# Chapter One

## *Introduction*

### *Statement of the Problem*

Science education researchers have been calling for changes in science educational practices that prepare scientifically literate students. Despite new insights about science learning and national standards-based scientific inquiry, reform documents reiterate that science learning in schools remains unchanged. It appears that schools are not doing enough to incorporate radical changes to motivate and foster student learning. The students and teachers deficiency in understanding scientific inquiry as defined by the National Science Standards should attract more educational research. Teachers need to be confident in teaching science through interactive and inquiry-based science courses as defined in the National Science Education Standards. More emphasis should also be on integrating all aspects of science content, implementing inquiry as instructional strategies as well as understanding scientific concepts and developing abilities of inquiry.

Science is developing very fast and students need to be acquainted with the important scientific concepts early at the high school level. This will prepare them for the next step at the college level. Chemistry and science teaching in high schools has many gaps. It does not relate the content to the important real world practices of science such as research. It is our job as teachers to expand the thinking of our students to more scientific concepts. We need to develop their abilities to investigate, analyze science questions, learn subject matter discipline in the context of inquiry as well as to understand scientific concepts.

I teach chemistry for 11$^{th}$ and 12$^{th}$ grades students. I also teach integrated natural science for 9$^{th}$ grade students. Children think and reason differently at different periods of their lives. Therefore, my research will focus on using inquiry-based approaches for instruction. I envision students' critical analysis of science-related real world context papers as a way of developing students' understanding of standard-based scientific inquiry. This should provide the opportunity for understanding the integration of the interdisciplinary concepts. Meaningful learning and active discovery should provide the opportunity to learn subject matter in an inquiry-based approach.

*Significant of the Study*

High school chemistry teachers can make a significant difference in the lives of their students. For many students, high school represents the single most significant period in their science education, a time when tentative career choices are made. Developing both a scientifically literate citizenry and the science specialists needed to advance our nation in an increasingly complex technological world, demands intellectually challenging, yet developmentally appropriate curricula taught by well-qualified teachers (Linn, 2003)**.**

We, as teachers, have experienced the means of attaining knowledge. We can be role models for our students. If we continuously strive for more education, are familiar with the changes in the science areas we teach and try to implement new knowledge in the classroom.

In this research project analysis of a scientific paper will be used to help chemistry students understand scientific inquiry. The following areas will be investigated:

1. Understanding of scientific papers,
2. Using interdisciplinary science concepts in an authentic, issue-based, problem setting.

3. Carrying out scientific inquiry.

The study will engage teacher and students within the classroom in standards-based learning, teaching and assessment strategies (Barnett & Hodson, 2001; Darling-Hammond & McLaughlin, 1995). It will immerse me as a teacher in the inquiry of scientific inquiry (Fishman, Marx, Best & Tal., 2003, Hofstein, Shore & Kipnis, 2004; Krajcik, Mamlok & Hug, 2001: Lee, hart, Cuevas, & Enders, 2004).

The way chemistry is being taught in high school is very dry except for some laboratory exercises and experiments that have little effect on the development of understanding, ability for inquiry and knowledge of science content. The results are usually similar for all the students and thoughtful public communication of students' ideas and work with classmate is not part of the results. I believe that giving the students the opportunity to learn subject matter disciplines in the context of inquiry should be a rewarding scientific experience to both students and teacher.

*Review of the Literature*

The literature review presented here covers the ongoing reform to implement standards-based science education at the K-12 schools. Those reform activities are supported by many scientific organizations such as American Association for the Advancement of Science (AAAS), National Research Council (NRC) and American Chemical Society (ACS). The literature covered here also addresses the changes that promote inquiry-based teaching that the National Science Education Standards envision. The teaching methods based on the learning theories established by Piaget and Ausbel will also be briefly outlined.

*Ongoing Education Reform*

There is a clear national consensus in the United States that *all* elementary, middle, and secondary school children need to be better educated in science, mathematics, and technology. Many scientific organizations in the United States support ongoing reform efforts in science education at all levels. Reform must be sustained. The organizations continue to support nationwide efforts to implement standards-based science education at the K-12 level. In addition, there is a need to develop new assessment instruments to evaluate students' learning outcomes, faculty effectiveness and the curriculum. Race, language, sex, or economic circumstances must no longer be factors in depriving students from receiving good scientific education and become nationally talented workers and informed citizens.

*American association for the advancement of science (AAAS)*

The American Association for the Advancement of Science (AAAS) has initiated Project 2061 reform efforts (AAAS, 1989). The latter provided a long-term, multiphase plan with specific recommendations for achieving scientific literacy for *all.* Project 2061 was organized into three phases. *Science for all Americans* - Phase I served as a starting point for the long-term reform process, by providing conceptual basis for the recommended changes. Sections of the conceptual frameworks were based on the belief that the scientifically literate person is one who: a) understands key concepts and principles of science, and b) is able to use and manipulate scientific knowledge for individual and social purposes (AAAS, 1989).

Phase II, *Benchmarks for Scientific Literacy* (AAAS, 1993) specified the knowledge, skills, and attitudes to be attained at each grade level, thus, emphasizing what *all* students should know at the end of each grade level.

The theoretical frameworks of documents I and II formed the bases for Phase III. The purpose of phase III was to facilitate the necessary and lasting changes to produce scientifically literate citizens.

*National research council (NRC)*

In 1996, the National Research Council (NRC) published the *National Science Education Standards*. The goal of the *Standards* was to create a vision for the scientifically literate person and guidelines for science education that would allow the vision to become a reality. According to the document, a scientifically literate person is the one who:

1- Can ask, find, or determine answers to questions derived from curiosity about everyday experiences,

2- Is able to read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions,

3- Can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed,

4- Is competent to evaluate the quality of scientific information on the basis of its source and the methods used to generate it.

*American chemical society (ACS))*

Secondary education has now become the focus of the president and counselors of the American Chemical Society (ACS), the world's largest association of individual chemical scientists and engineers. The society continues to play an important role in the development of national policies related to science education by providing advice to Congress and various federal agencies. The Society also provides comments on the annual budgets of the National

Science Foundation (NSF) Education and Human Resources Directorate, and the U.S. Department of Education. ACS has been involved in the educational reform movement for many years.

Nationally and at the state level, there has been an acceptance that standards-based science instruction should include emphasis on hands-on, inquiry based instruction to help K-12 students develop the knowledge and understanding of scientific ideas. Specifically, they need to understand how scientists use inquiry methods that involve making observations; posing questions; examining the literature to see what is already known through experimental evidence and communicating the results orally, in writing, and by other methods. Recognizing the importance of a sustained effort, ACS continues to support nationwide efforts to:

1- Implement standards-based science education at the K-12 level;
2- Promote a scientific curriculum that emphasizes scientific reasoning and scientifically validated data at all levels;
3- Develop introductory chemistry courses for both general students and science students that emphasize the current and future solutions of real-world problems.
4- Integrate chemistry core courses for undergraduates and graduates on an intra-disciplinary unifying concept basis that reflects how chemistry is actually practiced (ACS, 2002).

*National science education standards*

The National Science Education Standards envision change throughout the system. The science content standards encompass changes in emphases (Table 1) as well as emphases to promote inquiry (Table 2) (Science Content Standard, p. 113). It is clear that there should be changes of emphasis to promote inquiry in science education. Parts of the emphasis in teaching science should be directed toward understanding scientific concepts and developing abilities of inquiry as well as integrating all aspects of science contexts. Few fundamental scientific concepts should be studied at first. This will help to implement inquiry as instructional strategies. In addition, activities should be carried out to investigate and analyze science questions over extended period of time. Doing more investigation should be encouraged in order to develop understanding and knowledge of science content. Assignments should encourage management of ideas and information. Also, students should be encouraged to communicate their ideas and work with their classmates.

Table 1: Changing Emphases (Science Content Standard, p. 113).

Table 2: Changing Emphases to Promote Inquiry (Science Content Standard, p. 113**).**

| **LESS EMPHASIS ON** | **MORE EMPHASIS ON** |
|---|---|
| Activities that demonstrate and verify science content | Activities that investigate and analyze science questions |
| Investigation confined to one class period | Investigations over extended periods of time |
| Process skills out of context | Process skills in context |
| Emphasis on individual process skills such as observation or inference | Using multiple process skills-manipulation, cognitive, procedural |
| Getting an answer | Using evidence and strategies for developing or revising an explanation |

| | |
|---|---|
| Science as exploration and experiment | Science as argument and explanation |
| Providing answers to questions about science content | Communicating, science explanations |
| Individuals and groups of students analyzing and synthesizing data without defending a conclusion | Groups of students often analyzing and synthesizing data after defending conclusions |
| Doing few investigations in order to leave time to cover large amounts of content | Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content |
| Concluding inquires with the result of the experiment | Applying the results of experiments to scientific arguments and explanations |
| Management of materials and equipment | Management of ideas and information |
| Private communication of student ideas and conclusions to teacher | Public communication of student ideas and work to classmates |

*Learning Theories*

Piaget has been labeled an interactionist as well as a constructivist. He believed that children's spontaneous comments provided valuable clues to understanding their thinking. He discovered that children think and reason differently at different periods in their lives. Experiences help to naturally develop educated human beings. The teacher's task is not to talk, but to motivate and encourage students to discover principles by themselves. The students learn more about objects by acting on them, activity is essential (Siegel & Cocking, 1977). In active discovery students need to explore, manipulate, experiment, question, and search out answers for themselves. Learning is much more meaningful if the students are allowed to experiment on their own rather than listening to the teacher lecture. The teacher should present students with materials and situations and occasions that allow them to discover new learning. In conclusion, the students should be active participants and the teacher should be a facilitator giving them guidance for creations. Intellectual growth involves three fundamental processes: assimilation, accommodation, and equilibration (London, 1988; Piaget, 1972).

In Ausbel's meaningful learning theory, children relate new ideas, concepts, and information to what they already know. The learned concepts are considered to be subsumers because they provide anchorage for newly learned concepts. Concepts and ideas that have been learned meaningfully are supposed to be retained longer than those learned by rote (Marek & Cavallo, 1997).

*Inquiry-Type Laboratory in High School Chemistry*

Teaching and learning science through inquiry poses challenges to both students and their teachers. An inquiry-type laboratory was implemented into chemistry curriculum in high schools. Hofstein et al (2004) developed a series of about 50 experiments to teach chemistry. The students were assessed by means of a ”hot report” which is the group product prepared during or immediately after the laboratory exercise. The teachers were provided with long-term and continuous professional development to bring them to a higher level of knowledge. Each group of students underwent 2-phases in order to accomplish the inquiry task. This included: 1) asking relevant questions about the experiment, 2) formulating hypothesis, 3) choosing a researchable question and planning and experiment for further investigation. The results of the study showed that the involved students were more aware of the meaningful contribution of the inquiry method to their learning. Analysis of the students' reports showed improvements in their abilities regarding inquiry learning in the chemistry laboratory. The program was also challenging and enjoyable for the teachers (Hofstein et al., 2004).

*Summary and Conclusion of the Literature*

Science curricula need to be challenging to the students, and based on the "real world" of student interactions with nature. The National Science Education Standards and the Project 2016 Benchmarks, together with state and local frameworks, present a consensus on which to build such curricula. The 2002 NRC report on improving advanced study of mathematics and science in U.S. high schools, stresses that inquiry-based learning and laboratory experiences are essential components of chemistry and science instruction at all levels. To help meet standards of excellence, educational organizations support:

1- Developing science courses based on inquiry based learning, as defined in the National Science Education Standards, and evaluating performance using standards based assessment techniques. Classroom evaluation should assess higher-level cognitive skills, including the ability to apply science knowledge in new situations.
2- Redesigning chemistry courses to present a broad view of the scope of modern chemistry by including topics such as organic, polymer, biochemistry, and materials science.
3- Integrating science content across disciplines and throughout the years of the secondary school experience.

4- Enhancing articulation between high schools and two-year colleges.

During one portion of my research project, the students will have the opportunity to read and try to understand advanced scientific papers. The papers present a way of integrating science content across disciplines such as biochemistry, pharmacology, organic and inorganic chemistry. The other portion of the project will emphasize active learning. Scientific inquiry based learning, as defined in the National Science Education Standards will be attempted, including evaluating performance using standards based assessment techniques. Classroom evaluation will be attempted to assess higher-level cognitive skills such as the ability to apply science knowledge in new situations.

### *Overall Purpose of the Study*

The purpose of this study is to evaluate students' understanding of scientific inquiry as they critically analyze scientific papers. It will also investigate the use of interdisciplinary concepts of science in an authentic problem setting that is issue-based. The results of the study will be used to analyze the gap that the teachers and students have in understanding what scientific inquiry is, according to the standards. The National Science Education Standards emphases to promote inquiry will be also discussed.

### *Specific Research Questions*

The following research questions guided this study:

1. How well do students understand the nature or character of scientific inquiry when a teacher engages them in inquiry-based activities and in reading scientific papers?

The analysis will include the student's ability to:

1- Read

2- Understand the use of interdisciplinary concepts’

3- Identify theories

4- Critical analysis of data

5- Weigh competing theories based on conditions and content.

2. Is there a correlation between students’ understanding of scientific inquiry and their achievement, attitude toward science, and motivations?

*Hypotheses: Null and Alternative Hypotheses*

Null: Reading scientific papers will not help the students to understand the characteristics of scientific inquiry.

Alternative: Reading scientific papers will help the students to understand the characteristics of scientific inquiry

Null: There is no correlation between students’ understanding of scientific inquiry and their achievements, attitude toward science and motivations.

Alternative: There is a correlation between students’ understanding of scientific inquiry and their achievement, attitude toward science and motivation.

*Independent and Dependent Variables.*

Independent variables: standard based scientific inquiry versus traditional teaching; gender; SES, ethnicity.

Dependent variable: understanding of scientific inquiry, achievement, attitude toward science, career goals, and motivation.

*Terminology*

**Assimilation**: involves the incorporation of new events into preexisting cognitive structures. (Piaget, 1972).

**Accommodation**: means existing structures change to accommodate to the new information. This dual process, assimilation-accommodation, enables the child to form schema. (Piaget, 1972).

**Equilibration**: involves the person striking a balance between him-self and the environment, between assimilation and accommodation. (Piaget, 1972).

**Inquiry as content understanding**: in which students have opportunities to construct concepts, patterns and to create meaning about an idea in order to explain what they experienced (Hofstein et al., 2004).

# Chapter Two

## *Methods*

A quasi-experimental design was used in the study to determine the impact of real-world contexts on students' ability to understand scientific inquiry and their academic progress. The study focused on two subjects areas: Chemistry involving $11^{th}$ and $12^{th}$ grade students and integrated natural science involving the $9^{th}$ grade students. Data collection included observations, discussions and informal interviews.

### *Setting*

The study took place in a high school in the Detroit area. The high school was built in 1927. About 2,200 students were enrolled in the $9^{th}$, $10^{th}$, $11^{th}$ and $12^{th}$ grades. All of the students were of African American origin. The high school was composed of two separate facilities. One facility housed 9th grader students only (about 900 students) and was called the ninth grade success academy. The other facility housed 10th, 11th and 12th graders and had been newly remodeled. This facility was not connected to the ninth grade academy. Consequently, there was no interaction between the students of both facilities. The classes were made up of 35 students each and met 5 times a week for 55 minutes a session. The 9th grade students joined the high school from the local middle schools.

The average household income of the school district was $30,296. The district had a diverse ethnic makeup (15% Eastern European immigrants, 85% African American). Middle Eastern descents and immigrants as well as some Eastern European immigrants lived in specific areas of the district and constituted about 15% of its population. The other 85% were of African American origin.

*Participants*

Students from three 9th grade and two 12th grade classes participated in the study. The total number of 9th grade students in integrated natural science classes was 92 (47 females and 45 males). The total number of the 12th grade students, in the chemistry classes, was 60 (25 females and 35 males). There were no special education students or students whose native language was not English. The students had no previous laboratory skills and were rarely exposed to hands-on activities. The students' seats were arranged around large tables or benches allowing them to be in groups. The classrooms were moderately equipped for science projects. However, computers and Internet access were not available inside the classrooms.

*Data Collection*

The academic progress of the students was collected through student grades on assignment and tests. Personal interviews took place at some stages to determine students' views on the new instructional methods. Students' opinions and interpretations were recorded. Laboratory reports were be collected and analyzed. Students' ability to connect and summarize the results of their understanding in concept maps was encouraged and analyzed. Students were asked to write reports that reflected the degree of their progress in understanding as well as analyzing scientific data. Subsequent progress reports clarified and explained the newly presented concepts. Posters as well as oral presentations in the classrooms were part of the data collection. Classroom observations of students' behaviors and daily academic progress were recorded. During those observations, the teacher evaluated students' progress of the procedure and determined if any modification or alternate strategies should be implemented.

*Data Analysis*

Data from laboratory reports was analyzed for prior incorrect concepts, formation of new concepts and the full development of the concepts. The student's ability to understand interdisciplinary concepts was evaluated. The development of the students' abilities to collect, interpret and present scientific data were monitored. In one set of classes, the differences in average test scores grades were analyzed. Factors that promote or restrict the progress of the study were recorded. Those factors may include the availability of some resources in the school and community that were needed for the success of the study.

*Procedure of the Study*

Integrated science classes. For the first 3 weeks of the semester, I used a teaching strategy for 9th grades that involve little inquiry. In the mean time, I monitored closely the students in the classroom in terms of behavior, participation, attendance and motivation. Test results were recorded.

At the beginning of the fourth week, I started teaching chapter 7 of the science interaction book. This chapter emphasized biochemistry. Mini-labs were performed, during which the students had to write the procedure, record their observations and conclusions. The teacher played the role of facilitator and did not provide the answers. Several laboratories were conducted that helped the students to investigate over extended periods of time. Such investigations were in order to develop understanding, ability, values of inquiry and knowledge of science content. Student results and conclusion were collected, analyzed, posted and discussed in the classroom for several days. This provided the students with the opportunity to communicate their ideas and work to their classmates. Eventually, concept maps were developed to help the students organize and remember the concepts covered. Students practiced integrating some aspects of science content. Data on classroom behavior, participation, attendance, motivation, test results were collected.

*Chemistry classes*. For the 12th grade chemistry students, I tried to engage the students in reading and analyzing scientific papers to help determine their ability in understanding the nature of science. The scientific papers were from the top 45 pharmaceutical discoveries. The source was Journal of Chemical and Engineering News, a biweekly journal published by the American Chemical Society which was available on-line. The students had to choose a medicine and print the article on it. The students were asked to read the article, try to understand the use of interdisciplinary concepts, identify theories and critically analyze the data. Consequently, they had to communicate their finding to their classmates through oral or poster presentations. Discussion of the new concepts and scientific methods was carried out during the presentations. The teacher took the role of facilitator and directed the discussion as needed. The students were asked to do more research about the new concepts and provide more explanations. This project lasted six weeks.

Chapter Three

*Results*

The unit titled: "What is in the food you eat?" provided a remarkable opportunity to investigate inquiry-based scientific learning for the 9th grader students. The students had the opportunity to compare the molecular structures of the three major components of food (carbohydrates, fats, and lipids). They also did several activities to explore the importance of enzymes to biochemical processes and in digestion. In addition, they were able to investigate the mode of action of enzymes. Concepts maps were drawn after each unit to summarize the relationship between the revealed concepts. The teacher provided the students with activities that promoted inquiry. The students worked in groups of four to five students. The total number of groups who had good attendance record is 15. The teacher did not provide explanations of the purpose of each activity.

The teacher noticed that the activities promoted scientific discussion among most groups.

*Critical Analysis of Data*

The activity "where is fat?" allowed student to predict and observe the differences between the types of fat found in butter. They were allowed to observe that the amount of fat material remaining in a coffee filter is greater for the butter samples. The students were expected to analyze that butter had more of a fatty residue that did margarine.

Seven groups (47%) were able to reveal the purpose of the activity on their own. Their interpretations of the results exceed the teacher's expectation. Two groups were able to connect their results to real world application such as "The experiment proved margarine digest better than butter. The butter will stick to your blood vessels". That provided an example of the ability of some students to integrate some aspects of science. They showed an ability to analyze the scientific data and differentiate between the structure of margarine (unsaturated lipids) and butter (saturated lipids). Two groups wrote conclusions such as "The butter is thicker than the margarine. The margarine went through the filter while the butter did not and butter is thicker than margarine". One group of students developed concept map (**1**) (Appendix). It indicated that they were able to make the accurate connection between the various concepts.

The activity "lock and key model" investigated the student's ability to observe, make models, recognize cause and effect, compare and contrast. In the activity, the students had to make a model showing how enzymes "recognize" the molecules with which they react. They had to form a model from the key and lock that assisted them in understanding enzyme activity. They had the opportunity to observe how the breakdown of a reactant was like the unlocking of the lock with the proper key.

Five groups (34%) did a good analysis of the data. They drew the following conclusions:

1. Each lock has a specific key that fit into an area like the active site.
2. The lock and key model was very similar to the enzymes because if the key fitted in the lock, it opened. If the active site fitted into the substrate it would form an enzyme-substrate complex causing it to open or activate.
3. It is related to enzyme and substrate is because to activate to substrate and enzyme, you need the right active site or it would not activate. As a result of the key lock, you need to open the lock with the right shape to open the lock.

4. Just like the enzyme and the substrate, if the enzyme and the substrate did not fit it wont work and if the lock and key don't fit it will not open.
5. Each substrate fits into an area of the enzyme called the active site, just like the key when it fits into a lock. The key is the substrate and the lock is the enzyme.

They exceeded the purpose of the activity and discuss model of the active site and ability of the enzyme-substrate complex to activate the enzyme. By doing so these groups were able to apply the results of the experiment to scientific explanation. One group was able to draw concept map **2** (Appendix). It depicted a nice and accurate relationship between the enzyme, substrate, enzyme-substrate complex and product. Other concept maps drawing by the other groups did not provide a good understanding of the ability to relate the concepts.

The teacher observed that four groups could not reveal the scientific purpose of the activity. Instead, they drew conclusions about the shape of the key and the shape of the lock. About 15% of the students did not do the activity or try to figure out the purpose of it.

The investigation "Do enzyme influence protein digestion?" was introduced in order to develop more understanding, values of inquiry and knowledge of science content. Six groups (40%) of student were able to nicely analyze the data. During the activity the students observed the changes in protein breakdown in the presence of an enzyme. They had to hypothesize as how each item tested could affect the protein in prepared gelatin dessert. The activity allowed the students to observe some of the chemical changes taking place when protein was digested. The students were allowed to observe that the enzyme found in meat tenderizer and some fresh fruit such as pineapple can break down the solid structure of gelatin. They were monitored on their ability to determine that canned pineapple did not produce the same breakdown effect as fresh pineapple.

One particular group developed a nice data table that summarized their scientific findings.

The paragraphs below are copied from the students' science notebooks without any editing or corrections.

1. The meat tenderizer broke down the gelatin because it has papain in it, which causes the proteins in the gelatin to break down. The papain is the enzyme because it speeded up the process.
2. Papain is used in some meat tenderizers to break down protein, such as that found in gelatin into smaller amino acids units.
3. The enzymes in the meat tenderizer and the fruit break down the protein in the gelatin into smaller amino acids.
4.

| Gelatin with fresh pineapple | Gelatin with meat tenderizer | Gelatin with canned pineapple |
|---|---|---|
| Melted the 2nd fastest<br>Had effect but, it melted 2nd. | Melted the 1st fastest<br>Had a big effect on the gelatin | Did not melt<br>Had no effect on the gelatin |

5. In conclusion, the results show that the enzymes in the fresh pineapple and in the meat tenderizer were still activated, which can help in breaking down protein.  The canned

pineapple enzyme was deactivated, or died, because it was canned, and did not stay fresh to break down.

6. The gelatin is the protein and the pineapple and meat tenderizer have the enzyme. The meat tenderizer broke down quicker than the fresh pineapple and the canned pineapples.

One group of students was able to depict concept map **3** (Appendix), which help reinforcing the results of the experiments.

*Read with Understanding Scientific Texts*

The teacher did not explain to the students the purpose of each activity. The teacher attempted to test the students' abilities to read and understand scientific terms from scientific journals. In all the mentioned above activities, about 70% of the groups were able to understand and independently carry the investigation. The students were discussing the purpose and the procedure of each investigation.

About 20% of the groups repeatedly requested the help of the teacher to explain the method section and the purpose of the activity. The teacher noticed that those groups did not attempt to read the procedure.

The rest 10% of the groups were not interested in either reading or trying to do something with the material provided.

*Understand the Use of Interdisciplinary Concept*

Analysis of the students' results from the three mentioned above activities "Where is fat", "key and lock model" and 'Do enzymes influence protein digestion?" indicated that three groups (20%) of students were able to connected their findings to real world application. Conclusion such as "the experiment proved margarine digest better than butter" and " the butter will stick to your blood vessel" provided examples of the ability of some students to integrate some aspects of science.

Concept map **4** (Appendix) was developed by one of my excellent students. It provided a summary of a whole unit and showed the digestion of food starting from the mouth and ending with the intestines. It presented also the role and location of the different enzymes involved in the digestion process.

*Identifying Theories*

Analysis of the students' results from the three mentioned above activities "Where is fat", "key and lock model" and 'Do enzymes influence protein digestion?" indicated six groups of student (40%) were able to identify the theories attempted to be taught. Some used their own scientific expression such as "deactivated enzyme or died". Some of those expressions were better simplified for the understanding of their classmates.

*Weighing Competing Theories Based on Conditions and Content*

The activity " do enzymes influence protein digestion?' investigated the students' abilities of weighing competing theories based on conditions and contents. Six groups of students were able to reveal the accurate theory. One of the groups developed a nice data table that allowed an easy and smart way of identifying the theory based on conditions and contents.

*Correlation Between the Students' Understanding of Scientific Inquiry and the National Standard.*

The results of this study indicate that if the students have the appropriate scientific background, it is possible to correlate between the students' understanding of scientific inquiry and the national standard.  The students' level of understanding and participation allowed the teacher to implement activities that investigated and analyzed scientific questions.  The teacher was able to do more investigation in order to develop understanding, ability, and value of inquiry and knowledge of science content.  That included study guides and concept maps.  Studying the results of the above activities indicated that eight groups of students (54%) were able to apply the results of their experiments to scientific explanation.

During the project, the students were given the opportunity to communicate the students to communicate their work to their classmates, instead of private communication with the teacher (SCS p113).  For that purpose, the teacher analyzed the students' reports after each activity. Following the evaluation, each group was given the chance to write their conclusion on the large post-it papers and posted on the board.  They were given the opportunity to discuss and defend their findings with their classmate.  To reinforce the concept, a related transparency was placed on an overhead projector.  The teacher asked if any of the students was willing to explain to the classmates the scientific concept of the transparency.  Only 2-3% of the students were willing to participate.

*Participation*

The teacher noticed that the degree of participation of the students varied with the teaching approaches.  When an activity was planned 70-80% of the students participated.  The degree of participation increased to more than 90% when the students were asked to complete a study guide and answer questions about the content of the text in the book.  The teacher noticed that the degree of participate declined remarkably when the students were asked to present and discuss their findings in front of their classmates.

To help the students manage their results, the teacher developed some techniques that had a remarkable impact on the management skills of the students.

1- Filing system: the teacher organized the students by groups (e.g. group 1, 2, 3, 4, 5, 6, 7and 8). Each student in each group was offered a different color pocket folder. The student was responsible for filing his or her own papers after being checked by the teacher. The teacher had a three drawers filing cabinet in the classroom. The teacher assigned one drawer to each INS hour (Hour 1, 2 and 3). Inside each drawer, there were hanging folder numbered by the group numbers (group 1, 2, 3, 4, 5, 6, 7, and 8). Each student was responsible to save his work in his pocket folder, in the specific hanging folder for his group and in the specific drawer of his INS hour. The developed filing system remarkably improved the management of the students' results. The teacher graded the folders periodically, which encourage the students to accomplish most the work. Close to 95% of the students participated in this filling system.
2- The materials for each activity were also placed in a tray. The trays were numbered for each group. The students had to make sure they performed the activity in the tray and returned it clean at the end. More than 90% of the students were able to follow these instructions. This provided them with the experience to work safely in a designated area.

Three important strategies had a remarkable impact on the students' motivation:

1- Presentation of their findings and results: teacher allowed the best groups to write their finding on large post-it papers. The results were posted in the classroom for several days. The rest of the groups were asked to compare the best results with their own. This technique motivated the groups to do their best in order to post their results in the classroom. About 30% of the groups began posting their results. At the end of the study, close to 60% posted their results.

2- Daily grading: the teacher consistently moved around the groups during the activities. The students were graded daily on their participations and accomplishments. Daily class-work was given 30% of the final grade. Therefore, close to 80% of the students performed to accomplish their work daily.

The project for the 12th graders tended to evaluate student's understanding of scientific inquiry as they critically analyzed scientific papers. It provided an opportunity to investigate the following standard

*Activity to Investigate and Analyze Science Questions*

The project for the chemistry students was an investigation that extended over periods of time (2 months). The special issue of: "Top Pharmaceuticals" at Chemical and Engineering News looks at 46 drugs that have had a major impact on human health and society. The content of the project can be viewed as a way of integrating some aspects of science.

The students had to read and critique advanced scientific articles. Each article provided an interesting way of integrating science content across the disciplines such as biochemistry, pharmacology, organic, and inorganic chemistry. The students were asked to work in groups of 3-4 students.

The teacher provided the students with an index that listed 46 drugs by therapeutic class. The topics that the students choose for their projects were affected by real world application factors. Some of those topics were AIDS, cocain, anticholesterol, abortion, L-Dopa, antihistamine (allergy), vitamins etc.   The drug Viagra was not allowed as a choice because of some restriction that the district imposes on discussion of sexual issues in the classroom.

The teacher directed the students to use one specific web site related to the journal of chemical and engineering news.  Out of the 16 groups of students,13 groups (80%) accomplished the first part of the project and provided the researcher with printouts of the medicine.  The researcher noticed that some students used other websites and printed out information that did not apply to the purpose of the project.  The groups were asked to repeat their searches.

*Ability to Read with Understanding Scientific Articles*

At first, the students were not able to understand the articles.  They were not able to gather important information and draw conclusions.  The teacher had to provide the students with a second part of the project.  Part II consisted of a series of questions about how to look for scientifically important data.  After two weeks, the teacher collected 10 reports.  Analysis of the reports clearly demonstrated the ability of the students to retrieve the information that the project was attempting.   Apparently, those 10 groups (77%) were able to precisely identify the answers and give meaningful conclusions.

The paragraphs below are copied (without any editing or corrections) from the papers submitted by the chemistry students.

1. "L- Dopa is the treatment of Parkinson's disease.  It is caused in the brain.  Dopamine is in the brain. Patient with Parkinson lose the ability to produce this enzyme, which cause tremors, rigidity and slowness of movement.  Dopamine regulates your blood pressure. The drug L-Dopa is used to store dopamine in the blood vesicles in the presynaptic nerve

terminals. The drug is needed to be used in larger doses. L-Dopa has side effects, including nausea and dyskinesias."

2. "AZT is a drug used for the treatment of AIDS (the infection of human immunodeficiency virus). A critical HIV enzyme used the virus RNA genome as a template to build a DNA version that can be inserted into the host's genome. Because AZT has a 3' azido group instead of a 3' hydroxyl group, it can't make the necessary phosphate bend with the next nucleotide. This terminates the synthesis of the DNA copy of the virus RNA genome, preventing integration into the host and blocking viral replication. The drug is expensive. A year's supply cost around $10,000, making AZT unaffordable for those in the developing world."
3. "Allegra: When a susceptible person inhales pollen, the immune system begins pumping out immunoglobulin E (IgE) antibodies that are specific for the pollen proteins. That's how allergies are caused."
4. "Cholesterol lowering, Lovastatin: Akira Endo, a research scientist at Sankyo Pharmaceutical in Japan, discovered statins in 1971. It was introduced in the USA in 1987. The drug is used to lower cholesterol, an essential component that is present in all body cells. In particular, serves to build the cell membranes of the nerve system. The body requires cholesterol through diet or creates it in the liver. This drug works by inhibiting the enzyme HMG-CoA reductase, which is the main regulator of cholesterol synthesis. Statins lower LDL which raising HDL. This how it reduce clogging arteries. Side effect. It has been blamed for memory loss. It also may set off muscles disorder such as myotis or rhadomyosis which is a form of muscle break down".

*Ability to Evaluate the Quality of Scientific Information*

Ten of the 13 groups (77%) of students were able to evaluate the quality of scientific information. They were able to determine answers to questions derived from curiosity about everyday experience (example are provided in the previous paragraph). They were also able to choose and differentiate between the scientific and non-scientific information in the articles. Three groups of students choose to go to other websites and gather non-scientific statistical information. Their reports were not structured and did not provide good analysis. Below are examples of their reports.

5. "Librium is used in the treatment of anxiety disorder. It is also prescribed for short-term relief of the symptoms anxiety. Librium is habit forming and you can become depend on it. You should take Librium exactly as prescribed. If you miss a dose, you will need to take it as soon as you remember you have not took the dose. There are some side effects to his and they are if any develop or change in intensity, inform your doctor as soon as possible."
6. " Cocaine was discovered by Albert Neiman. The drug was discovered in 1860. It was published in 1569. Other causes of disease could be other than enzyme. Sometimes it depends on how much you take to treat. You might go to the hospital to get treatment for the drug. You can easily die from the drug if you don't get treatment from using the drug too much. It would cause the brain and body to strive for more as you proceed through the treatment sometimes. Cocaine also cause the release of dopamine from neurons in the brain".

7. “ The drug heroin was discovered in Germany (1898) by the Bayer company. When you use heroin, you will feel a warm feeling of relaxation, a sense of pain, fear, hunger and tension. When injected, it reaches the brain in 15-30 seconds. Smoked heroin reaches the brain in around 9 seconds. The drug sold yearly is unknown. It has not been discovered because heroin sold fast daily”

*Communicating, Science Explanations*

As a third part of the project, the students were given the opportunity to communicate their results orally through presentations using the overhead projector. During the presentations, discussions were carried out between the presenter and the classmates. The conversations revealed students’ abilities of scientific reasoning. The activity also provided the students with the opportunity to manage ideas and information. Especially, during presentations, the classroom was very quiet and the students were paying a very close attention to the presenter. The teacher interfered in some cases to explain in more details some of the students’ questions. The presentations had to included the important concepts that they had already submitted as reports in the second part of the project. The major covered aspects were:

A) History of the drug,
B) Mode of action of the dug (How does it treat?), mechanism of action, therapeutic effect, side effect (the undesired effect of the drug on other part of the body.
C) Cost.
D) Name and other names.
E) CAS registry.
F) Chemical formula and structure.

G) Your (student) opinion or other experts' opinions about the drug.

The 10 good reports included answers to all parts (A-G). The presenters had to communicate the contents of the reports to their classmates. Selected paragraphs of good presentations are provided above in examples (1-4). The presented information provoked some questions about the origin of the drug's name, its mode of action and its availability. Many new scientific terms were then introduced. On the other hand, the presenters of the other three reports did not provide good new learning experience for their classmates. As examples (5-7) shown above, the reports included very basic information available on the outside package of the drug, or are familiar for the public. Such presentations did not provoke a good discussion session.

During the fourth part of the project, the students were also asked to present their data as a poster presentation. The 10 group of students who did well in the first, second and third part of the project, were able to represent the information as a poster presentation. Some other posters (3 posters) did not have the required information because they tended to print and post on-line information. Therefore, they did not meet the purpose of the study.

*Motivation and Participation*

The teacher had a considerable number of groups participating in the project (13 out of 16). The rest of the students did not participate for different reasons such as absences and lack of interest in the chemistry subject. The project tended to motivate the students for some apparent reasons such as:

1- Working in groups

2- Project derived from curiosity about life experiences

3- Large choices of topics that matched student interests (46 drugs)

4- Assistance from the teacher to ease the understanding of scientific topics by providing a series of questions.

5- Oral presentations in the classroom and the undivided attention of the students to the presenter.

6- Giving the project 10% of the final grade.

# Chapter Four

## *Discussion*

Teaching the unit "Biochemistry" for the $9^{th}$ graders following the activities presented in science interaction book indicated the advantages of implementing scientific inquiry according to standard. A good percentage of the students were able to read, understand the use of interdisciplinary concepts', identify theories, critically analyze data, and weigh competing theories. The unit allowed examining the correlation between students' understanding of scientific inquiry, their achievement, attitude toward science, and motivations.

The teacher provided the students with materials, situations, and occasions that allow them to think about their learning. The students practiced the active inquiry by exploring, manipulating, experimenting, questioning, and searching out answers for themselves.

The project was aimed to test the students' intellectual growth in scientific inquiry. The activities of the unit in science interaction book were designed to implement scientific inquiry that involved three fundamental processes: assimilation, accommodation and equilibration. The students were provided a variety of teaching strategies, such as activities, study guides, scaffolding questions, and presentations. The teacher monitored the students' intellectual growth and understanding through daily checking of their performance.

The middle school scientific education was apparent in the students' understanding of scientific inquiry and their abilities to apply the scientific method to their activities. Two of the groups who did particularly well, had a good scientific background from their middle school's science classes. The majority of the students did not show any knowledge of having previously used the scientific method. However, some were able to learn the subject matter in the context of standards-based inquiry.

Students' participation reached the highest when they were given study guide questions and asked to retrieve the answers from the text. Some showed an inability to independently perform the activities and repeatedly asked the teacher for explanations. That could be due an extensive exposure to lecture type lessons in their middle school education.

The teacher tested the abilities of the students to communicate their results and explanations to their classmates using large post-it papers or overhead transparencies. Students were enthusiastic about their presentations. However, some students were uncomfortable using the overhead due to the lack of self-confidence, or the tendency of the classmate to joke at the presenter and reduce the importance of the presentation. The teacher had to interrupt in most cases to acknowledge and encourage the presenter. Some students had the ability communicate their ideas in their simple scientific language that still reflected the concept. That indicated that using students' ideas could be viewed as a strategy to impart scientific knowledge.

Some students had reading problems and that eventually affected their overall performance.

Three techniques were developed to improve the motivation and performance of the students. They were poster presentation, filing, and daily grading. The results had a positive impact on the overall performance and most importantly on classroom management.

The chemistry project was well versed with important scientific concepts. The teacher attempted to test the abilities of the high school students to investigate and analyze science papers. Analysis of the results indicated that some students were able to find answers to scientific questions. Some were able to read article about science in the popular press and engage in social conversation about their results.

The articles also presented a way to integrate multidisciplinary concepts that reflects how chemistry is actually practiced. The results revealed that some students were able to recognize the relationship between the interdisciplinary concepts. However, the teacher noticed that this was not necessarily related to their ability to understand the meaning of each concept. Apparently, there was a gap in the students information about the other fields of science mainly, biology. On the other hand, the students confidently communicate their results orally, in writing and by presenting poster.

*Conclusion and Implications*

Parts of the results of this project indicated that the secondary schools students can be exposed to more intellectually challenging yet developmental appropriate curricula to advance the nation in an increasingly complex technological world. The results are in accord with the ACS view toward developing both a scientifically literate public and science specialist require appropriate curricula taught by well-qualified teachers. The view also supports that teachers need to be comfortable teaching science through interactive and inquiry-based modern courses, and that they need to be appropriately recognized and rewarded for their successes. The release of the National Science Foundation Standards and the Project 2061 Benchmarks challenge current teachers to achieve new levels of excellence in their teaching. The meet the challenge, ACS advocates several ideas to give opportunities for teacher's professional growth. Especially in acquiring a stronger scientific background.

The results of this project also indicated that the students could be exposed to a challenging science curricula based on the "real world" of student interaction with nature. To help meet consensus standard of excellence, ACS supports several improvement of curricula such as integrating science content across disciplines and throughout the years of the secondary school experience. In addition, the results of the project indicated that it is possible to enhance the articulation between high schools and two-year colleges.

To teach high school science effectively, adequate facilities and resources are essential. This was a limitation of the project.

The results of the project clearly indicated that the pre-high school science education influenced the performance of the students. According to the ACS, teachers can play a pivotal role. They need to be confident in teaching science through interactive and inquiry-based modern courses as defined in the National Science Education Standard. To ensure the K-8 students receive quality science instruction, ACS supports several plans for teacher development. Their plan include supporting groups of leadership teachers and scientists to operate statewide as teams of in-service facilitators, and using only certified science teacher to teach science at the middle school level.

*Limitations*

The science classroom was a traditional one, lacking modern laboratory equipments. There were a sink and 10 tables allowing the students to work in groups. Technology, such as computers in the classroom or permission to use computers in the library was not available. However, these limitations did not have a major effect the study. The materials for the activities were purchased from a supermarket.

The high school building was newly renovated and the library was not ready yet for the students.  In addition, there was no accommodation for power point presentations in the classroom to incorporate the use of technology in the classroom.

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# Appendix

Samples of students' work