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Modified Useful-Learning Approach: Effects on Students' Critical Thinking Skills and Attitude towards Chemistry

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Abstract. This study was conducted to assess the effectiveness of the Modified Useful- Learning approach against the traditional teaching approach in improving students' critical thinking skills and attitude towards chemistry. Specifically, it sought to find out if the mean posttest score in the critical thinking appraisal and chemistry attitude scale is significantly higher for students exposed to the MUL approach than for the students exposed to the traditional teaching approach.Modified Useful-Learning (MUL) approach is a combination of Learning-for-Use model developed by Edelson (2001) and Hypothetico-Predictive Reasoning by Lavoie (1999). It is an innovative approach to teaching and designed using group learning, hands-on and laboratory activities, reflective thinking, discovery and inquiry learning and small group discussion to increase student's participation.This study used the quasi-experimental pretest-posttest control-group design. The sample of the study consisted of two intact sections of junior students at Diliman Preparatory School, Quezon City during the School Year 2005-2006. Thirty six (36) students were taught using the MUL approach, whereas thirty eight (38) were exposed to the traditional teaching approach. The instrument used in this study is the Watson-Glaser Critical Thinking Appraisal and the Chemistry Attitude Scale developed by the researchers. The instruments were content validated by group of experts and was pilot tested. The MUL group showed a significantly higher posttest mean score in the critical thinking test than the traditional counterpart. Moreover, the mean rating in the attitude scale of the MUL group was found to be significantly higher than that of the traditional group.Based on the results of the study, it is recommended among others, that the Modified Useful Learning (MUL) approach be used by science teachers in their teaching as it was shown in this study that the approach helps students improve their critical thinking skills and attitude towards chemistry.

Keywords: Modified-Useful Learning Approach; Critical Thinking Skills; Attitude towards Chemistry

Background of the Study

Educators believe that when students come to class they have ideas that are sometimes different from what is generally accepted by the scientific community. The different conceptions that students acquire have been called "alternative conceptions", "naïve theories", "children's science", or "misconceptions." The new knowledge acquired by the students interferes with their misconception. It is difficult for the student to picture out the link among science concepts and principles, and to apply the principles meaningfully to daily life (Sungur, Semra, CerenTekkaya&ÖmerGeban, 2001).

Gallagher (2000)enumerated four related facts why students are unable to understand and apply the new scientific concepts/information learned in class;

1) It is not clear to the students that the learned concept goes or should go beyond examinations and tests.
2) It is not clear to the students how to make sense of new information.
3) It is not clear to the students how to make connections between new and previous information in order to develop deeper understanding.
4) Little importance is given to the application of science knowledge in science classes and test (Gallagher, 2000, p. 311).

Furthermore, most of our students do not take chemistry seriously as one of the major subjects in high school level due to several reasons. First, it is hard for them to see the significance of what is being taught in real-life situation. There is a wide discrepancy between school where they take the subject – chemistry and real-life (Clarke & Biddle, 1993). In real life, problems tend to be chaotic, ill-defined, confusing and call for true problem solving. While inside the classroom they feel they have the pattern to memorize and to follow which is not evident in real-life (Clarke & Biddle, 1993). Thus, they have a hard time solving given problems and applying what they learned. Second, general chemistry concepts are taught and assessed in terms of facts; mathematical representation and procedural knowledge at the high school and university level are also taught without emphasizing conceptual understanding (Scalise, Claesgens, Krystyniak, Mebane, Wilson, & Stacy, 2003). Third, according to Johnstone (in Gabel, 2003), the main factor that prevents students from understanding chemistry concepts, is not due to the existence of the three levels of matter (macroscopic, microscopic and symbolic) but for the reason that chemistry instruction is presented on the most abstract level or symbolic level. Most of the students feel that the abstract nature of chemistry concepts is always confined to the four corners of the classroom. Thus, students think that it is not applicable outside the school (Stieff&Wislensky, 2002). Lastly, in traditional chemistry/science classroom settings, students rarely experience the source questions of inquiry, critical and logical reasoning, the challenges or the surprises in real-life (Clarke & Biddle, 1993). For these reasons, students are not engaged in deep, intense or deep critical thinking and concept understanding, thus enhancement of positive attitude towards chemistry does not occur.

Educators are engaged in significant reform in science teaching. The reform focuses on four main goals: 1) Science for all; 2) teaching for understanding; 3) application of science knowledge; and 4) application of science processes (Gallagher, 2000, p.310). According to Thomas (1999) the main goal of science education research and teaching science is enhancing student learning. On the other hand, educators before found it difficult because most of the students were said to lack"knowledge, awareness and control of their learning processes" (p.89). Thomas (1999) believed that the "students need to understand the thinking and learning processes" (p.89). To support meaningful learning, misconceptions must be eliminated (Sungur, Tekkaya&Geban, 2001).

Students' achievement in chemistry has been a challenge for many educators not only here in the Philippines but all over the world for the past few decades (Lavoie, 1999; Carale& Campo, 2003). Science educators are facing rapidly increasing demands. At the same time they are being asked to devote more time to having students engage in scientific practices (Edelson, 2001). There must be employment of interactive activities to elicit prior knowledge towards conceptual change and understanding (Carale& Campo, 2003).

Chemistry should cater to real-life and the teaching-learning context should be a combination of process and content learning activities, which equip students with a content in which they can structure their own questions and problems to answer through proper investigations (Clarke & Biddle, 1993). In order for the students to learn the abstract concepts in chemistry they must know how to make models or analogies, aside from doing laboratory tasks. In this way, students will have the potential of enhancing of their understanding (Gabel, 2003).

One of the important roles of learners in learning science is to explore. There must be an interaction with the real world and with the people around them to discover concepts and apply skills. To understand science conceptually, learners must know the ideas of science and the relationships among them. It includes the knowledge on how to explain the scientific ideas and predict natural phenomena and how to apply the knowledge to other events relevant to the science concepts (Dickinson &Reinkens, 1997). For many students the significance of learning experience can be measured by its applicability to their everyday lives (Songer&Mintzes, 1994; Dickinson &Reinkens, 1997).

This study proposes a Modified Useful-Learning (MUL) approach which is a combination of Learning-for-Use (LfU) and Hypothetico-Predictive Reasoning Learning Cycle (HPD-LC) models that focus on integrating content and process learning supported by varied learning activities. Unlike the LfU model, computers are not needed in this learning activity. The highlight of MUL is the use of "hands-on" and "minds-on" activities. It was hoped that this approach would improve student's achievement in chemistry.

The study sought to answer the following research questions: (1) Is the mean posttest score in the Watson-Glaser Critical Thinking Appraisal higher for students exposed to the MUL approach than for the students exposed to the traditional teaching approach?; and (2) Is the mean posttest score in the Chemistry Attitude Scale higher for students exposed to the MUL approach than for the students exposed to the traditional teaching approach?.

Learning Science

Learning science is one of the important learning experiences that students have to consider in the academic institution. Thomas (1999) believed that the main objective of science teaching and science education research is to enhance students' science learning. In learning science, it is not the content knowledge per se that is being developed in students but also the skills in order for them to become scientifically literate individuals (Christensen, 1995).Matthews (2004) and Gallagher (2000) explained that learners should have the physical experiences, concepts and models of science and be able to apply the acquired knowledge. In his studies, Sungur, et al. (2001) added that science skills are essential for understanding and applying scientific concepts.

Furthermore, Suvillan (in Powell, 2004) said that it is important for the students to experience the world outside the four corners of the classroom. Similarly, Wilson (in Murphy, 1997) explained that environment also plays an important role in learning science because it promotes a more flexible idea of learning and helps learners to develop skills and construct understanding. Learning is enhanced by communication interaction and conversation with other students, where reorganization of knowledge, construction of new knowledge and additional understanding take place (Murphy, 1997).Furthermore, educators believed that to promote deeper understanding of science processes and content, instruction must be properly designed and organized (Crawford, 1997).

Critical Thinking

Many of the educators agree that developing general thinking skills, specifically critical thinking skills, is one of the major goals of education (Gelder, 2003). The core purpose of teaching critical thinking in science education is to develop the thinking skills of the students and to prepare them to succeed in the world (Schafersman, 1991).

Critical thinking has been defined in different ways. Many educators and authors believe that critical thinking is more of reasoning. Halpern (in Van der Wal, 1999)defined critical thinking as "use of those cognitive skills or strategies that increase the probability of a desirable outcome" (p. 2). Critical thinking is used to illustrate thinking skills that is purposeful, reasonable, and goal directed. Goal-directed thinking involves solving problems, formulating inferences, calculating likelihoods and decision making. Hanford (in Murrell, 1999) proposed that, "Critical Thinking is succeeding for two basic reasons. First, students whose education involves critical thinking—the ability to evaluate information and make judgments-- learn more effectively because they have opportunities to think about what they are being told. Second, the movement relies on infusion rather than demonstration" (p. 2).

Critical thinking is also called "reflective thinking", "scientific thinking," and "critical inquiry" where learners investigate problems, ask questions, and discover new information (Schafersman, 1991; Cotton 2001a).Critical thinking ability is considered as higher-order cognitive synthesis ability that involves the use of synthesis and analytical skills (Crow, 1989; McMurray, Beisenherz& Thompson, 1991).

Marzano, et al. (1988) believe that critical thinking should not be considered a cognitive process unlike problem solving and decision making because critical thinking implies judgments about the quality of thinking that learners make. School plays an important role in helping students to think critically by enhancing their background knowledge and fostering their ability and commitment to quality thinking. Curriculum designers and educators recognize the importance of students' ability to think successfully through the challenges posed by the teachers and their experiences. These challenges encourage the students to show their ability to think critically, to make sound judgments and to let them think what to believe and how to act (Crow, 1989; Bailin, 1993).

In addition, Bailin, et al. (1993) supported the idea that thinking critically is not a matter of setting or finding correct answers to questions or problems. Critical Thinking involves making reasoned judgments where attributes of good thinking reside. Reasoning is linking of thoughts actively to provide support from one thought to the other thought. Bailin (1993) divided critical thinking into three dimensions:

1) Critical challenges – the task or situation that provides situations for critical thinking.
2) Intellectual resources- array of knowledge, strategies and attitudes needed to have good thinking when responding to critical challenges.
3) Critically thoughtful responses – responses to critical challenges where appropriate use of relevant intellectual resources were being demonstrated.

Bailin, et al. (1993) summarized the relationship among the dimensions as follows: "to think critically is to respond thoughtfully to a particular challenge by making use of the appropriate intellectual resources" (p. 5).Educators and students in different universities also define critical thinking by presenting the list of sub-skills that are significant to the concept of thinking.

Critical thinking comprises the ability to (Van der Wal, 1999, p.3):

- solve practical and situational problems;
- use logical reasoning skills; and
- bring different ideas together and synthesize them into new ideas.

Robert Ennis (in Crow, 1989) who is the coauthor of Connell Tests of Critical Thinking Ability defined critical thinking as "reasonable, reflective thinking that is focused on deciding what to believe or do" (p. 9). Ennis also defined critical thinking as "reflecting thinking", which needs reflective activity and is geared to understanding the nature of the problem and not just merely solving it (Crow, 1989). Moreover, Ennis (in Ornstein, 1995) identifies the 13 attributes of critical thinkers. Critical thinkers should:

1) be open-minded;
2) agree when evidence calls for it;

3) take the situation as a whole;
4) seek information;
5) seek precision about the information;
6) deal with an orderly manner;
7) look for options;
8) search for reasons;
9) look for clear statement of the issue;
10) focus to the original problem;
11) use credible sources;
12) remain relevant to the point and issue; and
13) be sensitive to the feelings and knowledge of others. (p.27).

Critical thinking also includes inductive reasoning, formulation of hypotheses, deductive reasoning and a mixture of mental process skills like analogy, extrapolation, and synthesis (Schafersman, 1991; Ostlund, 1998).

Student must be responsible for their own thinking; that is, they must understand how to think and act intellectually on their performance. Elder (2000) presented the model of critical thinking which emphasizes the following:

1) to think well, one must think clearly;
2) to think well, one must think accurately;
3) to think well, one must think precisely;
4) to think well, one must think relevantly;
5) to think well, one must think deeply;
6) to think well, one must think broad-mindedly; and
7) to think well, one must think logically. (p. 9).

According to Paul (in Elder, 2000), reasoning uses eight structures. These include questions, purposes, information, interpretations, assumptions, concepts, points of view, and implications. These "elements" are always embedded in our thinking for:

- whenever we reason, we do it for a purpose;
- our purpose requires to answer at least one question;
- to answer our question, we need information;
- to use the information, we must interpret the information;
- to interpret it, we must apply some concepts;
- to apply concepts, we must construct some assumptions;
- to make assumptions, we must think within a perspective; and
- however we think, our thinking has implications. (p.6).

Learners must have basic critical thinking abilities to function well in the complex and fast changing world. Learners must possess intellectual skills to competently answer new questions and problems in workplace.

Educators (in Stein, 2002) identified areas of critical thinking which are regarded as essential skills for students. Some skills identified are the ability to:

1) interpret numerical relationships in graphs.
2) identify evidence that might support or contradict on hypothesis.

3) identify new information that is needed to draw conclusions.
4) draw inferences between separate pieces of information and formulate conclusions.
5) recognize how new information might change the solution to a problem.
6) communicate effectively.

Johnson (2000) proposed that critical thinking has to do with organizing, analyzing, evaluating, or describing. He also enumerated the eleven critical thinking skills needed by students: 1) inferring; 2) comparing; 3) comparing and contrasting; 4) analyzing 5) supporting a statement; 6) decision making; 7) ordering; 8) evaluating/critiquing ; 9) creating groups; 10) investigating; and 11) experiencing. (p.46)

Another attempt to measure critical thinking skills has been done by the Basic Skills Council Created by the New Jersey Board of Higher Education (in Morco, 1994). These are some of the indicators of critical thinking identified by the board:

1) the ability to identify and formulate problems as well as the ability to prepare and evaluate ways to solve them;
2) the ability to draw reasonable conclusions for information found in various sources and to defend one's conclusion rationally; and
3) the ability to comprehend, develop and use concepts and generalizations. (p.16).

Another important work was that of Morco (1994), wherein she identified twenty (20) thinking abilities proposed as factors associated with the construct of critical thinking in Mathematics. Below are some of the factors associated with the construct of critical thinking: 1) Making valid inferences; 2) recognizing assumptions; 3) formulating generalizations 4) formulating hypotheses; 5) testing assertions; 6) making predictions; 7) identifying the problem; and 8) discerning relevance or irrelevance.

Lastly, according to Schafersman (1991) there are two ways to teach critical thinking. He described one of these methods as the easiest, least time-consuming and least expensive. This kind is simply attained by modifying once teaching approach and testing method. He added that critical thinking is an active process, hands-on and laboratory activity and quantitative exercises obviously enhance critical thinking.

Evidently, critical thinking skills play a significant role in the field of science education to solve practical and situational problems through reflective activities. Thus, the present study promotes hands-on activities which are reflective in nature to integrate content and process learning.

Constructivism

Constructivism is a theory about how people learn (Constructivism as a Paradigm, 2004). Learners construct their own understanding and knowledge through experiences and reflections (Rule &Lassila, 2005). Learners reconcile their previous experiences to the present ideas and experiences (Capstone Projects, 2003; Constructivism as a Paradigm, 2004). The meaning of constructivism varies according to one's point of view. Miami Museum of Science (in Carale& Campo, 2003) proposed that learners have their own views and understandings based on prior knowledge even before direct experience. The epistemology of constructivism, according to University of Massachusetts Physics Education Group, has shown that learners actively construct knowledge and are not just receivers of constructed knowledge. The learners also achieve this knowledge as it is locally constructed by making their own mental representations or models. It can also be derived from prior knowledge that is symbolically constructed in the learning process (Carale& Campo, 2003).

One of the important goals of constructivism is to improve students' reasoning strategies, which is vital to successful conceptual learning (Keys, 1997). Matthews (2004) further explained that the strategy attempts to connect human cognitive processes in science through collaborative learning. This is to recognize that knowledge acquisition is a social process where in a social group, communication and negotiation of ideas take place, meanings and concept constructions are formed (Carale& Campo, 2003). Matthews (cited in Dominguez, 2005) expressed that constructivism is a philosophy of learning that originates from the learners' experiences, and that learners construct their own ideas of the world. Constructivism transforms the students from passive to active participants in the learning process. Students learn to apply their existing knowledge on real-world experiences, to hypothesize and test their theories, and to draw conclusions from their findings (Constructivism as a Paradigm, 2004).

Constructivism could be best expressed using its two basic principles, the psychological and the epistemological nature, which emphasizes that knowledge and knowing are one. The first principle highlights that when a learner engages in construction of meaning, what the learner already knows is the most important. The second principle emphasizes the main purpose of cognition which is adaptive and enables the learner to construct possible explanations based on experiences (Hinton, 2005).

Shiland (1999) suggested that the "essence ofconstructivism is that knowledge is constructed in the mind of the learner"(p.107). The statement was expanded to the five postulates of constructivism, namely:

1) Learning requires mental activity. The process of knowledge construction requires mental effort; materials and concepts cannot simply be presented to the learner and learned in a meaningful way.
2) Naïve theories affect learning. New knowledge must be related to existing knowledge of the learners. The preconceptions and misconceptions may interfere with the ability of the learner to learn new material. The personal theories of the learners also affect what they observe. Personal theories of the learners must be made clear to facilitate comparisons.
3) Length occurs from dissatisfaction with present knowledge. To have meaningful learning, experiences must create dissatisfaction with

learner's present conceptions. If learner's present conceptions make accurate predictions about an experience, meaningful learning will not occur.

4) Learning has a social component. Knowledge construction is a social process. Meaning is constructed by communicating with others. Cognitive growth is achieved through social interaction. Learning is aided by communication that seeks and clarifies the ideas or knowledge of learners.
5) Learning needs application. Applications must be provided which demonstrate the utility of the new conception (Shiland, 1999, p. 107).

Spencer's (1999) comparison of objectivism and constructivism is presented in Table 1. In addition, Shiland (1999) admonished that "laboratory practice with respect toconstructivism is seen as being more than the acquisition of process skills; it is an essential ingredient in the understanding of science itself" (p.108).

TABLE 1Comparison of Objectivism and Constructivism

Objectivism	*Constructivism*
Truths are independent of the context in which they are observed. Learners observe the order inherent in the world. Aim is to transmit knowledge experts have acquired.	Knowledge is constructed. Group work promotes the negotiation and develops as mutually shared meaning of knowledge, individual learner is important.
Exam questions have one correct answer.	The ability to answer with only one answer does not demonstrate students' understanding.

Source: Spencer James (1999) New Directions in Teaching Chemistry: A Philosophical and Pedagogical Basis. *Journal of Chemical Education* 76, 4, 566-569.

Most of the approaches in teaching have grown from constructivism which suggest that learning is achieved best using hands-on. Learners learn through experimentation and not by plain lecture or discussion. They are encouraged to make inferences, discoveries and conclusions.

Significantly, constructivism is all about how learners construct knowledge through experiences and reflections to develop students' reasoning strategies. In this study students become engaged in active learning. They apply their existing knowledge in real-world experiences, hypothesize, test their personal theories through experimentation and hands-on activities, draw conclusions from their data and apply the new constructed knowledge in real-life situation for the students to have sound conceptual understanding and critical thinking.

Constructivist Teaching and Learning
According to Steffe and Gale (in Moussiaux& Norman, 1997) researches show that constructivist teaching is widely accepted in mathematics and science since the early 1980s. They further explained that cognitive psychology became their guiding principle for constructivist teaching. Piaget and Glaserfeld were the two early contributors of constructivist theories. The highlights of constructivist teaching are constructing, thinking, reasoning and applying knowledge, but it does not neglect the basic skills. The constructivist teaching and learning clearly aspire to assist and help the learners to construct meaning that lead to understanding of scientific concepts (Hinton, 2005).

In addition, Tolman and Hardy (in Moussiaux& Norman, 1997) pointed out that constructivist teaching is guided by five vital elements: 1) activating prior knowledge,
2) acquiring knowledge, 3) understanding knowledge, 4) using knowledge, and 5) reflecting on knowledge.

Moreover, Driver and Oldman (in Dominguez, 2005) enumerated the stages of constructivist-inspired teaching methods, which include:

1) orientation, where learners are given the opportunity to develop a sense of purpose.
2) elicitation, during which the learners make their current ideas on the topic of the lesson clear. This can be achieved by a variety of activities, such as group discussion, visual or written interpretation.
3) restructuring of ideas, which is the heart of the constructivist lesson sequence. It consists of a number of stages, including
   a. clarification and exchange of ideas;
   b. construction of new ideas; and
   c. evaluation of new ideas.
4) application of ideas, where pupils are given the opportunity to use their developed ideas in a variety of situations.
5) review, which is the final stage in which the students are invited to reflect back on how their ideas have changed by drawing comparisons between their thinking at the start of the lesson sequence, and their thinking at the end(p.18).

Furthermore, Savery and Duffy derived some instructional principles from constructivism with the practice of instruction, namely:

- learning should be significant.
- instructional goals should be reasonable with the learners' goals.
- students' ideas should be tested through collaborative learning groups.
- encourage reflection. (in Murphy, 1997, ¶ 3)

At the same time, constructivist view of learning can apply to different teaching practices inside the classroom. Constructivist learning means encouraging students to use active techniques such as experiments, real-world or real-life problem solving to create knowledge and reflect on it. Because when students reflect on the constructed knowledge based on their experiences, students gain more complexity and power to integrate new information. The students learn HOW TO LEARN (Constructivism as a Paradigm, 2004).

The student-focused active learning (SFAL) listed (as shown in the Table 2) the role of the students in constructing their own knowledge (Spencer, 1999).

TABLE 2The Role of the Student in Constructing their own Knowledge.

Traditional learning	*Student-focused learning (SFAL)*
Students:	Students:
Ask for the "right" answer	Explain possible solutions or answers and tries to offer the "right" explanations.
Have little interaction with others.	Try alternate explanations and draw reasonable conclusions from evidence.
Accept explanation without justification.	Have a margin for related questions that would encourage future investigations.
	Have a lot of interaction and discuss alternatives with other companions.
	Check for understanding from peers.
	Are encouraged to ask questions such as Why did this happen? What do I already know about this?
	Are encouraged to explain other students' explanations.
	Test/predictions and hypotheses.
Reproduce explanation given by the teacher/book.	Use previous information to ask questions, propose solutions, make decisions, and design experiments.

Source: Spencer James (1999) New Directions in Teaching Chemistry: A Philosophical and Pedagogical Basis. *Journal of Chemical Education* 76, 4, 566-569.

In the same study, Spencer (1999) recommended that, first; students must be given an opportunity to be involved in the learning. Straight lecture is no good for the students. Second, students must learn to work together not only because that is the way of learning science but also because students learn better through social interaction. Third, students should make their own conclusions and construct their own knowledge and not just verify what is written in their textbook. Fourth, students must be active learners. These recommendations made by Spencer (1999) were supported by a number of classroom and cognitive studies.

Hinton (2005) emphasized that based on the research there is a "need for new instructional strategies based on a constructivist model of learning emphasizing conceptual growth, conceptual change and the conditions that support conceptual change" (p.1). That is why the present study purposely employed new teaching approach using constructivist teaching.

According to Yore (2001) today, as described by the National Science Education Standard (NSES), developing a concise and clear image of constructivism and associated classroom practices are receiving less attention. Hence,teacher must give more emphasis on the items in Table 3.

TABLE 3Constructivism and Associated Classroom Practices

Less Emphasis on:	*More Emphasis on:*
Treating all students alike and responding to the group as a whole.	Understanding and responding to individual student's interests, strengths, experiences, and needs.
Rigidly following curriculum. Focusing on student acquisition of information. Presenting scientific knowledge through lecture, text, and demonstration. Asking for recitation of acquired knowledge. Testing students for factual information at the end of the unit or chapter. Maintaining responsibility and authority. Supporting competition. Working alone.	Selecting and adapting curriculum. Focusing on student understanding and use of scientific knowledge, ideas and inquiry processes. Guiding students in active and extended scientific inquiry. Providing opportunities for scientific discussion and debate among student. Continuously assessing student understanding. Sharing responsibility for learning with students. Supporting a classroom community with cooperation, shared responsibility, and respect. Working with other teachers to enhance the science program.

Source: Yore, Larry D. (2001) What is Meant by Constructivist Science Teaching and Will the Science Education Community Stay the Course for Meaningful Reform? Electronic Journal of Science Education Vol. 5 No. 4.Retrieved last April 17, 2006.

Teaching Strategies and Approaches for the Improvement of Students' Achievement in Chemistry and Critical Thinking Skills

Teaching for improvement of students' achievement in chemistry and critical thinking skills always demands for appropriate teaching strategies. According to Nakhleh (in Noh &Scharmann, 1997) most studies in chemistry education have focused on students' conceptions, but there have been relatively few studies which focus on instructional strategies, teaching and instructional strategies that aimed at sound understanding of chemistry concepts. Even though many researchers promoted different strategies which found to be effective in improving student conceptions than traditional instruction, still the success is far from perfect. Therefore, Noh and Scharmann (1997) concluded that there is a great need to provide instructional strategies to make meaningful connections between and among chemistry concepts and to improve students' conception. Moreover, it may serve as one of the key factors to improve student achievement.

This is why teachers look for the best approach that they can apply in order to achieve meaningful learning. This gives students time to identify and correct their preconception through proper investigation and to measure the soundness and utility of their own ideas.

According to BouJaoude and Barakat (2003) new instructional approaches and methodologies should be used so that students would become meaningful learners of chemistry. According to Johnson et al., (in Rule &Lassila, 2006, ¶ 9) the highlight of new teaching paradigm "is to help students construct their knowledge in an active way while working cooperatively with classmates so that students' talents and competencies are developed" (in Rule &Lassila, 2006, ¶ 9).Ramsden (in BouJaoude&Barakat, 2003) explained that "an approach to learning represents what a learning task or set of tasks is for the student" (p.3). The approach must not be about learning facts and concepts. Instead, it must be learning unrelated facts and learning the relation of facts to the concepts.

Evangelisto (2002) explained that constructivist teaching and learning knowledge is generated in the mind of the learner and the effectiveness of the teaching approaches is measured by means of "active learning; learner-generated inquiry; concrete, authentic experiences; collaborative investigations and discussions and reflection; and structuring learning around primary concepts" (Evangelisto, 2002, ¶ 3). Many of the teaching approaches that originated from constructivism explained that learning is best observed using hands-on approach. Through experimentation, learners acquire knowledge and they make their own inferences, discoveries and conclusions (Constructivism_learning theory, 2006). A variety of teaching strategies and approaches have been presented and used by many educators and authors on how critical thinking skills and achievement in chemistry can be improved among students. Most of the students wish for hands-on activities and small group discussion than other methods of teaching (Beale, 2003).

In the study made by Jones, Buckler, Cooper, and Straushein(1997) it surfaced that studentsinvolved themselves in active learning by means of constructing and evaluating their own models and spending most of their times in hands-on activities and small group discussion rather than in lecture.

Small Group Discussion

In small group collaborations, exchange of ideas and questions occurs frequently and spontaneously among students, so they learn to work together. Roth and Bowen (in Van Zee, 2001) presented a study on how questions create interactions with one another and with the setting. As a result, there is a positive effect on the students and their environment - other learners and the teacher.

Hogan, Nastasi and Presloy (in Van Zee, 2001) also documented the role of small group collaboration in promoting students' concept understanding and thinking skills even without the teacher interaction.

Ornstein (1990) explained that exposing learners to small group discussion provide opportunities for them to become actively involved in the learning process. He added that critical thinking skills are also enhanced. Dividing students into small group promote social interactions, social skills and cooperation with one another. Similarly, Allen (in Garcia, 2001) stated that the most effective methods for improving students' skills is the use of small group discussion because detailed verbalization of thoughts takes place. In small group discussion learners easily identify their misconceptions and incorrect answers.

Furthermore, Bianchini (in Garcia, 2001) also used small group discussion for investigating scientific knowledge. The main purpose of his study is to promote excellence and equity in science education among grade six students. Similarly, Alexpoulou (in Garcia, 2001) examined the performance of secondary school students on discussion through an open-ended, exploratory type of questions about physical phenomena. The discussion had positive impact on the students. Also the studies presented demonstrated the utility of small group discussion and the nature of the processes by which students developed their ideas about science as well as their reasoning which is an important feature of critical thinking.

According to the students (in Moussiaux& Norman, 1997) the most frequent instructional experience they like was working in groups (mathematics students 85% and science students 93%).

In addition, Alexopoulou (1996) stated that meaningful group discussions serve as a guide to balance the power in classrooms, so that it will provide security needed by the students for exploring their ideas.

Finally, the survey conducted by Miller, Nakhleh, Nash, and Meyer (2004)indicated that all of the students appreciate working in group and it was supported by many positive comments in the interviews.

Hands-on/Laboratory Activity

Spencer (1999) pointed out that there is no direct transfer of knowledge from the instructor to the learners. Students must see the laboratory as the proper place to construct new knowledge and not a place where all the concepts in textbook/manual are verified.

Presseisen (in Cotton, 2001b) insisted that student CAN learn to think better if they are taught HOW to do so. Most of the science programs regard the laboratory instruction as the cornerstone because it actively involves students in learning (Herrington &Nahkleh, 2003). Hence, laboratory activities are categorized under the student-centered instructional strategies. Students are interacting and discussing among each other and to understand certain efforts they measure, compare, classify and control variables (Dominguez, 2005). Further, most of the students appreciate experiment because they learned valuable skills. The valuable skills that students learned during experimentation were, resolving conflicting data and critical thinking.
Laboratory activities are also called practical work. According to Clive and Sutton (in Dominguez, 2005) laboratory activity is an instructional strategy that is ideal to science lessons, because most of the time students are actively

engaged in bench work. The ideas shared by Clive and Sutton were supported by Armstrong when he said that students who took any science courses must be involved in bench and work hard there (Dominguez, 2005).

It is stated (in Schafersman, 1991)that laboratory exercises in science are all excellent for teaching critical thinking. Students learn to apply scientific methods by putting them into action. Students agree that working in groups saves time, provides opportunity to discuss their ideas, and completes complicated task efficiently.

The major purpose for including laboratory activity to curriculum is to develop among students the mental process associated with science. Clarke and Biddle (1993) pointed out that "in order for the students to make sense of labs and to construct knowledge through an inductive process we have to help them to reflect on their own learning process" (p.238). It can be used to improve students' competency in scientific reasoning. Laboratory activities leave lasting impression on students (Chiapetta&Kobala, 1994). The study of Watt and Ebutt, (in Van Zee, 2001) showed that most of the students preferred laboratory activities because these give students opportunities to better understand the topics. This is supported by the research made by Rop (in Van Zee, 2001). He made an interview with high school chemistry students about the significance of laboratory activities. Students responded that success in learning is quite painless by 'doing the work'. This means, they better understand the concept if they have hands-on activities (Van Zee, 2001).

The employment of interactive activities leads prior knowledge towards new ideas and concept understanding (Carale& Campo, 2003). According to Edelson (2001) "With respect to process, they call at the same time for inquiry to play a much more prominent role in science learning to give students a firsthand experience of the dynamic process of questioning, evidence gathering and analysis that characterize authentic scientific practice" (p.355). Henry (in Chiapetta&Kobala, 1994) suggested that educators must give more emphasis on how to process data and make logical predictions about the topic rather than finding exact answer. Some educators encourage science teachers to conduct laboratory activities to de-emphasize memorization, illustration and demonstration (Chiapetta&Kobala, 1994).

McKeachie (in Blosser, 1990) stress out that first-hand experience with manipulation of the materials is superior to any other methods of developing understanding. Some of the positive findings of laboratory activity on science teaching were presented by Blosser (1990) on her paper. A substantial amount of research reported that laboratory teaching increased students' problem solving, and considered a valuable instructional technique in chemistry to encourage cognitive development (in Blosser, 1990).

Open-Ended Questions

Questioning is one of the key strategies that could enhance critical thinking and conceptual understanding. Open-ended questions encourage students' involvement in classroom interaction which requires students to respond. Such questions help students to have meaningful information processing. The use of divergent questions leads to new and creative insights (Crow, 1989).

Questions or open-ended questions stimulate students' critical thinking and enable them to check their understanding during class discussion. Questions could be used to focus students' attention to important concepts and to construct knowledge meaningfully (Chiapetta&Kobala, 1994). Open-ended questions stimulate personal response and de-emphasize the notion of finding correct and incorrect answers. According to Freedman (in Garcia, 2001) answering an open-ended question is an expression of students' content knowledge and helps the student to clarify the concepts learned. He also explained, "using open-ended questions for assessment allows students to express their own ideas honestly and with insight. Responses to open-ended questions will provide you with insight to your students' conception, strengths, and weaknesses" (p.20).

Learning Cycle

Farrell and his colleagues (in Dominguez, 2005) suggested that the ideas of constructivism and learning cycle principle in guided inquiry improve learning. Science processes used by scientists were highly advanced, so in order to cater to the needs and to advance teachers' and students' understanding, learning cycle was developed by educators and researchers as a way of translating processes. Learning cycle was patterned after the cognitive theories of Piaget. It was designed to address the limitations of traditional teaching approach in order to develop robust understanding (Edelson, 2001).

The earliest learning cycle was suggested by Chester Lawson. He described scientific invention as "Belief-Expectation-Test" but Robert Karplus proposed the first application of learning cycle to science teaching (Constructivist Models, 2005). Learning cycle (in Robertson, 1996 and in Carale&Ocampo, 2003) is the term used by developers of Science Curriculum Improvement System (SCIS) during 1960s. It consists of three stages: exploration, invention and discovery. Some educators used different names and versions and have different number of stages as presented in Table 4, but the main ideas are still the same. Most of the time educators and researchers use the three stages.

The learning cycle model has been adapted in high school chemistry course (Gabel, 2003; Libby, 1995), wherein the first phase (exploration) provides students with the item that they can use to explore the given concept. After exploration it is followed by interactive teacher-centered phase (invention or concept introduction) to describe the significance of the concepts. Once they have understood the concept, students apply the concept to a new situation (application phase), (Gabel, 2003).

The seven versions of the Learning Cycle enumerated show consistency with all the five basic elements of constructivism, as identified by Tolman and Hardy (in Carale& Campo, 2003; Constructivist Models, 2005): 1) recalling prior knowledge; 2) acquiring knowledge; 3) explaining knowledge; 4) applying knowledge; and 5) reflecting on acquired knowledge. (p.14)

In Constructivist Models (2005), Barman and the team of Lawson, Abraham and Renner introduced their own version of learning cycle model based on the work of Robert Karplus. They change the terminology into: exploration phase, concept introduction phase and application phase. These three phases serve as the foundation of learning science. First, exploration phase allows the learners to interact with the materials and with each other. It also allows the students to test and examine new ideas from their own ideas. Second, concept introduction phase allows the learner to name the important objects and events related to the lesson; students express their own ideas about the concepts. Third, concept application phase allows the learners to apply all the information acquired into a new and relevant situation.

The learning cycle model has been adapted in high school chemistry course (Gabel, 2003; Libby, 1995), wherein the first phase (exploration) provides students with the item that they can use to explore the given concept. After exploration it is followed by interactive teacher-centered phase (invention or concept introduction) to describe the significance of the concepts. Once they have understood the concept, students apply the concept to a new situation (application phase), (Gabel, 2003).

The use of learning cycle model creates content achievement, enhances thinking skills, and develops positive attitudes to science because it allows the students to: a) discover patterns in data; and b) formulate and test hypotheses (Libby, 1995).

Furthermore, Claxton and Murell (in Ballone&Czerniak, 2001) described that learners must engage in concrete experience to yield reflective observations. Once the reflective observations were achieved, these would lead to abstract conceptualizations which yield to generalizations of principles. Generalizations of principles direct or engage students in active experimentation, wherein higher-order concrete experience is evident.

Learning cycle is best when it is followed up with several hands-on activities (Robertson, 1996). A teaching that incorporates inquiry and hands-on activities was identified by the researchers as the learning cycle model (Dominguez, 2005). Likewise, learning cycle encourages the learners to construct declarative knowledge with the use of procedural knowledge, and engage learners in reasoning process and critical thinking skills (Bitner, 1991).

It is best to have a number of hands-on experiences because they help the students understand the concepts and solidify the students' understanding (Robertson, 1996).
According to Lavoie (1999) following learning-cycle instruction, students felt that:

- learning-cycle instruction was more interesting;

- learning-cycle instruction helped them understand concepts better;
- learning-cycle instruction helped them to think and reason more;
- interpeer discussions were helpful;
- they tend to asked more questions than they did with traditional instruction;
- science was a process of discovery rather than a collection of facts; and
- they liked science more following the learning cycle lesson (p.1137).

Learning cycle approach may be more effective in the sense that it show the relevance of what learners learn but science educators continue to explore ways to improve student understanding of science and to help the learners to see the relevance of science in today's world (Gabel, 2003). That is why this study present a new teaching approach based on learning cycle model.

Hypothetico-Predictive Reasoning or Prediction/Discussion-Based Learning Cycle (HPD-LC)

The Hypothetico-Predictive Reasoning (prediction/discussion phase) by Lavoie (1999) and the Learning-for-Use (LfU) designed by Edelson (2001) were constructivist and learning cycle-inspired approaches.

Lavoie (1999) designed the Hypothetico-Predictive Reasoning or the prediction/discussion-based learning cycle (HPD-LC). Hypothetico-Predictive Reasoning or the prediction/discussion phase is placed before the three-phases (exploration, term introduction and concept application) of learning cycle to improve students' process skills, logical-thinking skills, science concepts, and scientific attitudes. Hypothetico-Predictive Reasoning encouraged the students to debate, explore, and test their own predictions.

In Lavoie's (1999) study, the HPD-LC group relatively has higher mean scores, which indicate that students under HPD-LC have a propensity to:

- use more higher-level thinking skills;
- use more science process skills;
- interact more with their peers;
- show more evidence of conceptual change and understanding;
- interact more with the laboratory materials; and
- acquire greater conceptual understanding. (p.1135).

Lavoie (1999) explained that the significant change in students' process skills, logical-thinking skills, science concepts, and scientific attitudes were due to several factors. First, HPD-LC allows the students to construct and deconstruct their ideas because HPD-LC serves as knowledge development process. Second, students have active physical and mental engagement to verify whether their predictions are correct. Third, it allows the students to open and make clarification about their own beliefs based on newly encountered ideas or information. Fourth, it allows the students to have active interpeer discussion to promote and develop their logical thinking processes. These factors serve as active component for constructivist learning.

According to Doran (in Good & Lavoie, 1988) prediction is a science process skills in science education point of view. Good and Lavoie (1988) pointed out "prediction can be valuable strategy for the teacher to use in an attempt to learn what conceptions (or perhaps misconceptions) students have of concepts about to be studied or concepts already studied. Their responses can provide valuable information on which to base decisions about instruction" (p.336). However, little research has been done and associated with prediction. Good and Lavoie (1988) suggested that prediction better incorporated into the science teaching and learning cycle. Unfortunately, in learning cycle, prediction is not always emphasized.

Good and Lavoie (1988) enumerated the advantages of including prediction in learning cycle, the following are the advantages that learning cycle provides for the students and teachers:

1) encourage students to organize their existing knowledge;
2) make students aware of the diversity of belief held by classmates;
3) students will have greater commitment to follow up on their efforts;
4) students prediction can use by the teacher to aid their understanding; and
5) prediction may serve as pretest to judge student's initial understanding and later progress. (p. 337).

Like Learning-for-Use (LfU), research made by Good and Lavoie on prediction in learning cycle used computer-simulation program which found to be effective. Furthermore, Good and Lavoie (1988) suggested "effective ways of teaching and evaluating prediction need to be developed. This may involve testing various types of teaching strategies, learning sequences, and instructional materials designed to optimally organize and store both procedural and declarative knowledge in LTM" (p. 357). In this study prediction was added and given special emphasis.

Learning-for-Use

According to Edelson (2001) Learning-for-Use (LfU) and the Learning Cycle (LC) approaches have shared the same foundations and goals. The Learning-for-Use (LfU) and the Learning Cycle (LC) have many similarities. Both models are patterned to cognitive theories of learning, designed to integrate content and learning processes, and employed new knowledge structure (Edelson, 2001).

The Learning-for-Use (LfU) model by Edelson (2001) is based on four principles:

1) Learning takes place through the construction and modification of knowledge structures.
2) Knowledge construction is a goal-directed process that is guided by a combination of conscious and unconscious understanding goals.
3) The circumstances in which knowledge is constructed and subsequently used determine its accessibility for future use.
4) Knowledge must be constructed in a form that supports use before it can be applied. (p.357).

The main goal of this model (LfU) is to overcome inert knowledge by showing how learning activities foster useful conceptual understanding that can be used when it is needed. Moreover, Learning-for-Use (LfU) offers opportunity to increase students' deep content understandings and experiences through different and authentic activities.

In the study made by Edelson (2001), the ideas of the learners are being explored by doing hands-on activities in the first stage. In the second stage, concept introduction is explained and connected to hands-on activity for the learners to fully understand what they are doing. Lastly, in the third stage, learners apply constructed knowledge with new hands-on activity.

Table 8 shows the role of technology in supporting LfU. Highlighting the advantage of computing technologies, Edelson (2001) presented general guidelines that support content learning. To support this design process, LfU model has six different processes that serve as requirement for each step.

There are different assumptions behind LfU model that are as yet untested. Edelson (2001) highlighted three assumptions. His first assumption is that learning activities will master science content and process objectives compared with traditional activities (separate content learning and process learning). With this LfU approach, deep understanding will fully develop. Second, it will serve as useful framework for educators to implement effective learning activities. Third, in this research, technology-supported inquiry will contribute to the development of curricula.

TABLE 8The Role of Technology in Supporting Learning-for-Use.

Step	*Learning-for-Use Design Strategy*	*Role for Technology*
Motivate	Create demand	Tools that allow students to design or construct artifacts can support meaningful application tasks that demand understanding.
Construct knowledge	Elicit Curiosity Observe Communicate Reflect	Tools that allow students to express their beliefs or understanding enable them to articulate their conceptions and confront the limitations of their understanding. Tools that stimulate natural processes can serve as demonstrations of discrepant events. Investigation tools that offer students the opportunity to identify relationships through exploration of data. Stimulation tools can enable students to observe natural processes that may be impossible to observe in classroom settings.

Refine knowledge		Reference tools can provide students with access to information in a wide variety of media. Tools that enable students to maintain a record of their activities support reflection, with objects for reflection.
Refine knowledge	Apply	Collaboration and presentation tools that enable students to engage in discussions with others can facilitate reflection. Tools that allow students to design or construct artifacts can support meaningful knowledge application tasks.

Source: Daniel C. Edelson, Learning-for-Use: A Framework for the Design of Technology-Supported Inquiry Activities. (John Wiley & Sons, 2001.JRST 38; 3; pp 36).

Table 9 presents the steps and description of the processes in the Learning-for-Use model made by Edelson (2001) which used technology-supported inquiry learning to explore and integrate content and process learning.

TABLE 9Learning-for-Use with Descriptions of the Processes

Step	*Process*	*Design Strategy*
Motivate	Experience demand	Activities create a demand for knowledge when they require that learners apply that knowledge to complete them successfully.
Construct Refine	Experience curiosity Observe Receive communication Apply	Activities can elicit curiosity by revealing a problematic gap or limitation in a learner's understanding. Activities that provide learners with direct experience of novel phenomena can enable them to observe relationships that they encode in new knowledge structures. Activities in which learners receive direct or indirect communication from others allow them to build new knowledge structures based on that communication. Activities that enable learners to apply their knowledge in meaningful ways help to reinforce and reorganize understanding so that it is useful.
	Reflect	Activities that provide opportunities for learners

		to retrospectively reflect upon their knowledge and experiences retrospectively provide the opportunity to reorganize and reindex their knowledge.

Source: Daniel C. Edelson, Learning-for-Use: A Framework for the Design of Technology-Supported Inquiry Activities. (John Wiley & Sons, 2001.JRST 38; 3; pp 360).

To sum it up, LfU model/approach could be one of the most effective approaches provided that the schools have enough facilities (laboratory equipment, computers and other database technology) to execute this approach. In our educational setting, there is a lack of sufficient digital technology; thus, MUL could be one effectual alternative to traditional teaching approach.

Conceptual Framework

To address students and teachers difficulty in chemistry achievement, different researchers proposed different teaching approaches/models. Edelson (2001) developed a model called Learning-for-Use (LfU). The LfU model is divided into three stages namely: (a) motivate; (b) construct; and (c) refine. This model has six learning processes, including: 1) experience demand; 2) experience curiosity; 3) observe; 4) receive communication; 5) refine; and 6) reflect. At the same time, the LfU model applies to technology-supported curriculum. On the other hand, Lavoie (1999) proposed the Predictive/discussion-based learning cycle (HPD-LC), where there is an additional phase or stage before or at the beginning of a three-phase (exploration, term introduction and concept application) of learning cycle.

Modified Useful Learning (MUL) approach is a combination of Learning-for-Use model developed by Edelson (2001) and Hypothetico-Predictive Reasoning by Lavoie (1999). The modification made by the researcher is divided into two primary points: First, the hypothetico-predictive reasoning is incorporated in the motivation stage. The purpose of including HPD-LC in motivation stage is to have a significant change in students' process skills, logical-thinking skills, science concepts, and scientific attitudes. Second, the MUL approach has three learning activities to achieve the three learning processes. The learning activities of MUL approach is designed with the use of real-life situation instead of technology-based activities while the Learning-for-Use approach has six learning activities (design strategy) to achieve the six learning processes. In this model having six learning activities is possible in presenting a single lesson because it is designed with the use of technology or computer with database with this, data and information are easily obtain unlike MUL approach which uses only real-life situation. In addition, the researcher sees to it that the number of learning activities (3) fitted to the facilities of the school. Rodrigo (2002) pointed out that, "The Philippines is one of the many developing nations that had turned to information and Communication Technology (ICT) as a tool to improve teaching and learning" (Rodrigo, 2002, ¶ 1). . Unfortunately, the

Philippine educational system experiences problems in technology. Most of the public schools and some of the private schools do not have enough computers. In addition, Edelson (2001) pointed out that "However, the as-yet limited ability of a computer to understand the knowledge needs of a learner means that the computer as a judge of what information to present and when remains more promise than reality" (p.378).

LfU approach could be one of the most effective approaches provided that the schools have enough facilities (laboratory equipment, computers and other database technology). Since our educational setting is lack of sufficient digital technology MUL approach may serve as alternative solution which can be utilized in the absence and shortage of classrooms, laboratory equipments and computers both in public and private schools. Moreover, some educators encourage science teachers to make use of practical applications to impart the concepts and process skills among learners. Thus, MUL could be one effectual alternative to traditional teaching methods.

This study hypothesized that the Modified Useful-Learning approach has a positive effect on students' achievement, critical thinking skills and attitude compared to traditional teaching approach. Under MUL approach the students' achievement in chemistry, critical thinking and attitude towards chemistry are enhanced because students have direct experience and observation on the different activities. This is in contrast with the traditional teaching approach where the highlight is the teacher discussion and demonstration. Furthermore, using the Modified Useful-Learning approach students have direct interaction with one another and with the teacher, and are actively involved in the construction of knowledge to make it useful or meaningful for them.

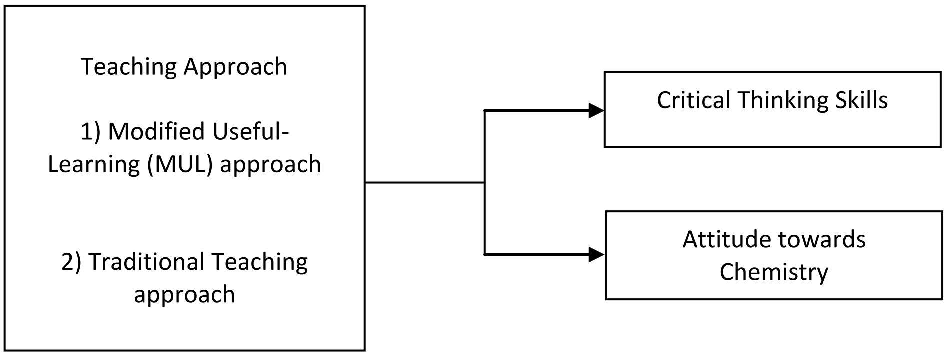

Figure 1. Conceptual Framework

Hypothesis

The mean posttest score in the Watson-Glaser Critical Thinking Appraisal is significantly higher for students exposed to the MUL approach than for the students exposed to the traditional teaching approach.The mean posttest score in the Chemistry Attitude Scale is significantly higher for students exposed to the MUL approach than for the students exposed to the traditional teaching approach.

The Sample

The sample included the third year students who were taking up chemistry at Diliman Preparatory School in Quezon City school year 2005-2006. The sections were known to be grouped heterogeneously, and two intact classes were chosen. These two sections were randomly assigned as MUL group and the other as traditional group. The III – Jose Abad Santos and III - Magbanua class schedules were 9:50 a.m. to 11:30 a.m. and 11:30 a.m. to 1:50 p.m., respectively. After random group selection, there were 36 students under treatment group (III- Jose Abad Santos), 33 of which were able to take the pretest and 34 took the posttest. The control group (III – Magbanua) was composed of 38 students, 36 of which were able to take the pretest and posttest. There were a total of 69 students who took the pretest and 70 took the posttest. The 65 students comprised the sample of the study. The researcher determined the MUL group and traditional group by tossing a coin.

The Instrument

Watson-Glaser Critical Thinking Appraisal (A Revised edition of Form Ym)

This is a standardized and popular critical thinking test which is intended to measure student critical thinking skills, developed by Watson and Glaser in 1964. WGCTA is a paper-and-pencil test of critical thinking, consisting of 100-items. The test is divided into five parts and each part has its own set of instructions and examples. The first part is called "Inference", which is composed of items 1-20. The second part is called "Recognition of Assumptions", which is composed of items 21-36. Third part is called "Deduction", which is composed of items 37-61, and the fourth part is called "Interpretation", which is composed of items 62-85. Lastly, the fifth part is called "Evaluation of Arguments", which is composed of items 86-100. The test is of the multiple-choice type. Table 11 below shows the reliability coefficients for the separate subtests of the critical thinking appraisal.

TABLE 11Watson-Glaser Critical Thinking Appraisal (WGCTA) split half reliability coefficient for the grade 10 normative groups.

Subtests	*No. of Items*	*Form Ym* *r**
Inference	20	.61
Recognition of Assumption	16	.74
Deduction	25	.53
Interpretation	24	.67
Evaluation of Arguments	15	.62

*Odd-even coefficient corrected by Spearman-Brown formula. Source: Watson, Goodwin and Edward Glaser (1964). Watson-Glaser Critical Thinking Appraisal-Form Ym.

Chemistry Attitude Scale (CAS)

The chemistry attitude scale (CAS) is a researcher-made test patterned after the attitude and perception scale developed and used by Abao (1997) and

Panlilio(2000). This is a Likert-type scale which consists of 25 statements on how students think and feel towards chemistry. The CAS was also given to a group of experts to validate the instrument. After the comments and suggestions from the experts were incorporated, the scale was then pilot-tested. This Likert- type instrument was initially composed of twenty five (25) statements on how students feel about chemistry. Based on the results of pilot testing, the reliability of the CAS was evaluated using Cronbach Alpha. The reliability coefficient of CAS was .8999. The test for reliability was done to determine the twenty (20) statements that constituted the final revised form of the Chemistry Attitude Scale (CAS). This instrument was used to measure the student's attitude towards chemistry. To support the use of comparative statistics, an ordinal scale was used. The scale is as follow: Strongly Agree (SA) = 5, Agree (A) = 4, Undecided (U) = 3, Disagree (D) =2 and Strongly Disagree (SD) 1.

To assess the mean scores of the two groups the attitude scale made by Belecina (2005) was used.

4.20 – 5.00	Very positive/Very favorable attitude
3.40 – 4.19	Positive/Favorable attitude
2.60 – 3.39	Undecided/ Neither positive nor negative attitude
1.80 – 2.59	Negative/ Unfavorable attitude
1.00 – 1.79	Very negative / Very Unfavorable attitude

Teaching Approaches

Traditional Approach

The traditional teaching approach is the usual lecture-discussion and demonstration wherein students' participation on experiments and activities was minimal. In this study, some of the teaching activities were games, inquiry, and puzzle which served as motivation for students.

Modified Useful Learning Approach

Modified Useful Learning (MUL) approach is a combination of Learning-for-Use model developed by Edelson (2001) and Hypothetico-Predictive Reasoning by Lavoie (1999).

MUL approach has three stages with three learning activities: motivate, construct, and apply. The three learning activities of MUL are designed with the use of real-life situation as an activity.

For this study, the MUL approach was designed to use group learning, hands-on and laboratory activities, reflective thinking, discovery and inquiry learning and small group discussion to increase student's participation. The students were trained to express their ideas using open-ended and guide questions. Teacher served as facilitator. Since teacher was not able to measure the ideas of each student in a certain topic in a short span of time, then group activity and presentation served as teacher's guide to monitor the students' conceptions.
The MUL approach includes the hypothetico-predictive reasoning at the motivation stage. At the start of the lesson, there is an activity that stimulates learner's attention and challenges students' conceptions. Students have the opportunity to give their personal theories, assumptions or conceptions based on

their prior knowledge as their initial response to the said activity/situation through group discussion and class presentation. Similarities and differences in their ideas emerge. Student attention (curiosity & interest) and demand for knowledge comes out. Students or teacher asks questions that require critical thinking. The given situation on the said activity serves as their motivation, where students predict and explore new materials and ideas with less expectation to their specific accomplishments.

The second stage in MUL approach is the lesson proper or knowledge construction. The purpose of this activity is to direct students' thinking and conception through reflective observation and open communication. Group discussion and presentation takes place to discuss students' observation and reasons on the said activity. Learners reflect and concentrate on what the experience means through proper exchange of ideas. The second activity requires the students to construct ideas and meanings based on the hands-on activity. This activity attempts to change students' personal theories and to construct new knowledge structure based on new information that they gain during group activity and class discussion. Concrete or direct experience permits knowledge construction through reflective observation and communication.

The third stage in MUL is the knowledge application wherein the constructed theory or knowledge by students through abstract conceptualization is applied, practiced, and scientific ideas connected (new knowledge structure) to real-life situation. To make their learning useful, students observe and reflect on previous activities (activity 1 and 2) and relate activity 3 to activities 1 and 2. The third activity focuses on the application of the constructed ideas based on previous activities (activity 1 and 2). Group discussion and class presentation take place. This activity gives the students the opportunity to strengthen their manner of constructing and connecting new knowledge structures through application in real-life situation, thus making it useful.

As students move from one activity to another, their ideas appear in numerous contexts so they have the multiple understanding about the materials thus they are able to construct robust understanding of science concepts. Table 12 presents the two teaching approaches used in this study.

TABLE 12Teaching Approaches

Teaching Strategy of Traditional (TRA) Teaching Approach	***Teaching Strategy Modified Useful Learning (MUL) Approach***
Motivation: • Games, puzzles etc.	*Motivation:* • Hypothetico Predictive Reasoning ▪ Brainstorming ▪ Group presentation of students predictions ▪ Hands-on Activity (1)
Lesson Proper (Knowledge Construction): • Demonstration	*Lesson Proper (Knowledge Construction):* • Hands-on Activity (2)

• Concept Presentation • Class Discussion	• Group presentation
• Presentation of Formula • Problem Solving • Solution Discussion *Application:* • Discussion of Concept Application	• Formulation of formula based on hands-on activity 2 • Problem Solving • Group Discussion of Solution • Presentation *Application:* • Hands-on Activity (3) • Group presentation (Students explain the significance of learned concepts in everyday living).

Small grouping promotes communication and participation using open-ended activities which require them to think critically. Students talk more and have greater opportunities to access materials as a result they learn a great deal (Bianchini, 1997). The product of students' brainstorming is presented by the member of the group (representative). Each student is given an opportunity and trained to express his/her personal theories, preconception, constructed knowledge and application of constructed knowledge. Hence, the student's concept and knowledge are not directly lifted from the books. This is to train the students to answer open-ended questions given in their activity sheets.

Data Collection Procedure

Two intact classes were involved in this study. One group was exposed to Modified Useful-Learning (MUL) approach and the other group to the traditional (TRA) approach. The researcher handled both groups to make sure that the same lessons, quizzes and assignments were carried out. The researcher requested another teacher to observe the classes. The observer used the classroom observation checklist in this study to ascertain that teacher bias is eliminated.

Before the start of the treatment, pretests in Watson-Glaser Critical Thinking Appraisal and Chemistry attitude Scale were administered to both groups. One group was taught using the Modified Useful-Learning (MUL) approach and the other group was taught using the traditional teaching approach. After the treatment, Watson-Glaser Critical Thinking Appraisal and Chemistry attitude Scale were again administered. The posttest was given simultaneously to both groups to eliminate possible occurrence of threats to validity such as time and place.

Results and Discussion

Initial Comparability Test

Table 13 presents the initial comparability of the MUL and traditional groups. The mean pretest scores of the two groups in the critical thinking (CT) test and chemistry attitude scale (CAS) of the students are given below.

TABLE 13 Equivalence of the CT, and the CAS Pretest Scores

	Group	N	Df	Mean	SD	t-ratio	Sig.
CT	MUL	31	63	56.65	7.58	1.182	0.242
	TRA	34		53.53	6.86		
CAS	MUL	31	63	69.19	7.63	4.012	0.000
	TRA	34		76.61	7.15		

Table 13 shows the critical thinking test results. It is noted that the mean pretest score of the MUL group is numerically higher compared to that of the traditional group. However, the computed t-ratio is not significant at 0.05 level. On the other hand, the chemistry attitude scale (CAS) mean pretest scores of the MUL group and traditional group are significantly different beyond 0.05 level. This shows that at the start of intervention, the MUL and TRA groups are comparable in terms of critical thinking skills but not in attitude towards chemistry.

Students' Critical Thinking Skills

One of the research questions presented in this study was: Is the mean posttest score in the critical thinking skills test higher for students exposed to the MUL approach than for the students exposed to the traditional teaching approach? To analyze the results of the critical thinking test, posttest scores were obtained for both MUL and traditional group. To confirm if the mean posttest is higher in the MUL group compared with traditional group, an independent *t*-test was used.

It is interesting to note that the mean posttest score of the MUL group is numerically higher than that of the traditional group as shown in Table 18. As indicated by the significance value, the difference in the mean posttest scores between the MUL and traditional groups is significant at 0.05 level.

TABLE 18 The Watson-Glaser Critical Thinking Appraisal (WGCTA) Posttest Scores Using Independent t-test.

Group	N	df	Mean	SD	t-ratio	Sig.
MUL	31	63	56.68	7.58	2.247	0.028
TRA	34		52.68	6.69		

Again, the use of MUL approach helps to improve student critical thinking skills. For the reason that MUL approach allows the students to activate their prior knowledge, correct personal theories based on constructed knowledge and apply the learned concepts (skills) through critical thinking. This support the statement of Gelder (2003), that the key to critical thinking is the word "skill" because critical thinking is a higher-order cognitive skill. Students will improve their critical thinking skills if they engage in lots of practice.

Students' Attitude towards Chemistry

It was hypothesized that students from the MUL group would show a significantly higher mean rating on CAS than those students in the traditional (TRA) group. The pretest rating in chemistry attitude scale (CAS) of MUL and traditional groups was presented in Table 13 (p.66) to observe for the initial comparability of MUL and traditional groups. Table 13 shows that a t-ratio of 4.012 suggests that the CAS pretest mean rating of the traditional group is significantly higher than that of the MUL group, thus it can be said that the two groups had different attitude toward chemistry before the implementation of the treatment.

Table 19 shows the posttest rating in chemistry attitude scale of the MUL and traditional group. The mean rating in chemistry attitude scale of the MUL group is 77.20 and traditional group is 76.30 while the standard deviations were 8.18 and 8.10 in favor of traditional group. It shows that the MUL group had a numerically higher posttest mean rating in the chemistry attitude scale test compared to the traditional group whereas the pretest mean rating was numerically higher for the traditional group.

TABLE 19 Means and Standard Deviations of CAS Posttest Ratings

Group	N	Mean	SD
MUL	31	77.20	8.18
TRA	34	76.30	8.10

To see if the mean posttest rating was indeed significantly higher, Analysis of Covariance (ANCOVA) was done using the CAS pretest mean score as the covariate. The results of the ANCOVA are shown in Table 20. As shown in the table, the main effect of treatment after removing the effects of the covariate is significant, $F(1, 61) = 8.792$, $\rho < .0005$. The observed F ratio indicates that there is a significant difference on the CAS posttest between MUL and traditional group. This means that the attitude of the students under MUL group was significantly enhanced.

TABLE 20 Results of the ANCOVA on the Posttest Chemistry Attitude Scale (CAS)

	Sum of Squares	df	Mean Square	F-ratio	Sig.
POSCAS Covariate PRECAS Main Effects grouping Model Residual Total	1219.956 408.728 1243.898 2835.852 4079.750	1 1 2 61 63	1219.956 408.728 621.949 46.489 64.758	26.242 8.792 13.378	0.000 0.004 0.000

Table 20 presents the MUL and traditional students' posttest mean rating in Chemistry Attitude Scale (CAS) per item. The analysis of the attitude rating per item of MUL and traditional groups revealed that the MUL group had a higher rating of positive response than the traditional group in most of the statements even though the traditional group got higher mean rating on statements no. 15, 16, 17, 18, and 19.

Furthermore, in Tables 21 the 20 statements are grouped qualitatively into three components based on the main thought of the statement. The first component pertains to innate interest of the student toward chemistry. The second component is concerned with how the students demonstrate proper skills and attitude towards laboratory work. Finally, the third component is about how students express the usefulness of chemistry in increasing critical thinking, self-esteem and social responsibility. Statements no. 16 to 20 were negatively stated and the ratings were also reversed for these items. Grouping of the statements was validated by experts.

TABLE 21The Three Components of Chemistry Attitude Scale and the Students' Posttest Mean Rating (Per Item) for the MUL and Traditional Group

Statement No.	**Components of Chemistry Attitude Scale**	**Group**	
	Student show innate interest toward chemistry.	**MUL**	**TRA**
1	No matter how hard chemistry as a subject is, I try to understand the concepts.	4.35	4.29
2	I am interested in chemistry-related topics.	3.84	3.50
3	I always want to learn chemistry.	3.74	3.50
6	Chemistry makes me more curious and motivated to learn more about scientific and chemical concepts.	4.00	3.94
8	I find more time studying my lesson in chemistry than in any other subjects.	3.26	3.00
9	I love to learn new ideas in chemistry from my teacher, classmates and friends.	3.90	3.91
10	I always want to participate actively in group discussion related to chemistry.	3.65	3.85
14	I am interested amazed and fascinated when I see chemical reactions.	4.23	4.23
16	I am (not) confused in my chemistry class.	2.77	3.12
18	I (do not) like chemistry as a subject.	3.74	3.85
19	For me studying chemistry is (not) just a waste of time.	4.13	4.26
	Student demonstrates proper/attitude skills towards laboratory work.		
11	I enjoy preparing laboratory report and visual representation in chemistry.	3.61	3.53
12	I do not mind the difficulty and repetition of experimentation just to find out the correct answer to the problem.	3.84	3.62
	Student expresses the usefulness of the chemistry in increasing Critical Thinking, Self-Esteem and Social Responsibility.		
	I believe that my logical and critical thinking		

4	will improve by studying chemistry.	4.19	3.91
5	I believe in the importance of chemistry in our society/community.	4.26	4.26
7	I feel contented every time I perform well in chemistry.	4.32	4.20
13	I believe that chemistry is an important part of our curriculum.	4.29	4.12
15	I believe that this subject helps me to reason out critically.	4.06	4.12
17	I feel (don't) hesitant participating in chemistry related activities especially if I am working with people who are knowledgeable in chemistry.	3.06	3.15
20	I feel that all laboratory activities in chemistry are difficult/ (easy) to comprehend and are irrelevant/ (relevant).	4.23	3.85

Based on the presented data the mean posttest rating is significantly higher for the MUL group. It can be concluded that in the three components, MUL group displayed positive attitude towards chemistry.

Table 21 shows that the MUL approach has contributed to the favorable change in attitude towards chemistry as shown by the following: 1) The innate interest of the students toward chemistry under MUL group is higher compared to traditional group, this may be because of the inclusion of HPD-LC in motivation stage, with these students prior knowledge about certain situation stimulated. 2) Student demonstrates proper/attitude skills towards laboratory work because three hands-on activities were included in each lesson in the MUL approach whereas; in traditional approach it is more of lecture-demonstration. Student's manipulative skills were practiced/enhanced inside the classroom/laboratory. 3) Student expresses the usefulness of chemistry in increasing critical thinking, self-esteem and social responsibility with the use of MUL approach because most of the learning activities were practical applications of concepts to everyday life and to society; for this reason students clearly express the usefulness of chemistry in increasing critical thinking, self-esteem and social responsibility.

TABLE 22The Posttest Mean Rating of the Three Components of Chemistry Attitude Scale

Components of Chemistry Attitude Scale	**GROUP**	
	MUL	**TRA**
Student show innate interest toward chemistry.	3.78	3.77
Student demonstrates proper/attitude skills towards laboratory work.	3.73	3.58
Student expresses the usefulness of the chemistry in increasing critical thinking, self-esteem and social responsibility.	4.06	3.94

Conclusion and Recommendations

Students from the MUL group had significantly higher critical thinking skills test mean score than students from the traditional (TRA) group after the treatment. Further, the students' mean rating in the chemistry attitude scale was significantly higher for the MUL group than the traditional (TRA) group after the treatment.The study indicates that the MUL approach may be useful in the teaching-learning process of chemistry. In addition it may help teachers, future researchers, curriculum planners and administrators in the improvement of critical thinking skills and positive attitude towards chemistry. For science teachers, Modified Useful Learning (MUL) approach may be used in their teaching to help students improve critical thinking skills and enhance positive attitude towards chemistry. For science teachers and future researchers, in this study the effectiveness of MUL approach on the attitude towards chemistry and critical thinking skills were observed. However, the impact of MUL approach must be considered in problem solving, self efficacy and task value to really measure its effectiveness. For school administrators, introduction and utilization of activity-based teaching approach such as the Modified Useful-Learning approach should be given academic support to enhance students' critical thinking skills and attitudes and thus maximize student performance.

References

Bailin Sharon, et al. (1993).*A Conception of Critical Thinking for Curriculum, Instruction and Assessment*.British Columbia Ministry of Education.

Clarke John & Arthur Biddle (1993).*Teaching Critical Thinking-Reports from Across the Curriculum*.Prentice.

Carale, Lourdes &Pia Campo. (2003) *Concept Development in Filipino Children, The Circulatory System*. Philippines: UP-NISMED.

Chiappetta, Eugene & Thomas Koballa Jr. (1994).*Science Instruction Middle and Secondary School,(*5th Ed.). McMillan.

Crow, Linda (1989). *Enhancing Critical Thinking in the Sciences.Society for College Science Teachers* Washington, DC.

Dela Cruz, Teresita C. (2001). *Interactive Chemistry*. Philippines: Instructional Coverage System.

Dioniso, Miriam C., Proserpina Cerna (1996). *Laboratory Activities (Text-Workbook) in Science and Technology III*. Philippines: Innovative Educational Materials.

Echija, Elena C., Cecilia V. Bayquen, Rafael L. Alfonso & Elmarita A. De Vera. (2002). *Frontiers in Science and Technology III*. Philippines: Diwa.

Echija, Elena C., Cecilia V. Bayquen, Rafael L. Alfonso & Elmarita A. De Vera. (2003). *Science and Technology for the Future*. Philippines: Diwa.

Ferguson, George A. & Yoshio Takane (1989).*Statistical Analysis in Psychology and Education*.(6th Ed.).McGraw-Hill.

Firestone, William, Roberta Schorr and Lora Frances Monfils. (2004). The Ambiguity of Teaching to the Test-Standards, Assessment and Educational Reform. Lawrence Erlbaum Associates.

Fraenkel, Jack R. Norman Wallen (1993).*How to Design and Evaluate Research*.(2nd Ed.).McGraw-Hill.

Gebelein, Charles G. (1997). *Chemistry and Our World*.Wm.C. Brown.

Grolund Norman and Robert Linn (1990).Measurement and Evaluation in Teaching.6th Ed. MacMillan.

Hein, Morris (1990). *Foundations of College Chemistry*.(7th Ed.). California: Brooks/Cole.
Hill, Graham, John Holman, John Lazonby, John Raffan& David Waddington (1989).*CHEMISTRY The Salters' Approach*. Uiversity of New York.
Huck, Schuyler W. and William H. Cormier (1996).*Reading Statistics and Research*.(2nd Ed.).HarperCollins.
Johnson Andrew P. (2000). *Up and Out: Using Creative and Critical Thinking Skills to Enhance Learning*. Allyn and Bacon.
Kubiszyn, Tom & Gary Borich (2003).*Educational Testing and Measurement Classroom Application and Practice*. (7th Ed.).John Wisley& Sons.
Mader Sylvia S. (1993). *Biology* (4th Ed.). Wm. C. Brown.
Magno, Marcelita C., Merle C. Tan & Amelia E. Punzalan (1989). *Workbook: Science and Technology for a Better Life Series*. (3rd Ed.). Philippines: Basic Media Systems.
Magno, Marcelita C., Merle C. Tan & Amelia E. Punzalan (2000). *Science and Technology for a Better Life Series*.(3rd Ed.).Phillipines: Diwa Scholastic.
Marzano Robert et al. (1988). *Dimensions of Thinking: A Framework for Curriculum and Instruction. Association of Supervision and Curriculum Development*. USA.
Mendoza, Estrella E. (2003). *Chemistry Laboratory Manual*. Quezon City: Phoenix.
Mendoza, Estrella E. & Teresita F. Religioso. (1997). *Chemistry Laboratory Manual*.(2nd Ed.).Quezon City: Phoenix.
Mendoza, Estrella E. & Teresita F. Religioso. (1997). *Chemistry*. (2nd Ed.). Quezon City: SIBS
Nueva España, Rebecca & Joy Apostol (2004) *Chemistry - Science and Technology III*.Philippnes: Abiva.
Ogena Ester & Vivien Talisayon (2000).*TIMSS-like Test Items in Science and Mathematics*. Department of Science and Technology Science Education Institute and University of the Philippines National Institute for Science and Mathematics Education Development (UP-NISMED). Quezon City.
Ornstein, Allan C. (1990). *Strategies for Effective Teaching*.Harper Collins.
Ornstein, Allan C. (1995). *Strategies for Effective Teaching*.Harper Collins.
Perrone Vito (1997). Assessment for Equity and Inclusion Embracing All Our Children.Edited by A. Lin Goodwin.Transforming Teaching Series.Routledge.
Salandanan, Gloria G. (2000). *Teaching Approaches and Strategies*.Katha.
Snyder, Carl (1992) *The Extraordinary Chemistry of Ordinary Things*. (2nd Ed.). John Wisley.
Teaching Resource Package, Science and Technology III- Chemistry. Quezon City: UP-NISMED.
Tombari Martin and Gary Borich (1999).Authentic Assessment in the Classroom Applications and Practice.Merrill Prentice Hall.
Torrance Harry (1995).Evaluating Authentic Assessment. Open University Press, Philadelphia.
Ungson, Olivia B. (1999). *Workbook: Science Fundamentals for High School III*. Philippines: Trinitas.
Watson, Goodwin and Edward Glaser (1964).Watson-Glaser Critical Thinking Appraisal-Form Ym. New York: Harcourt Brace Jovanovich.
Wilbraham, Antony C., Dennis D. Stanley, & Michael S. Matta (1997) Chemistry. (4th Ed.)Addision-Wesley.
Practical Chemistry. Quezon City: University of the Philippines.
Alexopoulou, Evinella (1996). Small-Group Discussion in Physics: Peer Interaction Models in Pairs and Fours. *Journal of Research in Science Teaching,* 33(10), 1099-1114.
Ballone, Lena & Charlene Czerniak.(2001). Teachers' Beliefs About Accommodating Students' Learning Styles in Science Classes.*Electronic Journal of Science Education*, 6 (2)

Bianchini, Julie A. (1997). Where Knowledge Construction, Equity, and Context Intersect: Student Learning of Science in Small Groups. *Journal of Research in Science Teaching,* 34 (10), 1039-1065.

Bitner, Betty L.(1991). Formal Operational Reasoning Modes: Predictors of Critical Thinking Abilities and Grades Assigned by Teachers in Science and Mathematics for Students in Grades Nine through Twelve.*Journal of Research in Science Teaching* 28 (3), 265-74.

BouJaoude, Saouma&HalaBarakat.(2003). Students' Problem Solving Strategies in Stoichiometry and their Relationships to Conceptual Understanding and Learning Approaches.*Electronic Journal of Science Education*, 7 (3)

Bunce M. Diane and Jessica R.VandenPlas (2006).Student Recognition and Construction of Quality Chemistry Essay Response. Chemistry Education Research and Practice, 7 (3), 160-169.

Capstone Projects 2003. [On-line] Available: thorensen@montana.edu

Campbell Bob, Loveness Kaunda, Saalih Allie, Andy Buffler, and Fred Lubben (2000).The Communication of Laboratory Investigations by University Entrants.*Journal of Research in Science Teaching,* 37 (8), 839-853.

Edelson, Daniel C. (2001). Learning-for-Use: A Framework for the Design of Technology-Supported Inquiry Activities. *Journal of Research in Science Teaching*.38 (3), 355-85.

Freedman, Michael P. (1997) Relationship among Laboratory Instruction, Attitude Toward Science and Achievement in Science Knowledge. *Journal of Research in Science Teaching,* 34 (4), 343-357.

Fusco, Dana and Angela Calabrese Barton (2001).Representing Student Achievements in Science.*Journal of Research in Science Teaching,* 38 (3), 337-354.

Gabel Dorothy. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future. *Journal of Chemical Education* 76 (4), 548-54.

Gallagher, James J. (2000). Teaching for Understanding and Application of Science Knowledge.*School Science and Mathematics*, 100 (6),310-8.

Good, Ron and Derrick R. Lavoie (1988) The Nature and Use of Prediction Skills in a Biological Computer Stimulation. *Journal of Research in Science Teaching,* 25 (5), 335-360.

Herrington, Deborah & Mary B. Nakhleh (2003). What Defines Effective Chemistry Laboratory Instruction? Teaching Assistant and Student Perspectives.*Journal of Chemical Education,* 80 (10), 1197-205.

Johnson, Margaret and Anton E. Lawson (1998). What are the Relative Effects of Reasoning Ability and Prior Knowledge on Biology Achievement in Expository and Inquiry Classes? *Journal of Research in Science Teaching,* 35 (1), 89-103.

Jones, Loretta, Harry Buckler, Nathaneil Cooper, &BeliaStraushein (1997).Preparing Preservice Chemistry Teachers for Constructivist Classrooms through Use of Authentic Activities.*Journal of Chemical Education,* 74 (7), 787-88.

Keys, Carolyn (1997).An Investigations of the Relationship between Scientific Reasoning, Conceptual Knowledge and Model Formulation in a Naturalistic Setting. *International Journal Science Education,* 19 (8), 957-70.

Lavoie, Derrick R. (1999). Effects of Emphasizing Hypothetico-Predictive Reasoning within the Science Learning Cycle on High School Student's Process Skills and Conceptual Understandings in Biology.*Journal of Research in Science Teaching,* 36 (10), 1127-47.

Libby, Daniel (1995). Piaget and Organic Chemistry –Teaching Introductory Organic Chemistry through Learning Cycles.*Journal of Chemical Education,* 72 (7), 626-38.

McMurray, Mary Anne, Paul Beisenherz& Bruce Thompson. (1991). Reliability and Concurrent Validity of a Measure of Critical ThinkingSkills in Biology.*Journal of Research in Science Teaching,* 28 (2), 183-92.

Miller, Larry S., Mary B. Nakhleh, John Nash, Jeanne Meyer (2004). Students' Attitudes toward and Conceptual Understanding of Chemical Instrumentation.*Journal of Chemical Education,* 81(12), 1801-08.

Noh Taehee and Lawrence Scharmann (1997).Instructional Influence of a Molecular-Level Pictorial Presentation of Matter on Students' Conceptions and Problem-Solving Ability.*Journal of Research in Science Teaching,* 34 (2), 199-217.

Okebukola, Peter Akinsola (1986). An Investigation of Some Factors Affecting Students' Attitudes Toward Laboratory Chemistry. *Journal of Chemical Education.* 63 (6) 531-532.

Schneider, Rebecca, Joseph Krajcik, Ronald Marx and Elliot Soloway (2002).Performance of Students in Project-Based Sceince Classrooms on a National Measure of Science Achievement.*Journal of Research in Science Teaching,* 39 (5), 410-422.

Shiland Thomas (1999). Constructivism: The Implications for Laboratory Work. *Journal of Chemical Education,* 76 (1), 107-9.

Songer, Catherine and Joel J. Mintzes (1994).Understanding Cellular Respiration: An Analysis of Conceptual Change in College Biology.*Journal of Research in Science Teaching* 31(6) 621-637.

Spencer James (1999). New Directions in Teaching Chemistry: A Philosophical and Pedagogical Basis.*Journal of Chemical Education* 76 (4), 566-69.

Stohr-Hunt, Patricia M. (1996). An Analysis of Frequency of Hands-On Experience and Science Achievement.*Journal of Research in Science Teaching,* 33(1),101-109.

Sungur, Semra, CerenTekkaya&ÖmerGeban.(2001). The Contribution of Conceptual Change Texts Accompanied by Concept Mapping to Students' Understanding of the Human Circulatory System.*School Science and Mathematics,* 101 (2), 91-8.

Teichert, Melonie and Angelica M. Stacy (2002).Promoting Understanding of Chemical Bonding and Spontaneity through Student Explanation and Integration of Ideas.*Journal of Research in Science Teaching,* 39(6), 464-496.

Thomas, Gregory (1999). Student Restraints to Reform: Conceptual Change Issues in Enhancing Students' Learning Processes. *Research in Science Education*, 29 (1), 89-109.

Van Zee Emily, MarlettaIwasky, Akiko Kurose, Dorothy Simpsom& Judith Wild (2001). Student and Teacher Questioning During Conversations About Science. *Journal of Research in Science Teaching,* 38 (2), 159-99.

Von Secker, E. Clare and Robert W. Lissitz (1999).Estimating the Impact of Instructional Practices on Student Achievement in Science.*Journal of Research in Science Teaching,* 36 (10), 1110-1126.

Willson, Victor L., Cheryl Ackerman and Cesar Malave (2000). Cross-Time Attitudes Formation, and Achievement in College Freshman Physics. *Journal of Research in Science Teaching,* 37 (10), 1112-1120.

Yore, Larry D. (2001) What is Meant by Constructivist Science Teaching and Will the Science Education Community Stay the Course for Meaningful Reform? *Electronic Journal of Science Education,* 5 (4).

Beale, Cyndie (2003). *Taking Action to Determine and AddressStudent Misconceptions in Genetics*. [On-line] Retrieved from the Capstone Projects 2003. Available: thoresen@montana.edu

Blosser, Patricia E. (1990). The Role of the Laboratory in Science Teaching.Research Matters- to the Science Teacher. [On-line] Retrieved on October 12, 2005.

Christensen, Marvin (1995). Critical Issue: Providing Hands-on, Minds-On, and Authentic Learning Experiences in Science. North Central Regional Educational Laboratory. [On-line] Available: info@ncrel.org Retrieved on January 3, 2006.

Constructivism as a Paradigm for Teaching and Learning:What is Constructivism? [On-line] Available: Thirteen Ed Online 2004, http://www.thirteen.org/edonline/concept2class/constructivism/ Retrieved on September 26, 2005.

Constructivism (learning theory) (2006). [On-line] Available: http://en.wikipedia.org/wiki/Constructivism_(learning _theory). Retrieved on July 1, 2006.

Constructivist Models. [On-line] Available: Meaningful Learning/Constructivist Models.htm, http://www.ncrel.org/sdrs/areas/issues/envrnmnt/drugfree/sa3const.htm Retrieved on October 22, 2005.

Cotton Kathleen (2001a) *Critical Thinking Across the Curriculum Aloha High School*.[On-line] Available: School Improvement Research Series (SIRS), NW Regional Educational Laboratory. Retrieved on October 12, 2005.

Cotton Kathleen (2001b) *Teaching Thinking Skills*. [On-line] Available: School Improvement Research Series (SIRS), NW Regional Educational Laboratory. Retrieved on October 12, 2005.

Crawford Barbara (1997). *Collaboration in the Classroom: A framework for Research and Practice*. [On-line] Avaiable: http://www.ed.psu.edu/ci/journals/97pap29.htm

Dickinson, Valarie & Kirk Reinkens (1997) *Mr. Reinkens' Neighborhood: Can You Say Conceptual Change?* [PDF On-line] Available: 1997 AETS Conference Proceedings, http://www.ed.psu.edu/ci/Journals/97pap29.htm .

Elder Linda (2000) *Why Critical Thinking is Essential to the Community College Mission And Why It Will Be Difficult to Achieve*. Available: The Critical Thinking Community, www.criticalthinking.com Retrieved on October 12, 2005.

Evangelisto, Tony (2002). *Constructivist Approaches to Teaching and Learning*. [On-line] Available: http://www.tcnj.edu/~evangeli/constructivism.htm Retrieved on July 1, 2006.

Gabel, Dorothy (2003). Enhancing the Conceptual Understanding of Science [PDF On-line]. Educational Horizons 70-76.

Gelder, Tim van (2003). *Teaching Critical Thinking: Lessons from Cognitive Science*. [On-line] Available: http://www.philosophy.unimelb.edu.au/reason/papers/Teaching_CT_Lessons.pdf#search='Teaching%20Critical%20Thinking%20Gelder%20Tim%20VAn'

Hinton, Brian (2005). *Constructivism Applied: An Example from the Teaching of Computing*. Learning and Teaching in Higher Education: Gulf Perspectives. [On-line] Available: http://www.zu.ac.ae/lthe/vol2no2/documents/lthe02_02_04.htm

Matthews, Michael R. (2004). *Constructivism in Science and Mathematics Education*. [On-line] Available: m.matthews@unsw.edu.au

Moussiaux, Sandra and John Norman (1997). *Constructivist Teaching Practices: Perceptions of Teachers and Students*. [On-line] Available: http://www.ed.psu.edu/ci/journals/97pap32.htm Retrieved on October 20, 2004.

Murphy, Elizabeth (1997). *Constructivist Learning Environment.* [On-line] Available: http://www.cdli.ca/~elmurphy/emurphy/constructivism.html

Murrell Greg (1999). *Critical Thinking Across the Curriculum*. [On-line] Available: http://planet.tvi.edu/ctac Retrieved on October 12, 2005.

Ostlund, Karen (1998). What the Research Says About Science Process Skills. *Electronic Journal of Science Education* 2 (4) [On-line] Retrieved on April 13, 2006.

Powell Alvin (1997). *MCB Outreach, ExperiMentors Host 5 Elementary Classes*. [On-line] Available: http://www.news.harvard.edu/gazette/2004/01.15/11-mcb.html

Robertson, William (1996). *Constructivism and the Learning Cycle*. [On-line] Avalable: http://www.educ.sfu.ca/narstsite/publications/research/learn.htm

Rodrigo Ma. Mercedes T. (2002). *Information and Communication Technology Use in Philippine Public and Private Schools*. [On-line] Department of Information Systems and Computer Science.Ateneo de Manila University, Quezon City

Rule Lita C. and KennethLassila (2005) *Innovative Teaching Approaches to Improve Science Education: Improving Student Learning in a Diversified Environment*. [On-line] Available: http://www.iitap.iastate.edu/reports/stafrica/rule.html Retrieved on July 1, 2006.

Scalise, Kathleen, Jennifer Claesgens, Rebecca Krystyniak, Sheryl Mebane, Mark Wilson, and Angelica Stacy (2003). *Perspectives of Chemists: Tracking Conceptual Understanding of Student Learning in Chemistry at the Secondary and University Levels*. [PDF On-line] Available: astacy@socrates.berkeley.edu

Schafersman, Steven D. (1991). *An Introduction to Critical Thinking*. [On-line] Available: An Introduction to Critical Thinking.htm. Retrieved on September 26, 2005.

Stein, Barry S. (2002). *TTU Initiative to Evaluate and Improvement Critical Thinking Skills*, (Second Year Report) [PDF On-line].

Stein, Barry S., Ada F. Haynes and Jenny Unterstein (2003) *Assessing Critical Thinking Skills*. [On-line] Available: Bstein@tntech.edu

Stieff, Mike and Uri Wislensky (2002).*ChemLogo: An Emergent Modeling Environment for Teaching and Learning Chemistry*. [On-line] Available: ChemLogo.com Retrieved on October 12, 2005.

Third International Mathematics and Science Study (2003) [On-line]

Van der Wal, Anita (1999). *Critical Thinking as a Core Skill: Issues and Discussion Paper*. HERDSA Annual International Conference, Melbourne.

Winther Austin A. and Trudi Volk (1994). Comparing Achievement of Inner-City High School Students in Traditional versus STS-Based Chemistry Courses.

Abao, Emelyn K. (1997). Open-Ended Physics Experiments: Effects on Students' Achievement, Laboratory Performance and Attitude. Unpublished Masteral Thesis, University of the Philippines, Quezon City.

Bardillon, Ricardo U. Jr. (2004). Student Filipino Verbal and Symbolic Translations, Problem Solving Ability and Attitude Towards Mathematics in Word Problems. Unpublished Masteral Thesis, University of the Philippines, Quezon City.

Belecina, Rene R. (2005). Portfolio as Alternative Assessment: Effects on Problem-Solving Performance, Critical Thinking and Attitude in Mathematics. Unpublished Masteral Thesis.University of the Philippines, Quezon City.

Carreon, Sheryllyn M. (2004). Effects of Multicultural Physics Teaching Approach on Student Concept Understanding and Attitude Towards Physics. Unpublished Masteral Thesis.University of the Philippines, Quezon City.

Dominguez, Edna (2005). Constructivist Semi-Structured Physics Practical Work: Student Skills, Motivation, Procedural and Conceptual Understanding. Unpublished Doctoral Dissertation, University of the Philippines, Quezon City.

Ferido, Marlene. (1995). Students Conceptions and Learning Approaches to Chemistry in a Cooperative Classroom Environment. Unpublished Doctoral Dissertation, University of the Philippines, Quezon City.

Garcia Lea C. (2001).Utilizing Local Environment Issues in Developing Critical Thinking in High School Student.Unpublished Masteral Thesis.University of the Philippines, Quezon City.

Hidalgo-Coral.(2004). Metacognitive Learning Cycle Model Effects on Conceptual Understanding and Problem Solving Skills in Genetics.Unpublished Ph D Dissertation U.P. Open University Los Banños Laguna.

Juanich, Angie Melea. (2003). A Model-Centered Approach in Teaching College Physics and Students Representational Skills' Conceptual Understanding and Retention. Unpublished M.A. Thesis College of Education U.P. Diliman, 2003

Medina, Rhoel. Hypothetico-Deductive Learning Cycle and Biology Conceptual Understanding, Self-Efficacy and Task Value. Unpublished M.A. Thesis College of Education U.P. Diliman, 2006

Morco, Ofelia M.The Construct of Critical Thinking in Secondary School Mathematics. Unpublished PhD Dissertation.College of Education U.P., Diliman, 1994.

Panlilio, Ma. Gracia Cooperative Learning: Its Effects on Academic Achievement and Attitude Toward Learning Chemsitry. Unpublished MA Thesis, College of Education, U.P. Diliman, 2000.

Reyes, Eredani D. Constel Chemistry Telecourse and Student Conceptual Understanding Achievement and Attitudes.Unpublished MA Thesis, College of Education, U.P., Diliman, 2003.