Progressive-Guided Inquiry in Chemistry: Effects on Students' Knowledge-Building Practices

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This study investigated the effects of Progressive-Guided Inquiry on students' knowledge-building practices in Chemistry. It utilized a quasi-experimental pretest—posttest research design with two heterogeneous intact classes. Seventy-four Grade 8 students from two sections in a laboratory school in Quezon City participated in the study. One section was exposed to the Progressive-Guided Inquiry Approach (PGI) whereas the other section was exposed to the Conventional Teaching Approach (CTA). The Knowledge-Building Practices Assessment Tool (KBPAT) was used to assess students' knowledge-building practices. The mean pretest scores of KBPAT were subjected to two-tailed test for independent samples to establish the initial comparability prior to intervention. To determine if the teaching approach was effective in improving students' knowledge-building practices, the posttest scores in KBPAT were subjected to one-tailed t-test for independent samples. The statistical analyses showed that there were significant differences in the KBPAT which means that PGI was effective in enhancing the knowledge-building practices of the students. Based also on the results of the study, it is recommended that PGI, as a model of teaching, be used in teaching Chemistry to enhance knowledge-building practices.

Keywords: *chemistry education, science inquiry, progressive-guided inquiry, knowledge building, knowledge elaboration, knowledge creation, knowledge advancement*

Introduction

The need to determine the best and most appropriate learning or teaching approach in classrooms to help students achieve their maximum potentials has paved the way for the conduct of various researches in different disciplines and across grade levels.

In science education, the use of scientific inquiry is regarded as a very effective way of teaching and learning the content. Scientific inquiry serves as the nexus of today's science education reform movement (Wenning, 2011). The American Association for the Advancement of Science (AAAS, 2009) pointed out that inquiry-based teaching methods are the best paths to achieving scientific literacy because these methods provide students with the opportunity to discuss and debate scientific ideas. Even the National Science Teacher Association (NSTA, 2004) stated that scientific inquiry is a powerful way of understanding science content.

The claims of international organizations such as AAAS and NSTA regarding the use of scientific inquiry are consistent with the goals of the Department of Education (DepEd). In the Philippines, the goals of the DepEd K to 12 science curriculum are geared toward molding literate and thinking individuals by implementing inquiry-based, constructivist, and integrative pedagogical approaches. The inquiry-based approach emphasizes the use of evidence in constructing explanations to demonstrate understanding of science concepts. Through scientific investigations, learners can apply their science content knowledge and their inquiry skills to address real-world problems (DepEd, 2016).

Although multiple studies have been done to investigate the effectiveness of inquiry-based approach, most of these studies focused only on one level of inquiry. Addressing this concern, the National Research Council (NRC) stated that there are inquiry levels and that these levels are not created equally (2000). In fact, inquiry should be seen as a continuum (Bell, Smetana, & Binns, 2005) and should also be treated systematically as a series of hierarchical approaches (Wenning, 2011). This then calls for further studies to explore the use of multiple levels of inquiry in other science disciplines such as Chemistry (Wenning, 2011).

Scardamalia and Bereiter (2006) suggested the use of a knowledge-building approach that would help students build their knowledge. A study by Hakkarainen, Lakkala, and Muukkonen (2004) revealed that progressive inquiry as an approach is an effective way of knowledge building of tertiary level students. They also asserted that inquiry should be knowledge-seeking and is not simply assimilating but constructing through problems of explanation and understanding. With the importance of developing knowledge building at an earlier age, they recommended to use this type of inquiry in elementary and high school students.

Considering the goals of DepEd K-12 science curriculum, the positive impact of inquiry-based approach in science education, the effects of progressive inquiry on students' knowledge building, and the need to explore further the different levels of inquiry in a science discipline, such as Chemistry, could be explored. Thus, this research was conceptualized.

Statement of the Problem

This study aimed to determine the effects of progressive-guided inquiry on student's knowledge -building practices. Specifically, this research sought to answer the research questions, "Do students exposed to Progressive-Guided Inquiry (PGI) have higher mean posttest scores than students exposed to Conventional Teaching Approach (CTA) in the knowledge-building practices assessment tool?" and "Is there a significant difference between the scores of PGI and CTA groups knowledge-building practices assessment tool?"

Significance of the Study

The results of this research may serve as a guide for teachers to modify or redesign their lessons and activities by incorporating the different levels of inquiry. For Chemistry teachers, the results of this study may bring new perspectives, such as modifications of the classroom activities and assessing the skills of students, in teaching and studying Chemistry especially to high school students. Since Chemistry is perceived as a difficult science discipline, the use of this approach may be useful in dealing with the challenges of learning the concepts in a progressive manner.

School administrators and supervisors can organize trainings for pre-service and in-service teachers on the use of progressive-guided inquiry. The materials or outputs used in the learning cycles of this study may help them integrate inquiry science teaching by conceptualizing seminar-workshops as part of their professional development activities of their respective schools or institutions. Also, the research instrument used in this research can be utilized in assessing the knowledge-building practices of students.

This study may also be useful for researchers who will conduct future investigations particularly exploring the spectrum of scientific inquiry to improve knowledge-building practices of students. Researchers could be guided in the studies on the effects of progressive-guided inquiry on 21st century skills such as scientific reasoning and problem solving. Moreover, future researchers could also explore knowledge-building practices of Filipino high school students.

Progressive Inquiry

Progressive inquiry is a heuristic framework for structuring and supporting students' epistemological advancement and development of epistemic agency and related skills (Lonka, Sintonnen, & Hakkarainen, 2000). The model of progressive inquiry was developed by Hakkarainen and his colleagues (Hakkarainen, 1998; Hakkarainen, Lonka, & Lipponen, 2004; Muukkonen, Hakkarainen, & Lakkala, 2004) as a pedagogical and epistemological model for representing principal features of scientific collaborative inquiry. Furthermore, progressive inquiry is primarily based on theories of knowledge building (Bereiter & Scardamalia, 1993), the interrogative model of scientific inquiry (Hakkarainen & Sintonen, 2002; Hintikka, 1985), and concepts of distributed expertise in a community of learners (Brown & Campione, 1984).

Muukkonen, Lakkala, and Hakkarainen (2005) posited that to arrive at a deeper understanding of phenomena and problems in an area of investigation, one has to take part in a deepening question-explanation process. In the progressive inquiry process, the initial questions are generally found to be decomposable into several subordinate questions, which in turn, become the focus of students' inquiry (Hakkarainen & Sintonen, 2002).

A study conducted by Muukkonen, Lakkala, and Hakkarainen (2005) tested the implementation of the progressive inquiry model in a cognitive psychology course. The research concluded that the pedagogical progressive inquiry model could be used as a basis for the development of metacognitive skills and corresponding practices within the computer-mediated collaboration. Furthermore, a study done by Seitama and Hakkarainen (2001) implemented progressive inquiry in a design course and also found a significant impact on the students' computer skills.

To further explore the model of progressive inquiry, Lonka, Sintonen, and Hakkarainen (2000) recommended progressive inquiry learning for young children. It was suggested in their narrative report that this inquiry model should be started at younger level of education, instead of just starting it at the higher level, in order to achieve better knowledge building and grasp of science content once students enter the higher levels and to prepare students in entering tertiary education.

Levels of Inquiry Model of Teaching

Not all inquiry activities are created equally (Bell, Smetana, & Binns, 2005). An educational scientific inquiry program has to have an accessible entry point and should progressively move to more complex structures (Hatfull, as cited in Hanauer, 2009). Even the National Research Council (NRC) (2012) recognized that inquiry in classrooms can take many forms as inquiry-based activities vary in the degree of guidance a teacher or text provides to students and can range from highly structured to open-ended. NRC also asserts that effective learning occurs when students take control of their own learning. Depending on the determined level of inquiry for an activity, the locus of control may be shifted entirely toward the students, giving them the opportunity to monitor and regulate their own learning (NRC, 2012).

Wenning (2011) presented inquiry as a spectrum. The inquiry spectrum consists of discovery learning, interactive demonstration, inquiry-oriented lesson, inquiry-lab, and hypothetical inquiry. This constitutes a progressive level of intellectual sophistication and changing locus of control that shifts from the teacher to the student. He proposed a more extensive continuum to delineate the levels of pedagogical practice and offer some suggestions as to the nature of associated inquiry processes. Table 1 presents the inquiry spectrum.

Table 1
Levels of Inquiry Spectrum

Discovery Learning	Interactive Demonstration	Inquiry-Oriented Lesson	Inquiry-Oriented Lab	Hypothetical Inquiry
Low		← Intellectual Sophistication →		High
Teacher		← Locus of Control →		Student

Source: Wenning, C.J. (2012). Levels of Inquiry: Using inquiry spectrum learning sequences to teach science. Journal of Physics Teacher Education, 5(3), p.11

Intellectual sophistication increases continuously from discovery learning to hypothetical inquiry. The intellectual sophistication discussed by Wenning was also consistent with the researches of Lawson (1995) and Rezba, et al., (2003) stating that sophistication has to do with the type of intellectual science process skills required to complete a specified level of inquiry-oriented activity. Meanwhile, the locus of control or the thought processes required to control an activity shift from the teacher to the student moving from left to right along the continuum. This means that the teacher in discovery learning is in nearly complete control; in hypothetical inquiry, the work depends almost entirely upon the student.

In terms of the levels of inquiry, Wenning (2011) delineated the features of each level of the spectrum. These levels were also operationally defined in other researches.

Discovery learning. This is the most basic form of scientific inquiry and consists of a teacher-controlled activity through which students are directed to make specific observations and reach predefined conclusions. The teacher introduces an experience to enhance the relevance or meaning of the activity, uses a sequence of question during or after the experience to guide students to a specific conclusion, and asks students to direct discussion that focuses on a problem or apparent contradiction (Wenning, 2005). On the other hand, students develop concepts on the basis of first-hand experiences (a focus on active engagement to construct knowledge) (Wenning, 2011). This concept of discovery learning is associated with Bruner (1989), Dewey (1970), and Piaget (1970), which is the most fundamental form of inquiry-oriented learning and first step in knowing. Its focus is not on finding applications for knowledge, rather, on constructing meaning or knowledge from experiences (Hassard, 2005; Wenning, 2011).

Interactive demonstrations. Interactive demonstration consists of teacher-controlled manipulation of a scientific demonstration and the request for a prediction or the explanation of the phenomena (Wenning, 2011). The emphasis is on the teacher's manipulation of scientific equipment which models the most fundamental level of appropriate scientific procedures, and thereby helps students learn implicitly about inquiry processes. Specifically, the teacher is in-charge of conducting the demonstration, developing, and asking probing questions; eliciting responses in pursuit of identifying alternative conceptions, putting students in a case of cognitive dissonance so that they might confront alternative conceptions that are identified, soliciting further explanations to resolve any alternative conceptions, getting students to commit to a prediction and comparing the prediction with the outcome, and helping students reach appropriate conclusions on the basis of evidence. (Wenning, 2011, p.12)

Inquiry-oriented (or inquiry) lessons. This level of inquiry consists of a teacher-controlled demonstration of an experimental procedure accompanied by verbalization of the conceptual and physical aspects of the experimental design. In an inquiry lesson, the emphasis subtly shifts to the process of scientific experimentation. The activity is based on the teacher taking charge of asking leading questions and giving appropriate teaching strategies. He or she also models the thought process involved in a scientific inquiry and explains the fundamental understandings of scientific inquiry while the students learn by observing and listening, and responding to questions (Hassard, 2005; Wenning, 2011). The students' task is to identify scientific principles and/or relationships (Wenning, 2011). This cooperative work used to construct more detailed knowledge could be a group laboratory activity or class presentation where students share their ideas about the science topic.

Inquiry-oriented lab. This fourth level of inquiry is subdivided into two: guided inquiry laboratory and bounded-inquiry laboratory.

Guided inquiry laboratory. This consists of a teacher-directed student inquiry. The teacher presents a question and defines and guides laboratory procedures. Students then conduct a scientific inquiry by being directed to find the answer to a specific question through the use of a provided set of procedures (Wenning, 2011). In a guided inquiry activity, the instructor provides the problem, guides the students in selecting variables, planning procedures, controlling variables, planning measures, and finding flaws through questioning that will help students arrive at a solution, and encourages students to work out the procedures to resolve the problem (Brickman, 2009; Buck, Bretz, & Towns, as cited in Brickman, 2009; Martin-Hansen, 2002). Although the teacher usually chooses the question for investigation, students, in one large group or several small groups, may then assist the teacher on deciding how to proceed in an investigation. Guided inquiry laboratory provides more direction to students who may be poorly prepared to tackle inquiry problems without prompts and instruction due to the lack of experience or knowledge or because they have not reached the level of cognitive development required for abstract thought. It is necessary that students in guided inquiry laboratory activities are provided with a clear and concise student performance objective (Lawson, Purser & Renner, as cited in Brickman, 2009).

Bounded inquiry laboratory. This sublevel of inquiry-oriented lab consists of a student scientific inquiry that is directed by a question identified and posed by the teacher. The students are expected to design the experiment and conduct the scientific inquiry (Wenning, 2011). At this level, students are presented with a clear and concise student performance objective associated with a concept, but they are expected to design and conduct an experiment without the benefit of a detailed pre-laboratory or written leading question. Also, students are entirely responsible for experimental design, though an instructor may provide assistance as needed. This assistance is more in the form of asking leading questions rather than by providing answers to student questions.

Hypothetical inquiry. The hypothetical inquiry is considered as the most advanced form of inquiry. At this level, students deal with hypothesis generation and testing. It also deals with providing and testing explanations to account for certain laws or observations (Wenning, 2005). Moreover, the primary pedagogical purpose of this level is to derive explanations for observed phenomena (Wenning, 2010). The advanced skills associated in this level are synthesizing complex hypothetical explanations, analyzing and evaluation of scientific arguments, generating predictions through the process of deduction, revising hypothesis and predictions in light of new evidence, and solving complex real-world problems (Wenning, 2005; 2011).

The Levels of Inquiry Model of Teaching is an approach to instruction that systematically promotes the development of intellectual and scientific process skills by addressing inquiry in a systematic and comprehensive fashion (Wenning, 2011). When taught using the Levels of Inquiry Approach, students have the opportunity to make observations, formulate predictions, collect and analyze data, develop scientific principles, synthesize laws, and make and test hypothesis to generate explanations. Inquiry-oriented teaching is no longer seen as an amalgam of convoluted and disconnected processes. Rather, inquiry must be handled systematically as a series of hierarchical approaches each with affiliated process skills. Wenning (2011) discussed further that a hierarchy must be provided for effective transmission of knowledge. He pointed out that all science teachers must have a comprehensive understanding of various pedagogical practices and inquiry processes if they are to teach science effectively using inquiry.

By systematically addressing the various Levels of Inquiry—Discovery Learning, Interactive Demonstrations, Inquiry Lessons, Inquiry Labs, and Hypothetical Inquiry (collectively known as the inquiry spectrum)—teachers help students develop a wider range of intellectual and scientific process skills. It is noteworthy that in a learning sequence or a lesson, the teacher has the option to include one or more levels of inquiry depending on available time and resources, as well as the interest of the students (Wenning, 2011). The claim of Wenning highlights the importance of instructional time in designing lessons using the levels of inquiry model. This is also consistent with the recommendation of Constenson and Lawson (1986) to consider the time factor in lesson planning in including inquiry practices in instruction.

Wenning (2011) further suggested the use of this model in teaching not only physics but also in other disciplines in science. His proposal to use this approach serves as basis to propose an intervention that would explore the inquiry spectrum in the teaching of Chemistry. The time constraint in developing learning sequences was the main reason why only four (4) levels of inquiry, namely, Discovery Learning, Interactive Demonstration, Inquiry-Oriented Lesson, and Inquiry Lab were used in designing the lesson plans and activities for this study.

Knowledge Building

Knowledge building as a pedagogical approach guides educator in providing venues for sharing ideas and thoughts within networked databases, thereby making these "objects" available for others to work on and further elaborate (Muukkonen, Hakkarainen, & Lakkala, 2004; Scardamalia & Bereiter, 2003). It is based on the Knowledge Building Theory in which knowledge is treated as conceptual artifacts that can be examined, tested, compared, and improved for developing deeper collective understandings (Scardamalia & Bereiter, 2003).

Knowledge building is a methodology in which a group works collaboratively to discuss and generate knowledge as well as to interpret information and share ideas from authoritative text sources (Scardamalia & Bereiter, as cited in Doto, 2015). Also, knowledge building highlights student collaboration.

In knowledge building, idea improvement is an explicit principle, something that guides the efforts of students and teachers rather than something that remains implicit in inquiry and learning activities (Scardamalia, 2002). The direct pursuit of idea improvement brings schooling into much closer alignment with creative knowledge work as carried on at professional levels. In addition, student works with problems that result in deep structural "knowledge of " instead of "knowledge about" which consists of all declarative knowledge one can retrieve when prompted to state what s/he knows. "Knowledge of" implies an ability to do or participate in activities and consists of both procedural knowledge and declarative knowledge that are drawn when engaged in the activities. Experts in the research world presuppose deep knowledge of the problem domain. A knowledge building technology, accordingly, ought to favor increasingly deep inquiry into questions of how and why rather than the shallower kinds of inquiry of what and when (Scardamalia & Bereiter, 2003).

A component of knowledge building related to teaching science is the creation of epistemic artifacts. These are tools that serve in the further advancement of knowledge (Sterenly, as cited in Bereiter, 2002). These may be purely conceptual artifacts (Bereiter, 2002), such as theories and abstract models, or epistemic things (Rheinberg, 1997), such as concrete models and experimental set-ups.

Knowledge-Building Practices

Knowledge building involves more than individual knowledge acquisition. It refers to students' productive practices or knowledge-building practices that include knowledge elaboration, knowledge creation, and knowledge advancement (Bereiter & Scardamalia, 1993).

One knowledge-building practice is knowledge elaboration. It refers to the use of prior knowledge to continuously expand and refine new material based on processes of organizing, restructuring, interconnecting and integrating new elements of information (Kalyuga, 2009). Also, the processes of knowledge elaboration result in knowledge components additional to those given in the task statement or instructional message by creating links between prior knowledge and the new information (Anderson, 1995; Mayer, 1984; Pressley, 1982; Reigeluth, Merril, Wilson, & Spiller, as cited in Kalyuga, 2009).

Knowledge elaboration is an important activity for promoting knowledge gains during collaborative learning (Zheng, 2017). Previous studies revealed that knowledge elaboration can facilitate the retention of the new information (Anderson & Wittrock, as cited in Zheng, 2017), can enhance meaningful learning (Novak, as cited in Zheng, 2017), and can stimulate the integration of information into prior knowledge (Kalyuga, 2009). It also has a significant effect on students' learning performance (Denessen, Hwang, as cited in Zheng, 2017).

Knowledge elaboration can be achieved better through collaborative learning because when group members interact with each other, they have to integrate prior knowledge with new information (Zheng, 2017). Researchers also believe that interacting with others could promote information processing and the adjustment of cognitive structures (Mitnik et al., Wilbeck et al., as cited in Zheng, 2017).

Aside from knowledge elaboration, knowledge creation is also described as a knowledge-building practice. It represents the process of enabling people to create new insights such as eureka moments or additional or alternative views on existing knowledge (Brix, 2014). It is defined by Nonaka and Takeuchi (1995) as the "justified true belief" that enables the organization's capacity for effective action (Brix, 2017). Moreover, Nonaka and Takeuchi (1995) argued that knowledge can exist on an individual level and on a social level (collective knowledge). Also, knowledge is created through a learning process, and that the same knowledge influences the learning occurring on different levels of organization (Crossan et al., as cited in Brix, 2014).

To make knowledge creation possible, Nonaka and Takeuchi (2005) proposed the use of the SECI model: socialization, externalization, combination, and internalization. Socialization aims at sharing tacit knowledge among individuals. Externalization, on the other hand, aims at articulating tacit knowledge into explicit concepts. Moreover, combination aims at combining different entities of explicit knowledge. Lastly, internalization aims at embodying knowledge into tacit knowledge (Brix, 2014; Brix, 2017).

Another general practice of knowledge building is the knowledge advancement. In knowledge advancement, the subskills are idea diversity, idea improvement, and idea convergence (Scardamalia & Bereiter, 2006). Idea diversity involves brainstorming of knowledge. Idea improvement refers to the skills of conceptual change. The third subskill, idea convergence, involves extending shared knowledge or collective wisdom.

Knowledge Building and Science Inquiry

The progressive inquiry model shares with the knowledge-building approach an assumption that inquiry is seen as a process mediated by shared knowledge objects such as questions, working theories, and explanations. Moreover, the defining characteristic of progressive inquiry is, accordingly, an inquiry that is object-oriented—pursuit of advancing shared knowledge objects across situations—rather than a particular group working method (Hakkarainen, Lonka, & Lipponen, 2004). Furthermore, the mediated nature of inquiry helps to distinguish knowledge building from mere learning (Bereiter, as cited in Hakkarainen, Lonka, & Lipponen, 2004).

Figure 1 illustrates the conceptual framework of the study. It shows the relationship of the teaching approaches (progressive-guided inquiry and conventional) on students' knowledge-building practices. The study was theoretically grounded on the positive impact of Progressive Inquiry Approach in learning (Muukkonen, Hakkarainen, & Lakkala, 2004) and the proposal to apply the Levels of Inquiry Model of teaching (Wenning, 2011). However, the study used an intervention that explored the combination of Progressive Inquiry and Levels of Inquiry approaches or the Progressive-Guided Inquiry (PGI).

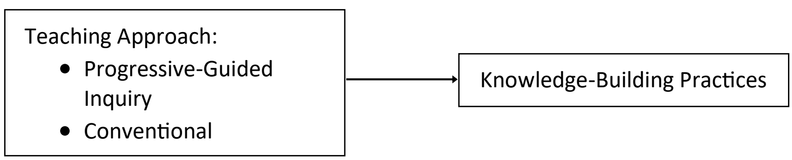

Figure 1. Conceptual Framework

Research Design

This study used a quasi-experimental two-group pretest-posttest design with two intact classes. The students were already in existing sections so complete randomization was not possible. The experimental group was exposed to Progressive-Guided Inquiry (PGI), whereas the conventional group was exposed to Conventional Teaching Approach (CTA).

The research design of this study is represented as follows:

PGI	O	X_1	O'
CTA	O	X_2	O'

where:
O and O' = Knowledge-Building Practices Assessment Tool (KBPAT) administered as pre test and posttest to the two groups exposed to PGI and CTA, respectively
X_1 = exposure to Progressive-Guided Inquiry (PGI) approach
X_2 = exposure to conventional teaching approach

The Sample

The participants in this study were 74 Grade 8 students enrolled in a laboratory school in Quezon City for the Academic Year 2016-2017. Two heterogeneous intact classes were involved. These two classes were taught by the teacher-researcher during fourth quarter of the same academic year. The assignment of the two classes as PGI group and conventional group was determined randomly. The two groups were relatively the same in terms of class size and the average age. The PGI group consisted of 38 students whereas the CTA group consisted of 36 students. The average age in years of both groups during the data gathering period was 14.5 years.

Knowledge-Building Practices Assessment Tool (KBPAT)

The Knowledge-Building Practices Assessment Tool (KBPAT) is a researcher-made instrument used to assess the knowledge-building practices of students. KBPAT consists of open-ended questions that presented questions or tasks related to the Chemistry topics such as matter (techniques in separating the components of mixtures), atomic theory, and periodic properties covered during the intervention. KBPAT has three parts pertaining to the three knowledge building practices: Part A –Knowledge Elaboration, Part B –Knowledge Creation, and Part C –Knowledge Advancement.

Part A is an 8-item subtest that measured students' knowledge elaboration specifically its subskills –interconnecting, organizing, restructuring, and integrating of ideas. Part B is also an 8-item test that assessed the practices of knowledge creation particularly the subskills socialization, externalization, combination, and internalization. Part C consists of six (6) items that assessed knowledge advancement and its three subskills, namely: idea diversity, idea improvement, and idea convergence.

The highest total score for the three-part test was 86 points. The maximum scores for parts A, B, and C were 44, 24, and 18, respectively. Two teachers who were considered experts in Chemistry rated the students' responses. Afterwards, the inter-rater reliability coefficient (ICC) values were obtained.

The computed inter-rater reliability coefficient (ICC) values were .952 for Part A, .837 for Part B, and .841 for Part C. These values indicated "very good" to "excellent" reliability coefficients (George & Mallery, 2000).

Pre-Intervention Phase

The permission from the school principal of the laboratory school was secured to conduct the pilot testing of the instruments, the lesson plans, and the intervention. After obtaining the permission, in coordination with the Science Department, the schedule of pilot testing and the actual conduct of the study and the classes that would participate in the study were determined.

Pilot Testing of KBPAT, KBPAT Rubrics, and Lesson Plans

The KBPAT and the rubrics were validated by three of the panel members composed of a university professor who taught undergraduate and graduate courses in chemistry education, a university professor in educational psychology, and a chemistry education doctoral student and professor in a laboratory school of the same state university.

Before the data collection, KBPAT was pilot tested in a grade 9 Chemistry class of the school where the study was conducted. Based on the results of the item total statistics values the items were reduced to eight items for Part A, eight items for Part B, and six items for Part C. After the pilot testing, the students' responses were rated by the researcher and two experts who were Chemistry teachers. To have higher reliability values and clearer marking scheme, the rubric was revised. After the revision of the rubric, the inter-rater reliability coefficient (ICC) values were recomputed.

The pilot testing of the instruments and the lesson plans was conducted for validation and revision. One cycle of the PGI Approach was pilot tested in one Grade 9 section. This was done for the researcher to gauge the time for the implementation of the selected learning cycle and also to finalize the Inquiry Lesson part B which included the five features of scientific inquiry as format of the last phase of the PGI approach. The grade 9 section composed of 32 students was chosen as participants of the pilot-testing because these students learned the target topics in their Science 8, more recently compared to the other higher grade levels. The PGI learning cycle used in the pilot-test, which lasted for four meetings, equivalent to five hours, was about periodic properties. The KBPAT and lesson plan were revised in coordination with the research adviser. The revised lesson plan served as guide in making the other lesson plans.

Pretest Administration

The KBPAT as pretest was administered for two consecutive meetings. KBPAT A was administered on March 30, 2017. KBPAT B and C were administered on March 31, 2017. Prior to answering KBPAT B, students were grouped and were given 15 minutes to discuss with their groupmates some chemistry ideas. This was to follow the socialization subskill and idea divergence which were the starting skills of knowledge creation and knowledge advancement practices. Part B was done for 30 minutes. Similar to the test administration procedure for Part B, students were also grouped and were given 15 minutes to discuss some chemistry ideas and 30 minutes were given to answer Part C.

Intervention Phase

Two classes participated in the intervention. One class was exposed to the Conventional Teaching Approach (CTA) whereas the other class was exposed to the Progressive-Guided Inquiry Approach (PGI). The lessons focused on Matter (Techniques in Separating the Components of Mixtures), Atomic Theory, Electronic Structure of the Atom, and Periodic Properties. The intervention was conducted during the fourth grading of academic year 2016-2017 and lasted for eight weeks. The intervention consisted of eight learning cycles which had the following topics (Table 2):

Table 2
Learning Cycles and Topics

Learning Cycle	**Topic**
1	Techniques in Separating Components of Mixtures
2	Atomic Theory
3	Subatomic Particles
4	Quantum Mechanical Model
5	Quantum Numbers
6	Electron Configurations
7	Periodic Table of the Elements
8	Periodic Properties and Trends

Conventional Teaching Approach (CTA)

In the CTA class, the learning cycle involved major phases — recall, activity, processing, and evaluation.

Each learning cycle began with a recall of the previous lesson facilitated by the researcher through question-and-answer and problem-solving activities. The objective of the recall was to review the previously-learned concepts to ensure students' knowledge of the prerequisite concepts and skills needed for the succeeding lessons. This also served as a venue to clarify and emphasize important concepts or ideas. This was followed by group laboratory or dry-lab activities such as simulations, model construction, and pen-and-paper activities.

For each activity, a set of guide questions (e.g., "Why don't all the marbles land in the same spot?" and "Based on your data, at which radius in your model is the probability of finding an electron the greatest? Explain.") was given to the students. The processing part of the cycle included the post-lab discussion, the discussion of the lesson, and an extension activity.

The students' answers to the guide questions served as bases for the post-laboratory discussions which were followed by the discussion of the lesson. In some learning cycles, extension activities were done to enrich the students' knowledge of the concepts. Some of these activities were individual and pair work exercises and games. To assess understanding of the concepts, each learning cycle ended with an evaluation activity such as seatwork. The evaluation tool for each learning cycle was patterned after a subtest in the KBPAT.

The Intervention

The Progressive-Guided Inquiry Approach (PGI) was a fusion of two teaching approaches—the Levels of Inquiry Model of Science Teaching proposed by Wenning (2011) and the Progressive Inquiry developed by Hakkarainen, Muukkonen, and Lakkala (2005).

In the PGI class, the major phases of a learning cycle included Recall, Discovery Learning, Interactive Demonstration, Inquiry Lesson A (Guided Inquiry), Inquiry Lesson B (Bounded Inquiry), Post-Activity Discussion, and Evaluation. Figure 2 shows the model of PGI.

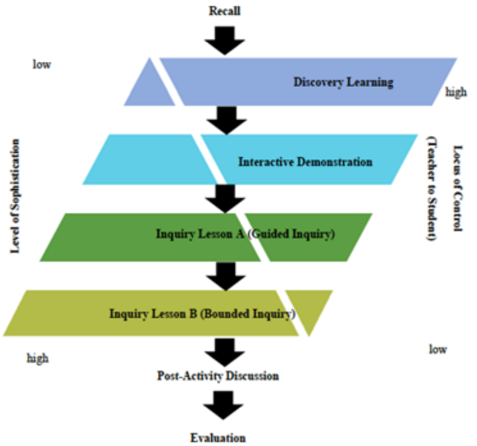

Figure 2. Progressive-Guided Inquiry (PGI) Model

The recall part of the lesson aimed to review and check the students' understanding of the previously-learned concepts and to clarify and emphasize important concepts or ideas. This part of the lesson was similar to the recall part of the CTA lesson. This was followed by a discovery learning activity such as showing of video clips, use of realia, laboratory activities, and model making to engage students and allow them to observe and give predefined conclusions (Wenning, 2005). The third part of the lesson was an interactive demonstration to develop student's ability to predict, observe, and provide explanations of the observed phenomenon.

The next phase was the Inquiry Lesson A or the guided inquiry in which students had to independently analyze data and provide explanations for their observations based on the information presented by the teacher. For example, in the fifth Learning Cycle (Quantum Numbers), students were asked to describe and determine the rules in assigning the possible azimuthal and magnetic quantum numbers. Since most of them could not answer the questions in the activity worksheet, the teacher had to explain the meaning of each question to the class and divide the tasks into smaller ones following a more step-by-step procedures. Afterwards, it was observed that the students were able to proceed to the next part of the Inquiry Lesson (part B).

The Inquiry Lesson B or the bounded inquiry served as a venue for the students to apply the concepts and skills learned in the previous phases from discovery learning activity to guided inquiry. This required students to answer a question given by the teacher by employing the five features of inquiry: questions, evidences, planning and process, conclusion, and justification. However, in Learning Cycles 3 and 5, it was observed that some students had difficulty answering the questions. To address this, the teacher had to provide question prompts to assist students in answering them. For instance, for the given question, "What are the possible azimuthal and magnetic quantum numbers if the principal quantum number is four?" the prompt given was "What concepts from the first activity are connected to this task? How about from the second activity? What concepts have we learned from the last activity?". Audio recordings of group discussions were obtained for every Inquiry Lesson B of the learning cycles. These recordings were transcribed for content analyses.

After students presented their outputs for the bounded inquiry activity, the teacher facilitated a discussion on the target lesson, concepts not covered in the previous phases , and gave exercises to develop students' mastery of the lesson. Similar to the CTA, the learning cycles ended with an evaluation using the same tool administered in the other class. The evaluation tool for each learning cycle was patterned after one of the practices in the KBPAT.

Discussion of Findings

Initial Comparability in Knowledge-Building Practices

The initial comparability of the CTA group and PGI group was determined by subjecting the KBPAT mean pretest scores to two-tailed t-test for independent samples. Table 3 shows the mean, standard deviations of both groups, and the computed t-value at 5% level of significance. The Levene's test of equality of variances was performed. The computed p value, $F(69) = 5.59$, $p = .021$, is less than the significant level, which means that variances are not assumed to be equal. The t-test value of the corrected Levene's test was reported instead. The t-test shows that there was no significant difference between the two groups, $t(69) = -1.32$, $p = .195$, in the KBPAT. Meaning, the two groups were comparable in terms of their knowledge-building practices before the intervention.

Table 3

Independent Samples t-test on the Pretest of Knowledge-Building Practices Assessment Tool (KBPAT)

Group	Mean	SD	t	df	Sig (2-tailed)
CTA	34.29	12.46	-1.32	46.58	.195
PGI	37.63	7.39			

Note. *$p < .05$. KBPAT Perfect Score = 86

To determine the initial comparability of the knowledge-building practices of the two groups, the independent samples *t*-test for every part of KBPAT was statistically determined. Tables 4, 5, and 6 show the results of the independent samples *t*-test for Knowledge Elaboration (Part A), Knowledge Creation (Part B), and Knowledge Advancement (Part C) are shown, respectively.

Table 4
Independent Samples t-test on the Pretest of KBPAT Part A

Group	Mean	SD	t	df	Sig (2-tailed)
CTA	19.10	8.37	-1.39	45.94	.173
PGI	21.45	4.86			

Note. **p* < .05. KBPAT Perfect Score = 44

Table 5
Independent Samples t-test on the Pretest of KBPAT Part B

Group	Mean	SD	t	df	Sig (2-tailed)
CTA	9.10	3.75	-1.65	67	.103
PGI	10.32	2.33			

Note. **p* < .05. KBPAT Perfect Score = 24

Table 6
Independent Samples t-test on the Pretest of KBPAT Part C

Group	Mean	SD	t	df	Sig (2-tailed)
CTA	6.10	2.34	.449	54.55	.655
PGI	5.87	1.76			

Note. **p* < .05. KBPAT Perfect Score = 24

The independent samples *t*-tests showed that there were no significant differences between the two groups in the three KBPAT parts ($p = .173$, $p = .103$, and $p = .655$, for KBPAT A, B, and C, respectively). Meaning, the two groups were comparable in terms of their knowledge-building practices before the intervention.

Effects of Teaching Approach on Knowledge-Building Practices

After the intervention, the KBPAT was administered as a posttest. To establish whether there was a significant difference between the CTA and PGI in terms of knowledge-building practices, the mean posttest scores of both groups were subjected to one-tailed *t*-test for independent samples. The Levene's test was performed and the results F (69) = .329, $p = .568$ indicated that the variances were assumed to be equal. Also, at 5% level of significance, the computed *p*-value was less than the significant level, t(69), 1.99, $p = .025$, as shown in Table 7. This means that there was a significant difference between the CTA group and PGI group, in terms of knowledge-building practices. It can also be noted that the PGI group (M=49.08, SD=8.43) has acquired a higher mean posttest score than the CTA group (M=44.48, SD=10.77). The results suggest that PGI was effective in improving the knowledge-building practices of students.

Table 7
Independent Samples t-test on the Posttest of KBPAT

Group	Mean	SD	t	df	Sig (1-tailed)
CTA	44.48	10.77	-1.99	67	.025*
PGI	49.08	8.42			

Note. *p < .05. KBPAT Perfect Score = 86

The positive result of PGI on knowledge-building practices is similar to the findings of Lin, Hong, and Chai (2011) on the effectiveness of having a knowledge-building environment to improve learning. They reported that students involved in a knowledge-building environment tended to ask and answer higher level questions. Examples of these questions were the "How" and "Why" questions of the students in different groups during the different learning cycles such as " Paano mo ba ipapakita yung figures yung relative masses ng isotopes? Para hindi simpleng values lang na nakuha natin ang irereport?" (*"How can you show figures of the relative masses of the isotopes so that we do not only report simply the values we got?"*) and "Bakit kaya magkaiba yung mass number saka atomic mass values dito? Baka merong ibang calculations na dapat nating i-apply para makuha yung atomic mass?" (*"Why is it that the mass number differ from the atomic number? Maybe there's a different calculation that we should apply to get the atomic mass?"*).

The collaborative nature of a knowledge-building environment also aided in improving ideas of students because they were able to compare their perceived concepts with their workmates. This result was similar to the impact of employing PGI as an inquiry approach which requires greater student collaboration in accomplishing the different phases.

These findings were evident in the conversations of students of Group 6 during the Inquiry Lessons A and B in which these phases provided opportunities for them to collaborate and address questions from the group members:

Student 27: Guys, meron bang malabo sa electron diffraction experiment? Tara sagutan natin para sure tayo na pareho tayo ng thinking. (Guys, is there something confusing on electron diffraction experiment? Let's answer (the report) so that we're sure that we have the same thinking.)

Student 20: Related ba yung electron diffraction sa movement ng water? (Is electron diffraction related to the movement of water?)

Student 27: Related in the sense na magkapareho ba sila? (Related in the sense that they are the same?)

Student 20: Oo. Yung electron diffraction ba parang sa water? Yung nagalaw parang may movement? (Yes. Is electron diffraction similar to water when it is disturbed?)

Student 27: Oo. Diffraction yung nagugulo mo yung tubig kasi may itinapon ka. (Yes. It's diffraction when you disturb water because you throw something on it.)

Student 28: Disturbance yung nagtapon ka ng bato sa tubig tapos may movement. Sa case na ito, electron ang nagdidifract. (Disturbance happens when you throw stone on water then it moved. It this case, it's the electron that diffracts.)

Student 10: Paano nangyayari ang diffraction ng electron? (How does electron diffraction happen?)

Student 9: Ang movement ng electrons parang wave kasi. (The movement of electrons is wave like.)

Student 10: parang sa gitara? (like on a guitar?)

Student 27: Oo. (yes)

Student 28: Yung idea ng diffraction parang hindi lang isang idea lang. (The idea of diffraction is not a single idea only.)

Student 27: Ano ibig mong sabihin? (What do you mean?)

Student 28: Connected ba ng energy ng electrons dito? (Is the energy of electrons connected to this?)

Student 27: Connected, I think. Connected sa energy; parang yung sinasabi ng emission spectrum, I think. Yun ba yung tanong mo? (Connected, I think. Connected to energy. Like what the emission spectrum says, I think. Is this your question?)

Student 28: Yeah. Parang link ng electron diffraction sa ibang experiments o theory. (Yeah. Electron diffraction is linked to other experiments or theories.)

These conversations were also similar to most of the groups during the learning cycle. They indicated that the groups exhibited a knowledge-building environment. That is, the different groups in the PGI class worked to discuss and address unclear ideas from some members upon encountering the tasks in the learning cycle. This observation is similar to the pedagogy of knowledge building of Scardamalia and Bereiter (2006) on student collaboration. They reported that students work to discourse and generate knowledge as well as to interpret information and share ideas from an authoritative text source.

It can also be noted that the PGI class employed steps such as organizing students into groups, asking students to accomplish inquiry tasks, and answering individual questions that arose during the group works. These observations reflect the results of the study by Perez Marin, Hijon-Neira, and Santacruz (2016) where a combination of active learning, collaborative learning, and knowledge building involved steps such as (1) organize students into groups, (2) ask students to discuss questions in their groups, and (3) answer questions individually. With these similar observations, it can also be inferred that PGI promoted a knowledge-building environment.

To further investigate the effects of PGI on the knowledge-building practices of students, independent samples t-test for every part of KBPAT Posttest was performed. Tables 8, 9, and 10 show the statistical results of independent samples t-tests of the posttests of KBPAT A, B, and C.

Table 8 shows the results of independent samples t-test on KBPAT A posttest. At 5% level of significance, the computed *p*-value was less than the significant level, $t(69) = -.509$, $p = .031$. This indicates that there was a significant difference in the KBPAT A which means that PGI was effective in enhancing the knowledge elaboration of students.

Table 8
Independent Samples t-test on the Posttest of KBPAT Part A

Group	Mean	SD	t	df	Sig (1-tailed)
CTA	24.39	5.93	-.509	56.57	.031*
PGI	25.05	4.70			

Note. $*p < .05$. KBPAT A Perfect Score = 44

The positive impact of PGI on enhancing knowledge elaboration of students was consistent with the study of Zheng, Huang, Hwang, and Yang (2015). They reported a positive effect of an instructional approach which promotes collaboration on the knowledge elaboration of students. Also, the level of knowledge elaboration was found to be significantly related to student involvement, group performance, and prior knowledge of the group. This means that the greater the student involvement in the group is, the greater the knowledge elaboration. Their finding is congruent with the results of this study because PGI involved different phases which allowed shift of locus of control from the teacher to the student. The progression of the phases in PGI was in line with the increasing level of student engagement, which may have contributed to the significant effect of the intervention to students' knowledge elaboration.

Table 9 shows the results of independent samples *t*-test on KBPAT B posttest. At 5% level of significance, the computed *p*-value was less than the significant level, $t(69) = -2.35$, $p = .012$. This indicates that there was a significant difference in the KBPAT B which means that PGI was effective in enhancing the knowledge creation of students.

Table 9

Independent Samples t-test on the Posttest of KBPAT Part B

Group	Mean	SD	t	df	Sig (1-tailed)
CTA	13.23	3.89	-2.35	51.32	.012*
PGI	15.16	2.67			

Note. *$p < .05$. KBPAT B Perfect Score = 24

This result is similar to the study conducted by Hakkarainen (2003) wherein progressive inquiry had a positive impact on the practices of knowledge creation of grades 5 and 6 students. It is also similar to the study of Jaleel and Verghis (2015) about the positive effect of *E*-learning, a constructivist approach, to the knowledge creation of secondary physics students. The significant effect of PGI on knowledge creation can be explained by how the teaching approach was able to capture the subskills of knowledge creation. Knowledge creation is achieved if there is a transfer of knowledge from the tacit (implied) knowledge to the explicit knowledge (Nonaka & Konno, 2000; Nonaka & Takeuchi, 1995). This transfer is done by the SECI processes (socialization, externalization, combination, and internalization). This was exemplified during the conversations of the students in Learning Cycle 7 (Periodic Table). It started when they associated the present lesson with their previous lesson in class and when they shared experiences in encountering the lesson in their elementary days. This was the socialization subskill. Externalization was observed when students were able to state more definite ideas of the topic they were discussing. Combination, as a subskill, was achieved, when students applied their idea in obtaining the relative number of subatomic particles given an element and when they were able to connect electron configurations to the parts of the periodic table. Lastly, internalization was achieved when they came up with a larger idea on the interconnectedness of the parts of the periodic table, electron configurations, and the number of subatomic particles.

Table 10 shows the results of the independent samples *t*-test of the posttest of KBPAT C. At 5% level of significance, the computed *p*-value was less than the significant level, $t(69) = -2.82$, $p = .003$. This indicates that there was a significant difference in the KBPAT C of students which means that PGI was effective in enhancing the knowledge advancement of students.

Table 10
Independent Samples t-test on the Posttest of KBPAT Part C

Group	Mean	SD	t	df	Sig (1-tailed)
CTA	6.87	2.78	-2.82	66.35	.003*
PGI	8.87	3.09			

Note. *$p < .05$. KBPAT C Perfect Score = 18

The significant effect of PGI on knowledge advancement of students could be the result of the Inquiry Lesson B task of each member of the group providing as many pieces of evidence or concepts that could be related to the question given. These pieces of evidence were not only about the concepts students learned from the previous inquiry levels but also from class discussions, personal experiences, and what they read, watched, and heard which were related to the topic. These were mentioned during the group sharing. These experiences became their source of ideas which they perceived to be connected to the evidences or concepts asked. Furthermore, answering the Evidences part of the report served as the groups' brainstorming activity and venue for giving diverse ideas –the first subskill of knowledge advancement. In the Inquiry Lesson B, the Planning and Process and Conclusion parts enabled students to exhibit idea improvement –the second subskill. Moreover, linking the concepts they learned to the new concept they stated in the Planning and Process and Conclusion parts served as venue to demonstrate idea convergence- the third subskill of knowledge advancement. This was exhibited in Learning Cycle 6 when students identified words or ideas related to electron configurations such as number of electrons, atomic models, and quantum numbers. Idea improvement, on the other hand, was observed when students stated that this idea on the electron arrangement involved deeper views on the structure of the atom after performing the electron configuration activity in Learning Cycle 6. Also statements of idea convergence were observed during the Learning Cycle 8 (Periodic Trends) when students were able to explain the existence of the trends in terms of energy levels, electron configurations, as well as the parts of the periodic table.

Conclusions and Recommendations

Based on the findings, the following conclusions are drawn:

The mean posttest score of students exposed to PGI was significantly higher than that of students exposed to CTA in terms of knowledge-building practices.

There was a significant difference between the mean posttest scores of PGI and CTA groups in the knowledge-building practices assessment tool.

Progressive-Guided Inquiry (PGI) teaching approach is effective in improving students' knowledge-building practices (knowledge elaboration, knowledge creation, and knowledge advancement) in Chemistry. It is also effective in improving each knowledge-building practice of the students. The Inquiry Lesson part of the approach allowed students to solve scientific problems which provided a venue for students to share knowledge which they used to elicit more ideas, generate their own concept, and expand and advance these concepts by incorporating what knowledge they acquired before to the new knowledge they encountered.

The following are the recommendations to address unanswered questions or issues in the study. These are presented for future use of different educational stakeholders to help them in advancing the body of knowledge about Progressive-Guided Inquiry (PGI) in the K to 12 curriculum setting:

It is recommended for future researchers to come up with a PGI model for other units in Chemistry and determine if the approach has more positive effects on knowledge-building practices in Chemistry.

The Levels of Inquiry Model of Teaching explains that inquiry is a spectrum. If one would consider the limited time given to cover all the required lessons in the curriculum, it would be impossible to use all levels in the spectrum. With this factor, it is recommended to just choose levels in the model to implement in lessons. As long as the levels chosen are arranged in increasing teacher to student locus of control, the model would still show progression which is the essence of the teaching approach studied.

Based on the results of the study, it is recommended to identify other teaching approaches that would improve the knowledge-building practices of students. Future researchers may consider other collaborative teaching approaches or learning strategies and determine if these could yield better effects on students' knowledge-building practices. In this study, the knowledge-building practices were observed to occur during a group discussion or activity. It is recommended for future researchers to explore the possibility of having group knowledge-building practices.

Moreover, the phenomena of knowledge elaboration, creation, and advancement of Filipino high school Chemistry students are not yet explored. It is recommended that a study be conducted that would explore how these knowledge-building practices are achieved in the DepEd K-12 curriculum.

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