an article. Only 1 student out of 10 remained at the novice level. Half of the students were masters or experts.

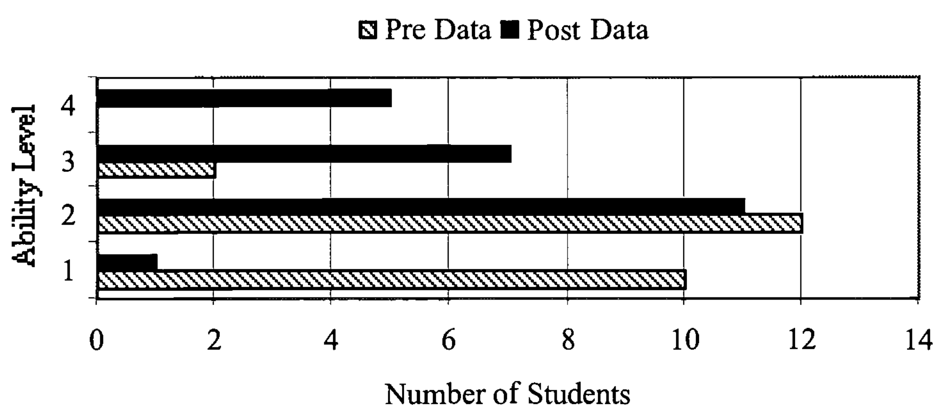

Figure 40. State the main point of the article

Figure 41 shows that one-third of the 24 students correctly indicated that the article gave facts and two-thirds thought both opinions and facts were given. These data do not show any improvement. The intervention focused on helping students identify facts but did not specifically ask them to separate fact from opinion as the articles were factual. Students might benefit from reading other articles that do contain opinion as well as fact.

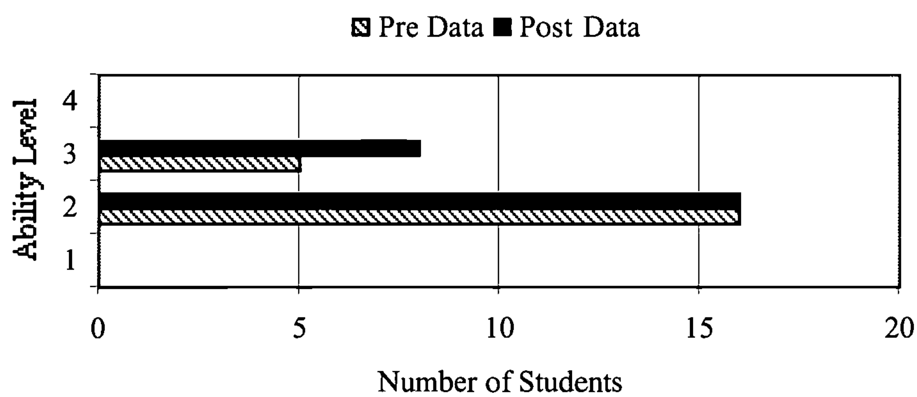

Figure 41. Fact vs Opinion

Figure 42 shows that with practice out of a total of 24 students 58% were able to determine the conclusions expressed in the article. Two students were novices, and eight were at an intermediate level. These results are significantly better than the results before intervention. The number of students who were unable to determine the conclusion dropped from 10 to 1.

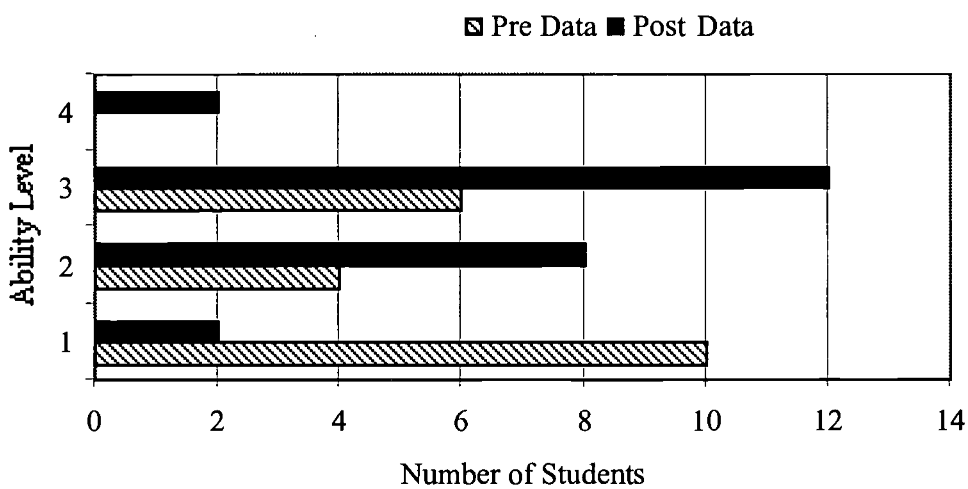

Figure 42. Stating the Conclusion

Figure 43 shows that half of the 24 students were at an intermediate level finding one fact to explain the evidence. Six students at the expert level found the two main facts. Six did not find any facts presented in the article. Compared with previous results more students were able to explain the evidence with eight students moving from the novice category. Five more students became experts.

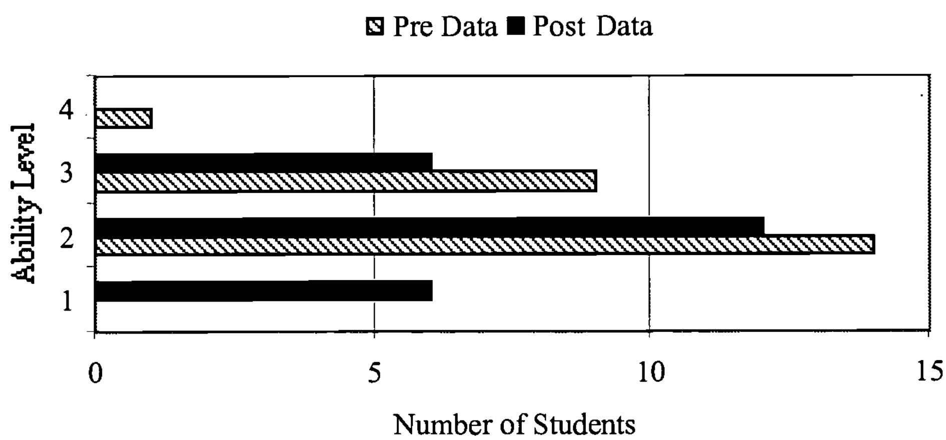

Figure 43. Explaining the Evidence

Figure 44 shows that just under half of the 24 students gave a good explanation about their opinion of the conclusions found in the article. The other half of the students gave a basic explanation. Again these results show significant improvement from September. Nine students moved up from the novice level. Eleven students became masters or experts.

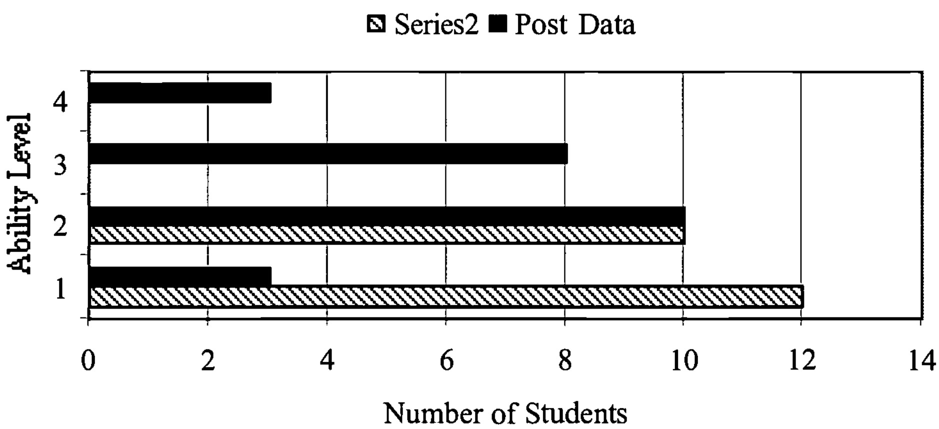

Figure 44. Conclusion Agreement

The total scores of the first five questions were added together for an overall score on analyzing the article. The novice scored 5 points for trying to answer all five questions, the highest possible score was 20 points for a master level on all questions. Figure 45 shows that student scores ranged from 8 to 17, the middle of the range. Fourteen students scored higher than the midpoint, and 10 students scored below the midpoint. The data show clearly that the students improved overall. Before practice only five students scored at the intermediate level. The rest scored as novices. With practice no students scored below 7 points and only three students scored less than 10 points as novices, the lowest score at the intermediate level. Fourteen students were at the intermediate level, and seven were experts.

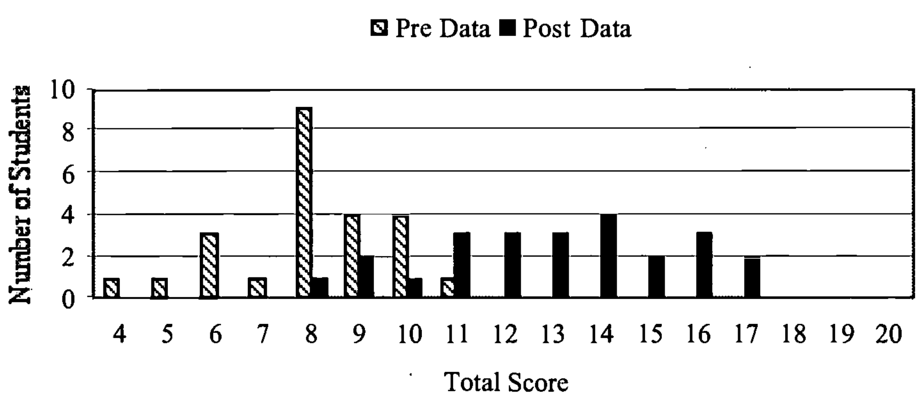

Figure 45. Total Score Questions 1-5

In the last two questions students were asked what else they would like to know and what they wanted town and company officials to do. The intervention included practice using both of these skills when the students read the weekly article. With practice students improved in both areas. Students were equally good at thinking of something that they wanted to know and at deciding what they wanted officials to do.

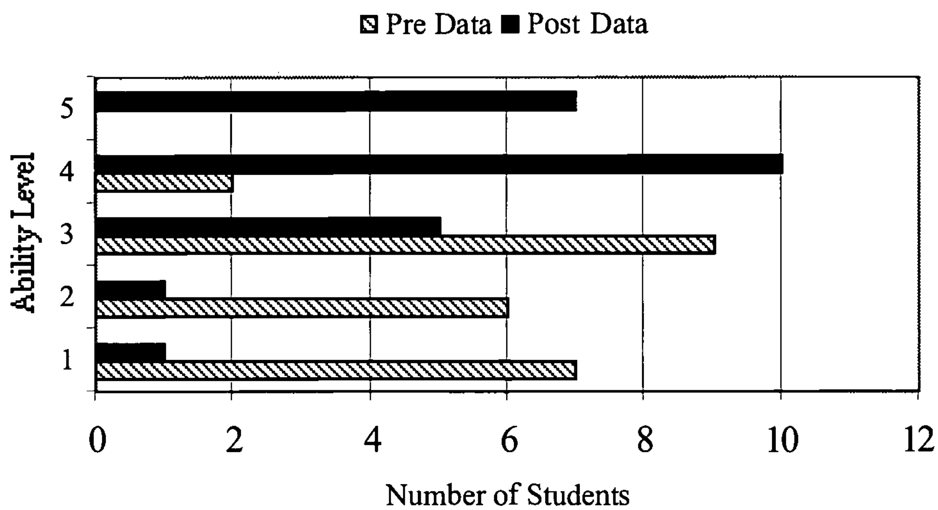

Figure 46. Quality of questions students want to know

Figure 46 shows that the quality of the information students needed to know improved. Out of a total of 24 students, about 29% of the students were masters, 42% were experts, 21% were at an intermediate level, one student was a novice, and only one student gave no answer.

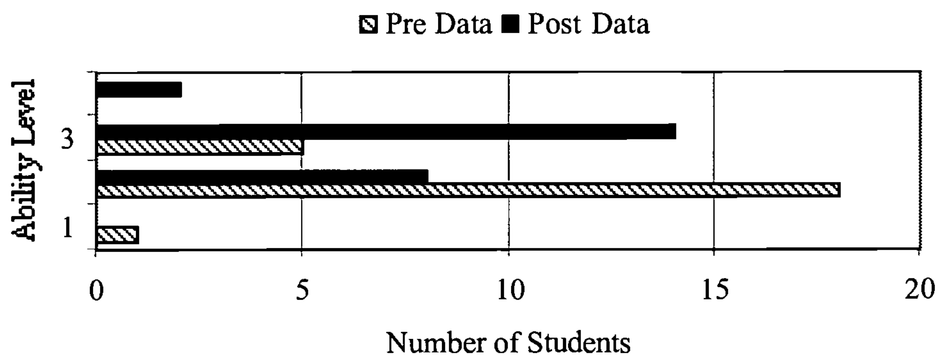

Figure 47. Quality of what students want officials to do

Figure 47 shows that all of the students could think of some action for officials to take. Two students were experts, 14 were experts and 8 were at an intermediate level. Eleven students moved up either from giving no answer or from the novice level.

Conclusions and Recommendations

Based on the presentation and analysis of the data, the students showed an improvement in scientific literacy. Students showed an increase in their awareness of scientific issues. They mentioned more issues and were better able to express the main idea about a single issue. They were better able to discuss an issue as shown by making many more, mostly valid, statements about the issue. Students were also asking more questions about real-world issues in the classroom.

Students also showed an increase in their ability to critically analyze scientific information. Students were better able to express the main point in an article and determine the conclusions presented. They could more clearly discuss their thoughts about the conclusion and not only identify more questions about the issue but also create more insightful questions. They also were better at describing appropriate actions that could be taken. Their overall score on analyzing the article was markedly improved.

Since the world is in a time of unprecedented change, largely driven by science and technology, students need to be scientifically literate. Traditionally, the science curriculum has presented students with a set of science facts unconnected to everyday life that must be memorized. The results of this project suggest that instead of maintaining this traditional approach, teachers can provide experiences to help their students develop the skills necessary to become more aware of real world scientific issues and how societies address them. When students tackle current topics of interest through investigations and by examining popular media coverage, they develop analytical skills. By bringing in real-world issues through the use of articles and television programs, students become more aware of the importance of science in their lives. Having students analyze these issues can help them to think critically and make decisions thus preparing them for making decisions as adults. When students analyze aspects related to science in their daily life, students see the importance and the applications of science in the world.

The results of this project show some success in advancing student scientific literacy. However, the duration of the project was not even a full semester. Continued research could extend the study for a full year. A new approach could break the project into two parts, the examination of science in the popular media and the use of inquiry-based investigations, and examine each one for a full year to see which, if either, is more effective alone. Another area of research could explore instruments to assess scientific literacy. A review of the literature indicates that there are few assessments that look at student scientific literacy as defined by the American Association for the Advancement of Science.

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APPENDICES

Appendix A
Science and Technology Assessment

ChemCom **Name** ___________________________

Questions about Science and Society **Period** ________ **Date** ____________

1. Your life is impacted by science and technology everyday. For example you would not have a CD player if the laser was not invented. Let's think about science and technology on a larger scale. List all of the issues in society that you can think of which relate to science and technology. They can be on local, regional, national or global scales.

2. Discuss one of the issues you mentioned above in more detail.
   a. State the issue in one or two sentences.

   b. Where did you learn the most about this issue?

   c. List other sources where you have learned about this issue.

   d. Discuss what you know about this issue. (Continue on the back.)
   (You might want to think about the cause, effect, solution, is it controversial, etc.)

Appendix B
Article Review

ChemCom **Name** ______________________________

Article Review **Period** __________ **Date** ______________

Read the attached article and answer the following questions as completely as possible on the paper provided.

Monastersky, R. (1999, November 20). Do offshore wells fight natural pollution? Science News, 156, 326.

What is the main point of the article?

Does the article present facts and/or opinions?

What conclusions do the scientists draw?

What evidence do the scientists find?

With which conclusion if any, do you agree?

What else, if anything would you like to know?

If you lived in Santa Barbara, what would you like the oil companies and county officials to do?

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