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METACOGNITION IN CHEMISTRY EDUCATION

***Abstract**: The study determined the cognitive and affective effects of metacognitive activities. Specifically, it sought answers to define the subjects' chemistry performance, motivation, and scientific attitude before and after the exposure to the intervention, to find out the significant improvement in the given parameters, and to design improved instructional activities in the light of the findings. The quasi-experimental study used the one group pretest-posttest design to answer the problems posed. At the outset, the cognitive and affective levels of the 42 subjects were determined. To find out the cognitive effects, a chemistry performance test developed by the researcher and validated by panel of experts was used. Chemistry Motivation Questionnaire and Science Attitude Inventory II were used to determine the subjects' affective status. After the intervention period, the subjects' exit competence was determined and differentiated from the pretest level. Through the t-statistic for paired observations, the difference between the tests was computed for the level of significance. As the final output, an enhanced instructional guide on integrating activities for metacognitive development among chemistry students was designed. There are seven metacognitive activities that were utilized in the present research undertaking, namely: Learning Portfolio (LP), Metacognitive Planning/Feedback/Discussion, Metacognitive Wrapper, Session Reflection Log, Goal-setting, Metacognitive Note-taking, and Learning Community. The activities correspond to specific episodes of the instructional cycles and were tweaked with the intent of purposefully helping students develop metacognitive skillfulness. It is recommended that related studies be explored to determine the effect of a prolonged exposure of the students to the different metacognitive activities. Chemistry teachers may also adopt activities which are known to effectively assist students in conceptual development of abstract concepts in Chemistry and if situations permits, subjects be taught with laboratory following the science inquiry philosophy. Further, course and class advisers should encourage students to write their goal statements. Schools should also provide ample and varied opportunities for students to succeed and move up in the academic rung. Schools can design online or semi-online platform to cater to working students, second coursers, and working professionals whose circumstance could hamper in their maximum compliance and access to classroom activities. Lastly, to make science relevant to career and the personal lives of the non-science majors, academic programs such as environmental science or science, technology, and society may be offered in lieu of non-laboratory Physics and Chemistry.*

***Key words**: Metacognition, Chemistry, Education, Pedagogy, Philippines, Cebu City.*

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Introduction

The need to teach our students to become self-propelling learners has become a global catch-cry. However, if our classrooms are to succeed in this tall order, we have to regard our students as partners in facilitating learning. They have to be taught as good managers of their own successes in the classroom and beyond. Our pedagogical processes should be designed so as to empower students to effectively manage their own learning. Students should share a sense of accountability of their own academic success. Processes such as planning how to approach a course or a chunk of topic, monitoring one’s progress in the course including taking necessary steps for improvement after a thoughtful reflection of the learning experience should be manifested in our classrooms. In actual practice though our classroom processes presupposes that teachers do the planning, monitoring, and evaluating activities in the classroom to ensure students’ academic success. Many teachers would agree that when students exercise these functions success rate in the classrooms is likely to increase. The researcher believes that every student under proper training and feedback will consciously endeavor to become self-propelling learners: leaners as “reflective practitioners” of his or her own learning. The key for this cogent point is teaching for metacognition. Metacognition is a term used to mean one’s thinking about his thinking processes or what cognitive psychologists consider as second order cognition. Purposive thoughts about one’s own thought processes or reflecting the different events and actions in life and their ramifications are few instances when one becomes metacognitive. Recently, though, it has come to encompass variables in the affective realms and the learners’ conscious and deliberate intent to do self-regulating processes (Louca, 2008). Reviewed researches around the globe echoed the impact of metacognition in promoting learnig in the different disciplines (Pulmones, 2002, Lin et. al, 2005, Cooper, 2009, Chalmers, 2009, Chalmers &Nason, 2003, Tanner, 2012).

In the classroom settings, instructors can help students develop metacognition by asking them about their learning processes and reflect on what they practice (Anderson, et. al., 2010). Along this line, Cornford (2012) suggests that learning events in the class must provide activities that will compel students to be reflective learners. This can be done through assessments of one’s weaknesses or strengths and drawing lessons from such an experience. In fact Pulmones (2015) found out that when students are exposed to this kind of activities rather than in straight forward manner, students did not only enjoy it, but they also showed improvement in terms of performance and metacognitive skillfulness.

Recent studies have explored on how activities that foster metacognitive development can be integrated in different courses in the tertiary level viz: Promoting Student Metacognition in College Biology Course, Tanner 2012; The use of metacognitive wrappers in chemistry assignments, Lovett, 2008; Designing Metacognitive Activities, in 2001; Teaching Chemistry in metacognitive environment, Pulmones, 2007. Their findings tend to suggest the effectiveness of these activities in promoting the cognitive and the affective aspects of learning the course. Two constructs which are very important if we were to imbue our students with life skills.

Attitudes and motivation are two essential affective components that are known to influence students learning (Sirhan, 2007). These variables are in fact intertwined. One who has positive attitude towards learning tends to be motivated and thus may put more effort in the different learning tasks. In fact students who have high self-efficacy exemplified great performance in different learning tasks (Nbina, J. B., & Viko, B., 2010)

One of those learning areas that could benefit from this nascent development in pedagogy is the general education courses particularly conceptual subjects such as Chemistry.

Chemistry is of the branches of natural sciences. Its role in shaping the technological landscape cannot be denied. Because its contribution permeates in the realm of other sciences such as Biology, Physics, Nutrition, Health and other disciplines, it is often regarded as the central science. However; against this backdrop, chemistry education as an academic discipline is in decline internationally. Similar trends have been observed across the globe. Price & Hill (2004) reported in their surveyed literature in chemistry education this alarming pattern in Japan, Australia, Unites States, and the United Kingdom. In the Philippine tertiary schools Chemistry is taught as one of the general education courses together with physics, biology and geology. ‘The chemistry portion presents the basic theories and principles of chemistry, their historical development and applications (Padolina & Magno, 2015). Chemistry is oftentimes perceived as a difficult subject – a shared assessment of students in secondary and higher institutions of learning. This is even true particularly to non-science major students whose only compelling reason to take the course is graduation (Breuer, 2002). This observation is particularly relevant in as much that students who are enrolled in the researcher’s classroom are non-chemistry major. Oftentimes, students, especially those who have unpleasant high school chemistry experience, meet the subject with much skepticism and resistance.

The difficulty can be attributed to the students’ failure to have a theoretical grasp of the chemistry lessons (Sirhan, 2007 and Ali, 2014). Although, there are several variables to consider why meaningful learning in chemistry classroom is scarce, reviewed literatures would agree that the main obstacle lies in the students’ shallow understanding of the fundamental concepts of the course. These difficulties block the students' ability to effectively navigate in a deeper investigations and more demanding investigation in the course (Sirhan, 2007 p4 and Alir, 2014).

The problem is even confounded by the nature of students who enter our classrooms. As observed by the researcher, being a teacher for almost ten years and from information gathered from interviews with the student welfare and guidance offices personnel, it has been noted that students in his workplace generally show poor study habits, that is, planning for their lessons and other study strategies for survival in the rigorous demand by the academe and later on as an IT (information technology) professional. This is understandable because of the open admission policy of the school.

Analyzing the academic performance of students in science subjects, that is, physics and chemistry from 1990's up to present would show that failing percentage revolves around 1% to 8% of the population enrolled in every semester with few exceptions on two or three semesters when the failing percentage has reached 14 to 16 percent. Closer data analysis; however, showed that while students indeed passed these science subjects, majority of them clustered in the segments with grades of 2.5 to 3.0. This means that students are struggling to grasp the concepts in physics and chemistry. Whether the cause is cognitive in nature or how ready the students are in facing college science academic demands or students' attitude toward science and science instruction, this dismal performance calls for some reforms.

This bleak reality calls for restructuring of teaching-learning processes in such a way that both conceptual understanding of the course is achieved as well as the development of the life skills that are transferable across the disciplines or even in the personal lives and career of the students beyond the academia. It is the contention of the researcher who is handling introductory chemistry course in a tertiary institution that instructors should purposefully incorporate and emphasize activities that promote metacognitive skillfulness among students. It is with these two fronts; teaching for chemistry understanding and teaching for metacognition (or teaching for metacognitive skillfulness) that the researcher has embarked in this study.

Methodology

This study aimed in finding out the cognitive and affective effects of metacognition. The present study used the experimental design specifically the one-group, pretest-posttest design to find out if there was a significant difference in Chemistry1 students' chemistry performance, metacognitive awareness, motivation, and scientific attitude before and after the exposure to the metacognitive activities.

The research subjects were second year students enrolled in Chemistry 1 course, first semester, school year 2016-2017. They were students who were in their third semester (second year, first semester) in the Information Technology program.

Verbal and non-verbal abilities. The researcher requested the profile of the participants from the office of the guidance and testing center of the school. As shown in the report, 69.23% of the total research participants manifest difficulty in perceiving the relational aspects of words and word combination. They also have trouble in understanding subtle differences among similar words and phrases as well as manipulate words to produce meaning. Data based on relevant psychometric test also showed that they have difficulty in using number to predict outcomes according to computational rules. However, around 38.46% of the students are able to comprehend and employ numbers that make them understand its relationship and manipulate spatially.

The current study attempted to find out the cognitive and affective effects of metacognition. To describe and measure the extent of effects of these variables the following tools were utilized in this study:

Cognitive Effect

Chemistry Achievement Test. To obtain the performance profile of the students in chemistry, a teacher-made test was used in this study. To ensure the validity and reliability of the test, the expertise of colleagues and other specialist in the field was sought. To check for readability and clarity, the tool was pilot tested to science major students of Cebu Normal University. Appropriate corrections were carried out based on the suggestions and recommendations both by the students, in terms of "comprehensibility" and usability of the tool, and the experts in terms of the validity of the items until a reliability index of $\alpha = 0.89$ is achieved.

Affective Effect

Science Motivation Questionnaire (SMQ) by Shawn M. Glynn and Thomas R. Koballa, Jr. This Likert-scale questionnaire developed by Glynn and Koballa was used in this study to assess the motivation profile of the students. It is a checklist with thirty (30) statements and corresponding responses of never (1), rarely (2), sometimes (3), often (4), always (5). The thirty item-science motivation questionnaire is subdivided into six components of motivation, namely: (a) intrinsically motivated chemistry learning (items 1, 16, 22, 27, 30); (b) extrinsically motivated chemistry learning (items 3, 7, 10, 15, 17); (c) relevance of learning science to personal goals (items 2, 11, 19, 23, 25); (d) responsibility; that is, self-determination for learning chemistry (items, 5, 8, 9, 20, 26); (e) confidence; that, self-efficacy in learning science (items 12, 21, 24, 28, 29); and, (e) anxiety about chemistry assessment (items 4, 6,13, 14, 18). The items about chemistry assessment are reversed scored. The SMQ maximum total score is 150 while the minimum is 30.

Scientific Attitude Inventory (SAI II). The Scientific Attitude Inventory II developed by Richard W. Moore and Rachel Leigh Hill Foy was utilized to assess the students' scientific attitudes. The SAI II has 40 Likert-type attitude statements and 12 position statements. Six positions are positive and are labeled 1-A through 6-A. Six are negative and are labeled 1-B through 6-B. The A and B pair for each position are opposites of each other. The useful scales for analysis are 1-AB through 6-AB for each position and the positive and negative scales consisting of 1-A through 6-A and 1-B through 6-B, respectively. The SAI II is scored by assigning point values to each of the attitude items. Scores for the various subscales can be determined by adding the scores for the respective items. Scores may be determined for the 12 subscales, a total for the positive items, a total for the negative items, and a total for the entire SAI II. The range of scores for each of the scales1-A through 5-B is 3–15 (1–5 points X 3 items). The range of scores for scales 6A and 6B is5–25 (1–5 points X 5 items). The range of scores for the entire SAI is 40–200 (1–5 points X 40 items).

Metacognitive Awareness

Metacognitive Activities Inventory (MAI). To measure the students' metacognitive awareness, a metacognitive activities inventory (MAI) was used in this study. The Metacognitive Activities Inventory is a self-report developed by Schraw and Dennison (1994) that allows to measure adults' metacognitive awareness. Items were classified into eight subcomponents subsumed under two broader categories: knowledge of cognition (metacognitive knowledge) and regulation of cognition (metacognitive skillfulness).

Results and Discussion

Status of Subjects Before Exposure to Metacognitive Activities

Every student who enters the portals of our classrooms brings with him or her preconceived notion about anything that is to be learned. They carry with them earlier experiences, understanding and misconceptions, feelings, and beliefs about the subjects to be learned and about themselves. Knowing these background knowledge and misconceptions is critical since they are usually enduring and difficult to purge (Arends and Kilcher, 2010). These factors along their personal perspectives of how well they would fare in the course may help or impede the level of engagements students are willing to take in the classroom. It is therefore imperative to find out the entry status of the subjects before the exposure to the intervention.

Affective Aspects of the Study: Motivation and Scientific Attitude

Earlier works on metacognition focused mainly on the role that metacognition in academic achievements. It is the contention of the present study that affective components play an integral role in making students thrive in Chemistry classrooms. For us to be effective facilitators of learning, knowledge of students drives and attitude towards Chemistry and science in general becomes imperative. The tables that follow show the affective components of the subjects based on the pretests.

Table 1. Summary of Entry Level Motivation

Subcomponent	Mean	SD	Description	Rank
Intrinsic	3.862	0.522	Very High	1
Self-determination	3.5238	0.4994	Very High	2
Extrinsic	3.3524	0.6134	Very High	3
Relevance to Personal Goals	3.2714	0.4994	Very High	4
Anxiety about Science Assessment	3.0524	0.6310	High	5
Self-efficacy	3.0333	0.5707	High	6
Totality	**3.3492**	**0.5607**	**Very High**	

The entry level motivation of the subjects is shown on Table 1. It can be noted that the subjects' intrinsic motivation tops all the subcomponents. This means that Chemistry students entered into the classroom with "Very High" motivation to learn the course. One might wonder where this motivation is rooted when in fact as narrated earlier Chemistry is a difficult subject. Moreover, the entry chemistry competence is below average which therefore would have been symptomatic of a "poor motivation level". One way to look at it is the innate desire of the students to able to demystify the puzzling nature of macroscopic phenomena in the light of molecular or symbolic world. For instance, students are intrigued of these common observations :"sir unsa'y kalahian sa iron sa bike ug iron sa dugo?" [sir, what's the difference between the iron found in our blodd and the ironfound in the bicycle?], "kanang, nganu tay-un man ang puthaw sir, pero ang aluminum dili lagi? […why does iron rust while aluminum doesn't?]. Questions like these provide some level of cognitive dissonance; hence, a higher level of intrinsic motivation. For classroom practice, this could mean that teachers should provide activities that highlight chemistry's practical applications in understanding the "mysteries" of world they live in.

Meanwhile, as revealed in table 4, the subjects' self-determination is "Very High". The subjects are aware to some extent that there are factors both those that involve themselves and those that are external that cause their successes or failures in earlier chemistry experiences. These factors include ability, effort, luck, and difficulty of the learning task (Weiner,1972). Extrinsically, Table 4 shows that the subjects are "Very Highly Motivated". Being a general education course, students do not necessarily feel that this subject is related in information technology program. This is even highlighted in the post interview script shown later. So what drives them to learn? Grades and graduation. After all, these two are the driving forces that propel them to enroll in the course. Many of the students are working scholars, food chain crew, and office staff. Therefore grades have to be maintained for them to stay as a scholar. Further, they feel that they have made big investment for the subject. It is therefore imperative to pass it or even earn a good mark.

In terms of relevance to personal goals, Table 4 reveals the subjects' "Very High Motivation" entry level. This could be viewed that in general, learning chemistry has its practical purpose or significance in the lives of our students who enter our classrooms. However, anchoring chemistry in the purpose or goals of the program where the subjects are enrolled might prove to be slightly challenging. How to prepare classroom materials and raise the level of discussion in chemistry that is attuned to the personal goals of the students is a valuable consideration in Chemistry instruction.

On top of the students' cause of anxiety are the chemistry examinations. This could be explained by the fact that results in examinations have implications not only in their social status in the class but also in the ultimate performance in the course. As presented, students are generally "Highly Motivated" consistent with other sub components in motivation. However; it is seen to be slightly lower in the spectrum. This means that while they have high confidence in learning chemistry lessons, assessment still creates a stigma among the students.

In all the motivation components, self-efficacy is relatively lower. Nonetheless, the subjects are still "highly motivated". This could mean that students may feel relatively less confident that they will succeed in the class. This could be a good target behavior using the metacognitive activities as a tool to develop learners to take control of their own learning.

Scientific Attitude Level Prior to the Intervention

Attitude towards science or as used in this study, scientific attitude, can be defined as the feelings, beliefs, and values held about an object that may be the endeavor of science, school science, the impact of science and technology on society, or scientists (Akcay, Yager, Iskander, & Turgut, 2010, p1). The subjects' attitude toward science may give us some insights and clues as to how students will fare in Chemistry instruction.

Table 2. Summary of Pretest for Scientific Attitude

Position Statement	Mean	SD	Description	Rank
5AB *Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.*	3.6310	0.6121	Strongly Positive	1
2AB *Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.*	3.3532	0.4327	Strongly Positive	2
3AB *To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.*	3.3056	0.5086	Strongly Positive	3

6AB *Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.*	3.2214	0.5732	Strongly Positive	4
1AB *The laws and/or theories of science are approximations of truth and are subject to change.*	3.1984	0.3458	Strongly positive	5
4AB *Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.*	3.1587	0.4131	Moderately Positive	6
Total	3.3114	0.4809	Strongly Positive	

Table 2 shows the subjects' attitude towards science as determined by the position statements in the Scientific Attitude Inventory II (Moore & Foy, 1997) prior to their exposure to the intervention. Position statement 5AB "*progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work"* tops the rank and merit a "Strongly Positive" attitude from the subjects. It can be construed that the subjects strongly believed that the every citizen should understand science. This is expected because the subjects, being Information Technology students, are bombarded everyday by different technological advancement in the field of computer. Both the production of materials they use and themselves as co-creator of software and other related IT products and services expatiate science as a human enterprise. Settled at the bottom of the ranking; however, is position statement **4AB** rendering it to be "Moderately Positive". This finding could mean that subjects agree lightly (mean = 3.1587) on the attitude statements pertaining to science as an idea-generating activity and the nature of theoretical systems that operates in science. This could be because students who are entering in the chemistry course viewed highly the most practical contribution of science such as development of materials for modern infrastructure, technology, medicine, and other inventions of practical value to society. Just like many of us, the research subjects are consumers of knowledge and technology and often have less understanding or exposure to the creative inventions of theoretical systems that operates in the scientific endeavors. On the average the subjects showed a "Strongly Positive Attitude" towards science. This is expected because the subjects are bombarded by plethora of scientific materials, be it gadgets or news, environmental issues, pollution, health, advancement in military warfare, and space exploration. More so that they are information technology students, access to these materials is within the reach of their fingertips. In other words, science and its contribution to humanity has become part and parcel of our students' collective consciousness thereby creating a good environment for the subjects to have "Strongly Positive" attitude towards science.

Chemistry Performance Before the Intervention

Table 3. Subjects' Entry Level Chemistry Performance

Skills	N	Mean	SD	Description	Rank
Periodic Table	42	2.381	1.652	Average	1
Electronic Structure	42	1.833	1.286	Average	2
Formula Writing	42	1.405	1.083	Below Average	3
Naming	42	1.095	1.031	Below Average	4
Quantum Numbers	42	0.667	0.687	Poor	5
Totality	42	1.4952	0.7448	Below Average	

Table 3 shows the subjects' performance in the chemistry pretest. It can be gleaned that the students' overall entry competence is below average (mean = 1.4952). Further, it showed that students struggled in quantum numbers but showed an average performance on items relating to periodic table and electronic structure, and "Below Average" for formula writing and Naming of inorganic compounds. Similar conceptual difficulties have been reported in earlier chemistry education researches (Maningo, 1999; Sirhan, 2007, Cardillini, 2012, Gafoor & Shilna, 2013). Students come to chemistry classrooms with conceptual difficulties. Students find it difficult to understand moles, atoms, quantum numbers (Maningo, 1999) periodic table and chemical bonding (Gafoor & Shilna, 2013) and related concepts that require a higher level of abstractions. The subjects' entry level competence may provide us some clues into the nature of concepts the students mastered in high school chemistry. Where the difficulty lies and what this means to college chemistry teaching? Key in finding answer to these questions is the very nature of chemistry concepts. Chemistry exists in three forms: the macro and tangible that is, what can be seen, touched, and smelled; the submicro that includes atoms, molecules, ions, and structures; and the representational that involves symbols, formulae, equations, molarity, mathematical manipulations and graphs (Johnstone, 2000 & Chang, 2000). Students come to our classroom replete with experiences of the macroscopic world. What they see, touch, manipulate and feel. This makes chemistry as a course that we all can relate well. However, for chemistry phenomena and processes to be fully understood students have to be engaged with activities that reach the submicro and representational levels. In fact many observable phenomena that seem to be a mystery are ably understood and expounded at this level. Johnstone (2000) believes that this is the strength of chemistry as an intellectual pursuit but a task that proves to be challenging among students. Another reason for such dole performance could be the kind of learning experiences that students have engaged in earlier chemistry classes. Where the lessons taught in a way that the three touch points of macroscopic, submicroscopic, and representational levels are best addressed? Ali (2012) underscores the importance of students' basic understanding of the learning situation, in this case, chemistry, because it may have direct effect coping with the advanced level knowledge. In this study, students wrote short essays on their earlier chemistry encounters. Although the students' comments shown on the table below is not everything about their previous chemistry lessons, it gives an insights of students personal journey, struggles and triumphs of chemistry before entering our college chemistry classrooms. Laboratory activities that draws in curiosity and support to the abstract nature of the Chemistry, the teacher's disposition and strategies of teaching are recurring themes that highlight the students earlier chemistry experience.

Another important consideration for the subjects' dismal performance could be the time when the subjects have been exposed to Chemistry lessons. It is worthy to note that it was in their 3rd year in high school or roughly three years since that they took the Chemistry performance test. The subjects may have difficulty recalling the different concepts learned. With these insights; college instructors may provide innovative teaching strategies that would both help reignite students' interest and at the same time present the subject cognizant of the touch points of chemistry learning presented.

Metacognitive Awareness Before the Intervention

One of the aims of this research endeavor is to assess the level of metacognitive awareness of the subjects prior to exposure to the metacognitive activities in chemistry instruction. One's metacognitive level of awareness is divided into two areas: knowledge of cognition or metacognitive knowledge and regulation of cognition also known as metacognitive skillfulness. Metacognitive knowledge refers to the awareness of one's thinking while metacognitive regulation is the ability to manage one's own thinking processes (Darling-hammond, et al, 2003). Metacognitive knowledge that includes, declarative, procedural and conditional are found in table 2, while the five metacognitive skillfulness components, that is, planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation are presented on table 3. The sub skills or performance indicator for each sub components were removed for simplicity of discussion. It can be gleaned from the tables that students are "Excellent" on the average in both metacognitive knowledge and skillfulness; yet when this is juxtaposed with their dismal performance in Chemistry Pretest, there seems to be some cognitive incongruity. This tends to run against the grain of findings of earlier researchers as it will be discussed later that high metacognitive awareness are high predictors of academic success. One may think that students sporadically answer haphazardly the questionnaire; However, this could not be the case because accomplishing the pre-tests as well as posttests was thoroughly explained and monitored by the researcher. An earlier work may provide answer to this dilemma. Lovett's (2008) earlier research on students' metacognitive skills and beliefs provide enlightenment to the current finding. She found out that students tend to overestimate their abilities or become overconfident about what they can do. New strategies that fosters for self-regulating behavior are suggested to address both cognitive and affective concerns, that is, overconfidence. Another way to look at it is that, students have their personal understandings of themselves, chemistry as a subject – ease or difficulty, and their "generic belief" about the use of strategies. This could mean that subjects enter the classroom loaded with their previous experiences, realizations, and insights that old routines may no longer work and as well as new (Dawson, 2008). This could mean that teachers can ably help students maximize this knowledge to achieve learning goals. Arends and Kilcher (2010) suggested that knowledge about the types of knowledge the students' are well verse or oriented has instructional significance because it helps determine the type of teaching strategy for a particular lesson. A student who is "overconfident" may be given challenging tasks paired with activities that provide opportunities for reflection. On the other hand student who is visually oriented may use concept maps as a way to understand and remember important information, or a student who is not good in memorizing long lists of names may use mnemonics.

Table 4. Summary of findings for Metacognitive Knowledge

Metacognitive Knowledge	N	Mean	SD	Description	Rank
Conditional	42	3.4849	0.5668	Excellent	1
Declarative	42	3.4179	0.5832	Excellent	2.5
Procedural	42	3.4179	0.5668	Excellent	2.5
Totality	**42**	**3.4402**	**0.5723**	**Excellent**	

Table 4 reveals the subjects metacognitive knowledge prior to the intervention. In general, the subjects who entered in the Chemistry classroom showed an "Excellent" metacognitive knowledge. This implies that our students come into our classrooms fully aware of what of their own capabilities and limitations. When accessed by the teacher, this information of students' interest, motives, and pitfalls could be utilized in designing instructional activities that are cognizant of these realities. For example when the students are beset with the challenge in managing information and organizing data, teachers can ably infuse classroom activities that would target these skills alongside learning chemistry. In terms of procedural knowledge, the students are "Excellent". This is expected because when the subjects come into chemistry classrooms, they have had problem-solving encounters. Hence they have a repertoire of learning strategies in earlier years of school in several subject areas. The automaticity in deploying these strategies though, "Excellent", appears to be slightly lower. One reason could be that knowledge and dealing with problems is "conditionalized" (Bransford,, Brown, & Cocking, 2000) . This could explain, too, the disparity in the Chemistry performance and the metacognitive awareness. Using a strategy requires context, specificity, and applicability. The students may show excellent knowledge and skills in programming or mathematics subjects, for example, but may find it challenging to solve things in Chemistry activities. One imperative in our teaching learning activities; therefore, is to allocate time for formative activities that fosters the development of these skills among our learners. Table 4 further shows that the subjects have "Excellent' conditional knowledge. This means that they learn best when they have full grasp of the topic to be learned and tasked to be accomplished. Essential to the success in chemistry lessons and beyond is the subjects' ability to use the appropriate declarative and procedural knowledge in different chemistry tasks. This means that it is not enough that students acquire knowledge; knowing when and where to use it to achieve one's ends are equally important (Turns and Van Meter, 2011).

Table 5. Summary of Findings for Metacognitive Skillfulness

Metacognitive Skillfulness	N	Mean	SD	Description	Rank
Planning	42	3.5748	0.5762	Excellent	1
Debugging	42	3.4961	0.4559	Excellent	2
Evaluation	42	3.4747	0.4636	Excellent	3
Strategy	42	3.4522	0.4776	Excellent	4.5
Monitoring	4	3.4522	0.4775	Excellent	4.5
Totality	**42**	**3.4874**	**0.4084**	**Excellent**	

As a whole, the entry level metacognitive skillfulness of the subjects is "Excellent". Top on the rank is the students' planning skills with a mean, followed by the debugging, evaluation, and lastly strategy and monitoring. A detailed analysis and discussion on the metacognitive knowledge and skillfulness will be devoted in the contrasting of pretest and posttests.

Integration of Metacognitive Activities in Chemistry Instruction

The metacognitive activities were integrated in the teaching learning activities (TLAs) in the Chemistry 1 lessons. Figure 3 shows a simplified three-step flow of Chemistry instruction integrating these activities.

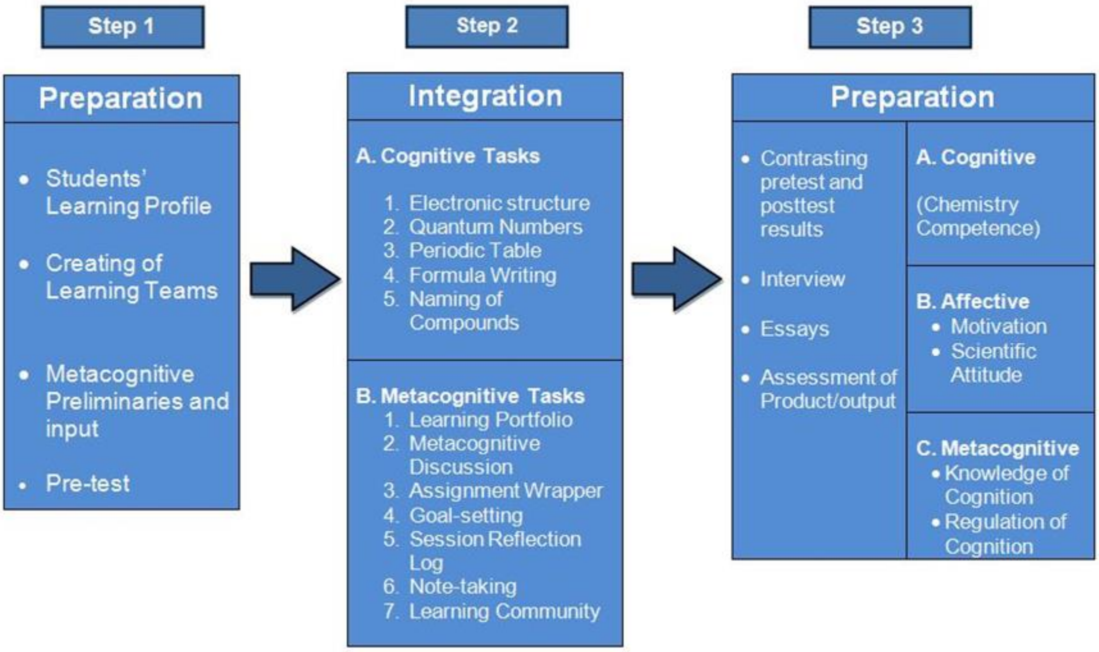

Figure 3. Implementation Flow of Metacognitive Activities

Step 1 is ***preparation*** which intended to prepare the class for the integration. It involves assessing the students' learning status which will be of great help in the creation of learning teams, and then students took the pretests. This was followed by mini-training on metacognition and self-regulated learning. In the present study, the students developed their own Cornell notes from recycled papers. Rubrics for assessing the quality of products were also presented and negotiated in the class. After seeking for clarifications the class was ready by this time for the integration proper. In ***step 2***, ***integration***, the students faced two instructional tasks: a) cognitive tasks which refer to the different chemistry activities like electronic structure, quantum numbers, periodic table, formula writing, and naming compounds; b) metacognitive tasks that include learning portfolio, metacognitive discussion, assignment wrapper, session reflection log, goal-setting, and learning community. ***Step 3***, is the checking on the effectiveness of the chemistry instruction. This stage, ***evaluation,*** requires observations of behavior changes in the subjects: the cognitive, affective, and metacognitive effects referred to as the center piece problem of the current research endeavor. This was done by providing different assessment tasks like written self- assessment, interviews, and products. The teacher also contrasted the pretest and posttest results to see significant improvements in the subjects' status. The findings and there implications will facilitate teachers and instruction implementers to feed forward for an improved chemistry instruction. In this framework, skills or conceptual development in Chemistry are achieved alongside the different metacognitive tasks. **Figure 4**, shows the constructive alignment of teaching learning activities (TLAs), intended learning outcomes (ILOs), and assessment tasks (ATs) that served as the guide posts in skill development. At the heart of metacognitive instruction is how students are guided to achieve the target skill from smaller progressions of sub skills. This learning progression model which was anchored from the work of Popham (2008) as quoted by Arends and Kilcher (2010), shows the iterative process in developing the targeted skill and the role of formative assessments and feedback as an indispensable tool for both cognitive and metacognitive development. The targeted skill is developed in smaller progression or development of the essential sub skills. The development of this skills is deeply rooted in the interwoven cognitive, in particular, the Chemistry tasks, with the different metacognitive tasks. Ultimately, the students' competence is primarily a function of both their ability to handle Chemistry lessons (cognitive) and planning, monitoring, and evaluating skills through the seven metacognitive activities (metacognitive tasks). The students' exit skills are assessed if the intended learning outcomes are achieved; thus providing feedback to the effectiveness to whole instructional design.

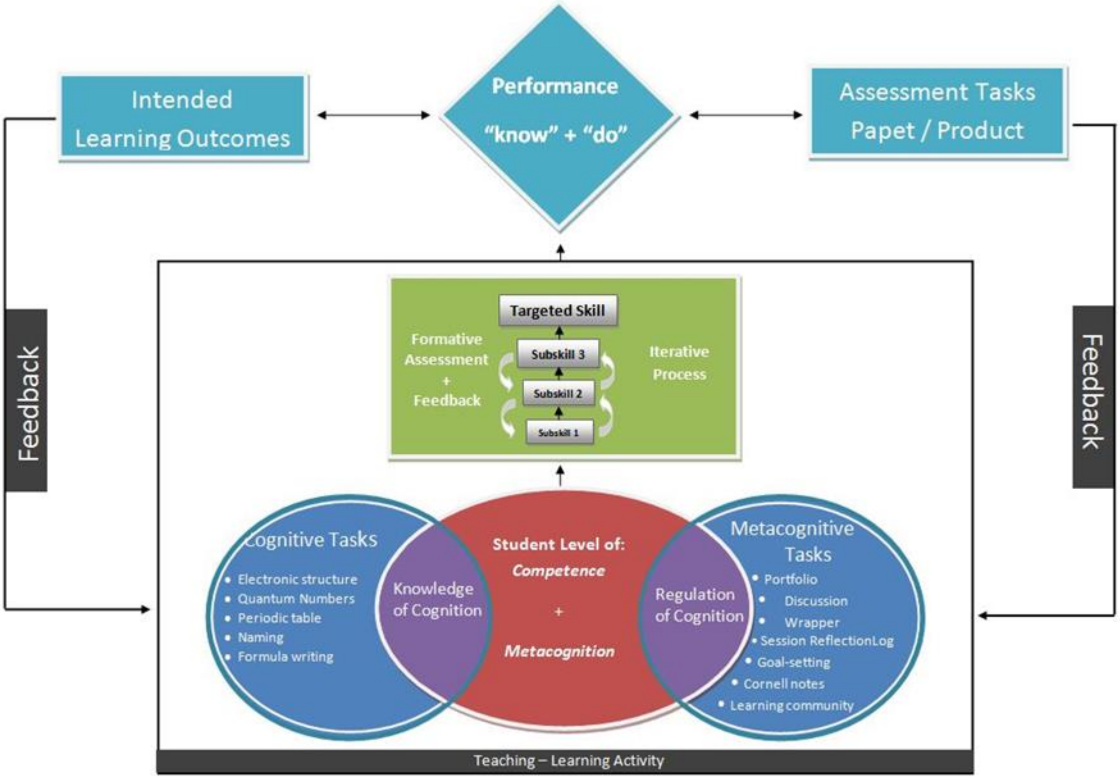

Figure 4. Skill Development with metacognitive Activities

The Metacognitive Activities

This study attempted to find out how classroom processes can be structured so that activities that foster metacognitive awareness can be infused in Chemistry instruction. As suggested by Weisler and Meyer (Cornford, 2002) there are two ways in which metacognition can be taught. First, metacognition can be integrated in our curriculum using adjunct approach in which case, a parallel training to develop metacognition is given to the students outside a certain subject. The second way is through a metacurricular approach. In this case, metacognitive activities that promotes students metacognitive skillfulness is integrated in a specific content subject. The present research undertaking used primarily the metacurricular approach both for practical (adding another mini-class for metacognition would entail time and resources for both the teachers and the students which make it improbable to use with the current school set-up) and pedagogical reasons. These metacognitive activities formed part of what the researcher will term as metacognitive tasks (MT). Rather than an add-on activity, researcher infused the MTs with the Cognitive Tasks (CT) that is, activities inherent to Chemistry. However, an adjunct teaching will be used to make explicit and overt the cognitive and metacognitive strategies which had been taught but embedded in the subject content. Lin (2001) and Cornford (2002) support this holistic approach. They contend that activities should be an integrated, natural part of the learning process rather than an add-on procedure. As commented by Louca (2008) on her review of the works of Vygotsky's Social Cognitive Development: "learning to learn does not happen in a vacuum, it is must be in a context of certain content". This is supported by earlier works in the field of science education that infused metacognitive activities alongside the content (Lovett, 2008). Metacognitive Skills are be developed or learned along with Chemistry topics. To achieve this, the researcher chose seven (7) metacognitive activities intended to foster metacognitive skillfulness among chemistry students. Each of the metacognitive activity is intended to explicitly teach students' metacognitive strategies and collectively to build a classroom culture conducive for metacognitive development. There are seven metacognitive activities that will be utilized in the present research undertaking, viz*: 1) Learning*

Portfolio (LP), 2) Metacognitive Planning/Feedback/Discussion 3) Metacognitive Wrapper, 4) Session Reflection Log, 5) Goal-setting, 6) Metacognitive Note-taking and 7) Learning Community. The activities correspond to specific episodes of the instructional cycles and were tweaked with the intent of purposefully helping students develop metacognitive awareness.

The discussion here is a humble attempt to narrate how these activities were implemented in the chemistry instruction adhering as much as possible to the guidelines set forth at the outset of the study. A short description about the activity as well as snippets of classroom events where these activities were used in the chemistry classrooms are hereby included. Students' brief accounts on these activities are also provided to flesh insights into the students' deeper thoughts regarding the MTs.

Learning Portfolio

Learning portfolio served as a repository of students output. It contained course outline in chemistry, conversion table, periodic table, student individual action plan, reflection log, goal-setting sheets, monitoring chart, student individual performance record (scores on quiz, seatwork, attendance, self-rated oral recitation), and different outputs from chemistry activities. The plan to give the students with a softcopy of an excel files with formula for grade computation for those who wish to make a personal assessment of their grades did not push through. Given the bulk of loads the students have in chemistry and other subjects, the researcher deemed it tedious in the part of the students to still go through the excel-grading activity. Students bring the portfolio every class period since all the materials for purposes already discussed. There were instances when some students forgot to bring their portfolio, they were not reprimanded but they were asked by the teacher to explain their side. Some students found the portfolio heavy and taxing to bring, while others found it useful as a repository of "items" not only in chemistry but also in other subjects. So why would the students bring the portfolio? It was ensured that every class period the materials found in the portfolio were used in the daily activities; hence; providing a natural motivation to bring it. One of the highlights in this activity was the use of daily class record, specifically, the personal oral recitations. Students were excited to record the rating they gave to themselves. Although, these ratings did not have a bearing on their grades, the researcher believes that it is a form of reflection that is instrumental for adaptive metacognition (Lin, Schwartz, & Hatano, 2005). Since the portfolio provides evidence symptomatic of the students' cognitive and metacognitive developments, it was assessed on the basis of completeness and quality of output. The portfolios were checked three times during the duration of the study. A detailed discussion of some portfolios will be dealt in details during the discussion of sample subject cases.

Metacognitive Planning/Feedback/Discussion

This activity allowed students to engage in the class-wide discussions concerning "understandings" or doubts, queries or problems they encounter as they wade through the different topics in chemistry class. While feedback and whole-class discussion were done in any part of the lesson, it was observed to be strategic at key phases of the instructional cycles. Used during the pre-lesson or lesson introduction, this activity served as a planning scaffolds. It was an important tool in tapping students' prior knowledge. It was also used during the lesson proper as a monitoring tool on learning check points. During the post lesson, this activity was used as "stabilizing" mechanism to galvanize students' understanding of the lesson.

Status of Subjects After Exposure to Metacognitive Activities

Affective Components After Exposure to the Metacognitive Activities

One of the ends of this research is to find out the affective effects of the seven metacognitive activities. Table 6 and 7 reveal the posttest results of the subjects' motivation and scientific attitude, respectively.

Table 6. Post Intervention Motivation Level

Subcomponent	N	Mean	SD	Description	Rank
Intrinsic	42	3.870	0.680	Very High	1
Extrinsic	42	3.7479	0.6199	Very High	2
Relevance to Personal Goals	42	3.6232	0.6026	Very High	**3**
Self-determination	42	3.6006	0.667	Very High	4
Self-efficacy	42	3.5216	0.5669	Very High	5
Anxiety about Science Assessment	42	3.4063	0.4723	Very High	6
Totality	**42**	**3.6283**	**0.601**	**Very High**	

Table 6 shows that the subjects' level of motivation have improved in all subcomponents to be "Very High". Whether there is a significant improvement in the subcomponents or as a whole, it will be determined after the pre-posttest results are contrasted. Meanwhile, the intrinsic motivation still remains to be the top factor for motivation of the students. Although, a marked improvement was seen in both self-determination and anxiety about science, the two subcomponents slid slightly in the ranking. One reason for this is the significant improvements the subcomponents "in relevance to personal goals" and "self-efficacy as will be discussed later."

Scientific Attitude after the Intervention

Table 7. Subjects' Post-Intervention Scientific Attitude Level

Position Statement	Mean	SD	Description	Rank
3AB *To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.*	3.3916	0.3834	Strongly Positive	1
5AB *Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.*	3.3518	0.3063	Strongly Positive	2
4AB *Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.*	3.3292	0.3063	Strongly positive	3
1AB *The laws and/or theories of science are approximations of truth and are subject to change.*	3.3254	0.3789	Strongly Positive	4
6AB *Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.*	3.2873	0.3252	Strongly positive	5
2AB *Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.*	3.2817	0.3642	Strongly Positive	6
Total	3.3278	0.3906	Strongly Positive	

The post intervention scientific attitude of the students toward science as shown on Table 7, is "Strongly Positive". On average, the subjects' attitude showed a very small increment in the different positions statements. First in the rank is the position statement **3AB** : *To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.* The "Strong Positive" attitude shown by the subjects toward this statement is expected because they have been witnesses to social and technological ramifications breakthroughs bought about by these technological breakthroughs. This could mean too that subjects have high regard to scientists as to the veracity of their claims and confident that the processes are done judiciously. In the contrary **2AB,** tail ended in the spectrum with a mean of 3.2817, although this is still "Strongly Positive" attitude. This could mean that students view science and scientist cannot provide answers to all our questions.

Table 8. Chemistry Performance

Skills	N	Mean	SD	Rank	Description	Rank
Periodic Table	42	4.286	1.785	1	Excellent	1
Electronic Structure	42	3.718	1.270	2	Excellent	2
Formula Writing	42	3.381	1.378	3	Excellent	3
Naming	42	3. 214	1.554	4	Excellent	4
Quantum Numbers	42	1.619	0.936	5	Average	5
Totality	42	3.2476	0.9008		Excellent	

Table 8 shows the subjects Chemistry performance after exposure to the metacognitive activities. It can be gleaned from the table that the overall performance is "Excellent". Their performance is "Excellent", too, in four sub concepts considered, namely, periodic table, electronic structure, and formula writing, and naming of inorganic compounds. However, although there was an improvement in terms of performance, that is, from "Below Average" or "Average to "Excellent", "Poor" to "Average", students level of difficulty in terms of the sub concept considered remain the same. Table 9 shows the comparison of ranking between the pretest and posttest in Chemistry performance. It is very interesting that in this study, the periodic table tops the students' performance, while in earlier research, usually this is considered by many students as the most difficult conceptual hurdle (Gafoor and Shilna, 2013).

Table 9. Subjects' Pretest and Posttest Results in Chemistry

Skills/Concepts	Pretest			Posttest		
	Mean	Description	Rank	Mean	Description	Rank
Periodic Table	2.381	Average	1	4.286	Excellent	1
Electronic Structure	1.833	Average	2	3.718	Excellent	2
Formula Writing	1.405	Below Average	3	3.381	Excellent	3
Naming	1.095	Below Average	4	3. 214	Excellent	4
Quantum Numbers	0.667	Poor	5	1.619	Average	5
Totality	1.4952	Below Average		3.2476	Excellent	

When compared to the work of Gafoor and Shilna (2013), periodic table, followed by chemical bonding, world of carbon was regarded as the most difficult concepts. However, looking into other concepts in their study indicated that in fact, these topics are relatively the most abstract and symbolic in nature compared to topics on mixture and nature of substances considered in their work. In essence the present study and their work draw the parallel experience that the difficulty is also a function of the Chemistry triangle proposed by Johnstone (2000). Maningo (1999) also found out similar observations. Although there were significant improvements in the subjects' performance using limericks, a chemistry-manipulation device, generally, the difficulty according to topics remain the same. However, among the most abstract topics, it is surprising that electronic structure which usually reported to be the most difficult to comprehend because of its very abstract nature, subjects in this research showed to have learned this concept well. When asked for reasons, student appreciated the use of "hotel analogies" used in this study and their personal analogies like *"ang energy levels and orbitals kay mura'g data folders man sab na sya sir. Naa sya's murag sequence-sequence"*. In effect, even the most abstract material can be understood by providing students with opportunity to grasp the concepts using similarities in the actual and more tangible world. The effectiveness of this strategy was also observed in other classroom settings where doing experimentation or physically observing the phenomena is not possible (Ali, 2012). Ali (2012), however, contend that though these models, analogies and imageries may help in the in facilitating learning topics such as atomic models, they may not provide sufficient conditions to help develop conceptual understating of the topic. It is therefore imperative for teachers emphasize that these symbols, formulae or models are representations of different properties of substance and not a copy of anything (Treagust, Duit & Niewswandt, 2000). Hence, in this research, classroom learning teams and discussions and feedback were used to support this end.

Table 10. Subjects' Post-Intervention Metacognitive Knowledge

Metacognitive Knowledge	N	Mean	SD	Description	Rank
Conditional	42	3.6810	0.5726	Excellent	1
Procedural	42	3.5833	0.5729	Excellent	2
Declarative	42	3.5506	0.4357	Excellent	3
Totality	42	3.6049	0.527	Excellent	

The post-intervention metacognitive knowledge of the subjects is shown on Table 10. On average they have an "Excellent" metacognitive knowledge just like the pretest. Conditional knowledge ranked first with a mean of 3.6 followed by procedural and declarative with means of 3.5833 and 3.5506, respectively. There is a slight increment in the means of the three metacognitive components. This means that the metacognitive activities may have helped in the students' ability to be aware of factors and conditions related to self and the course as they learn Chemistry.

Table 11. Post-Intervention Metacognitive Skillfulness

Metacognitive Knowledge	N	Mean	SD	Description	Rank
Debugging	42	3.8905	0.5963	Excellent	1
Planning	42	3.7449	0.5771	Excellent	2
Evaluation	42	3.5516	3.4747	Excellent	3
Strategy	42	3.4976	0.5771	Excellent	4
Monitoring	42	3.4762	0.4813	Excellent	5
Totality	42	3.6049	0.527	Excellent	

The other component of metacognitive awareness is the metacognitive skillfulness. This component involves planning strategy, monitoring, debugging, and evaluation (Schraw and Dennison, 1994). Table 11 shows that, debugging and planning topped the post-intervention metacognitive skillfulness of the group. It can be gleaned from the table that there were slight increments in all the areas considered. The subjects' average metacognitive skillfulness was "Excellent" after the intervention.

Table 12. Pretest and Posttest Results for Motivation

Sub component	Pre-test		Posttest					
	Mean	SD	Mean	SD	Diff	T-Value	P- Value	Description
Intrinsic	3.862	0.522	3.870	0.680	0.008	0.07	0.945	Not Significant
Extrinsic	3.3524	0.6134	3.7479	0.6199	0.396	3.49	0.001	Significant
Relevance to Personal Goal	3.2714	0.4994	3.6232	0.6026	0.352	3.14	0.003	Significant
Self-determination	3.5238	0.5281	3.6006	0.667	0.77	0.75	0.460	Not Significant
Self-efficacy	3.0333	0.5707	3.5216	0.5669	0.488	3.94	0.000	Significant

Anxiety about Science Assessment	3.0524	0.6310	3.4063	0.4723	0.354	2.96	0.005	Significant
Totality	**3.3492**	**0.5607**	**3.6283**	**0.601**	**0.2791**	**2.39**	**0.000**	**Significant**

** P < 0.05*

Table 12 reveals that contrasted pretest and posttest motivational level of the subjects. It can be gleaned from the table that there was an overall significant improvement of the students' motivation when exposed to the different metacognitive activities. Hence, the null hypothesis on this parameter is rejected. Four subcomponents, namely, extrinsic, relevance to personal goals, self-efficacy, and anxiety about science or Chemistry assessment, have shown a significant improvements with P value lesser than 0.05. The other two subcomponents, though, they have shown an increment, did not warrant significant improvement after the exposure. This could be because students have already considered themselves "Highly Motivated" in those areas at the beginning of the study. A closer look and discussion into these components is in place.

Table 13. Pretest and Posttest Results for Scientific Attitude

Position Statements	Pre-test		Posttest					
	Mean	**SD**	**Mean**	**SD**	**Diff**	**T-Value**	**P- Value**	**Description**
1-AB	3.1984	0.3458	3.3254	0.3789	0.1270	1.86	0.069	Not Significant
2-AB	3.3532	0.4327	3.2817	0.3642	0.0714	0.4100	0.265	Not Significant
3-AB	3.3056	0.5086	3.3916	0.3834	0.0860	0.99	0.326	Not Significant
4-AB	3.1587	0.4131	3.3292	0.3153	0.1705	0.4586	0.021	Significant
5-AB	3.6310	0.6121	3.3518	0.3063	0.2792	3.32	0.002	Significant
6-AB	3.2214	0.5732	3.2873	0.3252	0.0659	0.89	0.380	Not Significant
Totality	**3.3114**	**0.4809**	**3.3278**	**0.3906**	**0.0164**	**1.321**	**0.177**	Not Significant

** P < 0.05*

Subjects in the present study; however, tend to disagree with this result. While metacognitive activities made them reflect which is essential in any self-regulating tasks, they suggested that laboratory and relevant hands-on activities may provide opportunities for students to experience how scientists do science. The present study suggests that when instruction is fortified with activities that targets metacognitve skillfulness coupled with laboratory tasks that resemble the works of men of science, then attractiveness of science among our students may render a stronger pull in the hearts of our students.

One interesting question though that lingers is what could account for students significant improvement in position 4A (P value = 0.021) and the significant decline in position statement 5AB (P value = 0.002).

Significant improvement in Students' Attitude with regards to position statement 4AB:

Position Statement 4AB

"Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects"

One reason could be that the metacognitive activities did not only allow for a generic reflection of how their thinking processes; it also afforded them thinking processes that are inherent to developing hypothesis and theoretical systems. It is in these theoretical systems that scientists explain the world we live in. As Lawson (1995) puts it: "scientific knowledge is a product of human mental construction…" .This of course necessitates reflective components of self-regulation. Thus when subjects in this research look into where the difficulty lies and what models or diagrams can be made to simplify the concept they are learning, making sense of the explicit and implied patterns in periodic tables, and in devising better strategy for naming and formula writing; in effect they are exercising the creative and critical thinking process that are required of scientists to explain the different phenomena in nature. This could be the key why students after going through the different activities improved significantly in their appreciation of the theoretical aspects of science.

Observed Decline in Students Attitude with regards to position statement 5AB:

Position Statement 5AB:

"Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work".

It should be underscored here that science attitude for statement 5AB in posttest mean (M = 3.3518) is still "Strongly Positive" despite the decline. This could be interpreted that in fact students remained strongly supportive on position statements in the questionnaire that include: *"most people can understand science", "people must understand science because it affects their lives", "every citizen should understand science",* and opposed position statements such as*: "only highly trained scientists can understand science", "most people are not able to understand science", "scientific work is useful only to scientists".* The decline could be accounted well when it is viewed from the perspectives of the subjects as consumer of scientific products, that is, knowledge to expound several questions about nature, technology that provides connectivity, comfort or perhaps processes and procedures that saves lives. This seems to be counterintuitive since, these scientific outputs with all its benefits and advantages are supposed to draw science closer to people. However, in the context of the position statement 5AB, one may use any of the aforecited scientific advancement without having to go through the mental rigor associated in discovering them. A student may use an atm machine and appreciates the convenience he enjoys without knowing the actual mechanism that operates it. It is the same with Positron Emission Technology (PET) or Computerized Tomography Scanning (CT-Scan), used in modern hospitals. These technologies allow views on the internal organs for diagnostic and other medical purposes; but patients or medical practitioners would never care the minutiae of these technologies. In the context of the Chemistry lessons, it can be argued that, students after going through the mental processes cited in an earlier discussion in the discussion on "*significant improvement in Students attitude with regards to position statement 4AB*" may have realized that indeed Chemistry, like any other sciences, has its own unique set of requirements in terms of thinking processes and skill that will allow individuals to participate in scientific endeavors. This provides the rationale for the decline observed in the attitudes of the subjects with respect to position statement 5AB.

Contrasting Pretest and Posttest Chemistry Performance

Table 14. Pretest and Posttest Chemistry Performance

	N	Mean	SD	T-Value	P-Value	Description
Pre-Test	42	7.476	3.724	10.69	0.000	* Significant
Post Test	42	16.238	4.504			
Difference		8.762	5.314			

Table 14 and earlier at Table 9, show how the subjects fared in the chemistry performance test in both the pretest and posttest. It can be gleaned from tables that subjects were below average during the pre-test and are excellent during the posttest. At p value =0.000 at .05 significance, there is a significant mean gain in terms of performance. This means that after going through the different metacognitive activities as they learned Chemistry concepts, the subjects have shown a marked improvement in the course. This finding supports earlier claims that metacognition has significant role in teaching and learning Chemistry and other sciences in general (Rickey & Stacy, 2000; Peklaj, 2001; Pulmones, 2007; Lovett 2008, Nbina, J. B., &Viko, B., 2010;Tanner, 2012). Developing metacognitive skillfulness among students could greatly help students learn how to use their content knowledge more appropriately and flexibly Rickey and Stacy (2000). To do this, the use of instructional strategies like the ones used in the present research must be taught alongside the content. These activities may include, concept maps, concept tests, predict-observe-explain tasks (Rickey and Stacy, 2000), metacognitive wrappers (Lovett, 2008). Pulmones (2007), found out that when students were engaged in chemistry activities designed in a metacognitive environment, they had the ample opportunities to demonstrate planning, monitoring, and evaluation skills. These skills, with debugging and use of strategy together with the different metacognitive knowledge form one's metacognitive awareness. Rahman and Jumani (2010) reported that highly metacognitive aware students performed better on Chemistry tests than their low metacognitively aware counterparts.

In fact even researches in other field draw parallel findings that students who are strongly metacognitive, that is, self-regulated, who excel in planning, managing information, monitoring, debugging and evaluating are more successful learners (Tok, Ozgan, Dos, 2010; Sawney & Bansal,2015). It is justifiable, therefore, to deduce that the metacognitive activities integrated in the different chemistry lessons drew some positive effects in the students' performance. Thus, the null hypothesis on Chemistry performance as parameter is rejected.

Contrasting Pretest and Posttest Metacognitive Awareness

Table 15. Pretest and Posttest Results for Metacognitive Knowledge

Metacognitive Knowledge	**Pre-test**		**Posttest**					
	Mean	**SD**	**Mean**	**SD**	**Diff**	**T-Value**	**P- Value**	**Description**
Declarative Knowledge	3.4179	0.5832	3.5506	0.4357	0.133	1.20	0.235	Not Significant
Procedural Knowledge	3.4179	0.5668	3.5833	0.5729	0.165	1.43	0.162	Not Significant
Conditional Knowledge	3.4179	0.5668	3.6810	0.5726	0.1961	2.03	0.049	Significant
Totality	**3.4402**	**0.5723**	**3.6049**	**3.4402**	**0.1647**	**1.553**	**0.149**	Not Significant

* *$P < 0.05$*

Table 15 shows the pre-post results of the subjects' metacognitive Knowledge. While there is slight improvements in the different subcomponents only the change in conditional knowledge is significant at P value = 0.049. This finding confirms Schunk's (2012) assertions that conditional knowledge is independent from both declarative and procedural knowledge. In the context of the present study, the subjects did not only show some level of mastery of Chemistry concepts, but also the appropriateness of learning strategies called for. Students' reported their thinking process during the interviews: "kung dili me kahibaw kay mu ask me sa amo grupo" [if we don't know we ask help from our group mates] "mag net me sir usually… dugay man gud sa library mas paspas sa net" [we usually surf the internet… because it's faster using the net than readings books in the library], "Mangutana me sir, sa kung kanus-a gamiton and "ite" "ate" ug "ide" [we ask from the group members when to use the "ite, "ate", and "ide"]; "I think, nindot to nga hotel analogies kay ma visualize nimu ang problem regarding sa atoms" [I think the use of hotel analogy is helpful. You can really visualize the problems on atoms]. In can be noticed that, students' comments draw a parallel skills in the part of debugging which is defined as the students ability to apply strategies used to correct understanding and actions in the process of completing a task. As shown on table 16, debugging as a subcomponent of metacognitive skillfulness marked a significant improvement with a P value of 0.466.

Table 16. Pretest and Posttest Results for Metacognitive Skillfulness

Metacognitive Skillfulness	**Pre-test**		**Posttest**					
	Mean	**SD**	**Mean**	**SD**	**Diff**	**T-Value**	**P- Value**	**Description**
Planning	3.5748	0.5762	3.7449	0.5771	0.1701	1.70	0.096	Not Significant
Strategy	3.4522	0.4776	3.4976	0.5130	0.0454	0.47	0.638	Not Significant
Monitoring	3.4392	0.4775	3.4762	0.4813	0.0370	0.41	0.684	Not Significant
Debugging	3.4961	0.4559	3.8905	0.5963	0.394	3.95	0.000	Significant

Evaluation	3.4747	0.4636	3.5516	0.5341	0.677	0.74	0.466	Not Significant
Totality	**3.6322**	**0.4503**	**3.4874**	**0.4084**	**0.1448**	**1.211**	**0.314**	Not Significant

** P < 0.05*

This means that students are able to address questions such as: “I ask others for help when I don’t understand something”, “Change strategies when I fail to understand”, “Re-evaluate my assumptions when I get confused”. Apparently, the same questions are addressed while the students are trying to address the conditions upon which they could ensure successful performance in Chemistry class activities. This relationship of the two subcomponent skills lends answer to the significant improvement observed.

On the average; however, both knowledge and regulation of cognition of the subjects did not show any significant improvements after the intervention. Hence, the null hypothesis on this parameter that there is no significant improvement in the metacognitive awareness is hereby accepted. One reason that is at play in this research is the time of exposure. Perhaps when students are exposed to longer period of time then significant improvement may be seen on all the different subcomponents. As Schunk (2012) pointed out, metacognition develops slowly. Teachers may provide longer exposure to students in the different activities. Further, collaboration could be done among faculty members in different subjects where the students are enrolled so there could be a more comprehensive metacognitive exposure beyond Chemistry classrooms. Another interesting angle to explore is the role of students’ belief on one’s competence before the actual Chemistry activities than the actual conduct. If it were the case, then this finding lends support to our earlier assumptions that students may have overestimated their abilities at the outset of the study. Earlier work echoes the same observation. While assessing students metacognitive awareness during problem-solving in kinetics and homogeneous design course, Ramirez-Corona, Zaira, López-Malo, & Palau (2013) argued the same reasoning when a subject showed a decrease in its metacognitive awareness score, “we think that he over-assessed its metacognitive awareness in the pre-test and after a whole semester of practicing, recognized its limitations regarding his metacognition skills” (p 9). Students in this situations may have gained a more accurate understanding of themselves, thus, some students may show an increase while others a decrease in the metacognitive awareness scores. Prudence must therefore be taken when conducting researches that rely solely on self-report on metacognition since the subjects may not be able or are not willing to report accurate judgment (Hargrove, 2015).

The Cognitive Effects of Metacognitive Activities

Table 17. Ranking of Metacognitive Activities as to their Effectiveness in promoting Learning

Metacognitive Activities	**Frequency**	**%**	**Rank**
Learning Community	13	30.95	1
Discussion/feedback	10	23.81	2
Learning Portfolio	9	21.42	3
Cornell Notes	6	14.29	4
Goal Setting	2	4.76	5
Wrapper	1	2.38	6.5
Session Reflection Log	1	2.38	6.5
Totality	**42**	**100**	

Table 17 shows the ranking of the different metacognitive activities as to the felt effectiveness by the students. Thirteen or 30.95 % of the total students rated learning teams as the activity that help them learn in the chemistry lessons. Discussion and learning portfolio at rank 2 and 3 respectively. Wrapper and session reflection log tied at the bottom of the rank. The effectiveness of group and collaborative strategies has been explored in earlier works. Johnson and colleagues (2008) as cited by Brame (2015) contend that many instructors use small groups or peer-to-peer instruction to promote students working together to maximize their own and each other’s learning. The purpose could vary from increasing student understanding of content, to build particular transferable skills, or some combination of the two. In other words, when the class of 42 students was divided into mini-chemistry classes everyone was given the chance to participate. An opportunity which is often times not afforded to all due to class size and instructional time constraints. Further, students who engage in this "microcosmic" class are given the chance to see an academic task in varied perspectives.

The Affective Effects of Metacognitive Activities Students' Motivation

Table 18. Ranking of Metacognitive Activities as to their effectiveness in making students become more motivated in chemistry class.

Metacognitive Activities	Frequency	%	Rank
Learning Community	17	40.48	1
Discussion	11	26.19	2
Cornell Notes	9	21.43	3
Wrapper	2	4.76	4.5
Goal Setting	2	4.76	4.5
Learning Portfolio	1	2.38	6
Session Reflection Log	0	0	7
Totality	**42**	**100**	

Table 18 reveals that subjects regarded learning community as the metacognitive activity that made them feel motivated in chemistry class. There were 17 (40.48%) of the participants that ranked it first. It was followed by discussion/feedback which was chosen by 11 students (26.19%) and Cornell notes with nine (21.43%) students. Wrapping and goal setting are tied at ranked 4.5 with both chosen by two (4.76%) students. Meanwhile learning portfolio and session reflection log were posted at the bottom of the rank. The context of the ranking can be understood fully by listening to the voices of the students themselves.

Students' Scientific Attitude

Table 19. Ranking of Metacognitive Activities in terms of effectiveness in making students feel like a scientist while in Chemistry 1 class.

Metacognitive Activities	Frequency	%	Rank
Discussion/Feedback	15	35.71	1
Goal Setting	7	16.67	2.5
Learning Community	7	16.67	2.5
Cornell Notes	6	14.29	4
Learning Portfolio	4	9.52	5
Wrapper	3	7.14	6
Session Reflection Log	0	0	7
Totality	**42**	**100**	

Many students believe that science and chemistry in particular are essential for the societal advancement. However, as tackled earlier, students perceive science as a difficult subject removed from reality, and less fun. These reasons promoted researches like the current undertaking to peruse into the students personal point of view on the instructional provisions in science classrooms. What activities, materials, and instructional set-up may be given to augment students' positive outlook regarding science? On table 19 it can be gleaned that discussion/ feedback and learning community and goal-setting are the top meta-activities that students felt strongly about that help them "feel" like a scientist. There are two major things that have to be addressed here. First, what do we mean by "feel like a scientist" or have the students felt like one? Second, what are the common things about these three activities that when used as an instructional strategy, students had that "sense" of being a scientist. To answer these queries, students' exit interviews provide a glimpse of the subjects' thoughts on the matter. The table that follows shows a summary of the students responses when they were asked "about feeling" like a scientist. For students who responded negatively, believed that laboratory takes at the centerpiece of chemistry instruction. They contend that actual manipulations of chemicals and apparatuses would lend those experiences akin to scientific endeavors. In contrast, there were students who upon recognition at the outset that chemistry 1 course is only lecture made use of instructional provisions like, reflection, summarizing, inferring, and even simple and mental manipulations like naming, formula writing, predicting patterns in periodic table, and quantum number computations which has an effect as what "laboratory" can do. Therefore, feedback-discussion, learning community, and goal-settings are perfect avenues for students to explore these activities that provided the necessary engagements usually afforded by laboratory activities. This finding confirms earlier works that metacognition plays a key role in teaching in the theoretical framework of Teaching Science as Inquiry (Seraphin, Philippoff, ,Kaupp, &Vallin, 2012).This does not mean however that these activities may substitute the laboratory. Because while metacognition compliments with inquiry and other methods of teaching science, through regulation of their own learning and consequently do appropriate adjustments, students may still feel deprived of authentic science experiences deemed to promote positive attitude toward science among students.

Conclusion

In the light of the findings and the foregoing interpretation made, it was concluded that metacognitive activities integrated in the different learning episodes of Chemistry instruction rendered positive effects to the subjects' cognition, and affect to some extent. Specifically, the intervention scheme drew improvements in the subjects' chemistry performance and motivation.

Recommendations

With the validation of the points raised in this study and upon presentation of its output, the following recommendations are made:

1. Since in the present study, the subjects were exposed only to three-month intervention, a prolonged exposure to metacognitive environment is worth exploring. Further, ample time may be allocated for students to interact in groups. This could be done with some tasks at hand which will serve as a fulcrum so that discussion will not veer from the learning intent.

2. Topics which are abstract in nature may be taught using some activities that will relate to the tangible and macroscopic world. Analogy and activities with chips, and manipulative devices may be used. Further, Hands-on activities that provide rich opportunity for students to have a glimpse of the world of scientists are suggested to be in place.

3. Science courses such as chemistry are suggested to be taught with laboratory following the teaching science inquiry philosophy.

4. Since goals whether long term just like finishing the degree or short-term like passing a term or the course has an impact on how students will likely perform in the class, course and class advisers are encouraged to let their students write their goal statements. Hence; schools may develop advisory system or career-guidance program whether in the institution or college levels.

5. Schools could provide ample and varied opportunities for students to succeed and move up in the academic rung. Schools can design online or semi-online platform to cater to working students, second coursers, and working professionals whose circumstance could hamper in their maximum compliance and access to classroom activities.

6. For the curriculum framers, courses such as Environmental Science, Science Technology and Society may be offered in lieu of lecture classes on Chemistry or Physics in the curriculum of non-science majors so that relevance to students' personal lives and career may be achieved.

References:

1. Elliott, S., Kratochwill, T., Littlefield, J., & Travers, J. (1996). *Educational Psychology: effective teaching, effective learning*. Times Mirror Higher Education Group.
2. Fogarty, R. (1994). *The Mindful School: How To Teach for Metacognitive Reflection*. IRI/Skylight Publishing, Inc., 200 East Wood Street, Suite 274, Palatine, IL 60067.
3. Padolina, M. C., & Magno, M. (2003). *Chemical education in the Philippines*. Quezon City: UP Open University and UP ISMED.
4. Papaleontiou-Louca, E. (2008). *Metacognition and theory of mind.*
5. Lucas, M.R. D., & Corpuz, B. B. (2007). *Facilitating learning: A metacognitive process.* M.Mla. Lorimar Publishing.
6. Olson, M. H., & Hergenhahn, B. R. (2012). *Introduction to theories of learning*. 9th Ed. Singapore.Prentice Hall.
7. Schunk, D. (2004). *Learning theories: An educational perspective*. New Jersey: Pearson Prentice Hall.
8. Ali, T. (2012). A case study of the common difficulties experienced by high school students in chemistry classroom in Gilgit-Baltistan (Pakistan). *SAGE Open*, 2158244012447299.

9. Anderson, K. J. B., Courter, S. S., McGlamery, T., Nathans-Kelly, T. M., & Nicometo, C. G. (2010). Understanding engineering work and identity: a cross-case analysis of engineers within six firms. *Engineering Studies*, *2*(3), 153-174.
10. Bailey, P. D., & Garratt, J. (2002). Chemical education: theory and practice. *University Chemistry Education*, *6*(2), 39-57.
11. Breuer, S. (2002). Does chemistry have a future. *University Chemistry Education*, *6*(1), 13-16.
12. Broman, K., Ekborg, M., & Johnels, D. (2011). Chemistry in crisis? Perspectives on teaching and learning chemistry in Swedish upper secondary schools. *Nordic Studies in Science Education*, 7(1), 43-53.
13. Butler, M. B. (2009). *Motivating Young Students to be Successful in Science: Keeping It Real, Relevant and Rigorous*. National geographic, July.
14. Cardellini, L. (2012). Chemistry: why the subject is difficult?. *Educación química*, *23*(2), 305-310.
15. Chalmers, C. (2009). *Group metacognition during mathematical problem solving*.
16. Cooper, M. M., & Sandi-Urena, S. (2009). Design and Validation of an Instrument To Assess Metacognitive Skillfulness in Chemistry Problem Solving. *Journal of chemical education*, *86*(2), 240-245.
17. Cornford, I. R. (2002). Learning-to-learn strategies as a basis for effective lifelong learning. *International Journal of Lifelong Education*, *21*(4), 357-368.
18. De Jong, O. (2000). Crossing the borders: Chemical education research and teaching practice. *University Chemistry*, *4*(1).
19. Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching*, *44*(8), 1088-1107.
20. Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching*, 46(2), 127-146.
21. Glynn, S., & Koballa, T. (2006). *Motivation to lean college science.* In Joel J. Mintzes and William H. Leonard (Eds.) Handbook fo College Science Teaching (pp. 25-32). Arlington, VA: National Science Teachers Association Press.
22. Holbrook, J. (2005). Making chemistry teaching relevant. *Chemical Education International*, *6*(1), 1-12.
23. Johnstone, A. H. (2000). Chemical education research: where from here. *University Chemistry*.
24. Johnstone, A. H. (1997). And some fell on good ground. *University Chemistry Education*, *1*(1), 8-13.
25. Lin, X. (2001). Designing metacognitive activities. *Educational Technology Research and Development*, *49*(2), 23-40.
26. Lin, X., Schwartz, D. L., & Hatano, G. (2005). Toward teachers' adaptive metacognition. *Educational psychologist*, 40(4), 245-255.
27. Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision(SAI II). *Journal of Research in Science Teaching*, 34(4), 327-336.
28. Nbina, J. B., & Viko, B. (2010). Effect of instruction in metacognitive self-assessment strategy on chemistry students’ self-efficacy and achievement. *Academia Arena*, *2*(1), 1-10.
29. Peklaj, C. (2001). Metacognitive, affective-motivational processes in self-regulated learning and students achievement in native language. *jezik*, 200, 3550.
30. Price, W. S., & Hill, J. O. (2004). Raising the status of chemistry education. *University Chemistry Education*.
31. Pulmones, R. (2007). Learning chemistry in a metacognitive environment. *The Asia-Pacific Education Researcher*, 16(2), 165-183.
32. Rickey, D., & Stacy, A. (2000).The role of metacognition in learning chemistry. *Journal of Chemical Education*, 77, no. 7, 915-920.
33. Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational psychology review*, 7(4), 351-371.
34. Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish science education*, *4*(2), 2.
35. Tanner, K. D. (2012). Promoting student metacognition. *CBE-Life Sciences Education*, 11(2), 113-120.
36. Chalmers, C., & Nason, R. A. (2003). *Developing Primary Students' Group Metacognitive Processes in a Computer Supported Collaborative Learning Environment.* A paper presented at the Joint AARE/NZARE Conference, Auckland.
37. Cornford, I. R. (2005). Cognitive and metacognitive strategies as a basis for effective lifelong learning: How far have we progressed. *University of Technology, Sydney*.
38. Curaraton, E.P. (2009). *Self-learning Experience Approach in the performance of science students.* Unpublished Master’s Thesis, Cebu Normal University.
39. Dawson, T. L. (2008). Metacognition and learning in adulthood. *Prepared in response to tasking from ODNI/CHCO/IC Leadership Development Office, Developmental Testing Service, LLC.*

40. Liu, R., Qiao, X., & Liu, Y. (2006). A paradigm shift of learner-centered teaching style: Reality or illusion. *Arizona Working papers in SLAT, 13*, 77-91.
41. Lovett, M. C. (2008). Teaching metacognition. *Unpublished paper presented at the Educause*.
42. Perez, L. (2016). *Peer-assisted learning strategies in teaching trigonometry*. Unpublished Master's Thesis, Cebu Normal University.
43. Su, G.T. (n.d.). *Effects of starter-based experiment approach in physics: performance and values development.* Unpublished Master's Thesis, Cebu Normal University.
44. Cooper, S. (2016). *John Flavell Metacognition Theory*.
45. (n.d.). Retrieved April 12, 2016 from http://www.lifecircles-inc.com/Learningtheories/constructivism/flavell.html
46. Cooper, S. (2016). *Metacognitive Development in Professional Educators.*
47. (n.d.). Retrieved April 11, 2016 from http://www.lifecircles-inc.com/Metacognition.html
48. Jordan, J. (2011). *Teacher Practices and High School Chemistry Students' Metacognitive Skillfulness.*
49. (n.d.). Retrieved May 15, 2016 from http://tigerprints.clemson.edu/all_dissertations/688/
50. Livingston, J. (1997). *Metacognition: Teaching students to think about their thinking*. Retrieved April 11, 2016 from https://www.csun.edu/~vceed002/ref/reasoning/metacogntion/index.html
51. McLeod, S. (2014). *Lyv Vygotsky: Social learning theory*.
52. (n.d.). Retrieved April 11, 2016 from http://www.simplypsychology.org/vygotsky.html