Modified useful-learning approach: Effects on students’ achievement and conceptual understanding in chemistry

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This study was conducted to assess the effectiveness of the Modified Useful-Learning approach against the traditional teaching approach in improving student achievement in chemistry. Specifically, it sought to find out if the mean posttest score in the chemistry achievement test 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 Chemistry Achievement Test (CAT) divided into two parts: the multiple-choice (CAT-MC) and the open-ended (CAT-OE) questions on selected topics in Chemistry, developed by the researchers. The instrument was content validated by group of experts and was pilot tested. No significant difference was found between the mean posttest scores in the Chemistry Achievement Test-Multiple-Choice (CAT-MC) of the MUL and traditional group. However, a significant difference was found in the mean posttest scores in the Chemistry Achievement Test-Open-ended (CAT-OE) of the MUL and 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 achievement and conceptual understanding in chemistry.

Key words: Modified-useful learning approach, conceptual understanding, achievement in chemistry

INTRODUCTION

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, Ceren Tekkaya and Ömer Geban, 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
It is not clear to the students how to make sense of new information. 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 and 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 and 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, and 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 and 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 and 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 and 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 and 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 and 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 and 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 and Reinkens, 1997). For many students the significance of learning experience can be measured by its applicability to their everyday lives (Songer and Mintzes, 1994; Dickinson and 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 chemistry achievement test-multiple choice 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 achievement test-open ended 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).

Students’ achievement in science

Some of the educators identified assessment as a key mechanism for monitoring and intervening in the educational process, with attention being paid to the role of assessment in the education system as a system (as distinct from its implications for individual life chances), and with key research questions being framed less in terms of the extent to which assessments measure what they purport to measure (important though this still is) and more in terms of what impact assessment might have on the instructional process (Torrance, 1995, p.45).

Proponents of testing regard test as one of the best tools to improve teaching and learning. Educators believe that tests serve as a guide for the teachers and students to content areas that are important for society. Furthermore, other educators believe that test may drive teachers to make challenging content and activities to develop students understanding about mathematical and scientific concepts (Firestone, Schorr and Monfils, 2004).

In addition, Nickerson (in Torrance, 1995) explained that a truly adequate approach to educational assessment... not only will measure accurately what has been learned but will also provide useful diagnostic information for future instruction and ... will help drive the system as a whole, toward increasing effectiveness in the nurturing of understanding and thinking. (p.45)

In UK the achievement program showed increased student motivation and interest and improvement in the process of learning (Torrance, 1995).

Moreover, Task Group on Assessment and Testing (TGAT) expressed the positive benefits of assessment in the promotion of learning. According to them, (in Torrance, 1995), Promoting children’s learning is a principal aim of schools. Assessment lies at the heart of this process... it should be an integral part of the educational process, continually providing both ‘feedback’ and ‘feedforward’. It therefore needs to be incorporated systematically into teaching strategies and practices at all levels. (p.52)

In another study, researchers believed that testing is conducted to improve and develop learners’ skills and not simply identify learners’ deficiency and assign grades. Moreover, tests provide diagnostic information to help the teachers to focus their instructions (Tombari and Borich, 1999).

Meanwhile, Perrone (1997) admonished that assessment is a critical aspect in the field of education. Assessment provides important knowledge of students and their development as learners. Moreover, it brings up to date curricular and pedagogical practices to help students reflect on their own learning.

According to Gronlund and Linn (1990) testing can enhance student learning by assisting in (1) determining learners’ needs, (2) observing learning development, (3) identify learning difficulties, and (4) determining if the desired degree of learning outcome achieved (p.12). Summative (achievement) provide information for evaluating the course objectives and the effectiveness of the instruction used (Gronlund and Linn, 1990).

Fusco and Barton (2001) stated that there are demands for new tools for teaching science and representing student achievement in science that are inclusive, authentic, global, emergent and dynamic. A variety of goals for improving student learning in science led reformers to establish standards like what students should know and be able to do, and what instructional methods/approach should be used. Moreover, reformers suggested student-centered and inquiry-based approaches that promote deep understanding deep-rooted in the everyday world (Schneider, Krajcik, Marx and Soloway, 2002).

Similarly, Michigan Department of Education and National Assessment Governing Board (in Schneider, Krajcik, Marx and Soloway, 2002) admonished that parallel to improved instructional method of teaching are challenges to assess students’ knowledge and what they are able to do in comparison with standards, by means of large-scale achievement testing.

Different educational institutions adopted reforms like...
setting higher standards and by changing the way science is taught to increase student achievement. The Standards suggested a student-centered instruction to engage students in interactive inquiry and facilitates lifelong learning. Educators in the past believe that instructional strategy improved student achievement (Von Secker and Lissitz, 1999).

Another important work was that of Willson, Ackerman and Malave (2000) where they indicated dynamic interaction of conceptual understanding and improving achievement in Newtonian physics. As a result they suggested that if physics achievement is to improve more explicit attention to conceptual understanding and improving understanding should be done.

Based on the literature on science education, instructional characteristics are associated with student achievement. The strongest instructional recommendation was observed for instruction that emphasized laboratory inquiry or activity. Laboratory inquiry was associated with higher and more equitable achievement among students even if they were of different demographic profiles (Von Secker and Lissitz, 1999). A number of studies have traced that meaningful engagement of students with science concepts and experimental procedures are some of the evidences of successful achievement in science (Campbell, Kaunda, Allie, Buffler and Lubben, 2000).

Another related work is that of Winther and Volk (1994). They compared the achievement of the Inner-City high school students in traditional versus STS-Based chemistry courses. Based on their observation and analysis there was a significant difference in students' chemistry achievement posttest between two groups in favor of experimental group.

Likewise, Bredderman, Shymansky, Kyle and Alport (in Stohr-Hunt, 1996) conducted a research using activity-based science programs in elementary and high school students. They used 100 experimental studies and 18 different measures of student performance. The categories are as follows: achievement, process skills, and analytic skills. Based on their analysis it shows that there was a great increase in achievement and process skills development for the students who experienced activity-based programs. The study made by Bredderman, Shymansky, Kyle and Alport was reanalyzed by Shymansky (in Stohr-Hunt, 1996). Shymansky observed that the science programs were effective in improving student achievement and problem-solving skills compared to traditional teaching/programs.

Stohr-Hunt (1996) conducted a research involving hands-on activity (experience) and science achievement on eighth grade students. Based on the result it was concluded that significant differences existed across frequency variable with respect to science achievement.

Freedman (1997) investigated the use of hands-on laboratory program as a means of improving student attitude toward science and escalating student achievement levels in science knowledge. Based on the findings, students who belonged to the regular laboratory instruction group scored significantly higher on the achievement than traditional group and displayed a moderate positive correlation between their attitude and achievement in science. Instruction like hands-on activity makes the students become more excited and encourages them to have positive attitude toward science and to their achievement. It is apparent that the nature of science instruction strongly affects students’ attitude toward science, which may be a good predictor of student achievement in science. Based on the research (Freedman, 1997) laboratory, attitude toward science and achievement in science have been significant tools in the field of education.

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 and 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 and 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 and 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 and 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,
Table 1. Comparison of objectivism and constructivism

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

Source: Spencer (1999).

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 of constructivism 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 to constructivism is seen as being more than the acquisition of process skills; it is an essential ingredient in the understanding of science itself” (p.108).

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 and 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 and
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:
   i. Learning should be significant.
   ii. Instructional goals should be reasonable with the learners' goals.
   iii. Students' ideas should be tested through collaborative learning groups.
   iv. Encourage reflection. (in Murphy, 1997, p 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).

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.

**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 and 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 and...
Table 2. The role of the student in constructing their own knowledge.

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

Source: Spencer (1999)

Table 3. Constructivism and associated classroom practices.

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

Source: Yore (2001)
Lassila, 2006, p 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 and Lassila, 2006, p 9). Ramsden (in BouJaoude and 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, p 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 students involved 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 et al., 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 et al., 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 and 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 and 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 and Kobala, 1994). The study of Watt and Ebutt, (in Van Zee et al., 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 et al., 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 et al, 2001).

The employment of interactive activities leads prior knowledge towards new ideas and concept understanding (Carale and 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 and 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 and 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 and 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 and 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 and 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 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 and 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

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**Table 4.** The five categories of responses in terms of the types of relationships between the initial multiple-choice response and the associated explanation (Jensen and Finley, 1995).

<table>
<thead>
<tr>
<th>Degree of Understanding</th>
<th>Criteria For Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Understanding (BU)</td>
<td>A correct choice is accompanied by complete correct reasons. This is the best possible situation and indicates a sound understanding of the concepts.</td>
</tr>
<tr>
<td>Partial Understanding (PU)</td>
<td>A correct choice is accompanied by correct but incomplete reasons.</td>
</tr>
<tr>
<td>Functional Understanding (FU)</td>
<td>A correct choice is accompanied by incorrect reasons. Here, robust misconceptions (students holding onto their initial beliefs firmly) may enable the student to answer questions correctly, but for the wrong reasons.</td>
</tr>
<tr>
<td>Correct/incomplete (CI)</td>
<td>Accompanied by correct but incomplete reasons. A minor misconception may exist here, but more often the students’ knowledge is simply incomplete.</td>
</tr>
<tr>
<td>Worst Understanding (WU)</td>
<td>A wrong choice is accompanied by wrong reasons. This is the most flawed type of understanding and indicate either the lack of a conception or the presence of a dysfunctional misconception.</td>
</tr>
</tbody>
</table>

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:

i. Learning-cycle instruction was more interesting;
ii. Learning-cycle instruction helped them understand concepts better;
iii. Learning-cycle instruction helped them to think and reason more;
iv. Interpreter discussions were helpful;
v. They tend to asked more questions than they did with traditional instruction;
vi. Science was a process of discovery rather than a collection of facts; and
vii. 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.

Local and foreign researchers and educators used/developed several instruments, teaching strategies and approaches (Medina, 2006; Carreon, 2004; Hidalgo-Coral, 2004; Reyes, 2003; Juanich, 2003; Edelson, 2001; Lavoie, 1999; García, 2001; Ferido, 1995), and assessed their effectiveness in relation to conceptual understanding, student achievement, critical thinking, and attitude in science. Researchers utilized diverse scheme for classifying students' conceptual understanding to their achievement test in chemistry.

Ferido (1995) measured students' conceptions using a 35-item multiple-choice test with an open-ended portion for the reason or explanation of choosing a particular answer. Table 5 shows the scheme used by Ferido (1995) for rating students' conceptual understanding.

In her study, Reyes (2003) investigated the use of CONSTEL chemistry telecourse as teaching approach. Reyes (2003) used the scheme made by Ferido (1995) in Table 4. Reyes (2003) was able to measure student conceptual understanding using fourteen (14) multiple-choice items with an open-ended part to support or explain student answer.

Moreover, Abraham, Gzybowski, Renner and Marek (in BouJaoude and Barakat, 2003) developed and presented the concept-evaluation (Table 5) to analyze students' concept understanding in chemistry.

Finally, Hidalgo-Coral (in Medina, 2006) explored the usefulness of Metacognitive Learning Cycle Model on conceptual understanding in genetics using the attributes of alternative conceptions and correct conceptions and indicators of their strength. The scheme is presented in Table 6

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:

i. Use more higher-level thinking skills;
ii. Use more science process skills;
iii. Interact more with their peers;
iv. Show more evidence of conceptual change and understanding;
v. Interact more with the laboratory materials; and
vi. 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 and Lavoie, 1988)
Table 5. Categories of understanding for conceptual chemistry problems.

<table>
<thead>
<tr>
<th>Degree of Understanding</th>
<th>Criteria for Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>No response</td>
<td>Blank, I don’t know, I don’t understand</td>
</tr>
<tr>
<td>No conceptual understanding</td>
<td>Repeat question, irrelevant or unclear response</td>
</tr>
<tr>
<td>Partial conceptual understanding and Partial conceptual</td>
<td>Responses that show understanding of the concept but also make statements which</td>
</tr>
<tr>
<td>understanding with specific misunderstanding</td>
<td>demonstrate a misunderstanding</td>
</tr>
<tr>
<td></td>
<td>Responses that include at least one of the components of the valid response, but</td>
</tr>
<tr>
<td></td>
<td>not all components</td>
</tr>
<tr>
<td>Sound conceptual understanding</td>
<td>Responses that include all components of the valid response.</td>
</tr>
</tbody>
</table>

Source: BouJaoude and Barakat (2003)

Table 6. Attributes of alternative conceptions and correct conceptions and indicators of their strength (Adams and Griffard, 2001).

<table>
<thead>
<tr>
<th></th>
<th>Indicators of Relative Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The exploratory power of the alternative conception in</td>
<td>Low: The alternative conception is not used to explain everyday events.</td>
</tr>
<tr>
<td>everyday situations.</td>
<td>Medium: The alternative conception is used to explain some everyday events.</td>
</tr>
<tr>
<td>2) The interconnectedness of the alternative conception to</td>
<td>High: The alternative conception is used to explain a variety of everyday events.</td>
</tr>
<tr>
<td>other ideas or concepts held by the learner.</td>
<td></td>
</tr>
<tr>
<td>3) The accessibility to the correct conceptions through</td>
<td>Low: Direct experience of the concept is impossible or complex explanations</td>
</tr>
<tr>
<td>experiences.</td>
<td>are needed in order to interpret the experience.</td>
</tr>
<tr>
<td></td>
<td>Medium: Experiences can demonstrate the correct concept, but some</td>
</tr>
<tr>
<td></td>
<td>explanations are still needed to interpret the experience.</td>
</tr>
<tr>
<td></td>
<td>High: Experiences can demonstrate the correct concept with little or no</td>
</tr>
<tr>
<td></td>
<td>need for explanations.</td>
</tr>
<tr>
<td>4) Language sensitivity of the correct conception.</td>
<td>Low: Terms are not dependent on context or everyday terms are not required</td>
</tr>
<tr>
<td></td>
<td>to be redefined</td>
</tr>
<tr>
<td>5) The nature of the representation needed to understand the</td>
<td>Medium: Terms are somewhat context dependent or everyday terms are required</td>
</tr>
<tr>
<td>correct conception.</td>
<td>to undergo a little redefinition.</td>
</tr>
<tr>
<td>6) Explanatory power of the correct conception in everyday</td>
<td>Low: No representations are needed or they have direct correspondence to</td>
</tr>
<tr>
<td>situations.</td>
<td>the concept that is understood by most learner.</td>
</tr>
<tr>
<td></td>
<td>Medium: Representations have a correspondence to the concept that can be</td>
</tr>
<tr>
<td></td>
<td>understood by most learners after explanation.</td>
</tr>
<tr>
<td>7) The interconnectedness of the correct conception to other</td>
<td>Low: There are no connections to other ideas or concepts.</td>
</tr>
<tr>
<td>ideas or concepts held by the learner.</td>
<td>Medium: There are few connections to other ideas or concepts.</td>
</tr>
<tr>
<td></td>
<td>High: There are many connections to other ideas or concepts.</td>
</tr>
</tbody>
</table>

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 7 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 8 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.

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
Table 7. The role of technology in supporting learning-for-use.

<table>
<thead>
<tr>
<th>Step</th>
<th>Learning-for-use design strategy</th>
<th>Role for technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivate</td>
<td>Create demand</td>
<td>Tools that allow students to design or construct artifacts can support meaningful application tasks that demand understanding.</td>
</tr>
<tr>
<td>Construct knowledge</td>
<td>Elicit curiosity</td>
<td>Tools that allow students to express their beliefs or understanding enable them to articulate their conceptions and confront the limitations of their understanding.</td>
</tr>
<tr>
<td></td>
<td>Observe</td>
<td>Tools that stimulate natural processes can serve as demonstrations of discrepant events.</td>
</tr>
<tr>
<td>Refine knowledge</td>
<td>Communicate</td>
<td>Investigation tools that offer students the opportunity to identify relationships through exploration of data.</td>
</tr>
<tr>
<td></td>
<td>Reflect</td>
<td>Stimulation tools can enable students to observe natural processes that may be impossible to observe in classroom settings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reference tools can provide students with access to information in a wide variety of media.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tools that enable students to maintain a record of their activities support reflection, with objects for reflection.</td>
</tr>
<tr>
<td>Refine knowledge</td>
<td>Apply</td>
<td>Collaboration and presentation tools that enable students to engage in discussions with others can facilitate reflection.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tools that allow students to design or construct artifacts can support meaningful knowledge application tasks.</td>
</tr>
</tbody>
</table>

Source: Edelson (2001)

Table 8. Learning-for-use with descriptions of the processes.

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

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 (Figure 1).

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, p 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.

Hypothesis

The mean posttest score in the chemistry achievement test – multiple choice 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 achievement
test – open ended is significantly higher for students exposed to the MUL approach than for students exposed to the traditional teaching approach.

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

Chemistry achievement test (CAT)

Before the actual implementation of the treatment the researcher prepared 40-item multiple choice and 10-item open-ended questions based on the learning competencies in chemistry of third year students. The topics were Gas Laws and Solutions, distributed in a prepared table of specifications. The Chemistry Achievement Test (CAT) draft was given to the chemistry experts for content validation, comments and suggestions. The panel of experts included a professor and doctoral students from the UP Institute of Chemistry, a professor from the UP-NISMED, and a professor from the UP Integrated School.

Some of the questions were researcher-made questions and the others were adapted and revised from the Third International Mathematics and Science Study (TIMSS) released items (1995-2003), TIMSS-like test items in science and mathematics from the National Institute of Science and Mathematics Education Development (NISMED), and chemistry books (Foundations of College Chemistry by Heinz and Practical Chemistry by UP, etc.). The revised Chemistry Achievement Test (CAT) was pilot tested at UP Integrated School using one section of fourth year students. Fourth year students were chosen since they had already taken up the subject. The topics covered by the CAT are incidentally taken up during the fourth quarter. The pilot testing was done to determine the reliability of the test and the approximate length of time the students needed to answer the test questions. On the average, the students finished the CAT in 80 minutes. The indices of difficulty and discrimination of the test items were then evaluated. Based on the results of pilot testing, the reliability of the CAT was evaluated using Cronbach Alpha. The reliability coefficients of CAT-MC and CAT-OE were calculated to be .8620 and .7505, respectively. This test was used as a pretest and posttest. According to Fraenkel and Wallen (1993) these values are acceptable since the accepted value is an alpha greater than .70 (pp.149). Similarly, Nunnally (in Huck and Cormier, 1996) suggested that generally the accepted standard for reliability estimates is above .70.

In scoring the open-ended questions in the Chemistry Achievement Test (CAT-OE), a scoring scheme based on the concept-evaluation scheme developed by Abraham, Gzybowski, Renner and Marek (in BouJaoude and Barakat, 2003) was used to analyze students’ conceptual understanding (Table 9).

The scheme consisted of four categories: No Response (NR), No Conceptual Understanding (NCU), Partial Conceptual Understanding (PCU) and Sound Conceptual Understanding (SCU). In order to evaluate the problem comprehension and understanding of relationships among chemistry concepts and to support the use of comparative statistics, ordinal scale was used. The scale is as follow: for “SCU” response = 3, “PCU” = 2, “NCU” = 1 and “NR” = 0.

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 Lave and (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.
Table 9. Categories of understanding for conceptual chemistry problems.

<table>
<thead>
<tr>
<th>Degree of Understanding</th>
<th>Criteria for Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>No response</td>
<td>Blank, I don’t know, I don’t understand</td>
</tr>
<tr>
<td>No conceptual understanding</td>
<td>Repeat question, irrelevant or unclear response</td>
</tr>
<tr>
<td>Partial conceptual understanding and Partial conceptual understanding with specific misunderstanding</td>
<td>Responses that show understanding of the concept but also make statements which demonstrate a misunderstanding</td>
</tr>
<tr>
<td>Partial conceptual understanding</td>
<td>Responses that include at least one of the components of the valid response, but not all components</td>
</tr>
<tr>
<td>Sound conceptual understanding</td>
<td>Responses that include all components of the valid response.</td>
</tr>
</tbody>
</table>

Source: BouJaoude and Barakat (2003)

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 and 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 10 presents the two teaching approaches used in this study.

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
### Table 10. Teaching approaches.

<table>
<thead>
<tr>
<th>Teaching Strategy of Traditional (TRA) Teaching Approach</th>
<th>Teaching Strategy Modified Useful Learning (MUL) Approach</th>
</tr>
</thead>
</table>
| **Motivation:**  
i. Games, puzzles etc. | **Motivation:**  
i. Hypothetico Predictive Reasoning  
ii. Brainstorming |
| **Lesson Proper (Knowledge Construction):**  
i. Demonstration  
ii. Concept Presentation  
iii. Class Discussion  
iv. Presentation of Formula  
v. Problem Solving  
vi. Solution Discussion | **Lesson Proper (Knowledge Construction):**  
i. Hands-on Activity (1)  
ii. Group presentation  
iii. Formulation of formula based on hands-on activity 2  
v. Group Discussion of Solution  
vi. Presentation |
| **Application:**  
i. Discussion of Concept Application | **Application:**  
i. Hands-on Activity (3)  
ii. Group presentation (Students explain the significance of learned concepts in everyday living) |

### Table 11. Equivalence of the CAT-MC, CAT-OE, CT, and CAS Pretest Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Df</th>
<th>Mean</th>
<th>SD</th>
<th>t-ratio</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT-MC</td>
<td>MUL</td>
<td>31</td>
<td>17.35</td>
<td>4.31</td>
<td>0.457</td>
<td>0.649</td>
</tr>
<tr>
<td></td>
<td>TRA</td>
<td>34</td>
<td>17.85</td>
<td>4.46</td>
<td>1.374</td>
<td>0.174</td>
</tr>
<tr>
<td>CAT-OE</td>
<td>MUL</td>
<td>31</td>
<td>7.16</td>
<td>3.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TRA</td>
<td>34</td>
<td>8.53</td>
<td>4.12</td>
<td>1.374</td>
<td>0.174</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Before the start of the treatment, pretest in chemistry achievement test was 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, chemistry achievement test was again administered. The posttest was given simultaneously to both groups to eliminate possible occurrence of threats to validity such as time and place.

It can be seen from the table that the mean pretest score of the traditional (TRA) group is higher than that of the MUL group with a t-ratio of 0.457 in CAT-MC. However, this value is not significant at 0.05 level. This means that there is no sufficient evidence to prove that the mean pretest scores for the traditional and MUL groups are significantly different in terms of conceptual understanding using the multiple-choice test.

The chemistry achievement test – open-ended questions mean score of the traditional group in the pretest is numerically higher compared to that of the MUL group, with a t-ratio of 1.374, which is also not significant at 0.05 level. This shows that the mean pretest scores in this measure CAT-OE of the traditional and MUL group are not significantly different. This suggests that at the start, the two groups were not significantly different in terms of chemistry achievement using open-ended questions.

A paired t-test was performed (Table 12) to observe if there was a change in student’s mean scores during the pretest and posttest of the MUL and traditional groups. Relative to the pretest scores of the two groups, the
changes for both approaches (MUL and traditional) were found to be significant ($\rho < .05$). Therefore, there is satisfactory evidence to prove that there has been a change in the mean score after the implementation of either approach.

However, this does not prove that the MUL approach is better than the traditional approach since both treatments show significant difference between the mean pretest and posttest scores. The observed increases in the mean scores of MUL and traditional groups on the CAT-MC could have been because the students were already given participation on the topic discussed.

Furthermore, a paired t-test is also applied to the chemistry achievement test (open-ended questions). The significance value indicated that the implementation of MUL approach indeed heightens a significant difference in the chemistry achievement test of the MUL group. As in this case, it has been proven that the introduction or implementation of the MUL approach thus increases chemistry achievement test (open-ended) scores. However, the traditional group depicts the same significant increase.

As shown in the Table 12, the difference between the pretest and posttest of chemistry achievement test (CAT-MC and CAT-OE) scores for MUL and traditional group is significant beyond 0.05 level.

An initial question in formulating this research was to determine whether students’ achievement in chemistry would be enhanced by the implementation of MUL approach. To check if there is a significant difference in the mean posttest scores of the traditional and MUL group, an independent t-test was employed. As shown in Table 13, the difference between mean CAT-MC scores for the two groups is not significant at 0.05 level. This means that there is no sufficient evidence to show that the mean posttest scores for the traditional and MUL group are significantly different at the 0.05 level.

Table 14 shows the results of the analysis of the chemistry achievement test -open-ended questions posttest scores using independent t-test. It is statistically shown that the mean posttest scores of the MUL group is significantly higher than that of the mean score of the traditional group.

The result of CAT-OE supports Stohr-Hunt (1996) research studies. From his data, students in activity-based or hands-on activity scored significantly higher than students in traditional science programs. The same result was observed in other studies, (Bredderman, 1983; Bredderman, Skymansky, Kyle and Alport, 1983; Shymansky, 1989 in Stohr-Hunt, 1996).

Further, the frequency distribution of students’ responses to the test administered for the two groups is shown in Table 15. The table contains a per-item count on the number and percentage of students’ responses classified as NR (No Response), NCU (No Conceptual Understanding), PCU (Partial Conceptual Understanding) and SCU (Sound Conceptual Understanding) for both groups.

It can be seen from Table 15 that more than fifty percent of the students from MUL group had sound conceptual understanding (SCU) on question numbers 2, 3, 5, and 8 as compared to the students from the traditional group. These items are questions on the topics, Kinetic Molecular Theory, Boyle’s Law, Charles’s

### Table 12. The chemistry achievement pretest and posttest scores using paired t-test

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>t-ratio</th>
<th>Sig.</th>
<th>Mean</th>
<th>t-ratio</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CAT-Multiple-Choice</td>
<td></td>
<td>CAT-Open-Ended</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MUL</td>
<td>Pretest</td>
<td>31</td>
<td>17.35</td>
<td>-6.354</td>
<td>0.000</td>
<td>20.39</td>
<td>15.827</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>31</td>
<td>22.10</td>
<td>0.000</td>
<td>7.16</td>
<td>15.827</td>
<td>0.000</td>
</tr>
<tr>
<td>TRA</td>
<td>Pretest</td>
<td>34</td>
<td>17.85</td>
<td>-6.052</td>
<td>0.000</td>
<td>8.53</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
<td>34</td>
<td>21.82</td>
<td>0.000</td>
<td>14.21</td>
<td>5.903</td>
<td>0.000</td>
</tr>
</tbody>
</table>

### Table 13. The Chemistry Achievement (Multiple-Choice) Posttest Scores Using Independent t-test.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>df</th>
<th>Mean</th>
<th>SD</th>
<th>t-ratio</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUL</td>
<td>31</td>
<td></td>
<td>22.10</td>
<td>4.25</td>
<td>0.238</td>
<td>0.813</td>
</tr>
<tr>
<td>TRA</td>
<td>34</td>
<td>63</td>
<td>21.82</td>
<td>4.95</td>
<td>0.238</td>
<td>0.813</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Df</th>
<th>t-ratio</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUL</td>
<td>31</td>
<td>20.39</td>
<td>4.92</td>
<td>63</td>
<td>4.406</td>
<td>0.000</td>
</tr>
<tr>
<td>TRA</td>
<td>34</td>
<td>14.21</td>
<td>6.24</td>
<td>63</td>
<td>4.406</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Law, and Factors Affecting Solubility. These topics deal with behavior of solutions and the abstract concepts of gases. From these topics, it can be concluded that the MUL approach is useful in presenting the concepts in the said topics.

### Conclusion and Recommendations

The results suggest that the use of the MUL approach improves student achievement and conceptual understanding in chemistry. Specifically, the MUL group performed significantly better than the traditional (TRA) group in terms of student’s chemistry achievement test using CAT-OE (open-ended). The two groups were not significantly different in terms of student’s chemistry achievement using the CAT-MC (multiple-choice).

This 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 chemistry achievement, critical thinking and positive attitude towards chemistry.

Thus, the following recommendations are presented:

1. For science teachers, Modified Useful Learning (MUL) approach may be used in their teaching to help students improve achievement and conceptual understanding in chemistry.

2. For science teachers and future researchers, in this study the effectiveness of MUL approach on the CAT was observed. However, the impact of MUL approach must be considered not only in terms of students’ achievement, critical thinking and attitude in chemistry, but also with regard to conceptual understanding, problem solving, self efficacy and task value to really measure its effectiveness.

3. For school administrators and curriculum planners, the design of the MUL approach may be enriched in such a way that it will fit to other chemistry or science topics and...
enhance student learning and improve student’s chemistry achievement test specifically in the CAT-MC.  
4. 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.

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