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Mastery Level of Chemistry Cognitive Competencies by Pre-Service Science Teachers of Benguet State University

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Abstract

Mastery level of cognitive competencies covers the understanding of facts imperative for science teaching and learning in the new science curriculum following the Spiral Progression Approach. The study assessed the status of mastery level of Chemistry cognitive competencies by pre-service science teachers of Benguet State University as the basis for instructional recommendations to the College of Teacher Education. The mastery level was studied using mean percentage scores (MPS) with their differences in the grade levels and specialization (Biology and Physical Science). The quantitative descriptive method was employed using a reliable and valid Chemistry Achievement Test (CAT). Results revealed that pre-service teachers of both Biology and Physical Science majors had an overall performance of Average Mastery (between 35-65MPS). The mastery goal in basic education is 75MPS or better which was obtained only by the Physical science majors at the grade 7 level. The Physical science majors had significantly higher mastery levels on the chemistry cognitive competencies in grades 7 and 10 but had similar mastery levels with the biology majors in grades 8 and 9. In both majors, the grade 7 cognitive competencies were mastered best while the grade 9 chemistry cognitive competencies were least mastered.

KEYWORDS

Chemistry Achievement Test (CAT)
Chemistry Cognitive Competencies
Mastery Level
Pre-service Science Teachers
Spiral Progression Approach

Introduction

The implementation of the Enhanced Basic Education Curriculum (EBEC) embodied in RA 10533 uses the Spiral Progression Approach, which emphasizes mastery and retention of concepts and skills through the grade levels in Basic Education. The study assessed the level of mastery of cognitive competencies in Chemistry by pre-service science teachers who will teach the learning area of Chemistry in the Junior High School through Grades 7 to 10. The substantial preparation of pre-service teachers will depend on the extent of their understanding of K to 12 Secondary Science Curriculum (SSC) of the EBEC in terms of instructional contents (cognitive) integrated with science process competencies and pedagogical skills (Sakib & Obra, 2019). Content mastery of basic chemistry principles is necessary for these pre-service science teachers to prepare them in the spiral progression approach. The curriculum approach specifies that teachers impart to their learners the same science concepts from simple to a higher degree of complexity as they move from one grade level to the next, allowing for the retention and mastery of topics and skills as they progress (Quijano, 2012). This paradigm shift in teaching Science has posed a challenge to every Filipino science educator. Improving teachers' knowledge (content) and pedagogical skills is the most direct and effective way to raise instructional quality (Machina, 2012).

The spiral curriculum approach was only implemented by DepEd in 2013 with the core of scientific literacy in the new science curriculum as mastery learning in the science learning areas like Chemistry. It is important to have studies on whether pre-service science teachers are prepared to facilitate their learners to understand basic science concepts and apply science inquiry skills in greater depth as they are learned across the grades. The mastery of the teachers' cognitive competencies is an indication that they can facilitate students to grasp basic chemistry concepts better and show evidence of this understanding.

The College of Teacher Education (CTE) of Benguet State University accorded as Center of Excellence (COE) for Secondary Education should continuously demonstrate excellent performance in instruction. Science teachers graduating from COE's need to be assessed if they possess the mastery of basic concepts in the learning competencies they will impart to their learners once in the field. The quality of science education in schools is greatly influenced by the quality of science teachers produced and deployed into the field. The study determined if pre-service science teachers are sufficiently prepared and competent through their university preparatory program (Bachelor of Secondary Education, major in Science).

The study provides status data on whether pre-service teachers who are science majors have sufficiently mastered the cognitive aspect of Chemistry's learning competencies, which they will be teaching in one quarter from Grades 7 to 10. Mastery of these cognitive competencies will grant these pre-service teachers the confidence to impart all the learning competencies specified by the Department of Education (DepEd) and not skip on topics they have not mastered in their college program preparations. The heart of the spiral progression approach is for students to have mastery of the basic concepts specified by the content standards from where the learning competencies are based on the different grade levels. To obtain this mastery among learners, the teachers must first have the mastery of the knowledge or content aspect of the learning competencies. This research's status results and instructional recommendations will aid administrators, validators, educators, and curriculum implementers in Benguet State University by using the valid and reliable CAT to evaluate the competence and readiness of pre-service science teachers deployed to teach Chemistry in the Junior High School. The study results will help administrators craft curriculum enhancements, emphasizing mastery of fundamental concepts (cognitive competencies), which is the heart of the Spiral Progression Approach. It can also provide baseline data for future impact assessment studies of applying the spiral progression curriculum focusing on mastery of cognitive competencies in Chemistry among pre-service teachers. This will further evaluate, should the approach proves useful and attuned over a period of time, other needs of teachers and learners in the Philippine educational setting (Resurreccion & Adanza, 2015).

The beneficiaries of the study are the CTE administrators and their students. The study results identified which cognitive competencies in the different grade levels are mastered and which are not. This information can contribute to strengthen specific courses and objectives within the program to address mastery of all the cognitive competencies as specified in the DepEd science curriculum. Eventual beneficiaries of the study are the learners for whom the teachers can readily help apply the mastered cognitive competencies in higher education.

This study assessed the level of mastery of Chemistry cognitive competencies by pre-service science teachers of Benguet State University through a valid and reliable Chemistry Achievement Test (CAT) as a basis for instructional recommendations to the College of Teacher Education. Specifically, the study answered the following questions: 1) What is the level of mastery of these pre-service science teachers major in Physical Science on the Chemistry cognitive competencies in Grades 7 to 10 and overall; 2) What is the level of mastery of these pre-service science teachers major in Biological Science on the Chemistry cognitive competencies in Grades 7 to 10 and overall; and 3) Is there a significant difference between the level of mastery of Chemistry cognitive competencies by the respondents among the grade levels and according to science major?

Study Framework

Mastery of Cognitive Competencies Through the Spiral Progression Approach

The association of Filipino students' low achievement levels in Science with the difficulties encountered by teachers in teaching science concepts (Chavan, 2014) have been critical areas of concern for several years in Philippine education. This concern is especially true of the teachers' understanding of in-depth concepts (Resurreccion and Adanza, 2015) and teacher preparedness with effects on teaching practice that ultimately impacts student achievement (National Council for Accreditation of Teacher Education [NCAT], 2015). In the 2005 National Achievement Test (NAT), 4th year high school students obtained a mean score of 39.5%, and only 1.8% of the students attained mastery levels of science curriculum goals (Bernardo et al., 2008). This mean score has further dropped to 37.98% in 2006, ranking last in 2012, among other learning areas, with a mean score of 40.53%.

In the Philippines, the newly implemented K to 12 EBEC has basic programs which address the issues of the low achievement scores of Filipino students and the insufficient preparation of high school graduates who are too young to enter the labor force (Padre, 2010). Martin (2008) as cited by Ressureccion & Adanza (2015) emphasized that the spiral curriculum is a design framework that will help science teachers build lessons, activities, or projects aimed at developing thinking skills and arrangements that involves progression and continuity in learning Science.

Science curriculum and science teachers have big roles in achieving the K to 12 EBEC's vision of holistically developing learners and having a venue for honing students with 21st century skills (Southeast Asian Ministers of Education Organization Regional Center for Educational Innovation and Technology [SEAMEO-INNOTECH], 2012). The new science curriculum is for science teachers to guide their students to gain mastery of knowledge and skills of the subject after each grade level (De Dios, 2013). As learning progresses, more details are introduced while the basics are reemphasized many times by science teachers for connection and gradual mastery from one grade level to the next (Corpuz & Salandaan, 2015).

Clark (2010) cited that Jerome Bruner's spiral curriculum model inspired DepEd's Spiral Progression Approach in the EBEC curriculum. In the 1960s and 1970s, Bruner stressed that the spiral curriculum is organized to allow students to revisit a topic, theme, or subject several times throughout their school career. The teachers need to lead students to build upon what they have learned with mastery, gradually building up where the topic's complexity or theme increases with each revisit. Consequently, the new learning has a relationship with old learning, and teachers need to put in context with the old information with the new. Like Bruner's model, the spiral progression approach of the new K-12 curriculum challenges teachers to expose learners to a wide variety of concepts and disciplines until they are mastered by studying them over and over at different deepening levels of complexity.

The Spiral Learning Approach, also known as Bruner's Learning Approach, according to a member of CHED Technical Panel for Teacher Education, Dr. Brenda B. Corpuz, starts with learning basic concepts or general concepts like a "Macro to Micro" technique. The basic principles' input is done during the first grade and rediscovered in succeeding grades in more complexity (Sanchez, 2017). The teachers expose learners to the four science disciplines, Earth Science, Biology, Chemistry, and Physics, in each grade level. Every year, the teaching-learning encounters topics from each science discipline and restudy them with more complexity and more in-depth details to get the mastery of each lesson. Teaching-learning progresses in Spiral Progression Approach, more and more details are introduced. Simultaneously, the teachers reemphasize the basics, which lead to mastery of the lessons by the learners (Corpuz & Salandaan, 2015). This approach has been corroborated by Howard (2012), stating that the spiral curriculum is based on the cognitive theory advanced by Jerome Bruner. In other words, even the most complex material, if properly structured and presented by teachers, can be understood by very young learners.

Davis (2007) added that a spiral curriculum is organized around concepts, skills, or values in the horizontal integration of learning where there is a reiteration of concepts, subjects, or themes throughout the course. More in-depth knowledge is presented by the teacher each time a concept is repeated so that each subsequent encounter of the concept builds on the previous one. In 2013, Haeusler described the spiral curriculum as the sequencing done by teachers, which provides linkages between the lesson and the student's learning experience. He emphasized that previous knowledge learned in earlier visitations of the spiral is linked to future learning in later spiral visitation, increasing student proficiency. The student's achievement level increases with each visitation until finally, the concepts and subject content are mastered. The gains in achievement can then be tested through standard assessment procedures.

The New Secondary Science Curriculum and Chemistry Learning Competencies in the Spiral Progression Approach

The K to 12 science curriculum provides teachers and learners with a repertoire of competencies important in the workplace and a knowledge-based society. The curriculum provides for the development of scientifically, technologically, and environmentally educated decision-makers who are critical problem-solvers, responsible stewards of nature, innovative and creative citizens, informed decision-makers, and effective communicators. In addition, DepEd reiterated the acquisition of these domains by using the following approaches: multi/interdisciplinary approach, Science technology-society approach, contextual learning, problem/issue-based learning, and inquiry-based approach (DepEd, 2012).

The K to 12 curriculum intertwines science content and science processes. Without the content, it will be difficult for learners to use the skills in the science process as these processes are best learned in context. They are motivated to learn and appreciate science as relevant and useful by organizing the curriculum around situations and problems that challenge and arouse learners' curiosity. Rather than relying on textbooks alone, varied hands-on, minds-on, and hearts-on activities will be used to develop learner competencies. The spiral progression approach allows science teachers to formulate lessons or activities, or projects that are consistent with developing thinking skills that facilitate the acquisition of the desired performance or learning competencies (DepEd, 2016).

Integration of chemistry using the Grades 3 to 10 spiral progression means that the learning of chemistry concepts and skills in the curriculum is not divided into elementary school and high school the way it used to be. This is the concept emphasized by Corpuz and Salandaan (2015), where progression is both horizontal (broader application range) and vertical (increasing complexity). This vertical articulation is described as a seamless progression of competencies that will allow learners to continually return to basic ideas in chemistry or other learning areas as new concepts and competencies are added over the course or duration of the curriculum.

The mastery of initial concepts in Chemistry is spiraled up as the new concept is introduced in the next lessons allowing the students to reinforce what has already been learned, leading to a richer understanding and knowledge application which is solidified over periodic intervals. Understanding is the way students learn rather than merely memorizing concepts. Pre-requisite competencies must first be mastered, which provides linkages between each lesson as the students spiral up with higher competencies. Students learn Chemistry best by applying and experiencing a concept repeatedly.

The learning competencies (the abilities and skills) that students should learn in the learning area of Chemistry from Grades 7 to 10 are embodied in the new science curriculum which are as follows: the learner in Grade 7 should be able to describe what is meant by fair test, the components of an investigation such as research problem, hypothesis, method for testing hypothesis and conclusions based on evidence, and some properties of metals and nonmetals such as luster, malleability, ductility, and conductivity; should be able to investigate properties of unsaturated or saturated solutions, how fast solids dissolve in water, and properties of acidic and basic mixtures using natural indicators; should be able to recognize that a substance has a unique set of properties and that substances are classified into elements and compounds; the learner in Grade 8 should be able to explain the properties of solids, liquids and gases based on the particle nature of matter and physical changes in terms of the arrangement and motion of atoms and molecules; should be able to determine the number of protons, neutrons and electrons in a particular atom; should be able to trace the development of the periodic table from observations based on similarities in properties of elements; and, should be able to use the periodic table to predict the chemical behavior of an element; the learner in Grade 9 should be able to explain properties of metals in terms of their structure, how ions are formed, the formation of ionic and covalent bonds, chemical changes in terms of the breaking of bonds and the rearrangement of atoms to form new substances and how the structure of carbon atom affects the type of bonds it forms; should be able to recognize different types of compounds (ionic or covalent) based on their properties such as melting point, hardness, polarity, and electrical & thermal conductivity, the importance of ions when humans obtain nutrients from food and the general classes of organic compounds and their uses; be able to use the mole concept to express the mass of substances; be able to determines the percentage composition of a compound given its chemical formula and vice versa; and, the learner in Grade 10 should be able to investigate the relationship between volume and pressure at constant temperature of a gas, volume and temperature at constant pressure of a gas, explains these relationships using the kinetic molecular theory, solve problems using the different gas laws, recognize the major categories of biomolecules such as carbohydrates, lipids, proteins and nucleic acids, apply the principles of conservation of mass to chemical reactions, balance equations, given the formulas for reactants and products, recognize that all chemical reactions are accompanied by energy change, describe chemical reactions involved in plant, growth, food digestion and spoilage, and processes affecting life and the environment, enumerate and explains the factor affecting rates of chemical reactions, explain how the factors affecting rates of chemical reactions are applied in food preservation and materials production, control of fire, pollution and corrosion, and recognizes the importance of controlling rates of reactions in technology (DepEd, 2012).

Methodology

Research Design

This study employed the quantitative descriptive method. According to Creswell (2012), this quantitative descriptive method involves survey research that employs an instrument collecting performance measures through an achievement test; the process of data collection includes the following interrelated steps: determining the participants to study, obtaining permission needed from several individuals and organizations, considering what type of information to collect from several sources available, locating and selecting instruments to use that will net useful data for the study and administering the data collection process to collect data, then descriptive analysis of data reporting measures of central tendency and variation.

Study Respondents

The study respondents are a sample of thirty-four (34) pre-service science teachers selected through simple random sampling from a total population of forty-five (45). These pre-service science teachers are from the College of Teacher Education of Benguet State University of both Physical Science and Biological Science majors enrolled during the school year 2018-2019 (Table 1).

Table 1

Number of Respondents by Major

Respondents: Pre-service science teachers major in	Population
1. Physical Science	16
2. Biological Science	18

Instrumentation and Data Collection

A Chemistry Achievement Test (CAT) Questionnaire developed, validated, and pilot-tested by Ely (2019) covered Chemistry content competencies based on the DepEd Science Curriculum Guide and were lifted from K-12 learning modules/materials in Science covering the Chemistry learning area (Asuncion et al., 2017; Campo et al., 2013; Alvarez et al., 2017; Acosta et al., 2015) and K-12 compliant references used by the Junior High School in Science. The CAT was pilot tested at the University of the Cordilleras (UC) using 37 students from the Grade 11 STEM-strand who finished the chemistry spiral progression approach in grades 7 to 10. The CAT questionnaire was then subjected to a reliability test resulting in a Cronbach's alpha of 0.81, indicating high reliability. The instrument validity was tested with a validity score from the Chemistry experts of 4.37, indicating very high validity.

The following are the topics in chemistry where the test items in the CAT were derived: Grade 7- Doing Scientific Investigations, Diversity of Materials in the Environment (Solutions, Substances and Mixtures, Elements and Compounds, Acids and Bases, Metals and Non-metals); Grade 8- Particle Nature of Matter, Atomic Structure, Periodic Table of Elements; Grade 9- Chemical Bonding, The Variety of Carbon Compounds, Mole Concept; Grade 10- Gas Laws, Biomolecules, Chemical Reactions. Specific learning competencies in the above content standards were based on the test items constructed distributed according to the DepEd Table of Specification (TOS) requirement. The reliable and valid CAT instrument contains 60 items in consonance with the National Achievement Test (NAT) standard. The questionnaire also contains directions necessary before taking the CAT. The respondents' science majors were indicated on the answer sheets.

The pilot-testing of the CAT questionnaire determined the items retained, revised, or excluded from the original 100 items for the final CAT using the Statistical Package for Social Sciences or SPSS. Three Chemistry educators evaluated the content and construct validity of the CAT. The validators evaluated the test items to the required content competencies of the K to 12 curriculum using the Questionnaires for Evaluation. To further measure the test items' objectivity, the experts were asked to answer the CAT questionnaire. All suggestions and comments by the experts were included to improve the final CAT questionnaire.

To gather data, the pilot-tested CAT was administered to pre-service science teachers of the Bachelor of Secondary Education, College of Teacher Education of the Benguet State University during the school year 2018-2019. The permission to administer the achievement test was granted by Dr. Percyveranda Lubrica, who handles these pre-service teachers' course audits. The CAT was personally administered to the respondents by the researcher. The time required for the administration of the test was one hour. The researcher explained the directions for answering the test before the students answered the CAT.

Analysis of Data

After the test administration, the answer sheets were corrected, scored, and tabulated by the researcher. Statistical computations and analyses were referred to and discussed with a statistician. The MPS, ANOVA one-way classification, and t-tests were computed and correctly interpreted to give statistical meaning to the data gathered. Comparative results of the CAT on mastery level of Chemistry cognitive competencies according to science major were determined by obtaining MPS. *F*-test for repeated measures was used to test the significant differences between the respondents' mean scores. The *t*-test for two independent populations was used to test the significant differences between mean scores obtained by the respondents according to science specialization variables.

The following descriptive equivalent of scores used to interpret the NAT results were used in this study (DepEd, 2013):

96%- 100% - Mastered (M)
86%- 95% - Closely Approximating Mastery (CAM)
66%- 85% - Moving Towards Mastery (MTM)
35%- 65% - Average Mastery (AM)
15%- 34% - Low Mastery (LM)
5%- 14% - Very Low Mastery (VLM)
0%- 4% - Absolutely No Mastery (ANM)

The MPS of 75 percent as currently the set goal of DepEd was used as the standard for mastery.

Results and Discussion

The performance of pre-service teachers major in Physical Science is shown in Table 2, reflecting their level of mastery of the chemistry cognitive competencies at each grade level through their CAT scores. The highest mastery level of Moving Towards Mastery (MTM) was in the grade 7 subtest. This result means that the pre-service teachers are most proficient at the grade 7 chemistry cognitive competencies covering the concepts of scientific investigations and diversity of materials in the environment (solutions, substances and mixtures, elements and compounds, acids and bases, metals, and non-metals). They were also able to satisfy the DepEd goal of 75 MPS. On a general note, the pre-service teachers had average mastery (AM) levels consistent in the other grade levels with means of 65.42 in Grade 10 (covering the concepts of the gas laws, biomolecules, and chemical reaction), followed by a mean of 60.42 in grade 8 (covering the concepts of the particle nature of matter, atomic structure and the periodic table) and the lowest mastery level mean in the grade 9 subtest at 57.92 (covering the concepts of chemical bonding, carbon compounds, and the mole).

The Table of Specification (TOS) for the final CAT questionnaire represented all the learning competencies consistent with DepEd TOS requirements. An MPS 50 means that the pre-service teachers correctly answered 30 of the 60 test items (Fernandez, 2013). It can be deduced that the Physical Science pre-service teachers were able to master more than half of the Chemistry cognitive competencies in all grade levels. Specifically, at grade 7 level, they were able to master the highest mastery of 47 out of 60 items while they had the lowest mastery of 35 out of 60 items in grade 9. The minimum target is still DepEd's 75 MPS. Therefore, an emphasis on the learning competencies expected for these pre-service teachers to master needs to be discussed with course teachers in Chemistry. This is precisely how the concepts in the learning competencies can be clearly understood and mastered by the pre-service science teachers to teach their students in Junior High School accurately and sufficiently. Teachers' knowledge of the content blended with pedagogy and curriculum is a fundamental element for teachers' preparedness to teach effectively (Kalande, 2007) and be more successful with students since more substantial learning gains among students are implications from prepared teachers (Darling-Hammond, 2003). The vital point is the foundation of mastery of the content or the concepts that can be eventually blended with DepEd's appropriate pedagogies.

As shown in Table 3, the MPS of pre-service teachers major in Biological Science reflecting their level of mastery of the chemistry cognitive competencies at each grade level are lower than the Physical science majors. The scores' qualitative trend is the same, with the highest mastery level of Moving Towards Mastery (MTM) in grade 7 having a mean of 71.48, which falls short of the DepEd goal of 75 MPS. This result likewise means that the pre-service teachers are most proficient at the grade 7 chemistry cognitive competencies answering 43 items out of 60. For the rest of the grade levels, the Biology pre-service teachers had average mastery (AM) level with MPS of 59.63 in Grade 8, followed by MPS of 55.93 in grade 10 and MPS of 51.85 in grade 9. These MPS results from Grades 8-10 show an average of 34 items answered out of 60 items implying that the pre-service teachers could master at least half of the Chemistry cognitive competencies in these grade levels.

Table 2

Level of Mastery of Pre-service Teachers Major in Physical Science, 2018-2019

Grade Level	Mean Percentage Score (MPS)	SD	DE
Grade 7	77.92	8.33	MTM
Grade 8	60.42	2.52	AM
Grade 9	57.92	11.86	AM
Grade 10	65.42	6.07	AM
Overall	65.42	7.20	AM

Table 3

Level of Mastery of Pre-service Teachers Major in Biological Science, 2018-2019

Grade Level	Mean Percentage Score (MPS)	SD	DE
Grade 7	71.48	8.50	MTM
Grade 8	59.63	5.82	AM
Grade 9	51.85	11.78	AM
Grade 10	55.93	12.13	AM
Overall	59.72	9.56	AM

It is good to note that the MPS of grade 7 for both majors, as shown in Tables 2 and 3, have reached the Moving Towards Master (MTM) levels with MPS of 77.92 for the Physical Science majors and MPS of 71.48 for the Biological Science majors. The Grade 7 concepts and learning competencies related to scientific investigation and the diversity of materials in the environment can be considered the simplest. However, these basics are essential to be mastered by science teachers as their foundational concepts will be taught through the higher grade levels. A deeper grasp of the learning competencies in Grade 7 is imperative for a relevant connection to the higher and more complex learning competencies.

The MPS obtained an Average Mastery (AM) level by the Biology pre-service teachers are quite far from the DepEd target of 75 MPS for students in the Junior High. If the incoming teachers have these levels of mastery of the chemistry concepts, then that is what they will be imparting to their students. The adage "one cannot give what one does not have" is applicable here. Quijano (2012) already identified teachers' competence as one of the issues and challenges in implementing the New Science Curriculum. The suggestions of Cabansag (2014) and Arazo (2014) on the need to closely monitor the preparatory program (Bachelor of Secondary Education) of these pre-service teachers to assure that they are provided with sufficient preparations on mastery of science concepts (instructional contents) with the minimum requirement of DepEd's learning competencies. Therefore, administrators and educators must continuously assess the curriculum and the mastery of science concepts vis-à-vis the specified content standards and learning competencies.

In both science majors, the Grade 9 MPS were lowest at 57.92 for Physical Science and 51.85 for Biological Science. Although the MPS are within the Average Mastery (AM) category, the consistent trend of the lowest MPS in both majors should be noted. The abstract nature of the concepts of chemical bonding and the mole and the immense diversity of carbon compounds can account for the lowest MPS of these chemistry concepts and require more instructional time for conceptual understanding. This abstract nature of chemistry and other content learning difficulties (e.g. the mathematical nature of much chemistry) means that chemistry learning requires conceptual understandings in a meaningful way (Taber, 2002). Concepts and topics related to physical sciences (physics and chemistry) with abstract ideas and mathematical calculations were relatively least understood under teachers' instructional contents as verified by Sakib and Obra (2019). The challenge in the mastery of these difficult concepts is the thorough understanding of pre-service teachers' concepts when they take their chemistry subjects in their preparatory years. The pre-service teachers are required to take four major chemistry subjects, including Inorganic Chemistry, Organic Chemistry, Biochemistry, and Analytical Chemistry (both lecture and laboratory). These major courses are sufficient to cover the learning competencies of both content and skills. Together with the employment of active learning instructional strategies, they will impart the required learning competencies to their future learners. Teachers in the Chemistry Department of the Benguet State University who handle these major courses for the Bachelor of Secondary Education major in Science must understand the relationship of the subject content to the learning competencies. A professional teacher understands these specifics in the spiral progression approach being implemented in the Junior High School (grades 7 to 10) and can connect them to the appropriate contextual pedagogies. Cognitive science disciplines like Chemistry suggest that teachers with active learning approaches can increase student motivation, knowledge retention, and content transferability (Michael, 2006).

The emphasis of DepEd that only science majors teach chemistry and other science disciplines in Junior High School gives assurance that all learning competencies are adequately covered and handled with expertise in the spiral progression approach. This strategy contributes to the progressive and continuous mastery of learning in chemistry concepts and competencies (Martin, 2008). It should be recognized that the quality of teaching greatly influences the quality of learning. Only qualified teachers must be allowed to teach chemistry and science disciplines to realize the objective of raising the quality of science education. Only teachers who specialized in the science disciplines can impart mastery of concepts both horizontally (application of concepts) and vertically (increasing complexity of concepts), as cited by Corpuz and Salandaan (2015). This reality makes the preparation of these pre-service teachers more challenging.

Improving the educational system through the K to 12 curriculum must begin with the teachers because they have the most significant impact on students' knowledge and attitudes toward the subjects (NCAET, 2015). It was further pointed out that teacher quality is widely recognized as one of the most critical factors in education and therefore represents a promising focus for efforts aimed at school improvement. Research shows that effective teachers can cause student achievement to differ from an entire grade level within one school year when comparing effective teachers to ineffective teachers (Borman & Dowling, 2008; Cohen-Vogel, 2011). These pre-service teachers who graduate from Center of Excellence (COE) preparatory programs and will eventually be hired to teach in Basic Education should possess strong backgrounds in science, cognitive and skill competencies. Only when the teachers are well prepared, confident in their subject area, continually updating their skills, and utilizing important resources, will their learners be scientifically literate and receive the education necessary to make them future leaders in Science, math, engineering, and technology (Castleberry, 2010).

Differences in the Level of Mastery of Chemistry Competencies by the Pre-service Teachers in the Different Grade Levels

Table 4 shows the significance of the observed descriptive differences on the mastery level of physical Science pre-service teachers along with the different grade levels. The Analysis of Variance-Repeated Measures was run to test if at least two of the four grade-level scores are significantly different. Results reveal that some of the scores are statistically different, as indicated by the computed probability value of less than 0.01. This implies that the Physical Science pre-service science teachers had significantly different mastery levels possible on the four chemistry grade-level tests.

Since the ANOVA-repeated measures cannot specifically identify which four mean scores are significantly different, a post hoc test was further run. This test revealed that grade 7 MPS of 77.92 is the highest and significantly different from the rest. On the other hand, grade 10 MPS of 65.42 is not significantly different from the grade 8 MPS of 60.42, implying that the pre-service teachers performed equally under these tests. Finally, the students' collective scores under the grade 9 test and grade 10 are significantly different, with grade 9 having the lowest MPS scores.

The results show that mastery of Chemistry cognitive competencies is best in Grade 7, followed by the equal mastery of pre-service teachers' cognitive competencies in Grades 10 and 8 with the least mastery in Grade 9. While the connection to the basics in applying the spiral progression principles is better seen in grades 10 and 8, mastery learning on content should still be substantially enhanced to reach the DepEd goal of 75 MPS. Quijano et al. (2012) mentioned that it is in having thorough preparation of understanding the instructional content prescribed by the learning competencies where the pre-service teachers will have the confidence to apply the repetitive learning of the same chemistry concepts. This thorough preparation will increase depth and complexity in each grade as prescribed by the Spiral Progression Approach so that retention and mastery of these concepts will be achieved among learners.

Table 4

Differences in the Level of Mastery of Pre-service Teachers Major in Physical Science in the Different Grade Levels

Grade Level	Mean Percentage Score (MPS)	*Fc*	*P*-value
Grade 7	77.92[a]	19.17	0.00
Grade 8	60.42[bc]		
Grade 9	57.92[c]		
Grade 10	65.42[b]		

According to De Dios (2013), better understanding occurs when the essentials are emphasized and repeated many times for connection and incremental mastery from one grade level to the next among learners. Mastery of science concepts is rooted in these pre-service teachers' preparedness to realize this educational goal in the science curriculum.

The lowest of all MPS is in Grade 9, with learning competencies in chemical bonding, the mole concept, and carbon compounds. Taber (2002) suggested more instructional time for better conceptual understanding in a meaningful way for abstract concepts. It could be that the pre-service teachers did not sufficiently master the pre-requisite linking knowledge of these concepts. Sirhan (2007) reported that among the problem areas in Chemistry and the most difficult topics, from the students' point of view, which persisted well into university education, are chemical bonding, mole, and organic chemistry (carbon compounds), among others. The majority of the students would be expected to attain mastery only if they received optimal instruction quality and as much learning time as the problematic concepts require. The challenge is to provide enough time and employ instructional strategies so that these pre-service teachers can achieve the level of mastery expected of them as they go into their teaching field. This strategy is crucial in the transition period with DepEd's focus on strengthening Science and Math education in the enhanced Basic Education curriculum (DOST-SEI, 2011).

Table 5 shows the inferential tests on whether the observed qualitative differences in Table 4 are significant. The ANOVA-Repeated Measures reveals that some scores are statistically different as indicated by the computed probability value of less than 0.01. This result implies that the Biological Science pre-service teachers had significantly different mastery levels possible on the four chemistry grade-level tests. The post-hoc test revealed that grade 7 MPS of 71.48 is the highest and significantly different from the rest of the scores. On the other hand, grade 8 MPS of 59.63 is not significantly different from grade 10 MPS of 55.93, implying that the pre-service teachers have mastery levels of the chemistry cognitive competencies equally under these tests. Finally, the students' collective scores under grade 8 and grade 9 are significantly different, with grade 9 having the lowest MPS at 51.85.

Table 5

Comparison of the Level of Mastery of Pre-service Teachers Major in Biological Science in the Different Grade Levels

Grade Level	Mean Percentage Score (MPS)	*Fc*	*P*-value
Grade 7	71.48[a]	31.15	0.00
Grade 8	59.63[b]		
Grade 9	51.85[c]		
Grade 10	55.93[bc]		

Like the Physical Science majors, the results show that mastery of Chemistry cognitive competencies is best seen in Grade 7, followed by the equal mastery levels of the pre-service teachers in Grades 8 and 10, with the lowest mastery level at grade 9. Since all grade levels did not reach the DepEd goal of 75, mastery learning on content still needs to be substantially enhanced in the BSE preparatory program.

The implication is what these future teachers can eventually impart to their learners. Some scholars supported that poor pedagogical content knowledge of teachers leads to poor academic performance by learners. Subject matter knowledge is imperative, with pedagogy studies, professional development, and years of experience, all of which positively correlate with students' academic achievement (Kola et al., 2015). Likewise, Kalande (2007) emphasized that teacher preparedness can be associated with their knowledge of the content vital for effective teaching. Together with pedagogy and curriculum, it can be the predictor variables for student achievement. Darling-Hammond (1997) noted that teacher education is of great importance. Her study for the National Commission on Teaching and America's Future (NCTAF) provided evidence that students accorded much confidence in teachers who were well trained in subject content and pedagogy. The K to 12 SSC eventual teaching success is influenced by the extent of the teachers' instructional understanding (Resurrection & Adanza, 2015; SEAMEO-INNOTECH, 2012).

Table 6 gives the overall performance of both Physical Science and Biological Science pre-service teachers in the different grade levels. The ANOVA-Repeated Measures reveal that some scores are statistically different, as indicated by the computed probability value of less than 0.01. This result implies that both majors of pre-service teachers had significantly different levels of mastery, with the posthoc test revealing that their grade 7 MPS of 74.51 is the highest and is significantly different from the rest of the scores. Generally, all pre-service teachers of both majors performed best at the grade 7 level, indicating better mastery of the basic cognitive learning competencies. Although Grades 8, 9, and 10 showed similar Average Mastery (AM) descriptive equivalent, posthoc results showed that grade 10 MPS of 60.39 is not significantly different from grade 8 MPS of 60.00, implying that the pre-service teachers in both majors have equal mastery levels under these tests. Finally, the student teachers' collective scores under grade 9 are significantly different from the rest of the scores showing the lowest MPS scores in both majors. Post hoc analysis revealed that the pre-service teachers performed better in Grades 8 and 10 compared to grade 9 chemistry despite the average mastery in all these three grade levels.

The new science program is far different from the previous curriculum that offered specific science disciplines in every grade level. The old curriculum taught General Science to first-year students, Biology to second-year students, Chemistry to third-year students, and Physics to fourth-year students. In the new K to 12 science curriculum, these pre-service science teachers will teach the different science disciplines like Biology, Chemistry, Physics, and General Science incorporated in every level of learning following the spiral progression approach in teaching science concepts applications in all subjects. SEAMEO INNOTECH's K to 12 kit emphasizes that 'concepts and skills in Life Sciences, Physics, Chemistry, and Earth Sciences are presented with increasing

Table 6

Overall Differences of the Level of Mastery of Pre-Service Teachers of Both Biology and Physical Science Majors Compared in the Different Grade Levels

Grade Level	Mean Percentage Score (MPS)	DE	*Fc*	*P*-value
Grade 7	74.51[a]	MTM	51.63	0.00
Grade 8	60.00[b]	AM		
Grade 9	54.71[c]	AM		
Grade 10	60.39[b]	AM		

complexity levels from one grade level to another, thus, paving the way for a deeper understanding of key concepts.

From this scenario, the study conducted by Resurreccion and Adanza (2015) is hopeful that with no significant difference in the effectiveness of in teaching the science disciplines (Biology, Chemistry, Physics, and Earth Science) using the spiral progression in both public and private schools. The researchers described that this approach had greatly influenced the science curriculum, specifically in the four disciplines' content and transitions. Also, the approach has a great impact on the schools, the learners, and the teachers. One of the teachers' greatest challenges is teaching other branches of science without in-depth discussion because it is not their specialization (Santos, personal communication, February 2017).

It is then a good move by the CTE to phase out the Bachelor of Secondary Education majors in Biology and Physical Science to offer the Bachelor of Secondary Education (BSEd) major in Science as of their 2018 Curriculum with CHED Memo Order 75, s.2017. This change aligns the preparatory program with the K to 12 implementation mandate that science teachers handle all the different science areas of Physics, Biology, Chemistry, and Earth Science. The change in curriculum is a welcome development to the implementation of the new science curriculum. The challenge is to the university educators, especially those in the departments imparting the discipline areas (Departments of Chemistry, Biology, and Physics), to sufficiently establish content mastery vis-à-vis all the learning competencies required in the discipline areas. The K to 12 learning competencies in the science curriculum should be emphasized, focusing on understanding mastery to the different departments teaching the undergraduate science subjects in earth science, biology, chemistry, and physics. It would be advantageous only to allow professional teachers in the various departments to handle these courses. As among the academic disciplines, science subjects get major revisions in the K to 12 curricula.

The new science program has many innovations in terms of the arrangement of competencies, integration of each branch of Science in every grade level, mode of instruction, and learning pedagogies that professional teachers present in biology, chemistry, and physics departments can readily understand. Mastery of science content with an understanding of learning competencies and pedagogy as catered in the different preparatory departments is a major way science teachers can handle their future science classes. Teaching all science disciplines is required in the spiral progression approach. These pre-service teachers who will be among the future implementers of this change need to be adequately prepared in their undergraduate science courses. It should be inculcated in their preparatory years that mastery of science content and science processes in the K to 12 Curriculum should be intertwined and organized around situations and problems that challenge and arouse learners' curiosity and motivate them to learn and appreciate science as a relevant and useful subject (Cabansag, 2014).

Finally, Table 7 presents the differences in the students' scores according to specialization. It shows that the pre-service teachers major in Physical Science have higher mastery levels than the Biology majors, as indicated by their higher mean score on the overall test and across all subtests in the grade levels. These observed differences were statistically tested to determine if the data indicates that students in one specialization have significantly different CAT scores through the t-test for the independent sample. Results reveal that overall, pre-service teachers major in Physical Science had significantly higher scores. This result is consistent in some subtests, namely the grade 7 and grade 10 subtests. On the other hand, pre-service teachers from the Biological science specialization had mastery levels equally under the remaining subtests of grades 8 and 9. Considering the effect size for the *t*-test, the eta squared test computed at $\eta^2=0.50$ and interpreted using Cohen's guidelines for effect sizes of the two group MPS showed an overall medium effect size of 0.84, which signifies that the differences are statistically different.

It is significant to note that the Physical Science majors have higher mastery levels in Grade 7 and grade 10 cognitive competencies in chemistry. In contrast, in their preparatory programs, both majors have similar chemistry courses taken: General Inorganic chemistry (lecture and laboratory), Organic Chemistry (lecture and laboratory), Biochemistry (lecture and laboratory, and Analytical Chemistry (lecture and laboratory).

Table 7

Differences in the Level of Mastery of Pre-service Teachers According to Specialization

Grade Level	Physical Science Mean Percentage Score	Biological Science Mean Percentage Score	*tc*	*P*-value	COHEN'S d
Grade 7	77.92	71.48	2.22	0.03	0.76
Grade 8	60.42	59.63	0.23	0.82	0.08
Grade 9	57.92	51.85	1.49	0.15	0.51
Grade 10	65.42	55.93	2.93	0.01	1.01
Overall	65.42	59.72	2.45	0.02	0.84

It could be the interdisciplinary reinforcement of their major in their other course subjects where they use their fields of specialization in their requirements and experiences that contributed to the better mastery of the cognitive competencies. This result suggests that the basic chemistry concepts in grade 7 and more advanced chemistry concepts in grade 10 were better grasped by the physical science majors. This learning can be an advantage to the specializations.

There seems to be a similar difficulty of both majors where the more abstract content standards in grades 8 and 9 are concerned. There should be a more in-depth understanding of the foundational concepts and applications of the particle nature of matter, atomic structure and the periodic table (grade 8), the mole concept, chemical bonding, and carbon compounds (grade 9) and be able to gradually make connections between the fundamental ideas in grade 7 and new ones in grades 8 and 9. These areas are specific challenges, not only to the pre-service teachers, but the science teachers who handle the specific subjects in the undergraduate preparatory program. The overall performance shows that Physical science majors have a better mastery of chemistry cognitive competencies than biology majors. A significant challenge is these pre-service teachers' training to be effective facilitators in their K to 12 classrooms. It has to be understood that deep comprehension of the subject matter content by the teacher-facilitator is foundational to any student-centered pedagogy. This foundation is essential because the teacher must guide the students' performance to ensure that the correct learning path is being traced throughout the learning process.

Conclusions and Recommendations

The overall mastery level of pre-service teachers of both Physical Science and Biology majors on the Chemistry cognitive competencies through the CAT is Average Mastery (AM). Mastery learning of chemistry cognitive competencies should be substantially enhanced to reach the DepEd goal of 75 MPS. The Bachelor of Secondary Education, which accorded the BSU-CTE as COE, needs to improve the general result of Average Mastery (AM) in the grade levels and overall performance of the pre-service teachers to Moving Towards Mastery (MTM) at 75 MPS or better. They need to coordinate with the chemistry department that teaches the major chemistry subjects to emphasize content depth with the prescribed DepEd content standards and learning competencies. Professional teachers in the Chemistry department can be given the load to teach the chemistry subjects in the BSEd science majors. Professional teachers in the department can help thoroughly prepare these future teachers in understanding the instructional content as prescribed in the spiral progression approach.

As this study provided status results, continuing studies should be conducted on the mastery level of chemistry cognitive competencies using the CAT to the succeeding pre-service teachers of the BSEd major in science to evaluate their competence and readiness for deployment to teach Chemistry in the Junior High School. Impact assessment studies are done on mastery learning in connection to the spiral progression approach in curriculum. Similar researches should also be done in the other science learning areas of earth science, biology, and physics.

Future research may be conducted on chemistry skills competencies and specific contextualized pedagogies as the study was limited to the chemistry cognitive competencies. The CTE administrators with their new undergraduate preparatory program, Bachelor of Secondary Education major in Science, should consider professional teachers likewise in biology and physics departments to handle the other science learning areas of earth science, biology, and physics. Difficult lessons involving abstract concepts and mathematical calculations, especially in the grade 9 content standards, should be given more instructional time with appropriate contextualized pedagogies for better mastery of these cognitive competencies.

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