Inquiry-Based Formative Assessment in Grade 10 Electricity and Magnetism

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Abstract— This developmental and descriptive research using pre-experimental design aimed to develop lessons and determine their effects on student learning using inquiry-based formative assessment for Grade 10 Electricity and Magnetism. It focused on the developed lessons using inquiry-based formative assessment to promote student learning in Electricity and Magnetism, concepts on Electricity and Magnetism developed in the inquiry-based formative assessment process, activities designed by the students to verify their concepts and its effects on students' conceptual understanding. The respondents were the forty (40) Grade 10 students at Central Bicol State University of Agriculture – Laboratory High School SY 2017-2018. Qualitative analysis was used on the developed lessons, on developed concepts on electricity and magnetism, and on the activities designed by the students. Gain score and paired t-test were used to compare the pretest and posttest. The result showed that the develop lessons using inquiry-based formative assessment were on Magnet, Principles of Magnetism, Electric and Magnetic Fields, Current-Carrying conductor, Electromagnetic Induction, Faraday's Law of Electromagnetic Induction, Generators and Electric motors with features namely: competency-based, using inquiry-based formative assessment process, promotes open inquiry activities and collaborative learning. Moreover, these lessons are designed to promote student learning through the process of eliciting prior conceptions, brainstorming of concepts, revising of answers, designing activities, presenting activity results, and verifying their revised answers. Also, the students' concepts are developed and students' designing of the different activities provided an avenue to verify their concepts in electricity and magnetism. There were improvements in students' conceptual understanding, science process skills, metacognitive skills showed by the *10.25* mean gains. Therefore, these lessons aligned to K to 12 Science competencies with an inquiry-based formative assessment process, and that could promote open-inquiry activities that can be used as supplementary instructional resources.

Index Terms— Electricity and Magnetism, Formative Assessment, Inquiry-based Instruction, Physics Education

1 Introduction

The 21st century marks a new era in education for it opens myriad of challenges that require the development of scientifically literate citizens in countries worldwide. This is brought about by the fast rate increase in population, limited resources, and sophistication of technologies years after years. The basic literacy in and of science becomes one of the baselines of learning and knowing things, yet the majority of the countries' scientific literacy level is poor based on various international assessments. The new educational environment requires different ways of crafting the learning experiences as well as new approaches to teaching and assessment. This calls for educational reforms that aim to develop students who have a repertoire of competencies important in the world of work and knowledge-based society.

In the Philippines, the government enacted the Republic Act No. 10533 or the Enhanced Basic Education Act of 2013 as the mainstream of the educational system. It is the most comprehensive basic education reform ever done in the country since the establishment of its educational system more than a century ago. Reforms in educational structure, curriculum, and assessment are significant changes under K to 12 programs. This major educational reform is in response to the urgent and critical need to improve the quality of the country's educational system. Its new basic education framework puts science content in spiral progression and is organized around situations and problems that challenge and arouse learners to learn and appreciate science.

The K to 12 Science Curriculum specifically envisions the development of scientifically, technologically, and environmentally literate and productive members of society. It is a reason why science content and science processes are intertwined in this curriculum. As a whole, K to 12 Science Curriculum is a learner-centered and inquiry-based curriculum which recognizes the importance of student's participation in making judgement and constructing explanations. It is a clear manifestation that this curriculum wanted to develop a learner who is capable of critical thinking, innovation, and creativity. These are a high level of cognitive skills that can be developed using the inquiry process. When students are engaged in inquiry-based instruction, activities, and assessment, they tend to be more genuine and authentic in constructing their ideas because they have the chance to express and confirm their concept by designing their scientific investigation.

Furthermore, a formative approach to assessment is a significant part of the curriculum reforms concerning the K to 12 curricula. Classroom assessment is one of the daily tasks of a teacher to determine the level of learning of their students and the effect of their instruction, thus formative assessment is emphasized to ensure learning (K to 12 toolkit, 2012). This is also reflected in DepEd Order No. 8 series of 2015 which provides that formative assessment is given greater emphasis than ever. This DepEd Order highlights why formative assessment must be done by teachers in their teaching process, how it can be integrated in instruction, and what part of the lesson it can be integrated as an integral part of new curriculum implementation.

Assessment is often equated with tests and examination that is given at the end of the lesson but this thinking is mis-

leading (Lloyd-Jones and Bray, 1996). Assessment of student achievement is changing as today's students face a world that demands new knowledge skills and behavior that have not yet defined (Segers, et al. 2003). Assisting students to develop their knowledge, skills, and behavior requires changes in the assessment process that enable students to demonstrate a deep understanding of concepts. The National Science Education Standards acknowledges that inquiries also are used as a means of assessment in such a manner that any boundary between assessment and teaching is lost (p.202). The concept of an inquiry-based formative assessment arises as a modification to strengthen and attune our educational instruction and assessment to the constantly changing environment. It will provide scaffolding for the students to assess their prior understanding of scientific ideas at the same time guides them to learn through scientific inquiry and investigation of scientific concepts and phenomena.

The use of formative assessment anchored on inquiry is a new step that may make a turn-around in the present low academic performance of students evident in the result of the Second International Science Study (SISS), Third International Mathematics and Science Study (TIMSS), National Achievement Test (NAT) and the declining trend for fields such as mathematics, physics, and chemistry illustrated in the number of university graduates of up to 30-50% over the last 8 – 10 years (OECD, 2005). In SISS, the Philippines ranked almost at the bottom of the list of seventeen (17) nations which took part in this evaluation of educational achievement. The same result was revealed in TIMMS in 1995, 1999, and especially in 2003 were Philippines ranked 43rd out of 46 countries in High School II Science; and for grade 4, the Philippines ranked 23rd out of 25 participating countries in both math and science. The result in NAT is similar where the national passing rate for high school students in science was only 46.38% in SY 2009-2010.

As a government institution, Central Bicol State University of Agriculture-Laboratory High School in San Jose Pili, Camarines Sur is a SUC operated secondary high school with more or less 200 junior high school students. Around 50 students took part in the National Achievement Test of the Department of Education every year. CBSUA high school, like other secondary schools in the country, performs low in NAT with a Mean Percentage Score of 38.14% in science during SY 2013-2014. This NAT result is far below the 75% national passing percentage. This shows poor performance of the students in science which may be attributed to varied factors. A necessary intervention like Inquiry-Based Formative Assessment which allows students to be critical, innovative, and creative in reasoning and designing investigation is needed to raise the academic performance of these students in terms of science conceptual understanding, science process skills, and metacognitive skills.

In the context of the foregoing discussions, the researcher deemed it significant to conduct a study on lessons using Inquiry-based Formative Assessment in Physics especially in the topics on Electricity and Magnetism for the Grade 10 Science of Central Bicol State University of Agriculture-Laboratory High School.

Lessons and determine their effects on student learning using inquiry-based formative assessment for Grade 10 Electricity and Magnetism at Central Bicol State University of Agriculture –Laboratory High School.

Specifically, it sought answers to the following sub-problems:

1. What lessons using inquiry-based formative assessment may be developed to promote student learning in electricity and magnetism?
2. What concepts on electricity and magnetism are developed in the inquiry-based formative assessment process?
3. What activities are designed by the students to verify their concepts?
4. What are the effects of the inquiry-based formative assessment on students':
    a. conceptual understanding
    b. Science process skills
    c. Metacognitive skills

2 Methodology

This study used developmental and descriptive research using pre-experimental design. Quantitative data ware gathered as pre-test and post-test results of the teacher made a conceptual test, science process skills test, and metacognitive skills questionnaire. Qualitative data were gathered from the expert's evaluation of the designed inquiry-based formative assessment, the evaluation of the developed lesson with inquiry-based formative assessment, the activity designed by the students, the students' journal, the observers' observation sheet, and the developed concept using the inquiry-based formative assessment process.

Respondents

The respondents of the study were the 40 Grade 10 students of Central Bicol State University of Agriculture – Laboratory High School for the school year 2017-2018. This study was conducted involving the 40 science students of CBSUA High School Main Campus located at San Jose Pili, Camarines Sur. The respondents are among the top 50 of the ranking during the freshmen enrolment period. Two (2) teacher observers were present in the actual class discussions to observe the strong and weak points of the employed intervention. The two teacher observers were the high school coordinator and the Grade 10 science teacher. Likewise, physics education experts were evaluators of the lessons before the implementation.

Research Instruments

Teacher Made Conceptual Test. The researcher constructed a 40 item pretest-posttest on Electricity and Magnetism based on the lesson competency of the grade 10 science. The 40 test items consisted of the following: 7 items under Knowledge Level, 11 items under Comprehension Level, 3 items under Application Level, 15 items under Analysis Level, 2 times Synthesis Level, and 2 items Evaluation Level. The test items were submitted to Physics teachers for content and construct validity.

Science Process Skills Test. The science process skills test devel-

oped by the researcher consists of a 12 item test designed to measure the science process skills of the students which include observing, inferring, classifying, and communicating. The 12-item test consisted of 2 items for Observing, 2 items for Classifying, 4 items for Inferring, and 4 items for Communicating. Table 1 shows the descriptions of the science process skills that are included in this study.

The science process skills test did not measure the absolute science process skills of the students rather, it was used to gauge and determine changes in science process skills generally from the start and end of the implementation of the developed lesson.

Metacognitive Skills Questionnaire. The metacognitive skill questionnaire covers the necessary component of metacognition which is the "knowledge about cognition" and "knowledge about regulation". The metacognitive skill questionnaire was modified from the metacognitive awareness inventory of Schraw, G. & Dennison, R.S. (1994). The metacognitive skills questionnaire does not measure absolute metacognitive skills of the students rather it will be used to gauge and determine changes in the level of awareness of using their metacognitive skills included in the "metacognitive knowledge" and "metacognitive regulation" in performing the task generally from the start and end of the implementation of the inquiry-based formative assessment in each lesson.

Observers' Observation Sheet. This instrument was designed to determine and assess the strength and weaknesses teaching-learning process of the lessons in Electricity and Magnetism with an inquiry-based formative assessment process. The observer is present in the actual delivery of the lesson and writes any observation, comments, and suggestions in the conduct of the teaching process specifically its strong point and its weak points using the Observation Sheet.

Students' Journal. The insights of the students regarding the inquiry-based formative assessment process and the implementation of the developed lesson were written in a journal. The journal was a notebook where students wrote what they have learned from the particular lesson and identified aspects of classroom practice they found helpful in their learning. Guide questions were provided to facilitate the journaling of the students. An orientation on this use of journal was given to the students before the conduct of the study. This journal provided the researcher with in-depth information and insight into the qualitative data of the study.

Development and Validation of the Research Instruments. To establish the content validity and reliability of the instruments used in the study, consultation with the experts was done. These experts were Physics and Science teachers with units in masters, with a Master's degree, with units in Ph. D and with Doctorate who were teaching in the Deped Albay and Camarines Sur, and in State University and Colleges.

Pilot Testing. Before the pilot testing of the teacher-made conceptual test and the science process skills test, these data gathering tools were submitted to jurors for content and construct validity. Suggestions were carefully incorporated in the tests. The two tests were pilot- tested at Nabua National High School involving Grade 10 SOC 1 (Science-oriented Curriculum). Then, item analysis was done to determine the good and the poor items based on the result of the pilot testing. The test papers were arranged from highest to lowest where upper and lower twenty seven percent (27%) were used for item analysis. Frequency counting was used to determine the number of students who got the item right and the frequency-converted to a proportion. The method was used to determine the items to be retained, revised, or rejected for the final set of the tests.

Lesson Plan Evaluation by Jurors. A total of eight lesson plans with concepts anchored on the prescribed two learning competencies for Grade 10 Electricity and Magnetism were developed by the researcher to incorporate the inquiry-based formative assessment process to the teaching process seamlessly. An assessment tool was modified by the researcher from the previously used assessment tool to fit the requirements of an inquiry-based formative assessment. The criteria include the following: Learning Objectives, Learning Content and Activity, and Assessment which was subdivided into (a) Formative and (b) Summative assessment.

Table 1
Experts evaluation of the Developed Lesson

Major Component of the Lesson	Lessons								Overall	Description
	1	2	3	4	5	6	7	8		
Learning Objectives	3.8	3.2	4	4	4	3.4	3.6	4	3.75	Excellent
Learning Content and Activity	3.9	3.5	3.9	3.8	3.9	4	3.9	3.9	3.85	Excellent
Learning Assessment	3.9	3.4	3.9	3.9	3.9	3.9	3.9	4	3.85	Excellent
Mean	3.9	3.4	3.9	3.9	3.9	3.8	3.8	3.9	3.82	Excellent

Statistical Treatment

Mean is the average of a collection of data. Mean difference was used to analyze the data between pretests and posttests.

Weighted Mean also called weighted average, was used to average the 5-point rating scale results of the metacognitive awareness questionnaire.

Gain Score is the analysis of pretests-posttests score difference. This was used to compare the pretest-posttest result of the class.

Paired t-test provides was used to determine the difference between the pretest and posttest result of conceptual understanding, science process skills, and metacognitive skills of the

respondents.

3 Results and Discussion

Lessons using Inquiry-Based Formative Assessment to Promote Student Learning in Electricity and Magnetism

A Lesson plan is a detailed description of the course of instruction for a lesson. The process of lesson development is captured in a lesson plan (Corpuz et.al 2006). Teachers are encouraged to integrate formative assessment practice in lesson development, inquiry-based formative assessment shows potentials to engage students towards learning.

In this study, eight lessons using inquiry-based formative assessment were developed and validated by experts. The validated lessons have the following essential parts: Topic, Learning Competency, Objectives, Concepts, Time Frame, Lesson Proper, and Assignment. The 5Es were the Engage, Explore, Explain, Elaborate, and Evaluate, with an inquiry-based formative assessment on the Engage, Explore, and Explain parts.

Table 2
Matrix of Learning Competencies, Topics and objectives

Learning Competency	Lesson No. and Title	Objectives
Demonstrate the generation of electricity by the movement of a magnet through a coil.	Lesson 1: Magnet	1. Trace the poles and direction of the magnetic field of a permanent magnet using a compass 2. Illustrate the magnetic field lines pattern of a bar magnet 3. Acknowledge that the earth is a big magnet by discussing the orientation of its magnetic field
	Lesson 2: Principles of Magnetism	1. Perform an activity that shows the magnetic field strength of a magnet 2. Discuss that like poles of a magnet repel and unlike poles attract 3. Give an example of a device that uses magnetism as a key factor in generating electricity through a coil
	Lesson 3: Electric Field and Magnetic Field	1. Demonstrate in class that a changing magnetic field in time can produce an electric current in a coil of wire 2. Observe that an electric current in a current-carrying wire produces a magnetic field 3. Acknowledge the ideas of others
	Lesson 4: Current-Carrying Conductor	1. Craft activity to determine the polarity of a current-carrying conductor 2. Describe the direction of the magnetic field produced by a current-carrying conductor 3. Discuss the flow of the current and the orientation of the magnetic field of a current-carrying conductor through the right-hand rule
Explain the operation of a simple electric motor and generator	Lesson 5: Electromagnetic Induction	1. State principle of electromagnetic induction based on their understanding 2. Cite the ways on how to induce a voltage across a conductor 3. Explain why voltage is induced when there is a relative motion between the magnet and the conductor
	Lesson 6: Faraday's Law of Electromagnetic Induction	1. Enumerate the factors that affect the induced voltage in the process of electromagnetic induction 2. Discuss the observations of faraday in his experiment 3. Explain the basis of Michael Faraday in stating the Law in Electromagnetic induction
	Lesson 7: Generators	1. Enumerate the basic parts of a generator and its function 2. Discuss how generators generate electricity 3. Cite the importance that generator plays in the power plant, industries, and homes
	Lesson 8: Electric Motors	1. Enumerate the basic parts of an electric motor and its function 2. Discuss how electric motor works 3. Determine the difference between the electric motor and generator

The topic, learning competency, concepts, and time frame of lessons were adapted from the modules in Learners Manual of the K to 12 curricula. Objectives were formulated consistent and leading to the learning competency target of the lesson.

The eight lessons were taught for (4) four hours per week in 4 weeks. All lessons employed the use of 5E's learning format: Engage, Explore, Explain, Elaborate, and Evaluate. In the Engage part, students' prior knowledge was assessed by writing reasons whether they believe or not in a statement and concept which will undergo a process of brainstorming and revision. In the Explore part, students were grouped to design together an investigation to verify their concepts. In the Explain part, the students report and communicate the findings of their investigations. In this part, the teacher further discusses the concepts to the students. The real-life application of concepts was given in the Elaborate part. The teacher also asks the students to use the concepts learned to understand other related phenomena. The Evaluate part is a form of short assessment given at the end of the lesson. All lessons followed the inquiry-based formative assessment process from the Engage to Explain part however statements assigned in the Eliciting part, Elaboration, and forms of the evaluation were different as discussed below by lesson.

The inquiry-based formative assessment process is composed of three parts in its process of implementation. Part I of the process is eliciting the initial answers from the students. This part consisted of (A) Reading of Statement, (B) Making a Choice, (C) Writing of Reason. The initial answer is based on the choice made by the students and the reason they gave concerning the concept of the statement. Part II is the brainstorming of answers. It consisted of the same sequence in Part I except that it has a collective scientific discussion before the reading of the statement. Part III is verifying because their revised answer will be subjected to verification in the Learning activity write-up which consists of (a) Objectives, (b) Materials, (c) Procedure, (d) Observation, and (e) Conclusion.

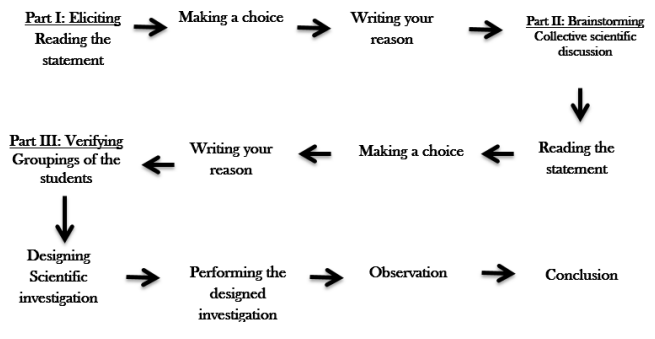

Figure 3 : Flow of the Inquiry-based Formative Assessment process process

In this study, the use of an inquiry-based formative assessment process in the eight lessons is the key feature that promotes student learning in Electricity and Magnetism. It was seamlessly integrated into a lesson using the 5Es learning format. The implementation of the process leads the students to reflect on their prior concepts towards the verification of ideas. The table shows the parts of 5E lessons that cover the formative assessment process together with the corresponding sub-processes.

Part I. Read the Statement. The statement is selected and formulated by the teacher before the instruction. The statement is specific, clear, and focus on relevant concepts that the students will encounter in the lesson. **Make a Choice.** The students will choose whether they agree on the statements or disagree, not sure or it depends. In making their choice, the students need to revisit their previous knowledge about the concept of the statement they read. They need to reflect and rethink their prior conception about the concept of the statement.

Table 5
Part of 5E Lessons Covering Inquiry-based Formative Assessment Process

5E Learning Format covered	Inquiry-Based Formative Assessment Process Parts and Processes	Sub-process
Engage	Part 1 Eliciting	Reading of statement
		Making choice
		Writing reason
	Part 2 Brainstorming	Collective Scientific Discussion
		Reading of statement
		Making choice
		Writing reason
Explore	Part 3 Verifying	Grouping of Student
		Designing Scientific Investigation
		Performing the Procedures
Explain		Observing
		Concluding

Writing of Reason. After the students have decided to choice from the option they will be asked to by the teacher to write their reason/s on by they prefer to answer agree, disagree, not sure or it depends. The students' written reasons both reflect their correct conception and misconceptions. This part is very important to see why the students believe in their preferred choice and assess whether they are grounded to a factual understanding.

Part II. Brainstorming. This part consists of four sub-processes. The first sub-process is the **Collective Scientific Discussion**. Based on the written reasons on the board, the teacher will ask the students which reason they think is not right and misleading and then they will express the reasons. The students may elaborate on their reasons, raise questions,

and reflect on the arguments raised by anyone in the class. The three other sub-processes are as follows: **Read the statement.** Again for the last time, the students will read the same statements on the sheet. **Make a choice**. For the revised answer part, students are still asked to choose whether they still agree, disagree, not sure, or answer it depends on the statements provided. **Writing of the reason.** The students are to write their reason for their revised answers. This reason will be subject to verification in Part III of the inquiry-based formative assessment process.

Part III. Verifying. Groupings of students. The students will be grouped to the "Agree" group, "Disagree" group, "Not sure" group, and "It depends" groups. The teacher must remember to keep the grouping smaller. The students will perform five sub-processes as follows: **(1) Designing the scientific investigation.** In this part, the students in the same group will think of an activity/investigation/experiment that will verify their revised answer. Only one activity per group following the given format consisting of (a) Objective (b) Materials (c) Procedure (d) Observation (e) Conclusion will be designed.
(2) Performing the designed investigation. The students have their choice to choose their preferred materials and ways to perform their investigation. After crafting their activities, students will get their materials and perform their procedures. **(3) Observing.** These are the direct events that are observable in the conduct of the group investigation. **(4) Concluding.** This is the last part of the activity which is the basis for the verification of the revised answers in the inquiry-based formative assessment process.

The inquiry-based formative assessment process assesses before conception and allows students to practice metacognitive thinking before and during the formal discussion. The presence of the statements and options in Part I and Part II of the inquiry-based formative assessment process provides a starting point to revisit their prior understanding and assess how deep they understand a concept. It can encourage students' scientific discussion through the process of defending or challenging scientific arguments that serve as a guide and driving questions to facilitate further understanding of the concept relevant to the lesson. This is important because according to Friesen (2013), guiding questions help focus the inquiry around enabling constraints and allow students to structure their inquiry to demonstrate their understanding of ideas, concepts, and content.

The inquiry-based formative assessment process will also guide the student to learn concepts and assess their learning in a way that it helps solidify their thinking, considering the alternative views of others modify their thinking and assimilated into the students' existing knowledge and beliefs. In this process, students will develop not only metacognitive thinking (Flavell, 1979) but also critical thinking (Martinez, 2006).

Concepts on Electricity and Magnetism Developed in the Inquiry-Based Formative Assessment Process

The use of the inquiry-based formative assessment process in the lessons aims to develop concepts in Electricity and Magnetism. The concept is operationally defined as the alternatives/misconception that the students have about Electricity and Magnetism. The alternatives/misconception serves as a learning gap for students. These alternatives/misconceptions were drawn from the "Initial Answer" of the students in the inquiry-based formative assessment process. This was observed and obtained based on how students give and express their reasons on why they answer "agree", "disagree", "not sure", or answer "it depends" on the statement. The inquiry-based formative assessment process is effective in assessing alternatives/misconceptions and developing these alternatives/misconceptions to a more meaningful and righteous interpretation of a concept or phenomenon.

In Lesson 1, the misconception elicited is that the magnetic field of the compass is the same at the poles so the compass cannot trace the north and south pole of the magnet. The student compared the set up with a "seesaw" that when two objects have the same weight, it will not move and is balanced. He further elaborated that since the magnetic field in the poles is the same; therefore compass will not move and will not point to the poles. This was observed from 36 students who agreed to the statement and reasoned out that when the magnet is brought near the compass, it will always point to the South Pole of the bar magnet. One (1) student who disagreed reasoned out that the compass cannot trace the poles of a bar magnet because both poles have the same magnetic field strength due to the circulation of the magnetic field forming a loop and three (3) students answered "not sure" reasoned out that they are not sure that using a compass can trace the poles of the bar magnet because they did not see an experiment before.

In their brainstorming, this misconception was contested by one of his classmates who argued that the analogy on a seesaw is not applicable to explain the concept of the statement. However, on their revised answer, the same student still believed his initial answer. The observations on their designed activity verified that the compass needle responded to the magnetic field of the bar magnet which runs from north to south, therefore poles can be traced.

In Lesson 2, the misconception elicited is on the understanding that the magnetic field is stronger at the part of the magnet where the two poles meet specifically at the middle where the North and South Pole is nearer. This was noted when the two (2) students who agree to the statement and reasoned out that the magnetic field of a bar magnet is stronger in the middle because the part of the North Pole and the South Pole is nearer at the middle.

In the brainstorming, one student contested that it would be stronger because the two poles are located and the magnetic field would be more focused in the middle part because North and South Pole combined its magnetic field. It is evident that after the brainstorming, most of the students' understanding

of the concept started to shift. This was noted when the student argued that the magnetic field of the bar magnet in the middle becomes weaker instead of becoming stronger because the two decision of the magnet are joined together and just become a body of the bar magnet, and another student raised that even if the magnetic field is distributed properly, the magnetic field ends tend to be stronger at the end because they are compressed or concentrated at the poles. This was coupled withdrawing. □

Table 4
Misconceptions of the Students

Lesson	Statement	Inquiry-based Formative Assessment Process		
		Eliciting	Brainstorming◎	Verifying
Lesson 1: Magnet	The poles of a bar magnet can be traced using a compass	The compass cannot trace the poles of a bar magnet because both poles have the same magnetic field strength	The poles have the same magnetic field strength, the compass cannot trace the poles of a bar magnet because the arrow will not know where to point.	No observed misconception
Lesson 2: Principles of Magnetism	The magnetic field of a bar magnet is stronger at the middle than at the ends	The magnetic field of a bar magnet is stronger in the middle because the part of the North Pole and the South Pole is nearer in the middle.◎	The middle of the magnet is stronger because it has a North and South Pole.◎	No observed misconception
Lesson 3: Electric field and magnetic field	The magnetic field of a magnet can produce an electric current in a wire◎	No observed misconception	No observed misconception	No observed misconception
Lesson 4: Current-Carrying Conductor	The magnetic field of a current-carrying wire surrounds the wire perpendicular to the direction of the flow of current	The orientation of the magnetic field around the current-carrying conductor depends on the position of the wire.	No observed misconception	No observed misconception
Lesson 5: Electromagnetic Induction	We cannot light a LED bulb by just using a magnet and a wire	A Led bulb cannot be lit by a magnet and wire; there is no electricity flowing on it. A battery (voltage source) is always needed to light a LED bulb.	A voltage source is always needed like the battery is light a LED bulb.◎	No observed misconception
Lesson 6: Faraday's law of electromagnetic induction◎	Moving the magnet faster near a conductor will increase the induced voltage	Moving the magnet faster will not increase the voltage induced because the number of the electron in the conductor is not changed and the magnetic field strength is the same so the voltage that will be produced would be the same.	Moving the magnet faster will not increase the voltage induced in the wire.	No observed misconception
Lesson 7: Generator	A generator converts mechanical energy to electrical energy	The energy conversion in generator depends on its type and is not always electrical to mechanical energy	No observed misconception	No observed misconception
Lesson 8: Electric Motor	An electric motor converts electrical energy to mechanical energy	No observed misconception	No observed misconception	No observed misconception

On the lesson on Electric field and Magnetic Field, the concepts elicited were: (1) Just like the generator, it has a magnetic field where the coil of wire rotates to produce electricity. Without a magnetic field there will be no electricity, and (2) There is a need for an applied force to produce electricity not just the presence of magnetic field and wire but also an ap-

plied force. These concepts were gathered when students made their choice and write their reasons. Sixteen (16) students who agreed to the statement reasoned out that just like the generator, it has a magnetic field where the coil of wire rotates, to produce electricity; without a magnetic field, there will be no electricity. They argue that the magnetic field supply the force needed to move the free electrons in the atoms a conductor. The 21 students who answered "not sure" reasoned out that they have not tried activity in line with the statement and that they do not know yet what to answer. Three (3) students who answered 'it depends" reasoned out that there is a need for an applied force to produce electricity not just the presence of magnetic field and wire but also an applied force like force applied in rotating the armature of the generators. It can be noted from the table that there was no observed misconception among the students during this lesson based on their initial answers. This can be explained by their correct responses and the limited answers that can not make a reason/point like "I have no idea about it', "I do not know yet if what is the answer" which the researcher cannot quantify to correct conception or misconception.

In the brainstorming, the expressed concept was elaborated when one student raised that magnetic field alone cannot produce electric current because there is a need for the movement of a coil relative to the magnetic field, and even if they have not tried the activity yet, they observed this in their surroundings. The students gave an example of a scenario that according to them after typhoon usually there is no supply of electricity, however home and store owners still have electricity because they use a generator which has a coil and magnet, therefore there is the production of electricity in the use of generators. The concepts were verified by the observation of the students' designed activities.

In Lesson 4, the misconception elicited from the student is that the orientation of the magnetic field of a bar magnet depends on the position of the wire and the flow of the current. This was assessed in the initial answer of the students specifically when twenty-eight (28) students who agreed to the statement reasoned out that the current-carrying wire attracts metals at any part of the wire not just at the ends, eleven (11) students who answered "not sure" reasoned out that they have no idea about it but according to what they read, the magnetic field can not be parallel to the flow of the current, and one (1) student who answered 'it depends" reasoned out that it depends to the positioning of the wire.

The students' misconception deals with the orientation of a magnetic field of a current-carrying conductor when it is wrapped in a metal or when it is coiled not just a straight current-carrying conductor. It was observed that after the brainstorming, the revised answer of the students was changed when one discussed that the magnetic field in a current-carrying conductor surrounds the wire perpendicular to the flow of current associated with the illustration of the right-hand rule. This student discussion happened after one (1) student said that the current-carrying conductor may produce a magnetic field but the orientation of the magnetic field that surrounds it depends if the conductor is coiled or wrapped on something if it is just straight and if the flow of the current is reversed. One student argued that whatever the position of the wire or direction of the current, the magnetic field will surround the current-carrying conductor at 90 degrees to the flow of the current. This concept was verified in the result of their investigation when the compass needle placed parallel below the conductor deflected when electricity flows and by the distribution of the iron fillings around the current-carrying conductor.

The misconception elicited in Lesson 5 is the presence of a voltage source like the battery is always needed to light a LED Bulb and magnet and wire cannot light a LED bulb. The brainstorming of the students focused on the concept shared by one of the students that magnet and wire can produce electricity to light the LED bulb but the magnetic field of the magnet must continuously pass on the wire. Another student said that if the magnet is weak it would not be enough to light the LED bulb and added that the wire used must be longer and coiled properly. However, in the revised answer, one student still does not believe that motion of magnet and wire can light a LED bulb. In the observation and conclusion of their own designed investigation, the students verified that an LED bulb could be lit up and there is just a need for relative motion between the coil and the wire to induce a current.

In Lesson 6, the students' misconception elicited is that the rates of change of the magnetic field around the conductor will affect the induced voltage. The student with misconception thinks that since the number of electrons present in the conductor and the strength of the magnetic field that will be changing in time is constant, therefore the voltage that may be induced will be constant even if the movement of a magnetic field near the conductor becomes fast. This was heavily argued by her classmate who said that even if the length of the conductor and magnetic field strength is not changed, the faster movement of a magnet near a conductor would still generate greater voltage than a slower one. Another student argued that whatever kind of magnet is used, moving this magnet at a faster rate will always result in a higher induced voltage than the slower rate of movement. In the final answer, she said that she was confused about what her classmates reasoned out so she wanted to perform an activity to know the right answer. Since this student is alone in choosing "not sure", she crafted her activity to verify her concept. She observed that when the coil moves slowly near the magnet the LED bulb will not light however until it is moving faster the LED bulb light up. She verified that it produced a higher voltage when the magnetic field changed faster than a slower rate of change.

The energy conversion in the generator depends on its type and is not always electrical to mechanical energy is the students' misconception elicited in Part I of the process. The misconception was noted when thirty-six (36) students who agreed to the statement reasoned out that the motion of the

coil inside the generator is a form of mechanical energy and the current produced is a form of electrical energy therefore the mechanical energy is converted to electrical energy. Only one (1) student who answered "not sure" reasoned out that he doesn't have a generator so he does not know if it counts mechanical energy to electrical energy. The 3 students who answered 'it depends" reasoned out that it depends on the type of Generator. In the brainstorming, the students' misconception was eliminated. This may be associated with the argument of one student who said and elaborated that, it may be true that the generator may start from a lot of energy sources, however, the center of the process in the generator is the conversion of mechanical energy to electrical energy. This concept was verified by the students in their investigations.

The concepts elicited from the students in Lesson 8 were that the electric motor of the electric fan makes use of electricity then converts it to mechanical motion of the blade of the fan and it may turn into another form of energy like into an electric fan, wind energy is produced. In this lesson, as in lesson 3, there was no assessed misconception in Lesson 8. Again, the students' answers reflect responses that were inadequate to make a point that cannot be considered misconceptions like "I don't know yet what an electric motor is". It can be noted that after the brainstorming, such responses were eliminated.

The development of the concept through the inquiry-based formative assessment process was supported by the observation of the teacher observers on the actual implementation of the lesson that it allows the student to think beyond ideas and answer to the statement, and gives opportunity to raise their ideas. The journal entry of the students also signifies that the inquiry-based formative assessment process helped them to better learn the concept.

They said that they find the use of the inquiry-based formative assessment process useful in learning the topic and assessing their learning progress. Constructivist stresses that the learners are active constructors of knowledge in which they construct new ideas or concepts based on their current/past knowledge/experiences rather than just a passive receiver of information. Also, the students were given time to reflect, assess, and evaluate their learning that leads to the development of concepts supported by Metacognition (Flavell, 1976) which involves active control over the cognitive process engaged in learning. Moreover, the dynamic assessment was used in this study to measure a relative change in cognitive performance with the help and instruction of more experienced individual and recognize the importance of providing students with enough support in the initial stages of learning new subject which was emphasized by the sociocultural theory of Lev Vygotsky (1978).

Activities Designed by Students to Verify Concepts

The goal of the present science education reform was to develop students who are capable of critical thinking, reasoning, and problem-solving. This requires instruction that allows students to think, reflect, judge, reason out, and prove scientific knowledge claims. Allowing the students to design a learning activity to verify the scientific claim is one way to practice this which was observed in this study.

According to Banchi and Bell (2008), most students need extensive practice to develop their inquiry abilities and understanding to a point where they can conduct their investigation from start to finish. In this study, the students designed their activities to verify their answers. In designing the activity, the students were grouped first according to the following choice: "agree", "disagree", "not sure" or "it depends". Students of the same choice will form the same group. Groups with a large number were still divided to form a smaller group. A total of 19 different activities were designed by the students to verify their concepts in the eight lessons in Electricity and Magnetism. In some of these lessons, the students arrived at the same design of activities.

Part III of the inquiry-based formative assessment process allowed the students to be critical in thinking and be authentic in their activities by designing their scientific investigation. This was related to the statement of WNCP (2011) which argued that students' tasks must have "an authenticity" that the work [activities] being taught. In all the designed activities, the availability of the materials in the learning environment was needed. It is the key to the verification of the concept in the inquiry-based formative assessment process. This part of the inquiry-based formative assessment process promoted the higher-order thinking skills because it is grounded on the highest form of inquiry – open inquiry, where students need to think of their objectives, materials, procedures to perform an activity, write their observation and draft their conclusions which are highlighted by Banchi and Bell (2008) that in this inquiry level, students have the purest opportunities to act like scientists, deriving questions, designing and carrying out investigations and communicating their results.

However, the role of the teacher is very important in how the groups of students could property design the experiment. The teacher must guide the students to design logical procedures of their activities and arrived at the right interpretation of the result. This adheres to the statement of Banchi and Bell (2008) that "just because students are designing their procedures does not mean that the teacher´s role is passive. On the contrary, students need guidance as to whether their investigation plans make sense".

Effects of the Inquiry-Based Formative Assessment

The effects of the inquiry-based formative assessment on students' conceptual understanding, science process skills, and metacognitive skills were evaluated quantitatively using the results of pre-test – post-test on Teacher-made Conceptual Test, Science Process Skills Test and Metacognitive Awareness Questioner, and qualitatively using results of written outputs and journals. The results of the tests were interpreted using the mastery level descriptive equivalence adopted from the DepEd Memorandum No. 8, s. 2015 as follows: 74 and below = Did Not Meet Expectation, 75-79 = Fairly Satisfactory, 80-84 = Satisfactory, 85-89 = Very Satisfactory and 90-100 =Outstanding.

Table 14
Activities designed by students to verify their concepts

Topic	Materials	Procedure
Magnet	Compass, Magnet	1. Try to point the North Pole of the magnet to the compass. 2. Try to point the South Pole of the magnet to the compass then observe. 1. Place the magnet beside the compass. 2. Observe if the compass reacts to the magnetic field.
Principles of Magnetism	Magnet Iron Fillings	1. Put the iron fillings/sand on the table or paper. 2. Let the magnet and put it near the iron fillings/sand. 3. Let the sand/iron fillings attract to the magnet.
	2 Magnets	1. Get the two magnets and face them to each other. 2. Observe the interaction of the two magnets.
	Magnet, A piece of metal	1. Try putting the metal at the end pole of the magnet. 2. Try putting in the middle.
	Magnet Paper, Sand	1. Put the magnet under a sheet of paper. 2. Now put the sand on the paper then observe the distribution of the sand.
	Circular shaped &U-shaped Magnet, Iron fillings	1. Put the circular shaped magnet near the iron filings 2. Then put also the U-shaped magnet in an iron fillings 3. Observe the distribution of the iron fillings.
Electric field and Magnetic Field	2 Dynamo LED light Battery	1. Connect 1 dynamo to the LED bulb and the other dynamo to the battery. 2. Face the two dynamos and let the dynamo with LED bulb spin as the dynamo connected to the battery spin.
Current-Carrying Conductor	Wire, Battery, Nail, Paper, Iron fillings	1. Put the paper in the working area. Make a small hole in the paper and put the wire inside the hole. Pour the iron fillings around the nail. 2. Observe the distribution of the iron fillings around the nail.
	Wire, Nail, Battery, Compass	1. First, wrap around the copper wire to the nail. 2. Then, connect the copper wire to the battery. 3. Place the compass nail near the current-carrying conductor. 4. Observe the deflection of the compass needle.
Electromagnetic Induction	Dynamo, LED bulb, Wire	1. Connect the wire in dynamo which has a magnet inside to the LED bulb, exert some force to do some mechanical movement.
	LED bulb, Magnet, Wire, Dynamo	1. Use a normal magnet and connect it to the bulb. 2. Use a dynamo connected to the LED bulb. Rotate the spinner of the dynamo and observe. Compare the set-up.
Faradays Law of Electromagnetic Induction	Voltage Tester Coil, Magnet	1. Connect multimeter (set to measure voltage) light bulb and coil. 2. Move the magnet inside the coil fast and slow then observe the bulb.
	Coil LED bulb Magnet	1. Get the coil and the LED bulb. 2. Place the magnet near the coil and move slowly to the magnet. 3. Then try moving the magnet faster near the coil. 4. Observe what will happen to the LED bulb.
	2 Dynamo Battery LED bulb	1. Connect the two dynamos (the dynamo powered by a battery and the dynamo connect to the LED bulb) to spin continuously. 2. Spin the dynamo connected to LED light by your hand. 3. Compare the brightness of the bulb.
Generator	Nail Spinning wheel Wire Magnet	1. Wrap the wire around the nail. 2. Attach the magnet to the spinning wheel. 3. Connect the ends of the wire to the galvanometer (multimeter was used set to measure voltage) then spin the spinning wheel.
	2 Dynamo 1 Battery 1 LED bulb	1. Connect the LED bulb to the first dynamo. 2. Then, connect the other dynamo to the battery. 3. Face the two dynamos to each other.
	Dynamo Bulb	1. Connect the dynamo and bulb. 2. Exert force by moving the dynamo by your bare hands. See whether the LED bulb lights.
Electric Motor	Dynamo, Battery Wire	1. Connect the dynamo and battery using wire. 2. Observe if the dynamo's wheel outside is moving or not.

The conceptual understanding was operationally defined as the ability of students to understand the physics concept which was determined based on the students' gain result of the post-test over pre-test in the teacher-made test. The table shows the mean gain of the class per competency for conceptual understanding.

In the pre-test, the mean score of the students is 16.03 with 40.08 performance level which is interpreted as "Did Not Meet Expectation" of the students; however, the post-test result showed a mean score of 26.28 with 65.7 performance level which is interpreted as the students are "Did Not Meet Expectation". This result is equivalent to *a 10.25* mean gain and corresponds to a *25.63* increase in the performance level (PL). The paired t-test result showed that this increase is significant. The test has df = 39, alpha value of 0.05, one-tailed, and critical value of -1.686. The t-value computed is -13.52 which is lower than the critical value, therefore, the researcher rejects the null hypothesis.

Table 15
Performance in the Conceptual Understanding Test

Learning Competency	No. of Item	Pre Test		Post Test		Gain	
		Mean score	PL (%)	Mean score	PL (%)	Mean score	PL(%)
Demonstrate the generation of electricity by the movement of a magnet through a coil.	20	8.63	43.15	13.18	65.9	4.55	22.75
Explain the operation of a simple electric motor and generator.	20	7.4	37	13.1	65.5	5.7	28.5
Total	**40**	**16.03**	**40.08**	**26.28**	**65.7**	**10.25**	**25.63**

a = 0.05; critical value = -1.686; t-value = -13.52

This suggests that the difference between the results of the pretest and posttest is significant. This was supported by the students' 3rd quarterly examination results where the students have 80 percent of mastery level which is interpreted as "satisfactory".

It can be observed that the competency on explaining the operation of electric motor and generator which has the lowest mean score result in the pre-test had the highest mean score gained in the post-test. This can be associated with the intervention which allowed the students to express and explain concepts on electricity and magnetism based on how they understood them. This suggests that when students are allowed to practice tasks like explaining reasons, observing investigations, reporting of findings which they are hesitant, the students can be familiarized with the task and be able to perform excellently.

Science Process Skills are building blocks of critical thinking and inquiry in science (Ostlund, 1992). According to Padilla (1990), science process skills are a set of broadly transferable abilities.

To determine the effects of the inquiry-based formative assessment on the selected science process skills, the science process skills test was used which was administered before and after the conduct of the lessons. In the pre-test, the mean score of the students is 5.5 with 45.75 performance level which is interpreted as "Did Not Meet Expectation" of the students; however, the post-test result showed a mean score of 9.3 with 77.5 performance level which is interpreted as the students are "Fairly Satisfactory". This result is equivalent to *a 3.8* mean gain and corresponds to a *30.75* increase in the performance level (PL). The test has df = 39, alpha value of 0.05, one-tailed, and critical value of -1.686. The t-value computed is -4.668 which is lower than the critical value, therefore, the researcher rejects the null hypothesis. This suggests that the difference between the results of the pretest and posttest is significant.

The results indicate that the all science process skills of the students were improved. The improvement of all the science process skills was associated with the implementation of the inquiry-based formative assessment process especially on the Explore part when the students design their investigation, perform the procedures of their designed activities, sort the materials needed, infer the activity results, observe the interaction of the materials used, and communicate the results of the investigation with their classmates. Moreover, writing of their reasons for believing their concepts and the collective group discussion where they defend their choice, and raise arguments and questions are part of developing communication skills.

Table 11 shows the mean gain of the class per science process skills.

Table 16
Performance in the Science Process Skills Test

Process Skills	No. of Items	Pre-test			Post-Test		
		Mean Score	PL (%)	Interpretation	Mean Score	PL (%)	Interpretation
Observing	2	0.9	45	*Did Not Meet Expectation*	1.5	75	*Fairly Satisfactory*
Classifying	2	1.1	55	*Did Not Meet Expectation*	1.6	80	*Satisfactory*
Inferring	4	1.8	40	*Did Not Meet Expectation*	3.0	75	*Fairly Satisfactory*
Communicating	4	1.7	43	*Did Not Meet Expectation*	3.2	80	*Satisfactory*
Total:	**12**	**5.5**	**45.75**	*Did Not Meet Expectation*	**9.3**	**77.5**	*Fairly Satisfactory*

a = 0.05; critical value = -1.686; t-value = -13.52

Classifying is the least improved skills with 0.5 mean gain that is equivalent to a 25 percent gain. It can be deduced that even the process skill was improved, the students found difficulty in looking for relationships between what is happening and observable. This was observed by the researcher in the implementation of the eight developed

lessons where one of the groups had difficulty sorting ideas in their investigation to verify their concept. The most developed skill is "Communicating" with a mean gain of 1.5 equivalent to 38 percent gain. This skill included constructing and using written reports to transmit information learned from a science experiment or investigation. The increase in the mean score can be associated with the daily expression of students on why they believe in their concepts and reporting their findings to the class.

Metacognitive Skills

In this study, it refers to the level of metacognitive skills in the in performing the task in the inquiry-based formative assessment process. These skills were determined using the pretest and post-test results of the metacognitive skills questionnaire. Table 12 shows the metacognitive skills of Grade 10 students based on the metacognitive skill questionnaire.

Table 17
Metacognitive skills of Grade 10 students

	Pre-Test		Post-Test	
	Mean	Interpretation	Mean	Interpretation
Metacognitive Skills	3.42	Average	4.01	Moderately High

The results reflect that before the implementation of the inquiry-based formative assessment, the least practiced specific metacognitive skills of the students were drawing pictures or diagrams that help to understand concepts while learning with a mean score of 2.55 which is interpreted as "Average", and the most practiced specific metacognitive skills were stopping and rereading when they get confused with a mean score of 3.96 and interpreted as "Moderately High".

After the implementation of the inquiry-based formative assessment process in each lesson, the posttest results show that the students' the lowest mean score was drawing pictures or diagrams to help the student understand while learning which is 3.10 and interpreted as "Average"; however, the highest mean score is 4.60 where students learn best when they know something about the topic and interpreted as "High".

The table further shows that the metacognitive skills of the students had improved. In the pre-test, the students have a mean score of 3.42 in the metacognitive skills which is interpreted as "Average", and a mean score of 4.01 in the posttest interpreted as "Moderately". The test has a 0.59 mean gain. The test has df=39, alpha value of 0.05, one-tailed and critical value of –

1.686. The t-value computed is -0.48 which is lower than the critical value, therefore, the researcher rejects the null hypothesis. This suggests that the difference between the results of the pretest and posttest is significant. This implies that the inquiry-based formative assessment process which allows the students to think whether they will agree or not to the statement, letting them reflect on the arguments raised by their classmates, allowing them to think on how they may prove their argument, promotes metacognition as argued by Flavell (1979) that metacognitive experiences that allow one to monitor and regulate one's cognition plays a major role in the development and refinement of metacognitive knowledge.

4 Conclusion

Based on the findings, the following conclusions were made. The lessons aligned to K to 12 Science competencies with an inquiry-based formative assessment process, and that could promote open-inquiry activities can be used as supplementary instructional resources for science teachers. The Grade 10 stu-

dents' concepts on Electricity and Magnetism are developed by the inquiry-based formative assessment process; The different activities designed by the Grade 10 students provided them an avenue to verify their concepts in Electricity and Magnetism; and the lessons using inquiry-based formative assessment are effective instructional tools in improving the conceptual understanding, science process skills, and metacognitive skills of the Grade 10 students.

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