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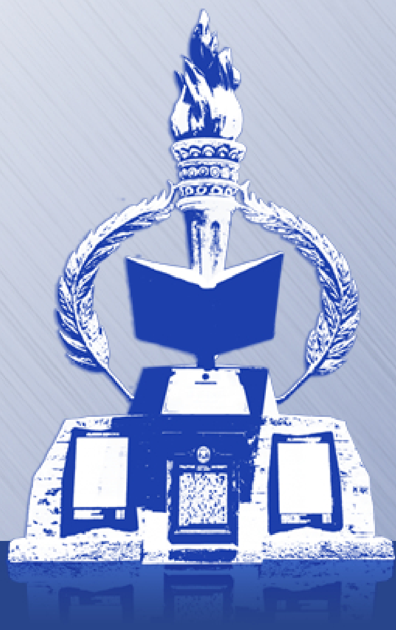
# Effects of Modified Historical Reconstructionist Teaching Approach on Students' Conceptual Understanding and Reasoning Pattern in Electromagnetic Induction

Michelle Z. Yakit
*Philippine Normal University*



# Effects of Modified Historical Reconstructionist Teaching Approach on Students' Conceptual Understanding and Reasoning Pattern in Electromagnetic Induction

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**Master of Arts in Science in Education**

**with Specialization in Physics**

**Michelle Z. Yakit**

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## ABSTRACT

**Name**: Michelle Z. Yakit

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The encountered difficulties in the teaching-learning of Physics topics have been the driving force of this study. Several chanced upon difficulties include the mathematical nature of a topic and the complex natures of a physical phenomenon, such as the interweaving concepts of electricity and magnetism in electromagnetic induction.

Numerous methods have been carried out to assist both teachers and students in managing these difficulties. One of these methods is the use of historical reconstruction approach. The modified version entails the use of some experiments from the past that can be recreated using available materials to experience and to visualize what seemed to be the suppositional nature of electromagnetic induction.

Encouraged by the other studies, this research has determined the effects of the Modified Historical Reconstructionist Teaching Approach (MHRTA) to students' conceptual understanding and reasoning patterns in electromagnetic induction. Specifically, this study aims to determine: (1) if there is a significant difference in the students' pretest and posttest scores on the conceptual survey in electromagnetic induction (CSEI) between the two matched groups; (2) if there is a significant difference between the posttest scores on the conceptual survey in electromagnetic induction between the two matched groups and; (3) if there is a significant difference in the reasoning patterns on the reasoning pattern survey in electromagnetic induction (RPSEI) between the two matched groups.

The matched subjects pretest posttest design was used. The students were matched and the control group is comprised of 27 students and the experimental group contained 25 students. The participants were Grade 10 students of Makati Science High School.

To identify the effect on the conceptual understanding of each approach, the t-test for matched samples at 0.05 level of significance between the pre and the posttest scores on the CSEI were determined. The achieved p-values for the control and the experimental groups were 3.38E-12 and 1.1E-13, respectively. This implies that both groups gained conceptual understanding. The same test was done to determine the difference between the posttest scores on the CSEI of the two groups and the obtained p-value is 0.20. The p-value attained at 0.05 level of significance using ANCOVA is 0.40. These values indicate no significant difference between the groups' posttest scores on the CSEI. However, further analysis on the posttest scores on the CSEI based on the objectives of the test revealed a p-value of 0.01 for items that aim to measure the students' ability to recognize how changes in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or by a magnetic substance. This indicates the strength of the MHRTA in emphasizing variables supporting the existence of and explaining the nature of electromagnetic induction. The responses in the RPSEI were scrutinized. The type of reasoning used per task was identified and coded as inductive a (ia), inductive b (ib), inductive c (ic), deductive a (da), and deductive b (db). The overall frequency reveals that majority of the students used inductive reasoning. This may be due to the fact that the participants were Science high school students. Based on the results, the MHRTA has been proven effective in promoting conceptual understanding of electromagnetic induction.

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## Background of the Study

Physics is perceived to be a challenging area because of its abstract nature. Most of the subject's conceptions, such as 'force' and 'electromagnetic field', discuss units and processes that are cultured by understanding intricate problem situations, where a certain law can be applied and in which numerous concepts can be used (Maloney et al., 2000; Richards, 2010). However, very few students learn the subject adequately well from textbook representations and relating "canned" experiments (Nersessian, 2003).

Pivotal works by physics education research groups across the world have produced better considerations of the cognitive aspects of teaching-learning physics (Jolly, 2010). A study conducted by Maloney, et al., (2000) explained that students have shown less familiarity with concepts that were less concrete and have little noticeable evidence supporting its existence, particularly the electromagnetic phenomenon. It is a topic comprising multiple interconnected abstract concepts that are time varying, three dimensional, extensively mathematical, and requires physical or intuitive models (Richards, 2010; Chetty et al., 2003).

Due to the observed difficulties, several efforts have been made to improve the students' conceptual understanding on electromagnetic induction, including the use of computer assisted instruction. Dori and Belcher (2005) used media-enhanced software for simulating and picturing that which was carried out in a specifically restructured classroom to facilitate group interaction. These materials were particularly useful in electromagnetism. It was able to assist students conceptualize the phenomena and the processes. As a result, the students' conceptual understanding was significantly higher on the subject matter than those in the passive lecture or recitation format. Anderson and Barnett (2013) suggested the use of a digital game simulation to facilitate the learning of basic electromagnetism with middle school students. This showed that "video games" can also lead to higher test scores than through the traditional inquiry-based learning. Hargunani also (2010) showed that teaching Lenz's and Faraday's 'electromagnetic induction concepts using "java-based lab simulations" improved students' test scores achievement, and the simulations made it possible for the students to understand the experiments easily without any risk.

Despite their potential, the instructional effectiveness of computer simulations has yielded inconsistent results. Computer simulations only provide a limited utility as substitutes for actual laboratories with the increased risk that students will perceive taking responsibility for their own learning inessential (Bryan, 2006). The potential of computer simulations via virtual laboratories outperforming and replacing traditional laboratory works be contingent on the nature of the presented material. Moreover, these simulations are not enough to promote learning as they limit the students' freedom to explore (Rutten et al., 2012). Therefore, a restraint remains that while simulations are exceptionally useful pedagogical tools, these simulations are not experiments.

Unlike simulations, experiments are avenues for exchange of meaningful claims and arguments based on facts and evidence. The scientific experiments in the discovery of electromagnetic induction - the dialogues among the scientists, their past experiments, errors in observations, and the complications they encountered in developing and proving an idea or the existence of the phenomenon, may be valuable tools in promoting conceptual change in electromagnetic induction (Heering, 2009; Chang, 2010; Klasseset al., 2009; Niaz, 2010; Besson, 2013; Teixeira, 2012; Mantyla 2012; and Cavicchi, 2006, 2008, 2011). Tying the history and philosophy of science (HPS) in the methods of experimentation may promote conceptual change since the students participate in the teaching-learning process. This would allow students to explore recreated historical models and experiments to form better understanding of electromagnetic induction (Mantyla, 2012).

In another way, knowing how scientists have dealt with scientific investigations and difficulties accompanying these investigations can be focal starting points in designing instruction that would engage students in scientific practice and reasoning. Lawson (2008) discussed that determining how scientists draw, argue, reason out, and explain scientific conclusions is a vital component of scientific literacy, which is a fundamental goal of science education. McNeill (2007) agreed that by successfully engaging students in scientific inquiry process, the assembly of scientific arguments to explain phenomena where students can justify their claims using evidence and reasoning, could result to learning gains. Li (2012) defined reasoning as "the ability to analyze information and to solve problems on a complex, thought-based level." Scientific reasoning may likewise be defined as "a representation of the cognitive skills necessary to understand and to evaluate scientific information or the inclusion of thinking and reasoning skills involved in inquiry, experimentation, evidence evaluation, inference, and argumentation that support the formation and modification of concepts and theories (Bao, 2009)."

Engaging and supporting students in: (1) concretizing such ideas in constructing explanations with evidence following the structure of scientific argument, (2) expressing these understanding, and (3) encouraging others of these explanations, will enable students to openly connect the evidence with their "knowledge claims" and promote learning gains (Berland, 2007). Just like observing the reasoning pattern of scientists as they try to explain a scientific phenomenon where it was observed that they had constructed and used models to remove noisy details that distract understanding and to string together to reason qualitatively about more complex processes (Heuvelen, 1991). Considering this reasoning pattern and reconstructing the models that they have used may allow students to explore the nature of a scientific phenomenon because transmission of information via lectures and "cookbook" laboratory exercises does not nurture conceptual understanding or scientific reasoning (Handelsman et al., 2004).

Conceptual or quantitative, designing instructions with a systematic approach that neither focuses on nor removes the mathematical or quantitative aspects of the phenomenon is essential in learning physics concepts, especially electromagnetic induction phenomenon deeply (Li, 2012). Engaging students with reconstructed experiments to give meaning to the quantitative aspects of the phenomenon is an essential part of HPS. Richards (2010) also argued that given the abstract nature of electromagnetic induction (EMI), knowledge construction must include qualitative reasoning in addition to symbolic and mathematical representations.

Based on the gathered studies, the integration of historical reconstruction in teaching EMI has been observed in Germany and Argentina (Teixeira et al., 2012), and minimal number of studies were observed yet in the Philippines which may be due to teachers choosing computer-assisted instructions in teaching EMI. However, in a developing country like the Philippines, this may not be largely the reason. Okabe (2014) discussed that even if the Philippine government has begun or has planned to supply the teaching resources, they still appear to be insufficient due to the considerably high number required to fulfill the goals of K-12. Durban and Catalan (2012) pointed out that the Philippine educational system does not receive much budget from the government resulting in limited and poor facilities. According to Marcial (2012), higher education institutions (HEIs) prioritize teaching and learning with technology but at a moderate level of implementation since there are some faculty members who are resistant to technology integration in the teaching-learning process. Though meaningfully integrating technology enhances students' understanding of science concepts (Morales, 2014), a fact remains that such technology is not accessible to all educational institutions. Such limitations must be considered by teachers, curriculum planners, and administrators. This should also be considered an opportunity for educators to find teaching approaches that can be effective despite the lack of technology.

With the aforementioned studies and limitations, this study explored a possible alternative to teaching EMI. It is dedicated on determining the effect of the modified historical reconstruction teaching approach (MHRTA) on student's conceptual understanding of electromagnetic induction. The approach is focused on the historical reasoning, argument patterns, and experimental procedures performed by Oersted, Ampere, Faraday, and Lenz using local school setting, method, and materials. MHRTA will be implemented to Grade 10 students and will be utilized parallel to the set competencies of K-12 Science Curriculum. MHRTA is a systematic approach of presenting the scientific concepts by providing pieces of evidence supporting the phenomenon, as well as the complications encountered by scientists, together with the mathematical aspects of the phenomenon to provide robust understanding. This approach can provide educators an alternative to teaching EMI despite the lack of technological tools in the classroom. This study also aimed to promote scientific inquiry and reasoning among students. Due to the dearth of studies conducted explaining student reasoning pattern together with the implementation of historical reconstruction interaction in physics classroom, this study probed student reasoning pattern in learning the concepts of EMI.

**Literature Review**

This section explores pertinent literature and related studies about students' difficulties in learning electromagnetic induction, different instructional approaches addressing these difficulties, particularly on developing conceptual understanding, significance of HPS in physics teaching to improve students' conceptual understanding, and students' reasoning pattern as they gain conceptual understanding of the topic.

Students' Difficulties in Electromagnetic Induction

An assembly of reasons shows why students perceive electromagnetic induction as a difficult topic. Maloney (2000) used the "Conceptual Survey in Electricity and Magnetism (CSEM)" to assess students' conceptual knowledge in "electricity and magnetism." CSEM is a wide-ranging tool that investigates students' understanding of "electric charge and force, electric potential, electric and magnetic fields, electric and magnetic forces, and Newton's laws in electromagnetic context (Leppavirta, 2010)." Analyzing their answers on the CSEM, students showed confusion in the directions and effects of electric and magnetic forces. Moreover, students have shown more familiarity with mechanics than electric and magnetic phenomena because it has more concrete and noticeable evidence supporting its existence. This shows that students become more familiar with ideas through recognizable experiences than abstract ones. Koudelkova and Dvorak (2015) identified students' misconceptions in electromagnetic induction such as charges disappearing once distributed on an insulator, limited understanding of the dependent quality of electrostatic force and of changes in magnetic flux. In support of Maloney's (2000) and Koudelkova and Dvorak (2015) was the assessment that engineering students find it difficult transferring mechanics' concepts to other domains such as electricity and magnetism (Miokovic et. al, 2012).

Another reason that hinders teaching and learning of electromagnetic induction is the heavy mathematical and fundamental constructs of the topic (Anderson & Mina, 2003). Mathematics should be used to support a physical understanding, but analyzing the difficulties students experience while dealing with mathematics in a physical context reveals that students were challenged to translate and to establish connection between computation and their meaningful interpretations (Uhden & Pospiech, 2011; So, 2010).

The typical lecture that closely follows provisions in textbooks is another reason because it diminishes the chance "to develop free, spontaneous exchange of ideas and encourages passive settings (Dori & Belcher, 2005)." A topic relying heavily on mathematical systems being taught in a passive background will even reduce the likelihood of the students being familiar with it.

The lack of visualization and extreme focus on equations is one reason that students do not see the importance of variables and constants even if these equations have deeper meanings (Hargunani, 2010). The electromagnetic phenomenon is supported by unified variables and constants which is why recognizing these variables and interconnecting them are important to better understand the phenomenon. It was revealed that graphical representations can be useful in visualizing quantities and identifying their relationships (Sanchez & Loverude, 2012). Dori and Belcher (2005) detailed that "visual imagery can indeed help make the abstract concepts encountered in electromagnetism more concrete."

These suggest the need to veer the focus from mathematical systems to visual representations and tangible evidence to support the existence of a law or an idea. This must be strongly considered in designing instruction for electromagnetic induction, and this is fortunately a main feature of the history and philosophy of science (HPS).

Addressing these difficulties using computer-assisted instructions

Largely, the several efforts made to improve students' conceptual understanding on electromagnetic induction include the use of computer assisted teaching approaches. The "Technology-Enabled Active Learning (TEAL) Project at the Massachusetts Institute of Technology (MIT)" by Dori and Belcher (2005) involved media-enhanced software to simulate and visualize a phenomenon in freshmen physics. It was carried out in a particularly re-modelled classroom to facilitate group interaction. These "technology-based learning materials are especially useful in electromagnetism to help students conceptualize phenomena and processes" because they have made students' conceptual understanding significantly higher on the subject matter than through the passive lecture or recitation format.

Anderson and Barnett (2013) suggested the use of a digital game simulation to enable understanding of "basic electromagnetism" with middle school pupils. Their study showed that "video games" can lead to an increase in test scores better than the traditional inquiry-based learning. Hargunani (2010) further showed that teaching "Faraday's law of electromagnetic induction" concepts using "java-based lab simulations" improved students' test scores achievement, and the simulations made it possible for the students to understand the experiments easily without any risk.

A study determining the effectiveness of a virtual laboratory revealed that the students who were taught through a virtual lab had learned the concepts better than those in a real lab (Bajpai, 2013). A similar study revealed that "Virtual Physics Systems" (ViPS) are more effective than real experimentation with pulleys in helping students learn and remediate their misconceptions (Myeni et al., 2013). Adding that the students find it difficult to assemble and use materials in an actual activity. Furthermore, "using simulations for pre-laboratory work leads to better comprehension of the techniques and contributes to students having better sense of direction during lab work," indicating that it is an effective tool for familiarization (Rutten et al., 2012). Simulations may also enhance students' experiment experience by limiting time for set-up, doing further arrangement to change variables, cleaning up, and providing more time focusing on the experiment with little attention on safety (Donnelly, O'Reilly, & McGarr, 2011).

Despite this potential, the instructional effectiveness of computer simulations has yielded inconsistent results. While many researchers find it engaging to use simulations in their classrooms, more researches have to be done to determine if they can improve understanding of learners or their interest in science and how they can be designed and used most effectively (Gok, 2011). Though "animations and simulations" make it conceivable to exhibit the ideas in visual forms, it is also important to determine existing misconceptions in various topics to find suitable computer-assisted materials (Tambade & Wagh, 2011).

The prospective of computer simulations as virtual laboratories outperforming and replacing traditional laboratory works rests on the nature of the presented material because the written instructions accompanying these simulations are not enough to promote learning as they limit the students' freedom to explore (Rutten et al., 2012). Additionally, there is very little time specified in discussing variations in the simulation that leads to students' inability to satisfactorily convey their predictions with consideration on the effects of errors (Donnelly, O'Reilly, & McGarr, 2011).

It should be remembered that although simulations are useful pedagogical tools, they are not and they cannot replace experiments. Computer simulations only provide a "limited utility as substitutes for actual laboratories" (Bryan, 2006). Further investigations must be done to provide more evidence that the use of computer simulations can promote conceptual gain and improve reasoning pattern. Renken and Nunez (2015) argued that adequate experimentation has a powerful influence in conceptual change and that it becomes even more significant over time. There is a "difference in variable control between computer and hands-on experiments" and this may be due to the adolescents' familiarity and comfort with simulated environments (Renken and Munez, 2015). The students are even more likely to "play" in the computer-simulated environment which may result in less regard for experimental control in this case. Moreover, while more research is necessary to better understand the role of computer-assisted simulations in learning, remote physical science computer simulations are no better in informing conceptual knowledge than are real life experiments (Renken and Nunez, 2015).

More than "canned" experiments, real life experiments do provide more tangible and visual representations of a phenomenon, an idea or a law. These can help students make sense of the mathematical systems necessary to explain the nature of an occurrence. Looking back in the history of science, before theories or laws are proven, several experiments have to be conducted. Before the variables were determined for such theory or law, observations were made.  Such pattern of scientific discovery and inquiry can be adapted to science classrooms.

History and Philosophy of Science in Science Teaching

"History showed that many models proposed in the past can supply a number of models, examples, and experiments, which can constitute useful resources to improve students' understanding, together with objectives of cultural value and of better scientific knowledge" (Besson, 2013). History of science does provide a fountain of valuable knowledge on how to "construct and to communicate scientific representations, and science educators could choose, transform, and integrate these resources into instructional procedures." Indeed, some historical resources can be used in education to support students' understanding of the phenomena and provide a broader and profounder view on several topics. Teaching with replicas, imageries, and ideas found in history may be useful images, analogies, or representations for helping introducing and understanding a concept, or correcting some common misconceptions. In replicating, the following steps were ensured to agree with the relevant historical situations and discoveries: (1) reconstructing the apparatus, (2) redoing the experiments, and (3) contextualizing the experiences in the first two steps. The experiments were described, and pictures of the setups were provided so that the physics teachers get to work with a reconstructed apparatus. The data gathered from the scientists' experiments were discussed, emphasizing on understanding the physical meaning of these data instead of just considering the numerical values (Heering. 2009).

Chang (2010) elaborated on the use of HPS in experiments by describing how they can help science education in four major ways: (1) "enrich the factual basis of science teaching," (2) "improve students' understanding of the nature of science," (3) "foster habits of original and critical inquiry," and (4) "attract students to science through a renewed sense of wonder." Similar to Heering (2009), historical experiments that arose from the study of earlier science, were replicated. The replication, which is more or less synonymous to reproduction, repetition, re-enactment, or recreation, was classified as either historical or physical. Trying to get "as close to the original as possible" is how Chang described historical replication. However, it is not always probable to equal exactly the historical instruments and operations described in historic papers because there may be times that "it is simply impractical to recreate what the past scientists had."

According to Cavicchi (2008), learning from historical experiments and experiences will show interrelatedness among materials, actions done with them, and science phenomena. Allowing students to perform and to interact with replicas emerges a sense of responsibility in what they do and interpret from these materials. This would allow inquiries to arise about these materials. Then, experiments were conducted. The materials became "their hands links to a world of curiosity, unexpected behaviors, and patterns. In their own struggles, questions and confusions, having space to reflect on these individually and collectively, the students came into respectful terms with each other and explorers of the past" (Cavicchi, 2011). The students made their own sense of history through the associations and the dissimilarities they observed between historic materials and activities, as well as things from their everyday experiences.

Some may argue that textbooks have been integrating the history and philosophy of science. They could be supplemental in enriching the historical reconstruction in written materials (Niaz et al., 2009). Moreover, various reform documents call for the "inclusion in textbooks of not only historical perspectives but also the meaningful introduction of terms, appropriate representation of key ideas, and the skillful use of models." However, Niaz et al. observed the overall characteristic that could be identified from these textbooks is the inconsistent nature of the insertion of the relevant historic information. It has been oversimplified and "tends to lack context, imagination, and engagement," which should not be the case. Nersessian (2003) agrees that very few students learn from textbook representations and relation of "canned" experiments, because they are not able to provide explanations and predictions even for simple physics phenomena due to the fact that it is the experience during which practices are learned in authentic situations, students learn the tacit as well as the explicit applications of the discipline (Nersessian, 2002).

It is possible that these learning guides may not be able to provide productive historical reconstruction to students that can offer tangible experiences from which they are allowed to participate in the learning process to have better conceptual understanding of electromagnetic induction (Niaz et al., 2009). Klasses (2010) added that reconstruction was able to show that science does not grow in the manner in which it is "stereotypically" offered in textbooks and that scientific discoveries do not arise in a "neat and orderly method." This could possibly make the students feel that they were part of a historical evolution.

These were the goals of Mantyla (2012) in involving the physics teachers in the "reconstruction of electromagnetic induction using similar reasoning patterns and experiments of Faraday." The results showed that the physics teachers have "improved in describing how the electromagnetic induction law can be formed using physical knowledge through experiments and models, highlighting the importance of recognizing the historical cognitive processes that were essential for the formation of the concept." These showed that practices discovered in cognitive-historical studies can provide a pivotal point for observational studies, for designing experiments, and for designing instruction (Mantyla, 2012; Nersessian, 2002).

With historical or physical replications (Chang, 2010), the visual, qualitative, and intuitive nature of models can assist students' assumption, and at the same time their "historical origin" can give them more constancy and "cultural value" to reinforce students' focus. Such structural models can benefit students in apprehending the importance of small variations in physics, which are often insignificant in the calculations but are essential in understanding the phenomenon. These varieties of "models and theories are capable of stimulating significant cognitive processes," which can open doors for students' better conceptual understanding (Besson, 2013)

The students exposed to historically reconstructed experiences will be able to make sense of interweaving historical experiences in the laboratory experiments (Cavicchi, 2006, 2008, 2011). Furthermore, such actions put the students "in relation to those of historical investigators who also developed science understanding through experimental action with materials." Remarkably, it was noted that the learners' actions met with notable observations from the past.

Having the students realize these benefits and the values that developed with these scientists' endeavors is one of the goals of historical reconstruction. As supported by Cavicchi (2011), students as explorers themselves, did "science and history" and this action extended their relation with the phenomena, with their forerunners, and with their learning.

It is evident that history of physics does not just offer models and reasoning patterns to promote conceptual understanding. It is also filled with ideals that the students might be able to relate to and to develop in the process of instruction.

However, Heering's (2014) overall analysis of "the historical approaches and their role in German science education" publicized that there is limited use of historical approaches in the fields of physics, chemistry, and biology education. A similar study on the German "history and philosophy in science teaching" agrees that there is indeed poor employment of "history and philosophy of science (HPS) in science teaching" and that there is a need for collaboration to address its poor status.

A systematic review of studies on HPS from various countries (Teixeira et al., 2012) exposed that only Germany and Argentina used history and philosophy of science in electrostatics and electric field lines, respectively. Though few, these studies, along with that vast majority of selected studies aimed at attaining conceptual change.

Some concerns regarding the implementation revolve around incoherent teaching practices and innovative teaching methods that are "usually far from everyday practices, routines, and skills of science teachers." Worrisome as it may sound but this may lead to teachers finding HPS demanding and draining, and later on may result to decline number of teachers integrating HPS in science teaching, especially in teaching electromagnetic induction (Hottecke et al., 2012).

Despite the challenges and the methodological peculiarities employed in integrating HPS in science teaching, there is still a continuing growth of HPS implementation. With these developments in HPS, the central motivation remains that methods of employing HPS should be student-centered and should be promoting improvements in students' attitudes toward and understanding of scientific ideas as compared to conventional teaching approaches. Some methodological approaches operationalizing HPS that were developed were the reconstruction of experiments from the history of physics, use of science stories for educational purposes, creative writing, and role-playing (Heering, 2014; Hottecke et al., 2012; Teixeira et al., 2012). Several researches have also been made on the employment of these methods and on their effects in physics teaching.

The use of history in science education to promote conceptual development has been proven prolific in guiding facets of research in the "learning and instruction of science (Mantyla 2012)." Such an approach can help develop scientific learning and an understanding of science as a process in which learners can participate (Heering, 2009). Visual representations (Dori & Belcher, 2005; Hargunani, 2010; Sanchez & Loverude, 2012;), tangible experiences from models and experiments that would allow learners' participation (Cavicchi, 2006, 2008, 2011; Heering, 2009, 2014; Chang, 2010; Besson, 2013) can be the viewpoints in designing instruction for electromagnetic induction to promote conceptual understanding. Some may argue that such an approach has been incorporated in other K-12 physics learning materials, such as the Basic Education Assistance for Mindanao learning guide and the module on electromagnetism by the Effective Alternative Secondary Education and the Open High School Program. Textbook representations tend to lack context, imagination and engagement (Niaz et al., 2009) and few students learn from textbook representations (Nersessian, 2003).

Having teachers equipped with reconstruction as an alternative approach to teaching electromagnetic induction, they can design and implement instructions that may allow students to explore recreated historical experiments and models to form better understanding of electromagnetic induction. This is why the study has designed an approach adapting Mantyla's historical reconstruction for electromagnetic induction, to see whether the approach yields the same results to Grade 10 students.

However, there are restrictions in designing and implementing instruction for electromagnetic induction using the history of physics. Scientists are experts whereas students are novices. This means that the "history of physics" cannot be repeated in teaching as such, rather, the "historical cases" have to be modified to be parallel to the needs of the current education (Mantyla 2012). The study combined Heering's (2009) replication method with Mantyla's approach and a few written historical accounts (Byrnes, 2015; Kingman et al., 2001; Tooker, 2007) in "designing and implementing didactic materials that enhance students' conceptual understanding of electromagnetic induction." Through the reconstructed apparatus, the students were able to visualize (Hargunani, 2010; Sanchez and Loverude, 2012; Dori and Belcher, 2005) the electromagnetic induction phenomenon and analyze its physical nature through experiments (Heering, 2009, 2014; Besson, 2013; Chang, 2010; Cavicchi, 2006, 2008, 2011). The use of these instructional materials in the classroom evoked in students "the same mental image as in the teacher, thereby making words more comprehensible and providing a common starting point to get the class thinking along similar lines (Akinbobola & Ikitde 2008)." This with redoing the experiments resembling those of the scientists promoted conceptual change or development, which is the "change in the students' understanding of the concept and conceptual system in specific subject-matter during the learning process (Mantyla, 2012)." Considering the part of experiments in the "history of science" in science teaching, the thoughts and engagements of past scientists can be used as guiding principles for designing learning activities that would allow students to relate and to compare their experiences with those described by the scientists. As the students perform the experiments, interpret experimental evidence, draw conclusion, and create theoretical ideas, they gained an increased ownership of the contents being learned as they actively engage in the learning process (Teixeira, Greca, & Freire, 2012).

## Cognitive Historical Reconstruction

It was identified that the abstract nature and the mathematical content of a physics concept make it difficult for students to understand, especially electromagnetic induction (Maloney, 2000; Leppavirta, 2010; Anderson & Mina, 2003; Uhden & Pospiech, 2011; So, 2010). Teachers must not just rely on textbooks and "canned experiments" in teaching electromagnetic induction (Dori & Belcher, 2005; Nersessian, 2003). The use of visual representations to concretize quantities explaining the phenomenon is useful in assisting students in understanding the topic (Hargunani, 2010; Sanchez & Loverude, 2012). This happens to be one of the main features of history and philosophy of science (HPS) in classroom instruction. Cavicchi (2006, 2008, 2011), Heering (2009, 2014), Chang (2010), Mantyla (2012), and Besson (2013) all used history in teaching science since history offers many methods, experiments, and models that may contribute to effective classroom instruction that improves students' understanding of scientific concepts and phenomenon. Mantyla (2012) used cognitive-historical approach so that "cognitive processes in the history of physics are combined with current physics knowledge to create cognitive-historical reconstructions.” The reconstruction uses “similar reasoning patterns and experiments to Faraday” and is adapted for modern physics education.

The goal of reconstruction is to incorporate “historical models and cognitive processes” that include the essential reasoning development, model construction, and experimental works that have directed the creation of new scientific concepts or ideas. Applying “historical-cognitive processes” involved in the formation and development of electromagnetic induction to existing physics education appears to “lead to more rational and coherent argumentation in students’ experimentation, reasoning, and knowledge justification” (Heering, 2009).

The integration is anchored to the notion that the reasoning patterns of scientists in investigating and exploring the nature of a physical phenomenon may be used in improving how students learn the same scientific idea. Their integration is focused on reconstructing experiments to allow students to experience and practice scientific investigations, and models to represent and simplify complex processes.

This is where physical replication may be useful, because its main objective is “to reproduce the physical phenomena that were created and observed in past experiments.” The physical replication makes use of any suitable instruments and procedures that “will help one create the phenomena of interest,” and can still be faithful to the details of the original experiment. Moreover, it is important to note that physical replication “is not simply a subset of historical replication, or an inferior version of it.” Extension can be done afterward. It is described as a follow-up to replication. It is characterized as embracing the natural curiosity spurring the experimenter on to the next experiment, “which may be a variation of the original one, or an altogether different experiment designed to pursue a further question that arises from observations made in the original experiment" (Chang, 2010).

In the modified version of cognitive historical reconstruction which is the modified historical reconstructionist teaching approach (MHRTA), the reasoning patterns and the experiments of scientists from the past, such as Oersted, Ampere, Faraday, and Lenz, were used to scaffold a chain of reasoning that will assist students in constructing and interpreting the electromagnetic induction theory. Comparable studies used similar materials or almost similar models from the past, which may be difficult to find or to prepare in the local setting. Also, though the instructions were designed to parallel the reasoning patterns or thinking processes of the scientists, these studies did not identify the reasoning pattern that students developed during implementation. This study did not only attempt to reconstruct the experiments used by scientists in the past using locally available materials so students can certainly relate with the setup, but also determined if there was a reasoning pattern via written explanation or argumentation as the students understanding of the topic progresses.

## Reasoning Pattern

Dori and Belcher (2005) agree that "learners "learn by doing" to accommodate new knowledge through experiencing and assimilating the newly acquired knowledge into their current understanding." Likewise, scientific teaching stresses that "active participation in lectures and discovery-based laboratories help students develop the habits of mind that drive science."

“Engaging students in discovery and scientific processes improves learning and knowledge retention (Handelsman et al., 2004).” Also, involving the students in the learning process allowing active participation is one of the main features of the modified historical reconstructionist teaching approach, where cognitive processes and practices from the past are combined with the students’ current knowledge and experiences in physics.

Several studies identified the students reasoning pattern in science. The complexity of scientific reasoning during inquiry (CSRI) matrix divided the cognitive processes of reasoning into four levels of complexity with the most complex reflecting the depth of reasoning (Dolan and Grady, 2009). The levels of reasoning were identified using the structure of the learned outcomes (SOLO) taxonomy as a theoretical model (Jurdak and Mouhayar, 2013). Five levels of physics reasoning were presented by Eaton et. al (2015) based on the students interactions on Newton’s laws of motion. The five levels are non-verbal enhance interactions, concrete specifications, concrete reasoning, formal physics reasoning, and formal physics reasoning with Newton’s laws. Bloom’s taxonomy, SOLO, and phenomenography were used by Newton and Martin (2013) as tools in assessing cognitive complexity based on students’ exam responses.

Dori and Belcher (2005) reiterated that “knowledge is not the property of individuals” and that it is shared and distributed in a group setting where “peers help each other by offering alternative and sustaining reasoning activities.”

Similarly, in the MHRTA, groups of student-investigators explore and exchange observations based on reconstructed experiments from the past. A social circumstance of cognitive activities as such shifts the focus of education on learning as “communities of scientists” or group of students and requires a change in the environments where learning occurs, which is observed in the MHRTA classroom.

Lawson (2008) discussed that "knowing how scientists reason and argue to explain and to draw scientific conclusions" is a key component of scientific literacy, which is an essential goal of science education. Lawson observed that the inferences made revealed the if-then-therefore reasoning and argumentation pattern.  The if-then-therefore reasoning and argumentation pattern is known as conditional reasoning which is a type of deductive reasoning. "Deductive reasoning is the process of reasoning from one or more general statements regarding what is known to reach a logically certain conclusion (Sternberg et al., 2012)."

In a logical argument, premises are proposals about which arguments are made. Conditional reasoning is guided by the presence of "contextual information that converts a problem from abstract deductive reasoning to something that applies to an everyday situation." In categorical syllogism, which is also a type of deductive reasoning, conclusions are drawn from two positive or two negative propositions (Sternberg et al., 2012). A major difference between conditional and categorical syllogism is that in the latter, it is difficult to draw logically valid conclusions. A few suggestions on improving deductive reasoning skills include translating abstract terms to concrete ones or creating mental models based on propositions.

Engaging and supporting students in concretizing such ideas in constructing explanations with evidence following the structure of scientific argument, expressing these understanding, and influencing others of these explanations will enable them to unambiguously link the evidence with their claims and promote learning gains (Berland, 2007).

Though scientists are experts, the inferences, reasoning, and argumentation patterns can provide fruitful starting points for designing instruction to aid students in developing scientific practices that could aid in improving their learning. Parallel patterns can be reflected in MHRTA where the steps developed follow the reasoning and argumentation patterns of Oersted, Ampere, Faraday, and Lenz.

Another form of reasoning is inductive. Inductive reasoning is "the process of reasoning from specific facts of observations to reach a likely conclusion that may explain the facts." Unlike deductive reasoning, individuals cannot reach a "logically certain conclusion" in inductive reasoning, only a probable conclusion. A causal inference is one type of inductive reasoning, which examines "how people make judgments about whether something causes another." Categorical inferences, however, examine the basis of drawing inferences using "both information from their sensory experiences and information based on what they already know or have inferred previously" (Sternberg et al., 2012).

Reasoning by analogy is another type of inductive reasoning. When people make analogical inferences, they use a source analog to form a new assumption. Moreover, in analogical reasoning, people tend to find mappings that maximize similarity of corresponding elements, structure, and importance between the source analog and the new inference. (Holyoak, 2005; Sternberg et al., 2012)

Aside from deductive and inductive, there were other two complementary systems of reasoning that were also suggested by cognitive psychologists about how and why people reason as they do which are the "associative system and rule-based system." The "associative system" can lead to “speedy responses” based on patterns and general tendencies. The “rule-based system” of reasoning, nevertheless, requires “more deliberate and sometimes painstaking procedures for reaching conclusions by analyzing relevant features of the available data, based on rules stored in memory.” There is no single model of reasoning that can explain how we reason and make judgments, but these reasoning models may be able to explain at least some patterns based on data satisfactorily (Sternberg et al., 2012).

Integrating or reinforcing reasoning and argumentation patterns and conducting scientific practices in a physics classroom are promising mediations to improve students’ conceptual understanding, especially of electromagnetic induction. Nussbaum (2003) inferred that in order for conceptual change to occur, students must compare and restructure existing conceptions with new information and process and the merits of these ideas deeply. Additionally, the process of thinking deeply engages students to deep processing, using of elaborative strategy, and reflecting in metacognitive manner, which the students are often not willing to engage in. Berland (2007) mentioned that “constructing scientific explanations and participating in argumentative discourse are seen as essential practices of scientific inquiry.”

To foster scientific practices, “explanations and models of scientific phenomena are constructed or developed through argumentation” (Berland, 2007; Kontra et al., 2015). This means that using evidence can help students make sense of the phenomena being studied hence allowing the students to explain and to argue about the phenomena, which is an indication of a good reasoning ability. Brief exposure to laboratory experiments, such as to forces associated with angular momentum, significantly improved quiz scores and performance based on the way students reasoned about the topic. Additionally, the physical experience can activate the "sensorimotor brain systems" that add kinetic detail to the students' thinking (Kontra et al., 2015).

Li (2012) added that "when people reason, they go beyond the information given, they attempt to infer patterns, concepts, or rules that best characterize relationships or patterns in variables and deduce the consequences or implications of a rule, set of premises, or statements using warrants or evidence that are rendered acceptable or are assumed true within the community of discourse."

Granting that there is no universal definition for scientific reasoning or scientific reasoning ability, analyzing these definitions will show that it is not one-dimensional, and cannot be taught, but it can be developed if teachers will engage students into activities and situations that would entail such skills.

McNeill (2007) agreed that successfully engaging students in "scientific inquiry process, the construction of scientific arguments to explain phenomena in which students justify their claims using evidence and reasoning, could result in learning gains." In addition, "teachers' oversimplification of this complex practice resulted in decreased learning gains in terms of students' ability to write scientific arguments and to explain phenomena using appropriate evidence and reasoning." Since these are practices within a community of scientists, it is imperative that teachers are also scientists who compare, counter, and justify claims, thus engaging themselves in thinking and acting like scientists.

Teachers must trace the students "reasoning skills and learning outcomes" since they can provide insights on how to deliver effective instructions to increase their reasoning skills and learning (Li, 2012). Eberbach and Crowley (2009) stressed that seeing is different from observing. Teachers who had underestimated the complexity of scientific practices limit the students in making scientifically meaningful observations. Experts and novices do have fundamental differences in making scientifically meaningful observations, but following the experts' means of making these observations, the teachers can create a framework, a learning environment, and a set of identified essential skills, knowledge, and tools that may aid students in creating meaningful observations, interpretations, and connections.

Making meaningful observations and connections is quite the challenge teachers and students face in the teaching and learning of electromagnetic induction. Teachers may consider a means of visualizing the abstract nature of electromagnetic induction to assist students in identifying and correlating the variables supporting the theory following the trails of the scientists in reasoning.

Gooding (2010) argued that "representations are essential to visualization or visual inference," which scientists used to develop and to interpret scientific phenomenon. Representation of differing type and complexity invokes a range of cognitive capacities, such as "recognition of patterns and of similarities between pattern-like features." Moreover, a model of visual inference is "compatible with the held view that scientific reasoning is abstract thinking and that it can develop a crucial role in arguments about theories."

The abstract nature of EMI, knowledge construction must include qualitative reasoning in addition to symbolic and mathematical representations (Richards, 2010). Recalling the students' difficulties in electromagnetic induction, despite its abstract nature, electromagnetic induction still includes quantifiable variables and equations that can show the relationships of these variables, but these have to be slowly introduced.

Conceptual or quantitative, designing instructions with a systematic approach that neither focuses on nor removes the mathematical or quantitative aspects of the phenomenon is essential in learning the electromagnetic induction phenomenon deeply. Instruction and learning environment should “support the practice of constructing and defending scientific explanations via claims, evidence, and reasoning.” Therefore, it is important to design instructions and situations where these components will be met to engage the students to reasoning about a claim using evidence. This means that carefully constructing “learning environments can facilitate students’ understanding of scientific concepts,” which is why reconstruction with historical context in science teaching may be a valuable tool to facilitate learning.

The complex processes and the mathematical content accompanying the physics phenomena, especially the abstract nature of electromagnetic induction are causes why students find learning the subject area challenging. Educational technology supports meaningful learning and it enables presentation of dynamic images to portray relationship among complex concepts and phenomenon (Dori and Belcher, 2005; Anderson and Barnett, 2013; Hargunani, 2010;Myeni et al., 2013;and Rutten et al., 2012). However, when to implement such method and how the students reason or support claims during and after implementation were not deeply explored when technology is integrated in a physics classroom.

The modified historical reconstructionist teaching approach (MHRTA) is anchored on the reasoning patterns of the scientists in explaining a new scientific idea using experiments as visual tools and evidence to gather data and to justify the physical nature of the phenomenon to promote conceptual understanding. History can supply a number of models, examples, and experiments which can establish useful resources to improve student understanding and better scientific knowledge. Structural models can help students understand the significance of small variations, often negligible in calculations, but are essential in understanding the phenomenon (Besson, 2012).

Since the MHRTA is based on Mantyla's cognitive historical reconstruction, the method is assumed to promote conceptual understanding through the use of reconstructed or recreated experiments or incidences from the past that are relevant to developing the law of electromagnetic induction. Scientists support their theories and laws with experiments and with their ability to support such claim through reasoning. Richards (2010) mentioned that given the abstract nature of EMI, in order to construct knowledge, qualitative reasoning must be added to symbolic and mathematical representations. Successfully engaging students in "scientific inquiry process, the construction of scientific arguments to explain phenomena in which students justify their claims using evidence and reasoning, could result in learning gains (McNeill (2007)."

Seemingly, CATA and MHRTA can engage students in scientific inquiry process. Both are essential to the growth of science education. It is also the goal of this study to determine if these teaching approaches will establish some form of reasoning pattern when the subjects were asked to explain or evaluate the, or infer from given situations, either from computer simulations or by following how scientists conduct experiments and infer from these experiments.

To aid students in understanding the nature of EMI, visualizations or presentations are needed. These can be via a computer-assisted teaching approach (CATA) or via a modified historical reconstructionist teaching approach (MHRTA). CATA has been proven effective in improving conceptual understanding, yet, can only be offered to institutions with technological tools. Integration of HPS may have been limited due to the challenges brought about by such approach, it has the ability to provide real experiments for the students. Since the focus of these methods were on how to improve conceptual understanding, the reasoning patterns were not deeply explored. This is why the study implemented these approaches to determine their effectivity in improving the students' conceptual understanding on EMI and to identify reasoning patterns developed during implementation.

From the studies gathered, the two prolific approaches in teaching EMI are:

| Teaching Approach | Structure |
| --- | --- |
| Computer-assisted instructions | integration of technology to provide visualizations or visual representations on EMI |
| Historical reconstruction | use of historical discoveries, methods, or experiments to visualize and explore EMI |

Figure 1. *Research Map*

**Conceptual Framework**

The CATA has been proven effective in improving conceptual understanding, yet technology is not accessible to all educational institutions (Morales, 2014). The integration of HPS in science education has been prolific yet it has not been intensely implemented and explored in the Philippines. The cognitive historical reconstruction of Mantyla (2012) have been modified to make the approach suitable for Grade 10 students.

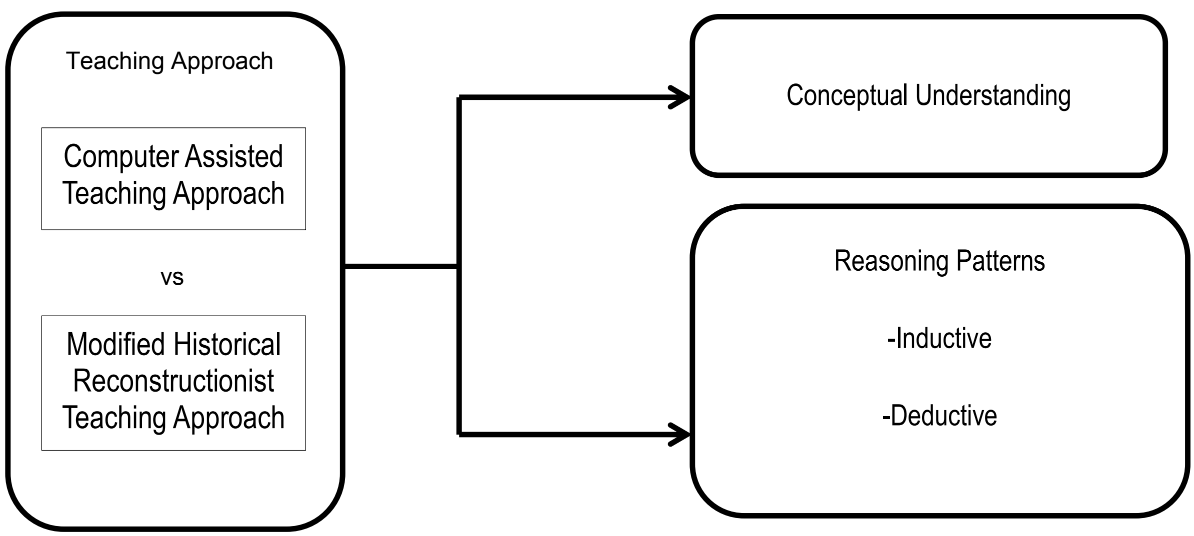



Figure 2. *Conceptual Framework*

From the original eight intricate steps, it has been modified and narrowed down to the following stages:

1. "Observation and identification of EMI phenomenon. The starting point for exploring induction is knowledge that magnetism can be produced through electricity and vice-versa (Oersted's and Ampere's discoveries)."

2. “Qualitative experimentation of induction current. It aims to show that the varying magnetic field experienced by the secondary coil is essential.”
3. “Qualitative dependency: A changing magnetic flux through a coil. Finding out that the common changing property in the qualitative experiments is changing magnetic flux through a coil.”
4. “Representation of measurement results. The results of experiments are discussed and represented algebraically.”
5. “Experimental law of induction and model for representation of results. Examining and interpreting the result using earlier knowledge and trying to represent it in a more general means.”
6. “Interpretations and predictions. The new is now in form $E = -dU/dt$, which is known as Faraday’s induction law.”
7. “Extension of theory. The law was used to explain how motors and generators work. “

These effect of these methods in conceptual understanding will be measured using the conceptual survey in electromagnetic induction (CSEI). To identify the reasoning pattern developed during implementation, the reasoning pattern survey in electromagnetic induction (RPSEI) was administered once a competency has been completed.

**Research Problems**

The main goal of the study is to determine the effects of the modified historical reconstructionist teaching approach (MHRTA) on students' conceptual understanding and reasoning patterns in electromagnetic induction.

Specifically, it aims to answer the following questions:

1. Is there a significant difference between the pretest and the posttest scores of the CATA and MHRTA groups in the Conceptual Survey in Electromagnetic Induction?
2. Is there a significant difference between the posttest scores of the CATA and the MHRTA groups in the Conceptual Survey in Electromagnetic Induction?
3. What are the observed reasoning patterns in the CATA and the MHRTA groups on the Reasoning Pattern Survey in Electromagnetic Induction?

**Hypotheses**

To carry out the purposes of the study, hypotheses for specific questions numbers 1 and 2 were tested:

1. The posttest scores of the CATA and MHRTA groups in the CSEI will not be significantly different from the pretest scores.
2. The posttest scores of the CATA group in the CSEI will not be significantly different from the posttest scores of MHRTA group.

## Significance

Students, who find challenges in learning the abstract nature of electromagnetic induction, will be provided with models and experiments that would allow them to observe the phenomenon and to substantiate the ideas explaining and supporting its occurrence.

Teachers, who had experienced difficulties teaching electromagnetic induction such as concepts, variables, and mathematical forms and their interpretations, will have an alternative approach in introducing and conveying the principles of EM induction. Recognition and development of scientific skills and the integration of values through the individual scientists' characteristics and attitudes, and their interactions with each other can now be given more attention in the process of instruction.

Future researchers, who are in constant search of methods that could lead to enriched teaching and learning process in different subject areas, will have an alternative teaching approach to explore. Such exploration may give rise to other variables that may be considered to ensure the realization of the teaching approach since it can be adjusted to ensure effectivity in tracking reasoning patterns and in promoting conceptual understanding of challenging topics.

## Scope and Limitations

This study used the modified historical reconstructionist teaching approach (MHRTA) adapted from Mantyla's (2012) cognitive-historical reconstruction approach in teaching electromagnetic induction. The approach was designed to identify and to categorize reasoning patterns and to promote development of conceptual understanding of electromagnetic induction. The approach was modified to meet the learning competencies as prescribed by the 2013 DepEd K12 Curriculum. The method of Mantyla (2012) was more complex since it's intended for undergraduate physics teachers. However, the goal is the same and that is to aid students in making sense of the equations explaining the nature of EMI.

The magnets used by the MHRTA group were broken after the implementation because the students had the tendency to be too enthusiastic once the setup started working. The method required close monitoring of the students while performing the experiments.

The approaches were implemented at the second quarter of the school year when the annual intramurals were scheduled. After completing a competency, a question from the reasoning pattern survey was given to the students on both groups. The implementation followed a strict schedule to ensure that both groups cover the same topics at the same time. The same take home tasks were given to both, which mostly included visual representations. The two-week implementation was interrupted due to the aforementioned event and might have affected the overall outcome of the approach. Since most students on both groups have internet connection at home, there is a possibility that some of the CATA and MHRTA students surf the net for more references for review, which may include simulations or videos readily available online. All these might have affected the validity of the findings of the study.

**Definition of Terms**

The following terms were described based on how they were utilized in the study.

**Associative system**. "The first of the dual-process reasoning theory that can lead to speedy responses that are highly sensitive to patterns and to general tendencies (Sternberg et al., 2012)."

**Categorical Inference**. A type of inductive reasoning that examines the basis of drawing inferences using information from their sensory experiences and known information or previously inferred ones (Sternberg et al., 2012).

**Categorical Syllogism**. A type of deductive reasoning that is "comprised of a major premise, a minor premise, and a conclusion." The terms in the premises are categorized to make conclusions (Sternberg et al., 2012).

**Causal Inference**. A type of inductive reasoning that examines how people make judgments about something causing another. (Sternberg et al., 2012).

**Computer-Assisted Teaching Approach (CATA)**. An approach that combines lecture, use of visual aids or visual representations, and available forms of technology, especially computers.

**Conceptual Survey in Electromagnetic Induction (CSEI)**. “A multiple-choice test designed to measure conceptual understanding in electromagnetic induction (Maloney, 2000: Leppavirta, 2010).”

**Conceptual Understanding**. The appropriateness of students’ constructed ideas from acquired knowledge, such as the concepts, variables, and directions of variables (magnetic and electric field lines, flux, and induced voltage, current, and magnetic field) (Mantyla, 2012).

**Conditional Reasoning**. “A type of deductive reasoning where the reasoner draws conclusion based on an if-then proposition (Sternberg et al., 2012).”

**Deductive Reasoning**. “One type of reasoning process from one or more general statements regarding what is known to reach a logically certain conclusion or reasoning regarding what is known to a specific application of the general stamen (Sternberg et al., 2012).”

**Inductive Reasoning**. “One type of reasoning process from specific facts or observations to reach a probable conclusion that may explain the facts and predict future specific instances (Holyoak, 2005; Sternberg et al., 2012).”

**Modified Historical Reconstructionist Teaching Approach (MHRTA)**. A set of guidelines combining historical episodes presenting scientific practices and skills, values, and replicated experiments to promote conceptual understanding of the topic. (Mantyla, 2012).

**Reasoning by Analogy**. A type of inductive reasoning where the reasoner observes the first pair of terms and must induce one or more relations from these two items to be applied in the second part of the analogy (Holyoak, 2005; Sternberg et al., 2012).

**Reasoning Pattern**. The observed arrangement of written scientific arguments or explanations demonstrating the "cognitive skills necessary to understand and to evaluate scientific information, or the inclusion of thinking and reasoning skills involved in inquiry, experimentation, evidence evaluation, inference, argumentation that support the formation and modification of concepts and theories, or an attempt to infer concepts, patterns, or rules that best characterize relationships or patterns in variables (Bao, 2009; Li, 2012)."

**Reasoning Patterns Survey in Electromagnetic Induction (RPSEI)**. A test with parallel competencies to the Conceptual Survey in Electromagnetic Induction where respondents are required to make a written scientific explanation to answer a question to identify observed patterns of explanation.

**Reconstructed Experiments. "**Experiments reproducing the physical phenomena that were created and observed in past experiments using any convenient instruments and procedures necessary for recreating the phenomena of interest (Chang, 2011)."

**Rule-based system**. "The last of the dual-process reasoning theory that requires more deliberate, and sometime painstaking procedures for reaching conclusions and includes analyzing relevant features of the available data, based on rules in memory (Sternberg et al., 2012)."

## Chapter II

## Methodology

The study focuses on determining the effects of the Modified Historical Reconstructionist Teaching Approach (MHRTA) on students' conceptual understanding and reasoning pattern in Electromagnetic Induction (EMI). This chapter describes the research design, participants of the study, validation of research instruments, research framework, and data analyses.

### Research Design

The quasi experimental with matched subjects in a pretest posttest design was used. The CATA group (control) and the MHRTA group (experimental) were matched using their grades in Science, English, and Mathematics from the previous school year as well as the pretest scores. The pre and post test scores were compared to determine the effects of the MHRTA in the students' conceptual understanding between groups.

| | | | |
|---|---|---|---|
| $M$ | $O_1$ | $X_1$ | $O_2$ |
| $M$ | $O_3$ | $X_2$ | $O_4$ |

Figure 2. *Research Design*

Key:
M = matching
$O_1$ = pretest on experimental group (MHRTA)
$O_2$ = pretest on control group (CATA)
$X_1$ = MHRTA
$X_2$ = CATA
$O_2$ = posttest on MHRTA group
$O_4$ = posttest on MHRTA group

**Sampling and Participants**

Purposive homogeneous sampling was used to determine the participants of the study. The study was conducted in a Science High School located at one of the prime cities in Metro Manila. The school implements the special science and technology curriculum adapting the standards set by the Regional Science High School. The school accommodates students who do not have an average grade below 85.00 in any subject area and an overall average grade of 85.00 or above on their Grade 6 report cards. Once the entrance test is administered, the students are ranked and a cut off score is set. The overall population of the incoming students is comprised of 50% coming from private schools and 50% from public schools. The school's retention policy holds that students must get an average grade of 85.00 or above per subject area and an overall grade of 85.00 or above. The student will be on probationary status if he/she fails to meet the said grade requirements and must perform better in the incoming school year to stay in the institution.

Aside from the basic subjects, additional mathematics and science subjects per grade level, called the add-ons, are included in the curriculum. In Grade 7, the add-on science is environmental science with research, biotechnology and research in Grade 8, consumer chemistry and research in Grade 9, and electronics and research in Grade 10. The teachers are provided with laptops and lapel microphones as aids for teaching. Each classroom and laboratory is equipped with a flat screen TV mounted on the wall for ease of instruction.

The participants were Grade 10 students of the aforementioned Science High School who have six-hour physics class per week. All of the students were Grade 9 students of the same school and have met the prerequisites for Grade 10 physics. The students were sectioned at the beginning of the school year. From this set of students, the CATA group and the MHRTA group were identified by finding which groups match. To make sure that the groups were a match, their final grades in Grade 9 physics, mathematics, and english were averaged and compared. The results in comparison are shown on table 1.

Table 1.
*Comparison of the averaged physics, mathematics, and english grades between the CATA and the MHRTA groups.*

| Group | N | $\bar{x}$ | Σ | df | $t_{crit}$ | $t_{comp}$ | p-value | Interpretation |
|---|---|---|---|---|---|---|---|---|
| CATA | 27 | 89.52 | 1.51 | 47 | 2.01 | 0.31 | 0.76 | No significant difference |
| MHRTA | 25 | 89.38 | 1.79 | | | | | |

$*p < 0.05$

The CATA and the MHRTA groups' CSEI pretest scores were also compared. The results are shown on table 2.

Table 2.
*Comparison of the CSEI pretest scores between the CATA and the MHRTA groups.*

| Group | N | $\bar{x}$ | Σ | df | $t_{crit}$ | $t_{comp}$ | p-value | Interpretation |
|---|---|---|---|---|---|---|---|---|
| CATA | 27 | 8.04 | 2.72 | 50 | 2.01 | 0.50 | 0.62 | No significant difference |
| MHRTA | 25 | 7.68 | 2.44 | | | | | |

$*p < 0.05$

The CATA group is composed of 13 males and 14 females while the MHRTA group is composed of 10 males and 15 females. The school's retention policy requires the students to get an average of 85.00 on each subject and an overall average grade of 85.00 to pass and to be promoted to the next higher grade level. The CATA groups' mean grades in english, mathematics, and physics are 92.06, 86.09, and 90.25 respectively. The MHRTA groups' mean grades in english, mathematics, and physics are 92.46, 85.88, and 89.80 correspondingly. Based on the figures, both groups were able to obtain passing grades in all three subjects with english having the highest mean, followed by physics, then mathematics.

The CATA group stays at the 7$^{th}$ floor while the MHRTA group stays at the 6$^{th}$ floor of the ten-storey Science High School building. Classes for both groups were held at the Physics laboratory equipped with six workstations, a flat-screen television, and several materials for laboratory work. Moreover, concerned parents, students, and school administrators were given full disclosure of the nature, the risks, and the benefits of the study. All information gathered regarding the students before, during, and after the study, were held confidential. The teacher-researcher carefully planned and thought of means to maximize the benefits and to reduce harm that may occur in the implementation of the teaching approaches.

The Computer-Assisted Teaching Approach (CATA) uses computer simulations and virtual labs where students can see the abstract nature of the electromagnetic phenomenon. The focus of the CATA is to help students visualize the electromagnetic phenomenon. The variables explaining the physical nature of EMI were later incorporated. Several visual representations were used during the discussions, as well as on their written exercises and take home tasks.

The MHRTA uses reconstructed hands-on experiments that were based on Oersted's, Ampere's, Faraday's, and Lenz's experiments in the development of the law of electromagnetic induction. After each experiment, the groups shared their findings with the class. The students had the freedom to interpret, predict, defend their observations, or even question the findings of the other groups. However, there were times when the setups used during the experiments did not work which delayed the actual result of the experiment.

After meeting a competency after instruction, the RPSEI was administered as a formative assessment. Since the effects of the approach on the students' conceptual understanding and the reasoning pattern in electromagnetic induction was the emphasis of the study, the relation of conceptual understanding and reasoning pattern was not measured.

**Research Procedure**

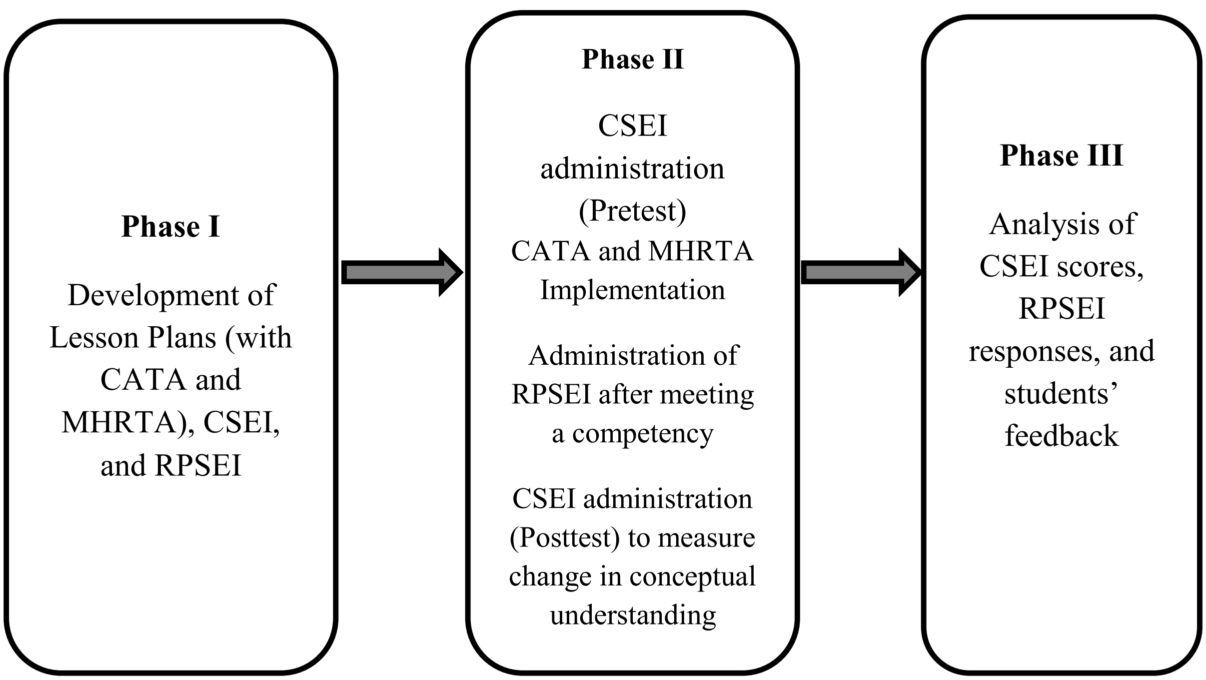



Figure 3. *Research Procedure*

Phase I: Development and Validation of Research Instruments

1. Lesson plans using the computer-assisted teaching approach (CATA) and the modified historical reconstructionist teaching approach (MHRTA) were prepared by the researcher. The said lesson plans include topic, objectives, time allotment, motivation, materials, lesson proper for the discussion and formation of ideas, and references. The teacher's activity and student's responses were written on adjacent columns. CATA lesson plans included a combination of lecture and visual representations commonly used in teaching electromagnetic induction. MHRTA lesson plans included the seven steps of the modified historical reconstruction that are as follows:

   Stage 1. Observation and identification of the electromagnetic induction phenomenon

   Stage 2. Qualitative experimentation of induction current

   Stage 3. Qualitative dependency: the change of flux through the coil

   Stage 4. Representation of measurement results

   Stage 5. Experimental law of induction and model for representation of results

   Stage 6. Interpretations and predictions

   Stage 7. Extension of theory

The CATA and MHRTA lesson plans were evaluated by three experts using an evaluation checklist with a 5-point Likert scale. The interpretations of evaluation, adapted from Pantig (2013), are shown on table 3.

Table 3.
*Levels of acceptability for the CATA and the MHRTA lesson plans, the RPSEI, and the CSEI.*

| Scale | Range | Level of Acceptability | Description |
|---|---|---|---|
| 5 | 4.50 – 5.00 | Very acceptable | If the criterion/criteria is/are highly recognized in the instrument. |
| 4 | 3.50 – 4.49 | Acceptable | If the criterion/criteria is/are recognized in the instrument. |
| 3 | 2.50 – 3.49 | Moderately acceptable | If the criterion/criteria is/are moderately recognized in the instrument. |
| 2 | 1.50 – 2.49 | Least acceptable | If the criterion/criteria is/are poorly recognized in the instrument. |
| 1 | 1.00 – 1.49 | Not acceptable | If the criterion/criteria is/are poorly recognized in the lesson plan.<br>If the criterion/criteria is/are not recognized in the instrument. |

The results for the CATA lesson plan are shown on table 4.

Table 4.
*Evaluation summary for the CATA lesson plan.*

| Criteria | E1 | E2 | E3 | ***Overall*** | ***Interpretations*** |
|---|---|---|---|---|---|
| Overall Plan | 4.00 | 4.50 | 3.75 | *4.08* | *Acceptable* |
| Contents | 3.67 | 5.00 | 3.67 | *4.11* | *Acceptable* |
| Objectives | 3.00 | 4.33 | 4.00 | *3.78* | *Acceptable* |
| Preliminary Materials | 4.00 | 5.00 | 3.00 | *4.00* | *Acceptable* |
| Lesson Introduction | 4.00 | 5.00 | 4.33 | *4.44* | *Acceptable* |
| Lesson Presentation | 4.00 | 5.00 | 3.33 | *4.11* | *Acceptable* |
| Closure | 4.00 | 4.67 | 3.67 | *4.11* | *Acceptable* |
| Activities | 3.67 | 5.00 | 3.33 | *3.00* | *Acceptable* |
| ***Overall*** | *3.79* | *4.81* | *3.64* | **3.95** | **Acceptable** |

Table 4 shows the summary of scores for the Computer-Assisted Teaching Approach lesson plan from each evaluator and for each criterion. The highest average, 4.44 out of 5, is under the lesson introduction while the lowest, 3.00 out of 5, is under the activities. The overall mean of the CATA lesson plan is 3.95 out of 5. The materials and activities for the CATA were easier to produce and provide, so this might have accounted for the high mean under that criterion. The CATA lesson plan got an overall mean of 3.95 which has an interpretation of acceptable.

The competencies on the CSEI to measure conceptual understanding were reflected during the lesson presentation, closure, and the activities.

Table 5.
*Evaluation summary for the MHRTA lesson plan.*

| Criteria | E1 | E2 | E3 | ***Overall*** | ***Interpretation*** |
|---|---|---|---|---|---|
| Overall plan | 4.00 | 5.00 | 4.75 | *4.58* | *Very Acceptable* |
| Contents | 5.00 | 5.00 | 4.00 | *4.67* | *Very Acceptable* |
| Objectives | 4.00 | 5.00 | 4.67 | *4.56* | *Very Acceptable* |
| Preliminary Materials | 4.33 | 3.33 | 4.33 | *4.00* | *Acceptable* |
| Lesson Introduction | 5.00 | 5.00 | 4.33 | *4.78* | *Very Acceptable* |
| Lesson Presentation | 5.00 | 5.00 | 4.33 | *4.78* | *Very Acceptable* |
| Closure | 4.00 | 5.00 | 4.67 | *4.56* | *Very Acceptable* |
| Activities | 4.33 | 4.67 | 4.67 | *4.56* | *Very Acceptable* |
| ***Overall*** | *4.46* | *4.75* | *4.47* | **4.56** | ***Very Acceptable*** |

Table 5 shows the summary of scores for the Conventional Teaching Approach lesson plan from each evaluator and for each criterion. The highest average, 4.78 out of 5, is under the lesson introduction and lesson presentation, while the lowest, 4.00 out of 5, is under the preliminary materials. The overall mean of the MHRTA lesson plan is 4.56 out of 5. The process should be a slow yet steady progress in introducing electromagnetic induction using MHRTA to build a stronger foundation for the topic. The MHRTA lesson plan got an overall mean of 4.56 which is interpreted as very acceptable.

Similarly, the competencies on the CSEI to measure conceptual understanding were reflected during the lesson presentation, closure, and the activities.

Table 6.
*Evaluation summary for the 5-item Reasoning Pattern Survey Instrument in Electromagnetic Induction.*

| General Criteria | E1 | E2 | E3 | ***Overall*** | ***Description*** |
|---|---|---|---|---|---|
| Objectivity of questions | 4.25 | 4.75 | 2.50 | ***3.83*** | ***Acceptable*** |
| Ability of questions to prompt reasoning | 4.75 | 4.25 | 2.60 | ***3.87*** | ***Acceptable*** |
| Layout and clarity | 4.67 | 4.67 | 4.33 | ***4.56*** | ***Very Acceptable*** |
| ***Overall*** | ***4.56*** | ***4.56*** | ***3.14*** | **4.09** | ***Acceptable*** |

Table 6 shows the summary of evaluation scores for the reasoning pattern survey in electromagnetic induction (see appendices F and G) from each evaluator and for each criterion. The highest average, 4.56 out of 5, is under the layout and clarity while the lowest, 3.83 out of 5, is under the objectivity of questions. The evaluators suggest adding diagrams or graphs to give more information under each circumstance. The RPSEI received an overall mean of 4.09 out 5, which is acceptable.

The Conceptual Survey in Electromagnetic Induction was developed to meet the competencies indicated in the K-12 curriculum. It was then face validated by three experts. A five-point Likert-scale was used for evaluating the test. The results of the validation are shown in Table 7.

Table 7.
*Evaluation summary for the 25-item Conceptual Survey Instrument in Electromagnetic Induction.*

| General Criteria | E1 | E2 | E3 | ***Overall*** | ***Description*** |
|---|---|---|---|---|---|
| Objectivity of items | 4.33 | 4.42 | 4.5 | *4.42* | *Acceptable* |
| Layout and clarity | 4.33 | 4.67 | 5.00 | *4.67* | *Very Acceptable* |
| ***Overall*** | *4.33* | *4.55* | *4.75* | **4.54** | ***Very Acceptable*** |

Table 7 shows the summary of evaluations scores for the conceptual survey in electromagnetic induction (see appendices C and D) from each evaluator and for each criterion. The layout and clarity got a higher mean score, 4.67 out of 5, than objectivity of items, 4.42 out of 5. This may be due to some items with varying lengths of choices which may serve as hints for the examinee. Overall, CSEI is very acceptable.

The intraclass correlation coefficient was determined for the CATA and MHRTA lesson plans, the RPSEI, and the CSEI. Fleiss Kappa, which is the adaptation of Cohen's Kappa for 3 or more raters was used to measure interrater reliability. Tha Kappa coefficients may range from -1 to +1, where 0 means the amount of agreement that can be expected from random chance, and 1 represents perfect agreement between raters. The interpretations of the Fleiss Kappa correlation coefficients are shown on table 8 as adapted from Salinas (2016). The ICC coefficients are shown on Table 9.

Table 8.
*Levels of agreement between raters of the CATA and the MHRTA lesson plans, the RPSEI, and the CSEI.*

| Kappa coefficient | Level of agreement |
|---|---|
| 0.810 – 1.000 | Almost perfect agreement |
| 0.610 – 0.800 | Substantial agreement |
| 0.410 – 0.600 | Moderate agreement |
| 0.210 – 0.400 | Fair agreement |
| 0.010 – 0.200 | Slight agreement |
| 0.000 or below | Poor agreement |

Table 9.
*Fleiss Kappa Correlation Coefficients Agreement.*

| Subject | Kappa Coefficient | *Interpretation* |
|---|---|---|
| CTA lesson plan | 1.000 | *Almost perfect agreement* |
| MHRTA lesson plan | 1.000 | *Almost perfect agreement* |
| RPSEI | 1.000 | *Almost perfect agreement* |
| CSEI | 1.000 | *Almost perfect agreement* |

The ICC reliability ranges from -1.00 to 1.00. What is considerably an acceptable reliability value varies considerably among authors (Ottenbacher et.al, 1996). A value of 0.81 or above indicates a good reliability and values below 0.81 indicate moderate to poor reliability (Portney & Watkins, 2000; Landis & Koch, 1977). The ICC (A,3) [ICC (A,3) = 0.073] for the CTA and the MHRTA lesson plan raters shows slight agreement. The ICC (A,3) [ICC (A,3) = -0.067] shows poor agreement between MHRTA raters. There was a slight agreement [ICC (A,3) = 0.112] between RPSEI raters and an observed [ICC (A,3) = 0.320] fair agreement between the CSEI raters.

2. The Conceptual Survey in Electromagnetic Induction was administered before the lesson began.

Phase II

1. During the implementation of the CATA lesson plans and the MHRTA lesson plans, the research Adviser and the department head were invited to observe the execution of the CATA and the MHRTA lesson plans in classroom instruction.

Table 10. *Comparison Matrix for CATA and MHRTA*

| Topic/Objectives | CATA | MHRTA |
| --- | --- | --- |
| Current-carrying conductors<br><br>To identify factors affecting the strength of induced magnetic field or force in a conductor given certain conditions | 1. Students familiarize themselves with Oersted's discovery;<br>2. Then, they identify variables affecting magnitude and direction of magnetic field and force. | 1. Students are familiarized with the phenomenon verifying Oersted's and Ampere's discoveries via reconstructed experiments<br>2. From the experiments, the students share their observations and identify variables affecting magnitude and direction of magnetic field and force |

| | | |
|---|---|---|
| Magnetic Flux and Faraday's law<br><br>To recognize how change in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or a magnetic substance | 1. Through visual representations, the students are introduced to magnetic flux and its variations.<br>2. Students move a magnet through a coil and observe when deflections occurred.<br>3. Students identify variables comprising Faraday's law and relate magnetic flux to the galvanometers readings.<br>4. Students use RHR in determining directions of current induced. | 1. Students perform Faraday's experiment and observe galvanometer's deflections<br>2. Through visual representations, the students recognize magnetic flux<br>3. Students relate magnetic flux to Faraday's experiment<br>4. Students practice using the right-hand rule (RHR) in determining directions of current induced due to flux |
| Faraday's and Lenz's law<br><br>To generate electricity by moving a magnet or a magnetic substance through a coil and determine the factors affecting magnitude and direction of induced current through a conductor | 1. Students recall magnetic flux relate magnetic flux to previous electricity generation activity.<br>2. Students know about Lenz's discovery using a simple experiment showing 'resistance' of non-magnetic materials.<br>3. Students relate variables that make up Faraday's law.<br>4. Students practice using the RHR. | 1. Students gather data using Faraday's setup and Lenz's inference focusing first increasing flux and its effect on current and voltage induced; then decreasing flux and its effects on current and voltage.<br>2. After gathering data, the students create a graph where they can correlate change in flux and magnitudes of current and voltage<br>3. Students know about Lenz's discovery using a simple experiment showing 'resistance' of non-magnetic materials.<br>4. Students add Lenz's findings to previous correlations |

| | | |
|---|---|---|
| | | 5. Students practice using the RHR. |
| Applying EMI in motors and generators<br><br>To explain the working principle of a simple electric motor and a generator using electromagnetic induction | 1. Students relate magnetic flux, Faraday's law, and Lenz's observations.<br>2. Students use these ideas to explain how motors and generators work. | 1. Students interpret the graphs and relate variables.<br>2. Given similar conditions or cases, students analyse predict what will happen.<br>3. Students use these ideas to explain how motors and generators work. |

The students in both approaches were familiarized with the EMI phenomenon first. The CATA group used computer simulations while the MHRTA group used experiments. The MHRTA group was identifying variables to explain the phenomenon. The CATA group was shown videos and animations to observe the phenomenon. The CATA group did use a simple experiment to verify the Lenz's law, but the MHRTA group performed faraday's experiment first then connected it with Lenz's discovery. Both groups had visualizations and representations to perceive the EMI phenomenon. Each group were tasked to reason and explain how motors and generators work using their conceptual understanding on EMI.

An observation checklist was used in evaluating these classroom instructions. Right after completing the competencies and the instruction, the CSEI was administered again to measure conceptual understanding gains.

2. After the MHRTA group was introduced with the topic using Oersted's discovery, the RPSEI Question 1 was answered before proceeding. Then, Oersted's discovery was reinforced with Ampere's experiments and interpretations. RPSEI Question 2 was then administered. After establishing that current-carrying conductors induce magnetic fields, the group then turned to Faraday's claim that the process could be reversed. After exploring Faraday's and Lenz's experiments, the students answered RPSEI Questions 3 and 4. The students were then tasked to summarize and relate the findings of the scientists and finally, RPSEI Question 5 was administered. The CTA group underwent a parallel format of discussion, however, pictures and simulations were mostly used in the discussion of electromagnetism. The CTA group did perform an experiment, but it was used to verify Faraday's discovery. To avoid contamination, similar competencies were achieved at the same period of time. After the two-week implementation, the CSEI was administered to both groups again.

## Phase III

After the CSEI pretest and the posttest have been administered in the CATA and the MHRTA groups, the pretest and posttest scores within and between groups were analyzed. After the pretest, the means of the group were compared to make sure that the samples were matched.

After administering the posttest, the t-Test for matched samples was used to analyze the scores within groups. Between groups, the means from the posttest scores were used to identify whose posttest scores were significantly higher. The matched sample t-Test was based on the difference between paired scores rather than the scores themselves. The computed t-value determined whether the difference between the means was significant. The level of significance was 0.05 and IBM SPSS Statistic 20 software was used for statistics.

To further determine if there was any significant difference between the groups, the Analysis of Covariance was used. It was used to find out if the method used, conventional or modified historical reconstructionist, would have a significant effect on the CSEI posttest scores while controlling for the pretest scores.

Students' answers on the written assessment (RPSEI) after every session were reviewed to identify the reasoning patterns during implementation. Based on the frequency of responses, the emerging recurring pattern was used to determine the reasoning pattern of the students. Since each student was asked to write their observations and interpretations in a journal, a few randomly selected ones were used to determine if it supports the established reasoning pattern.

After determining the reasoning patterns from each group, subgroups were formed. Inductive and deductive are two general categories for reasoning. Inductive reasoning allows students to gather data, identify relevant features of these data, make conclusions from these sets of data, and apply the developed theory to cases with similar features as the data gathered. Inductive reasoning was divided into three subcategories, analogical (ia), causal inference (ib), and evidence based (ic). Deductive reasoning uses logic in making claims and is subcategorized into conditional (da) and syllogistic (db). The syllogistic reasoning pattern follows the if-then proposition while the syllogistic reasoning is drawing conclusions from two premises or grounds, which are known to be true. Syllogism may be in statement or in graphic form (Sternberg et al., 2012).

**Statistical Tools**

The following variables and tests were used to analyze the data gathered.

- Mean ($M$) – is the average of the pretest and the posttest scores of the CATA and the MHRTA groups on the CSEI
- Standard deviation ($SD$) – used to identify the spread of posttest scores on the CSEI of the CATA and the MHRTA groups from the mean
- Intraclass correlatio (ICC) – was used to assess the reliability or the absolute agreement of the average evaluation ratings from sets of raters for the CATA and the MHRTA lesson plans, the RPSEI, and the CSEI.
- t-test – was used to identify the difference between the pre and the posttest scores on the CSEI of the CATA and the MHRTA groups as well as the difference between the posttest scores between the CATA and the MHRTA groups

## Chapter III

## Results and Discussions

This chapter includes the analysis of the data collected, discussions, and implications on the use of the modified historical reconstructionist teaching approach in students' conceptual understanding and reasoning patterns in electromagnetic induction.

### Results of the Conceptual Survey in Electromagnetic Induction

Table 11.
*Pretest and posttest scores of the CATA and the MHRTA groups in the Conceptual Survey in Electromagnetic Induction.*

| Group | N | Pretest | | Posttest | |
|---|---|---|---|---|---|
| | | $\bar{X}$ | σ | $\bar{X}$ | σ |
| CTA | 27 | 8.04 | 2.72 | 17.81 | 3.21 |
| MHRTA | 25 | 7.76 | 2.45 | 18.56 | 3.06 |

Table 11 shows the mean pretest and posttest scores between the CATA and the MHRTA groups. The CATA group got a higher pretest mean score of 8.04 (*SD = 2.72*) while the MHRTA group had a pretest mean of 7.76 (*SD = 2.45*). The CATA group had a lower posttest mean score of 17.81 (SD = 3.21) while the MHRTA group got a posttest mean of 18.56 (*SD = 3.06*). To further explore differences between the CATA and the MHRTA groups, the students' scores per objective, as indicated in the CSEI's table of specification, was determined. The objective was adapted from the K-12 curriculum competencies for Grade 10 Second Quarter Science. Each objective is worth five points. The posttest scores per competency are shown on table 14.

Table 12.
*Test of difference between pretest and posttest scores of the CATA and the MHRTA groups in the Conceptual Survey in Electromagnetic Induction.*

| Group | | $\bar{x}$ | σ | N | df | $t_{crit}$ | $t_{comp}$ | p-value | Interpretation |
|---|---|---|---|---|---|---|---|---|---|
| CATA | pretest | 8.04 | 8.04 | 27 | 26 | 1.71 | 11.74 | 3.38E-12** | significant difference |
| | posttest | 17.81 | 3.21 | | | | | | |
| MHRTA | pretest | 7.76 | 2.45 | 25 | 24 | 1.71 | 14.52 | 1.1E-13** | significant difference |
| | posttest | 18.56 | 3.06 | | | | | | |

*$*p < 0.05$ $**p < 0.001$*

Table 12 shows that the CATA group's posttest (*M = 17.81, 3.21*) scores were significantly higher than the pretest (*M = 8.04, SD = 2.72*), $t(50) = -11.74$, $p < 0.001$ . The table also reflects the MHRTA group's posttest scores (*M = 18.56, SD = 3.*06) being significantly higher than the pretest scores (*M = 7.76, SD = 2.*45), $t(50) = -14.52$, $p < 0.001$.

There was a significant difference between the pretest and the posttest CSEI scores of the CATA group. The posttest scores were significantly higher than the pretest scores after implementing CATA. The CATA group was more exposed to computer-assisted representations and animations to support the discussion of the topic and to facilitate understanding. The use of computer-assisted instructional materials were also used by Anderson and Barnett (2013), Hargunani (2010), and Rutten et al. (2012) which also lead to an increase in the test scores. It was easier to use these computer-assisted materials for students to understand the experiments of Oersted, Ampere, Faraday, and Lenz without any risk (Hargunani, 2010).

There was a significant difference between the pretest and the posttest scores of the MHRTA group. The posttest scores were significantly higher than the pretest scores after implementing MHRTA.

The MHRTA group was more exposed to hands-on experiments, adapting and modifying the experiments performed by Oersted, Ampere, Faraday, and Lenz in the development of the theory with simplified models, graphs, and diagrams. Besson (2013) suggested that teaching with models, images, and theories found in history may be useful representations for introducing and understanding a concept. When Heering (2009) used reconstructed apparatus in training teachers, the teachers were able to develop a conceptual understanding more reasonably than attending seminars and reading modules alone. Heering added that taking these into the classroom with the appropriate apparatus and experiment may also yield the same results to the students.

Since the students were allowed to perform and to interact with replicas, this materialized a sense of responsibility in what they do and interpret from these materials (Cavicchi, 2008). These findings imply the need to deviate from the lecture approach and from reliance on the heavy mathematical context of electromagnetic induction when introducing the topic to students. Visual representations, historical overviews, hands-on experiments, and skillful use of models are a few keys to consider in teaching electromagnetic induction. Depending heavily on textbooks, modules, and oversimplified experiments to support student's understanding should no longer be an option.

Despite the demanding nature of incorporating these enrichments to teaching science, a persistent support to its implementation and progress may promote further improvements in students' conceptual understanding.

Table 13.
*Test of difference between overall posttest scores of the CATA and the MHRTA groups in the Conceptual Survey in Electromagnetic Induction.*

| Group | N | $\bar{x}$ | σ | df | $t_{crit}$ | $t_{comp}$ | p-value | Interpretation |
|---|---|---|---|---|---|---|---|---|
| CATA | 27 | 17.81 | 3.21 | 50 | 1.68 | -0.86 | 0.20 | No significant difference |
| MHRTA | 25 | 18.56 | 3.06 | | | | | |

*$p < 0.05$

TABLE 14.
*Posttest scores of the CATA and the MHRTA groups in the CSEI for each objective.*

| Objectives (adapted from DepEd K-12 Curriculum competencies) | CATA | | MHRTA | |
|---|---|---|---|---|
| | $\bar{x}$ | σ | $\bar{x}$ | Σ |
| *I* | 4.30 | 0.87 | 4.24 | 1.16 |
| *II* | 4.07 | 0.83 | 4.36 | 0.70 |
| *III* | 3.30 | 0.78 | 3.80 | 0.76 |
| *IV* | 3.48 | 1.16 | 3.68 | 1.22 |
| *V* | 2.67 | 1.36 | 2.48 | 1.08 |

*N (CATA) = 27 N (MHRTA) = 25*

*I. ascertain the directions of the magnetic force of the induced magnetic field given the direction of current;*
*II. identify factors affecting the strength of induced magnetic field or force in a conductor given certain conditions;*
*III. recognize how change in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or a magnetic substance;*
*IV. use the demonstration of generating electricity by moving a magnet or a magnetic substance through a coil in determining the factors affecting magnitude and direction of induced current through a conductor;*
*V. explain the working principle of a simple electric motor and a generator using electromagnetic induction*

Table 14 shows that there is no significant difference between the posttest scores of the CATA (*M = 17.81, SD = 3.21*) and the MHRTA (*M = 18.56, SD = 3.06*) groups, $t(50) = -.86$, $p > .05$.

The highest possible score per competency is five. As shown in table 13, the mean score in objective *I* of the CATA group is highest (*M = 4.30, SD = 0.87*), while the mean score of the MHRTA group in objective *V* is the lowest (*M = 2.48, SD = 1.08*). Objective *I* aims to gauge the student's ability to ascertain the directions of the induced magnetic force given the direction of the current while objective *V* focuses on their ability to explain the working principles of a simple electric motor and generator using electromagnetic induction.

To determine if there was a significant difference between the pretest and the posttest mean scores of the CATA and the MHRTA groups, the t-test for independent samples was used.

TABLE 15.
*Test of difference between the posttest scores of the CATA and the MHRTA groups in the CSEI for each objective.*

| Objectives (adapted from DepEd K-12 Curriculum competencies) | Group | Mean | SD | df | $t_{crit}$ | $t_{comp}$ | p-value | Interpretation |
|---|---|---|---|---|---|---|---|---|
| *I* | CATA | 4.30 | 0.87 | 44 | 1.68 | -0.20 | 0.42 | no significant difference |
| | MHRTA | 4.24 | 1.16 | | | | | |
| *II* | CATA | 4.07 | 0.83 | 50 | 1.68 | 1.35 | 0.09 | no significant difference |
| | MHRTA | 4.36 | 0.70 | | | | | |
| *III* | CATA | 3.30 | 0.78 | 50 | 1.68 | 2.36 | 0.01* | significant difference |
| | MHRTA | 3.80 | 0.76 | | | | | |
| *IV* | CATA | 3.48 | 1.16 | 49 | 1.68 | 0.60 | 0.27 | no significant difference |
| | MHRTA | 3.68 | 1.22 | | | | | |
| *V* | CATA | 2.67 | 1.36 | 49 | 1.68 | -0.55 | 0.29 | no significant difference |
| | MHRTA | 2.48 | 1.08 | | | | | |

*$p < 0.05$ **$p < 0.001$

*N (CATA) = 27 N (MHRTA) = 25*

I. *ascertain the directions of the magnetic force of the induced magnetic field given the direction of current;*
II. *identify factors affecting the strength of induced magnetic field or force in a conductor given certain conditions;*
III. *recognize how changes in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or by a magnetic substance;*
IV. *use the demonstration of generating electricity by moving a magnet or a magnetic substance through a coil in determining the factors affecting magnitude and direction of induced current through a conductor;*
V. *explain the working principle of a simple electric motor and a generator using electromagnetic induction*

To determine further if there was significant difference between the posttest scores of the CATA and the MHRTA groups, the posttest scores were divided and clustered per objective.

Table 7 shoes that the mean of the posttest scores of the CATA (*M = 3.30, SD = 0.78*) in objective *III* are significantly different from the posttest scores of the MHRTA (*M=3.80, SD = 0.76*), $t(49) = 2.36$, $p = 0.01$.

There was no significant difference between the posttest scores of the CATA and the MHRTA groups. However, there was a significant difference in the posttest scores on questions under objective III of the CSEI. The questions measure the student's ability to recognize how change in magnetic flux affects the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or by a magnetic substance.

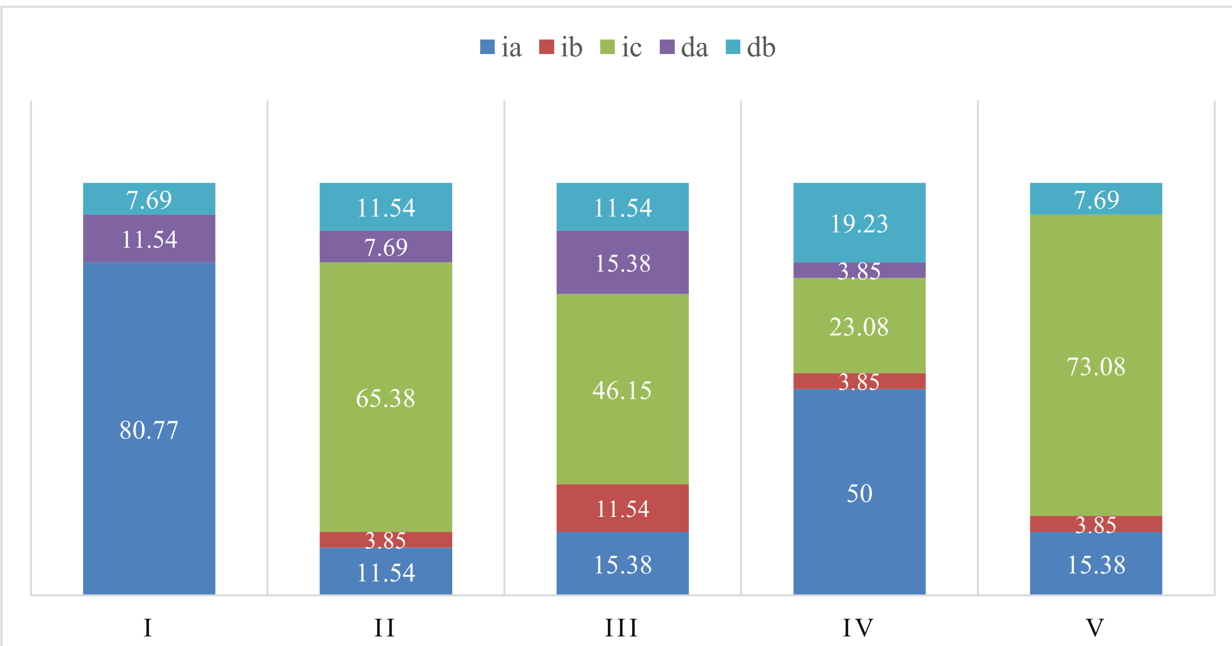
When Mantyla (2012) used historical reconstruction in teaching electromagnetic, the results showed that the models and experiments found an essential role in the individual's argumentation in qualifying knowledge and instead of only remembering the formula of electromagnetic induction, they better understood how the variables formed the law, which was not initially the case.

This is one of main features of MHRTA, to help students recognize the roles of variables in explaining the phenomenon. Some of the intricate details which may be left out when focusing on the mathematical systems in explaining the EMI phenomenon can now be given attention.

**Results of the Reasoning Pattern Survey in Electromagnetic Induction**

To further investigate the effects of historical reconstructionist approach in teaching electromagnetic induction, the reasoning patterns of the CATA and the MHRTA groups were assessed by categorizing the responses from the RPSEI using deductive and inductive reasoning and their sub-categories. Inductive reasoning was divided into three subcategories, analogical (ia), causal inference (ib), and evidence based (ic). Deductive reasoning was subcategorized into conditional (da) and syllogistic (db) (Sternberg et al., 2012).

After scrutinizing and cross-validating the student responses, the overall recurring reasoning pattern for each task has been determined.

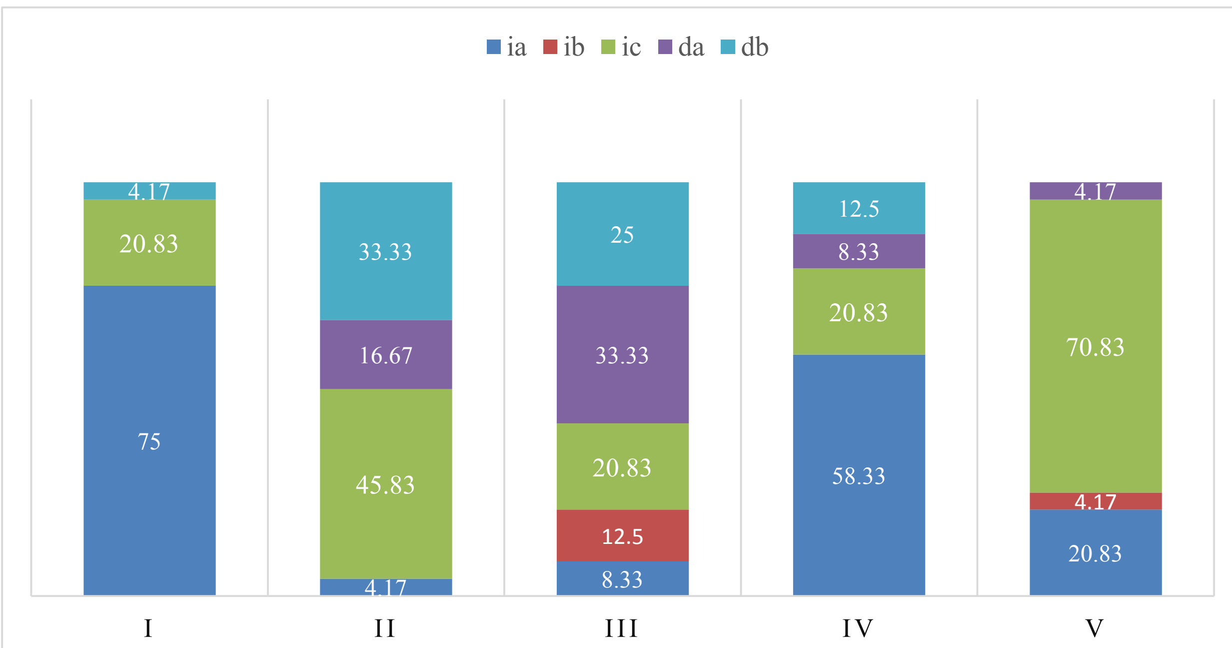



*Legend: ia – inductive reasoning subcategory A; ib - inductive reasoning subcategory B; ic – inductive reasoning subcategory C; da – deductive reasoning subcategory A; db – deductive reasoning subcategory B*
*I – RPSEI task 1; II – RPSEI task 2; III – RPSEI task 3; IV – RPSEI task 4; V – RPSEI task 5*

Figure 4. *Observed reasoning patterns of the Computer Assisted Teaching Approach group in the Reasoning Pattern Survey in Electromagnetic Induction.*

In the CATA group, about 80.77 percent used *ia* to answer task 1 in the RPSEI and 7.69 percent used *db*. To answer task 2, 65.38 percent used *ic*, and only 3.85 percent used *ib*.

Approximately 46.15 percent used *ic*, and 11.54 percent used *db* and *ib* to answer task 3. To answer RPSEI task 4, 50.00 percent used *ia*, and 3.85 percent used *da* and *ib*. About 73.08 percent used *ic*, and 3.85 percent used *ib*.




*Legend: ia – inductive reasoning subcategory A; ib - inductive reasoning subcategory B; ic – inductive reasoning subcategory C; da – deductive reasoning subcategory A; db – deductive reasoning subcategory B*
*I – RPSEI task 1; II – RPSEI task 2; III – RPSEI task 3; IV – RPSEI task 4; V – RPSEI task 5*

Figure 5. *Observed reasoning patterns of the Modified Historical Reconstructionist Teaching Approach group in the Reasoning Pattern Survey in Electromagnetic Induction.*

In the MHRTA group, 75.00 percent used *ia*, and only 4.17 percent used *db* to answer RPSEI task 1. About 45.83 percent used *ic,* and only 4.17 percent used *ia* to answer task 2. To answer task 3, 33.33 percent used da, and 8.33 percent used *ia*. To answer task 4, 58.33 percent used *ia* and 8.33 percent used *da*. About 70.83 percent used *ic* and 4.17 percent used *da* and *ib* to answer task 5.

Table 16. *Overall Reasoning Pattern of the CATA and the MHRTA groups.*

| RPS EI | CATA | | | | | | | | | | MHRTA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I_A$ | | $I_B$ | | $I_C$ | | $D_A$ | | $D_B$ | | $I_A$ | | $I_B$ | | $I_C$ | | $D_A$ | | $D_B$ | |
| | f | % | f | % | f | % | f | % | f | % | f | % | f | % | f | % | f | % | f | % |
| Task 1 | 21 | *80.77* | - | - | - | - | 3 | *11.54* | 2 | *7.69* | 18 | *75.00* | - | - | 5 | *20.83* | - | - | 1 | *4.17* |
| Task 2 | 3 | *11.54* | 1 | *3.85* | 17 | *65.38* | 2 | *7.69* | 3 | *11.54* | 1 | *4.17* | - | - | 11 | *45.83* | *4* | *16.67* | 8 | *33.33* |
| Task 3 | 4 | *15.38* | 3 | *11.54* | 12 | *46.15* | 4 | *15.38* | 3 | *11.54* | 2 | *8.33* | 3 | *12.50* | 5 | *20.83* | 8 | *33.33* | 6 | *25.00* |
| Task 4 | 13 | *50.00* | 1 | *3.85* | 6 | *23.08* | 1 | *3.85* | 5 | *19.23* | 14 | *58.33* | - | - | 5 | *20.83* | 2 | *8.33* | 3 | *12.50* |
| Task 5 | 4 | *15.38* | 1 | *3.85* | 19 | *73.08* | - | - | - | - | 5 | *20.83* | 1 | *4.17* | 17 | *70.83* | 1 | *4.17* | - | - |

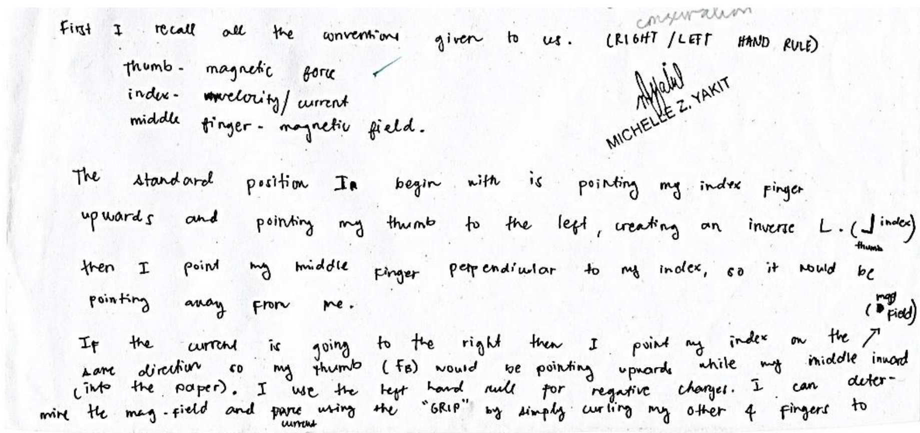



Figure 6a.

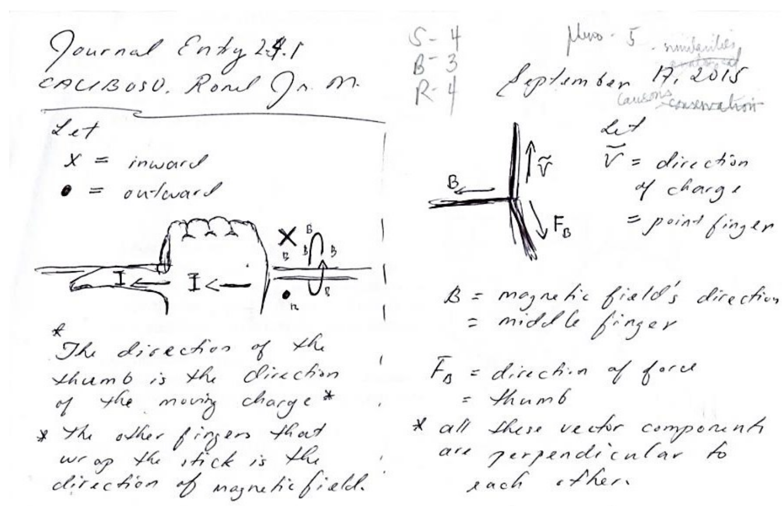



Figure 6b.

*Figures 6a, 6b, 6c. Sample MHRTA student responses in Task 1.*

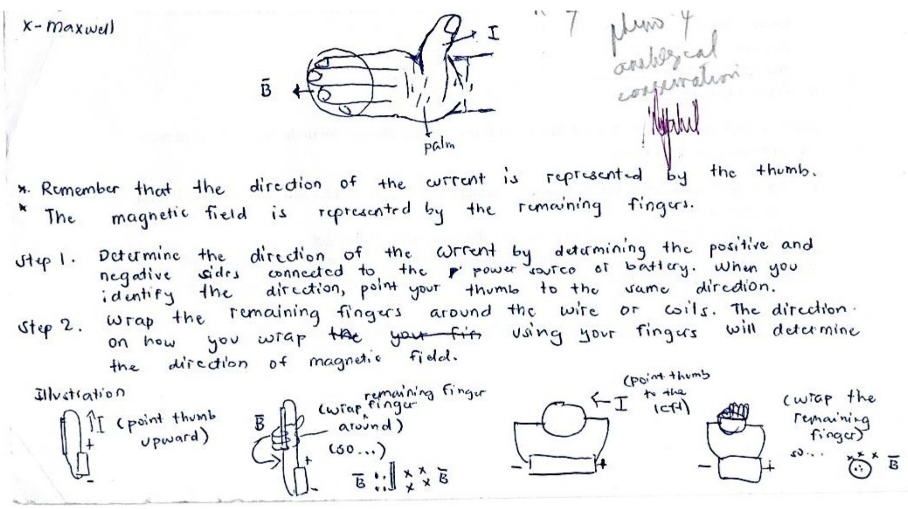



*Figure 6c.*

Figures 6a, 6b, and 6c show students' responses when asked to relate the strengths of current, induced magnetic field, and magnetic force. *Figures 6a, 6b, and 6c* show that the students recalled the rules, experiences, and elements with similar features or patterns in order to answer the question. Rule-based (ia) inductive reasoning was used.

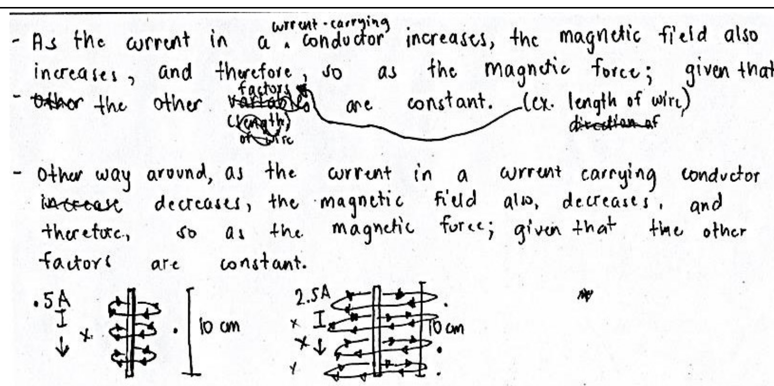
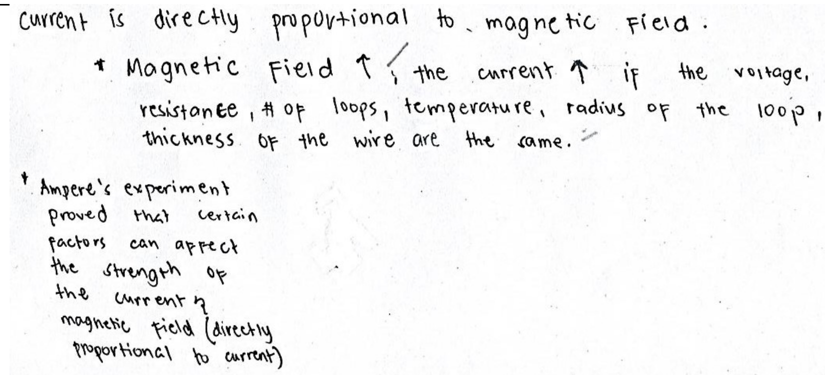



*Figure 7a.*

*Figures 7a, 7b, 7c. Sample MHRTA student responses in Task 2.*

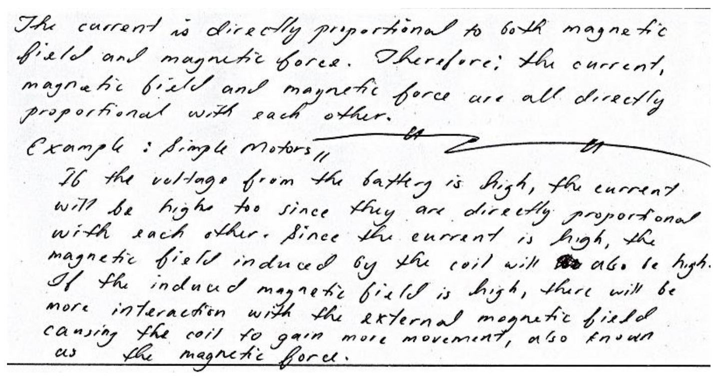


current is directly proportional to magnetic field.

* Magnetic field ↑, the current ↑ if the voltage, resistance, # of loops, temperature, radius of the loop, thickness of the wire are the same.

* Ampere's experiment proved that certain factors can affect the strength of the current & magnetic field (directly proportional to current)

*Figure 7b.*



The current is directly proportional to both magnetic field and magnetic force. Therefore; the current, magnetic field and magnetic force are all directly proportional with each other.

Example : Simple Motors

If the voltage from the battery is high, the current will be high too since they are directly proportional with each other. Since the current is high, the magnetic field induced by the coil will also be high. If the induced magnetic field is high, there will be more interaction with the external magnetic field causing the coil to gain more movement, also known as the magnetic force.

*Figure 7c.*

Figures 7a, 7b, and 7c show students' responses when asked to explain how the strength of the current relates to the induced magnetic field strength and magnetic force. *Figures 7a* and *7b* show that the students used the results of the experiments. Evidence-based reasoning (ic), inductive reasoning was used. *Figure 7c* shows that the student used two correct statements to make his claims. This qualifies as syllogistic reasoning (db), under deductive reasoning.

Figures 8a, 8b, and 8c show students' responses when asked to explain how the magnetic flux variations affect the magnitude and direction of the induced current in a coil of wire. Evidence-based inductive reasoning (ic) was used by the student's response in *figure 8a*, conditional deductive reasoning (da) was used in *figure 8b*, and syllogistic deductive reasoning (db) was used in *figure 8c*.

*Figure 8a* shows that the students used the results of the experiments. Evidence-based reasoning (ic), inductive reasoning was used. *Figure 8b* shows that though the students recalled the experiment, the more noticeable pattern is the if-then format; conditional reasoning (da) of deductive reasoning was used. The student in *figure 8c* used two correct statements and mental models/ representations to make his claims. This qualifies as syllogistic reasoning (db), under deductive reasoning.

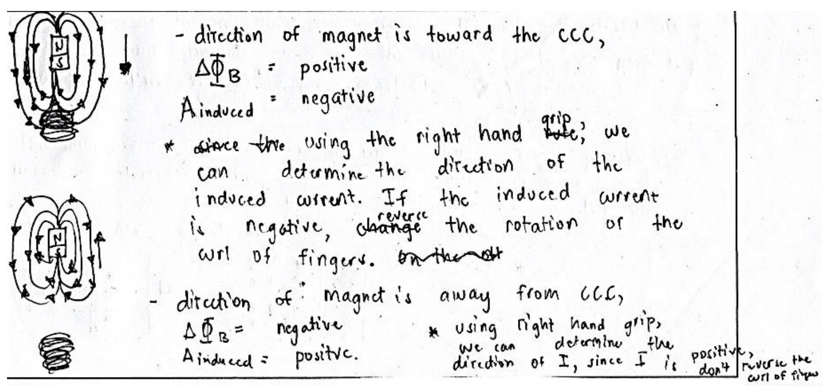



*Figure 8a.*

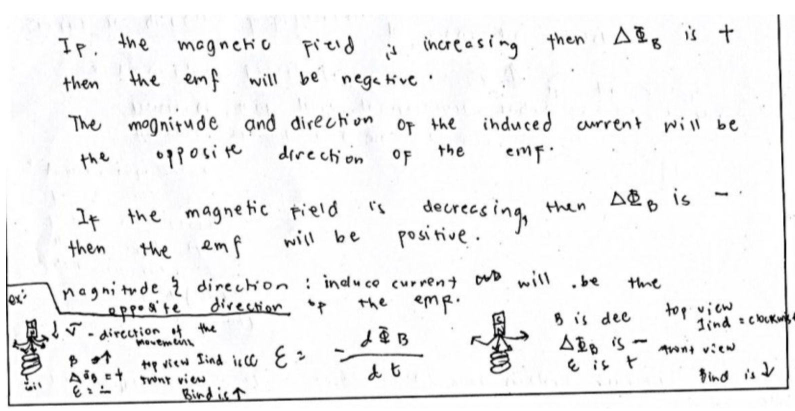
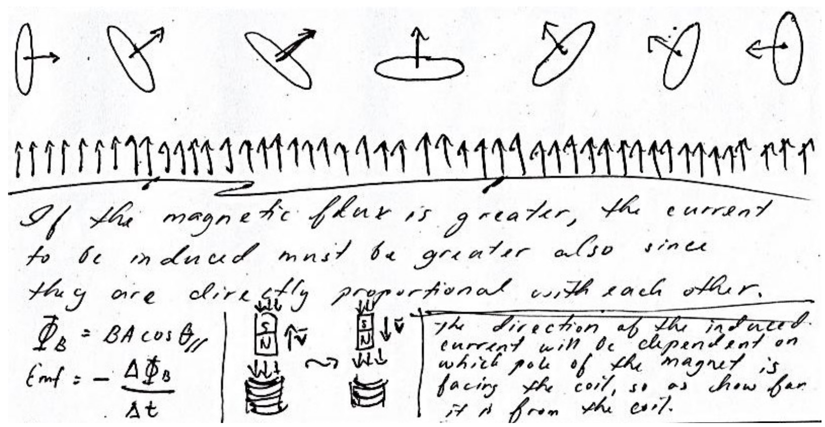



*Figure 8b.*

Figure 8c.




*Figures 8a, 8b, 8c. Sample MHRTA student responses in Task 3.*

Figure 9a.

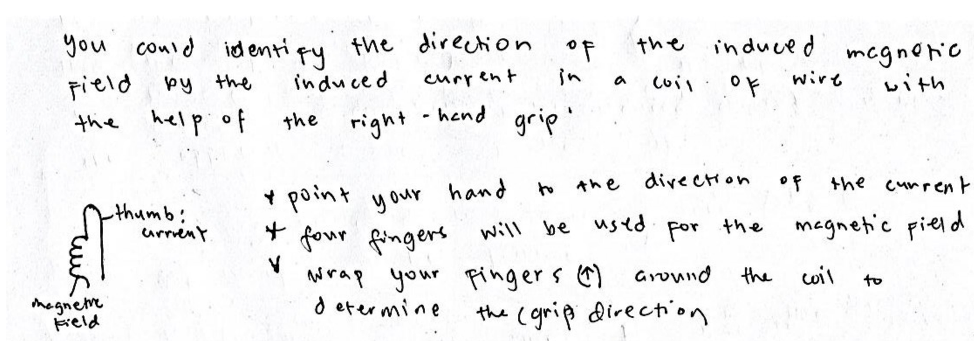


Figure 9b.

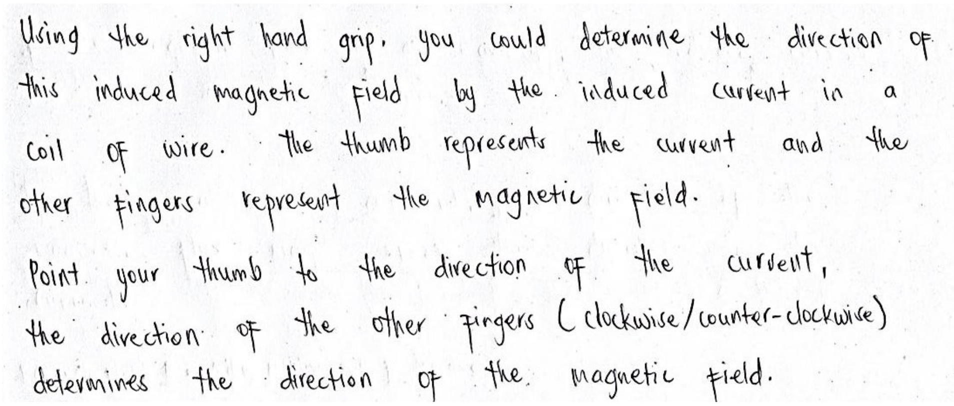
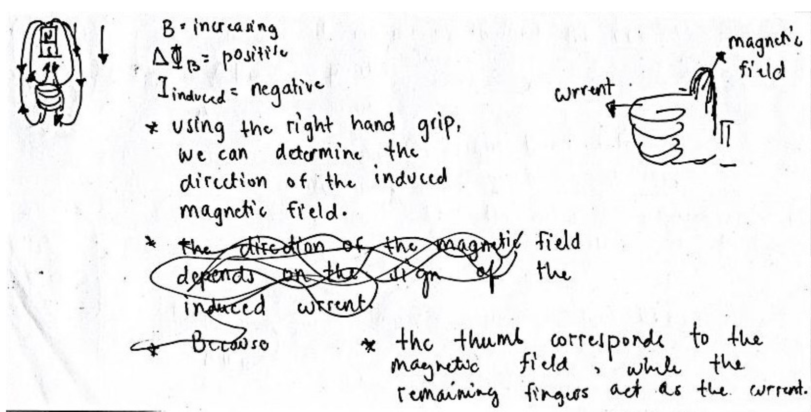

Using the right hand grip, you could determine the direction of this induced magnetic field by the induced current in a coil of wire. The thumb represents the current and the other fingers represent the magnetic field.
Point your thumb to the direction of the current, the direction of the other fingers (clockwise/counter-clockwise) determines the direction of the magnetic field.

Figure 9c.




*Figures 9a, 9b, 9c. Sample MHRTA student responses in Task 4.*

Figures 9a, 9b, and 9c show students' responses when asked to explain how to determine the direction of the induced magnetic field by the induced current in a coil of wire. The students' responses in *figures 9a and 9b* show that they remember the rule and experiences and elements with similar features or patterns. Rule-based (ia) inductive reasoning was used. The student in *figure 9c* though a rule was used, he enumerated the variables that resulted from the experiments. Evidence-based reasoning (ic), inductive reasoning was used.

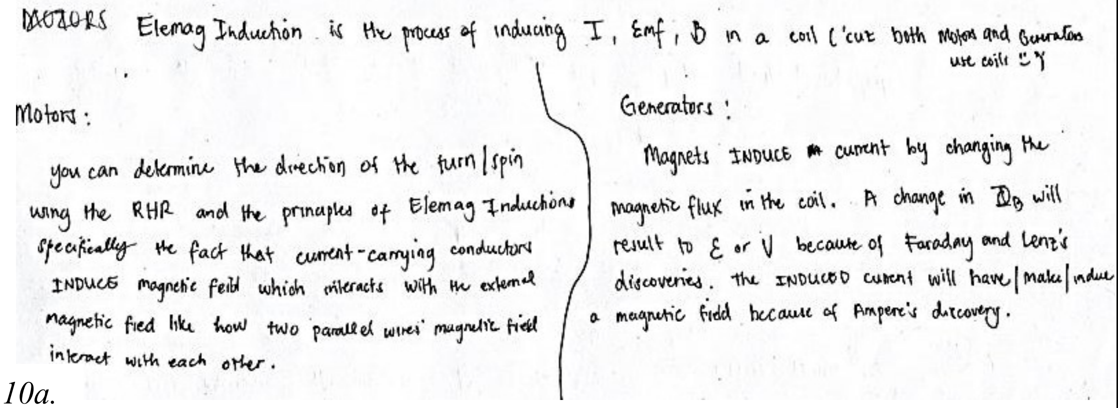



*Figure 10a.*

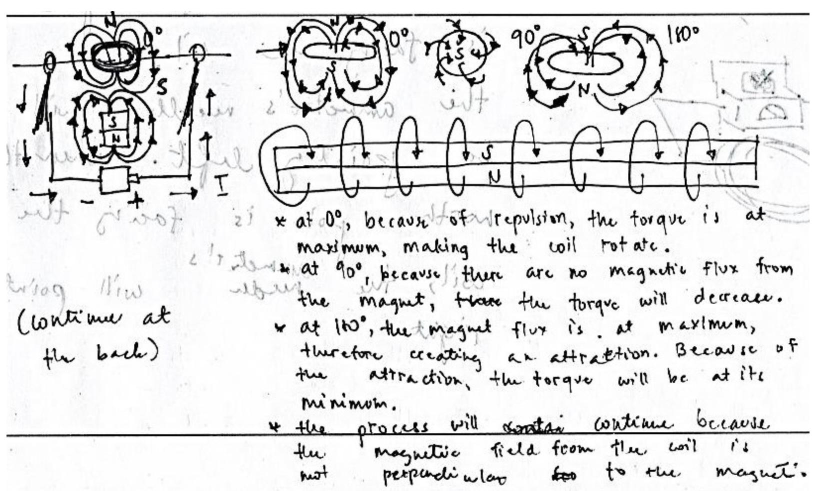



*Figure 10b.*

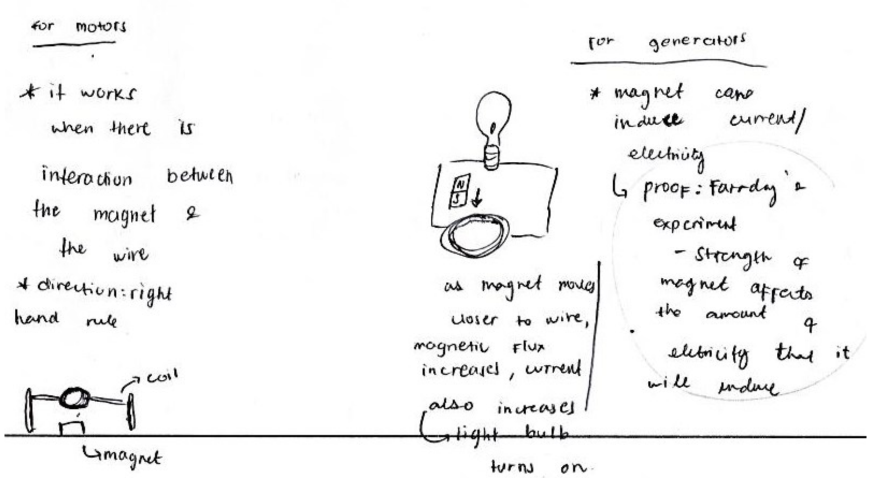



*Figure 10c.*

*Figures 10a, 10b, 10c. Sample MHRTA student responses in Task 5.*

Figures 10a, 10b, and 10c show students' responses when asked to explain how motors and generators work using electromagnetic induction. *Figures 10a, 10b,* and *10c* show that the students sustained with the results of the experiments and applied the rule that was developed from these results. Evidence-based inductive reasoning (ic) was used.

When the students found themselves as explorers, this deepened their interaction and relation with the phenomena being taught (Cavicchi, 2011). Some students from the MHRTA group wrote the following reactions:

**Student 1**: *"I enjoyed doing the experiments and I learned a lot from the exercises given to us."*

**Student 2**: *"The topic was confusing but the use of concrete examples and the use of experiments helped me understand the topic deeper."*

**Student 3**: *"What helped me understand the topic was the teacher's unique way of teaching with concrete examples and situtions."*

**Student 4**: *"I am a visual learner. That's why the hands-on experiments and the diagrams made learning easier for me."*

**Student 5**: *"I was used to teachers providing all the information I need that's why it was hard for me at the beginning, but realizing that I can learn on my own from the hands-on activities, I find learning easier."*

Almost the same reasoning pattern can be observed in both groups. In task one, most students from the CATA and the MHRTA groups used *ia*, *ic* in task two, *ia* in task 4, and *ic* in task 5. However, it is noticeable that most students from the CATA group used *ic* in answering task 3, while most from the MHRTA group used *da*. The *ic* reasoning type suggests that an individual may use both information from their sensory experience and information based on what they already know or have inferred previously (Sternberg et.al, 2012). These CATA students may have used the evidence from the simulations and known facts about EMI to answer the question. The *da* reasoning type proposes that an individual may follow the reasoning that if a certain condition is met, then a consequent occurrence shall follow. The MHRTA group may already have extended the applications of EMI in such a way that any familiar incident may produce a subsequent occurrence since a well-established connection has been met. Despite this difference, the overall reasoning pattern that was observed was inductive.

**Implications of the Study**

The pretest and the posttest scores on the CSEI revealed that both the CATA and the MHRTA groups have gained conceptual understanding. The participants in the CATA were more exposed to computer-assisted visualization which were somehow similar to efforts done by Dori and Belcher (2005), Anderson and Barnett (2013), Hargunani (2010), and Rutten, Joolingen and van der Veen (2012) in utilizing computer-assisted instruction to visualize the phenomenon which resulted in increase in test scores. The CATA group did find the visual representations easier to understand. The use of experiments was not removed from the CATA group but the main function of the experiment was to verify the law or theory being discussed. The MHRTA group was allowed to discuss the results of the experiments and sufficiently share their observations and findings. Both groups were exposed to visual representations which were useful to them in picturing quantities and identifying their relationships (Sanchez & Loverude, 2012). Both groups did not experience the typical lecture that closely follows provisions in textbooks and the heavy mathematical constructs of the topic were avoided as suggested by Anderson and Mina (2003).

The results imply that digressing from the heavy mathematical concepts of electromagnetic induction may help students focus on the fundamental nature of the phenomenon. The mathematical nature of electromagnetic induction is relevant to profoundly understand the phenomenon but delaying it in introducing the topic to the students may give the students more opportunities observing and concretizing the phenomenon while slowly familiarizing with the variables.

Analyzing the student responses in the RPSEI, the researcher perceived that the students used inductive reasoning in answering the questions. Inductive reasoning appears to be the ruling reasoning pattern. According to McNeill (2007), successfully engaging students in “scientific inquiry process, construction of scientific arguments to explain phenomena in which students justify their claims via evidence and reasoning could result in learning gains.” The students’ ability to reason and think critically was promoted in both CATA and MHRTA groups. The MHRTA group practiced thinking and acting like scientists thus engaging them in comparing, countering, and justifying claims based on evidence and experiments. However, as Gooding (2010) argued, “representations are essential to visualization or visual inference, which scientists used to develop and to interpret scientific phenomenon.” Moreover, representation of various types and complexities raise a range of cognitive capacities. The CATA group’s exposure to various forms of representations and visualizations may have invoked similar inferences as the MHRTA group.

This result may be due to the fact that the participants are Science High School students which makes most of them inductive reasoners. This finding implies that the skillful and appropriate use of experiments and visual representations is useful in promoting and reinforcing the understanding of electromagnetic induction. The students’ ability to reason shall not be limited by the aforementioned supplementations in the teaching-learning process. The difference in the manner of answering the RPSEI is quite noticeable between the CATA and the MHRTA participants. Though both groups were observed to use diagrams and other forms of representations, the MHRTA group seemed to pay more attention to detail. When the reasoning patterns were analyzed and coded, the pattern of reasoning was observed and not the depth or quality of inference made. Perhaps, the pattern of reasoning may be similar, but the depth of inference made is different.

Analysis of the student responses in each task, revealed that the student responses show how relevant visualizations and tangible experiments were in making their claims. The reconstructed experiments supersede these potentials because aside from the visual support, they allowed the students to experience the very nature of electromagnetic induction. Scientists gather data, analyze the data gathered, make interpretations based on the evidence, and generate principles, theories, or laws from these steps. Engaging the students into activities that will allow them to follow similar ways of thinking and reasoning may support conceptual growth. Allowing the students to experience and visualize the physical nature of electromagnetism made knowledge acquisition more achievable.

Moreover, the MHRTA students' responses to the RPSEI questions reveal depth, quality, and attention to details. The promising results of continued adept implementation of the historical reconstructionist approach should be practiced so students may show better understanding of abstract ideas such as on how electricity can be generated with the use of magnets, the factors affecting the current generated, and how the process can be reversed. If the students have gathered and seen the actual results of electromagnetic induction experiments, they will use these pieces of evidence gathered and apply the facts learned in explaining the electromagnetic phenomena and evaluating phenomenon with similar patterns or features. These features of MHRTA promote conceptual understanding and improved reasoning ability.

Such qualities of MHRTA make it valuable in promoting scientific literacy and scientific growth in the K-12 curriculum. Unlike in the previous curriculum, where more topics are targeted per quarter that makes it impossible for both students and teachers to understand each topic profoundly, fewer topics were given more attention with the new curriculum. The K-12 curriculum aims to concentrate on particular topics per quarter where MHRTA can be sensible. Indeed the approach requires time and effort on the part of the teachers (Heering, 2009), but the point of K-12 is to decongest the curriculum to pave way for more learning time focusing on a particular topic. The MHRTA can be beneficial to the K-12 curriculum's aims. As the significant difference in objective three suggests, the students under MHRTA having the ability to recognize how changes in magnitudes and directions of variables through a series of reconstructed experiments proves the substantial effect of the approach to intricate topics, such as electromagnetic induction. If such approach can yield these positive results in just a short period of time it was implemented, modifying or further implementing the approach with the same topic or other complex topics to see the extent of its effects should be a point of interest for educators and curriculum developers. As the curriculum takes full employment, methods, such as MHRTA, that will help it meet its goals should also be explored.

# Chapter IV

## Summary, Conclusion, and Recommendations

This chapter includes the summary of findings on the effects of the modified historical reconstructionist teaching approach in the students' conceptual understanding and reasoning pattern in electromagnetic induction. It also includes the conclusion drawn from the analyses of the data gathered and recommendations for future researches.

### Summary of findings

The observed difficulties in understanding Physics concepts may be traced from the nonconcrete nature and the heavy mathematical content of a topic. Electromagnetic induction is one particular topic that requires three-dimensional and physical models to be clearly understood. Textbook representations and repeating canned experiments do not support conceptual gains because of the limited explicit applications. Computer simulations provide limited utility as substitute laboratory works but it comes with the increased risk that students will see no need to be more eager and take responsibility for their own understanding (Bryan, 2006).

The historical reconstructionist approach can help familiarize and even deepen students understanding of Physics concepts such as electromagnetic induction, that were less concrete and have little noticeable evidence backing its existence. Reconstructing historical experiments, recording observations, and recreating their practice of exchanging ideas into the classroom can be beneficial to both students and teachers. Based on the literature gathered the practice has not been observed in the local school setting, so this study attempted to use the approach locally using readily available materials. Incorporating these practices may allow better understanding of the topic and develop scientific reasoning amongst the students. The effects of historical reconstructionist approach were determined through the students' conceptual understanding and reasoning pattern.

The CATA group was taught with computer-assisted visualizations with an experiment for verification while the MHRTA group experienced historical reconstruction with supporting models and other forms of visual representations. The CATA and MHRTA groups were matched using grades in Math, Science, and English from the previous school year, and the CSEI pre-test. During implementation, the RPSEI was administered after meeting a competency. After the implementation, the CSEI was re-administered.

The mean scores on the pretest and the posttest between the CATA and the MHRTA groups were computed. The pretest and posttest mean scores of the CATA group were 8.04 and 17.81 respectively. The pre and posttest mean scores of the MHRTA groups were 7.76 and 18.56 respectively. In the test of difference between the pretest and the posttest scores of the CTA group, the value obtained using t-test is 3.38E-12. In the test of difference between the MHRTA group's pretest and posttest scores, the value obtained using t-test is 1.1E-13.

In the test of difference between the posttest scores of the CATA and the MHRTA groups, the value obtained using t-test is 0.20. There was no significant difference between the posttest scores of the groups. To further investigate the difference between the posttest scores of the CATA and the MHRTA groups, the posttest scores were grouped according to the objectives of the CSEI items as indicated by the table of specification which were adapted from the K-12 competencies. In objective one, the posttest mean scores of the CATA and the MHRTA groups were 4.30 and 4.24 respectively. In objective two, the posttest scores of the CATA and the MHRTA groups were 4.07 and 4.36 correspondingly. In objective three, the CATA group had a posttest mean score of 3.30 and the MHRTA group had a posttest mean score of 3.80. In objective four, the CATA group had 3.48 while the MHRTA group had 3.68, and on objective five, the CATA group had a posttest mean score of 2.67 while the MHRTA group had 2.48. Further analysis of the posttest scores per objective using t-test returned a value of 0.01 for the third objective.

The overall reasoning patterns were identified from the 5-item RPSEI. The type of reasoning used per task was identified. In task one, 21 used inductive a (ia), 3 used deductive a (da), and 2 used deductive b (db) from the CATA group. Similarly, 18 used inductive a (ia), 5 used inductive c (ic), and 1 used deductive b (db) from the MHRTA group.

In task two, 3 used inductive a (ia), 1 used inductive b (ib), 17 used inductive c (ic), 2 used deductive a (da), and 3 used deductive b (db) from the CATA group. On the same task, I used inductive a (ia), 11 used inductive c (ic), 4 used deductive a (da), and 8 used deductive b (db) from the MHRTA group.

In task three, 4 used ia, 3used ib, 12 used ic, 4 used da, and 3 used db from the CATA group. Correspondingly, 2 used ia, 3 used ib, 5 used ic, 8 used da, and 6 used db from the MHRTA group.

In task four, 13 used ia, 1 used ib, 6 used ic, 1 used da, and 5 used db from the CATA group. On the same task, 14 used ia, 5 used ic, 2 used da, and 3 used db from the MHRTA group.

Lastly, in task five, 4 used ia, 1 used ib, and 19 used ic from the CATA group. As for the MHRTA group, 5 used ia, 1 used ib, 17 used ic, and 1 used da.

**Conclusion**

In light of the findings from the analysis of the data gathered, the following conclusions were drawn:

1. The t-test results revealed that the CATA and the MHRTA groups' posttest scores in the conceptual survey in electromagnetic induction were significantly higher than each group's pretest scores.
2. The results of t-test showed that the posttest scores of the CATA and the MHRTA group in the conceptual survey in electromagnetic induction were not significantly different. Further analysis showed that the posttest scores of the CATA group differ significantly from the MHRTA group on questions in the CSEI measuring the students' ability to recognize how change in magnetic flux affects the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or by a magnetic substance. This proves the strength of the MHRTA in making sense out of variables responsible for explaining and quantifying the phenomenon.
3. The overall coded responses on the reasoning pattern survey were revealed to be inductive reasoning for both the CATA and the MHRTA groups.

The results have shown that the CATA group which was exposed more to computer-assisted visualization and with an experiment used for verifying the law had same conceptual gains as the MHRTA group who was exposed more to recreated models and experiments of Oersted, Ampere, Faraday, and Lenz.

In the test of difference between the pretest and posttest scores of the CTA and the MHRTA groups based on the objectives of the CSEI as adapted from the K-12 curriculum, the results showed a significant difference in the third objective. The questions under this objective aim to measure the students' ability to recognize how change in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or by a magnetic substance, which is one of the goals for using the modified historical reconstructionist approach in teaching electromagnetic induction.

These findings suggest that both CATA and MHRTA improve students' conceptual understanding in electromagnetic induction. In classrooms with limited access to computer or technology, the MHRTA can be an alternative to teaching electromagnetic induction.

The observed reasoning pattern in the CATA and the MHRTA groups from the students' answers in the RPSEI is inductive reasoning. The results may be due to the students being in a Science high school, hence observation of such reasoning pattern is expected.

**Recommendations**

Based on the findngs drawn from the study, the following recommendations were made:

- Due to the limited knowledge of the examinees during the development of the CSEI when it was pilot-tested, the measured reliability was less than the prescribed value. It is strongly recommended that the CSEI's reliability be measured again.
- For future researches on the same topic, a more reliable instrument can be used to test conceptual understanding and reasoning pattern. There are instruments or frameworks that can be used to determine reasoning patterns but there is no standard.
- The subjects of the study were grade 10 Science high school students. It is recommended to employ MHRTA to other grade levels, either from Science or from regular secondary schools.
- The approach can also be studied on other topics or settings fit for the said approach. Other supplementations to the approach can also be explored.

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Appendix A

Days 1-2 Lesson Plan on EMI using CATA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics
Lesson: Electromagnetic Induction
Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- During the lesson, the students should be able to identify variables explaining electromagnetic induction phenomenon
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the generation of magnetic field by a current-carrying wire shall be demonstrated by the students (*from K12 curriculum guide*)
- At the end of the lesson, the students should be able to correlate variables explaining electromagnetic induction phenomenon

Materials:
For discussion-laptop, television
For the activity-Compass, copper wire, galvanometer, battery, alligator clips
Guide

| Teacher's activity | Student's response/activity |
|---|---|
| Motivation:<br><br>Students recall the use of the right hand rule for a moving charge in determining the directions of the magnetic force.<br><br>What does a generator do?<br><br>What else do you know about generators?<br>What phenomenon can be observed in generators?<br><br>That's right. Generators convert mechanical energy to electricity via electromagnetic induction.<br><br>(Show pictures of scientists who worked on Electromagnetic induction then.) Do you know | <br><br><br><br><br>Students respond:<br><br>They make electricity by converting mechanical energy to electricity.<br>They contain magnets.<br>The Electromagnetic induction phenomenon can be observed in generators.<br><br><br>The students mention: |

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| the scientist who made relevant contributions in the development of electromagnetic induction?<br><br><br><br><br><br><br>Very good.<br><br><br><br>Lesson Proper<br><br>**Current-carrying conductors**<br>(The variables will be presented to students, such as B for magnetic field, I for current, q for charge, l for length, Φ for angle, and the equations combining these variables to establish relationship. A simple experiment will be performed to be familiar with a current-carrying wire becoming a magnet.)<br><br><br>The teacher ask the following questions:<br><br>Can a straight current-carrying wire be surrounded by a magnetic field?<br><br>If a current-carrying wire can become a magnet, can a moving charge be surrounded by a magnetic field?<br><br><br>Can a current-carrying coil be surrounded by a magnetic field?<br><br>What should be the conditions so that they all are surrounded by a magnetic field thus creating a magnet? | Hans Christian Oersted discovered that when a current-carrying wire was placed over a compass, the needle deflected.<br><br>Andre'-Marie Ampere also worked on current-carrying wires.<br><br>Michael Faraday investigated if a magnet can generate electricity in a coil of wire.<br><br>Heinrich Friedrich Emil Lenz discovered that the electric to magnetic phenomenon can be reversed.<br><br><br><br><br><br><br><br>Students perform the simple experiment using a compass, a battery, a straight copper wire, and alligator clips. |

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| What relationship exists between magnetic field strength and the current if all other variables remain constant?<br><br>Correct! Now, in determining the directions of the magnetic field or current in the magnetic field source, we can use the right-hand rule (RHR).<br><br>Using visual aids, the students will see what the source of magnetic field is and will use RHR in determining either the directions of the current or of the magnetic field. | Students practice RHR. |
| Generalization:<br><br>When does a non-magnetic conductor become magnetic? | It can be a magnet if a current is running through it. |
| Good. What relationship exists between magnetic field strength surrounding the conductor and the current running through it? | There is direct proportionality between these variable, provided that all other variables remain constant. |
| Assessment: Administration of RPSEI questions.<br>1. How do you determine the direction of the magnetic force and magnetic field given the direction of the current along the straight or coil of wire?<br>2. How does the strength of the current relate to the induced magnetic field strength and magnetic force? | On an answer sheet, the students explain their answer the question. |
| Take home task:<br>Now that Ampere has confirmed that current-carrying conductors may induce magnetism, | |

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| analyze your findings and observation further. The next question is can magnets produce currents? Can the process be reversed? Explore more about the causes and the effects of the electromagnetic induction phenomenon. | |

Days 3-4 Lesson Plan on EMI using CATA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics

Lesson: Electromagnetic Induction

Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- During the lesson, the students should be able to interpret representations of variables explaining electromagnetic induction
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the generation of electricity by movement of a magnet through a coil shall be demonstrated by the students (*from K12 curriculum guide*)
- At the end of the lesson, the students should be able to explain the operation of a simple electric motor and generator using the variables in and the mathematical form of the theory (*from K12 curriculum guide*)

Guide

| Teacher's activity | Student's response/activity |
|---|---|
| Motivation:<br><br>The students will be shown diagrams of magnets and current-carrying wires.<br><br>Using the right hand rule, they will be asked to determine the direction of the magnetic field on the current-carrying conductor and compare it with the magnetic field lines of the magnet.<br><br>Very good.<br><br>Lesson Proper<br><br>**Magnetic Flux**<br>The students will be asked to recall and draw the magnetic field lines from the N and the S magnetic poles. | <br><br><br><br>There is a similar magnetic field pattern for magnets and current-carrying conductors. |

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| What if these field lines pass through the area of a conductor and variations in the number of field lines passing through it occurs, what do we call this quantity then?<br><br>Good. (Present the equation for flux.)<br><br>Based on the equation, what relationship exists between:<br><br>magnetic flux and magnetic field with the area and the angle between the magnetic field and the area of the conductor constant?<br><br>magnetic flux and the area of the conductor with the magnetic field strength and the angle between the magnetic field and area vector constant?<br><br>magnetic flux and the angle between the magnetic field and the area vector of the conductor with the area and the magnetic field strength constant?<br><br>Very good. Now how do all these occurrences support electromagnetic induction?<br><br>(Using visual aids, the students will see magnetic flux variations.)<br><br>Verification: Explain the activity using a coil connected to a galvanometer and a magnet.<br><br>**Faraday's law**<br><br>When does magnetic flux increase?<br><br>Good. When does magnetic flux decrease? | The varying number of field lines that can pass through an area is magnetic flux.<br><br>There is direct proportionality between the magnetic flux and the magnetic field.<br><br>There is direct proportionality between the magnetic flux and the area of the conductor.<br><br>As the angle between the area vector of the conductor approaches zero, the magnetic flux increases.<br><br>Students perform the activity by moving the magnet through a coil and noting observations.<br><br>It increases when the magnetic field or the area of the conductor increases or if the angle between the magnetic field and the area vector increases.<br><br>It increases when the magnetic field or the area of the conductor increases or if the angle |

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| That's correct. (Present variables and relationships between variables that form Faraday's law equation.)<br><br>Based on the expression, how does the induced magnetic field change, regardless of the negative sign?<br><br>How do these induced voltages relate to the currents induced in the conductor with the same resistance?<br><br>Very good. The negative sign here is an indication that every time something is induced in a conductor, the conductor always resists these changes.<br><br>Now, let's practice using the RHR in determining the directions of the induced voltage or current due to a changing flux. Let us follow these steps:<br><br>1. Define a positive direction for the vector area *A*.<br>2. From the directions of *A* and *B*, determine the sign of the magnetic flux and its rate of change.<br>3. Determine the sign of induced emf or current. If the flux is increasing, so Ɛ is positive, then the induced emf or current is negative.<br>4. Finally, determine the direction of the induced emf or current using your right hand. Curl the fingers of your right hand around the *A* vector, with your thumb in the direction of *A*. If the induced emf or current in the circuit is positive, it is in the same direction as your curled fingers, otherwise, opposite. | between the magnetic field and the area vector increases.<br><br>As the change in flux vs time increases, the induced voltage increases as well. As the change in flux vs time decreases, the induced voltage decreases as well.<br><br>As the induced voltage increases, the induced current increases as well. There is direct proportionality between induced voltage and current.<br><br>Practice using RHR in determining directions of induced voltage or current by considering changes in magnetic flux and sign of induced voltage. |

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| Assessment: Administration of RPSEI question.<br>How does magnetic flux variation affect the magnitude and direction of the induced current in a coil of wire?<br><br>Take home task:<br>Now that Ampere has confirmed that current-carrying conductors may induce magnetism and Faraday discovered that the process can be reversed, recall and analyze which among the variables we have encountered can be accounted for the induction of electric current and voltage from a moving magnet.<br>Practice using the RHR in determining directions of induced current or voltage using the steps discussed. | On an answer sheet, the students explain their answer to the question. |

Days 5-6 Lesson Plan on EMI using CATA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics
Lesson: Electromagnetic Induction
Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- During the lesson, the students should be able to correlate variables explaining electromagnetic induction
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the demonstrated generation of electricity by movement of a magnet through a coil shall be explained by the students (*from K12 curriculum guide*)
- At the end of the lesson, the students should be able to synthesize prior discussions and variables to simplify Faraday's law

Guide

| Teacher's activity | Student's response/activity |
|---|---|
| Motivation:<br><br>Recall the verification activity with a coil connected to a galvanometer and a magnet. | |
| What observations can you share? | Every time the magnet moves, there is a deflection in the galvanometer. If the magnet is not moving, there were no observed deflections. |
| Good. | |
| When does magnetic flux increase? | It increases when the magnetic field or the area of the conductor increases or if the angle between the magnetic field and the area vector increases. |
| Good. When does magnetic flux decrease?<br><br>Lesson proper:<br>**Follow-up on Faraday's and Lenz's laws** | It increases when the magnetic field or the area of the conductor increases or if the angle between the magnetic field and the area vector increases. |

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| That's correct. (Present Faraday's law equation.)<br><br>Based on the equation, how does the induced magnetic field change, regardless of the negative sign?<br><br>How do these induced voltages relate to the currents induced in the conductor with the same resistance?<br><br>Very good. What's the negative sign for?<br><br>How do we determine the direction of the induced voltage or current? | As the change in flux vs time increases, the induced voltage increases as well. As the change in flux vs time decreases, the induced voltage decreases as well.<br><br>As the induced voltage increases, the induced current increases as well. There is direct proportionality between induced voltage and current.<br><br>The negative sign is an indication that every time something is induced in a conductor, the conductor always resists these changes.<br><br>We first define a positive direction for the vector area $A$, then determine the sign of the magnetic flux and its rate of change. After that, we determine the sign of induced voltage or current. If the flux is increasing, so Ɛ is positive, then the induced voltage or current is negative. Finally, we determine the direction of the induced voltage or current using your right hand. Curl the fingers of your right hand around the $A$ vector, with your thumb in the direction of $A$. If the induced voltage or current in the circuit is positive, it is in the same direction as your curled fingers, otherwise, opposite. |
| Let us use this simple experiment and find out further how non-magnetic conductors react to induction.<br><br>This is an indication that there is resistance coming from the copper pipe. Induction is causing a change and the pipe tends to resist that change, causing the magnet to slow down. | Perform dropping of magnet in PVC and a copper pipe.<br><br>Students observe the difference in the rate of fall.<br><br>Practice RHR in the rotating loop inside the motor. |

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| Let's use these steps to determine the direction of induced voltage or current in a loop inside a motor.<br><br>The negative sign is an indication of resistance as mentioned by Lenz. In agreement with Faraday's discovery, if there is current, then this current induces a magnetic field. So, the induced current will induce another magnetic field, which is the resistance Lenz was referring to. We can use the RHR too in determining this induced magnetic field that opposes change.<br><br>Assessment: Administration of an RPSEI question. The induced current in a coil of wire induces another magnetic field. How do you determine the direction of this induced magnetic field by the induced current in a coil of wire?<br><br>Take home task:<br>Read about how simple motors and generators work and relate what you learned about current-carrying wires, magnetic flux, and electromagnetic induction. | <br><br><br>The students follow the previous steps in determining the directions of induced current or voltage by analyzing the change in magnetic flux first. Then, after determining the direction of the induced current or voltage, they will determine the direction of the induced magnetic field.<br><br>Students explain their answer on an answer sheet. |

Days 7-8 Lesson Plan on EMI using CATA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics

Lesson: Electromagnetic Induction

Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- During the lesson, the students should be able to correlate variables explaining electromagnetic induction in explaining how motors and generator work
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the students should be able to explain how generators induce electricity using the demonstration of generating electricity by movement of a magnet through a coil
- At the end of the lesson, the students should be able to synthesize prior discussions and variables to simplify Faraday's law

Guide

| Teacher's activity | Student's response/activity |
|---|---|
| Motivation:<br><br>Shown a picture of Faraday's experiment/setup. We can recall that magnetic flux is essential in electromagnetic induction. What causes variations in magnetic flux? | It increases when the magnetic field or the area of the conductor increases or if the angle between the magnetic field and the area vector increases. |
| Based on the Faraday's mathematical expression for induction, how does the induced magnetic field change, regardless of the negative sign? | It increases when the magnetic field or the area of the conductor increases or if the angle between the magnetic field and the area vector increases. |
| How do these induced voltages relate to the currents induced in the conductor with the same resistance? | As the change in flux vs time increases, the induced voltage increases as well. As the change |

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| | in flux vs time decreases, the induced voltage decreases as well.<br><br>As the induced voltage increases, the induced current increases as well. There is direct proportionality between induced voltage and current. |
| Very good. What's the negative sign for? | The negative sign is an indication that every time something is induced in a conductor, the conductor always resists these changes. |
| How do we determine the direction of the induced voltage or current? | We first define a positive direction for the vector area *A*, then determine the sign of the magnetic flux and its rate of change. After that, we determine the sign of induced voltage or current. If the flux is increasing, so Ɛ is positive, then the induced voltage or current is negative. Finally, we determine the direction of the induced voltage or current using your right hand. Curl the fingers of your right hand around the *A* vector, with your thumb in the direction of *A*. If the induced voltage or current in the circuit is positive, it is in the same direction as your curled fingers, otherwise, opposite. |
| How about in determining the induced magnetic field that opposes change? | Then, after determining the direction of the induced current or voltage, they will determine the direction of the induced magnetic field. |
| Lesson proper:<br>**Applying electromagnetic induction in motors and generators.** | Students explain their answer on an answer sheet. |
| The teacher will show an improvised simple generator and ask one student to operate in class to show how it works. | |
| How do we know if current is induced? | Using a galvanometer, the student confirms that there is current induced. |

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| Can someone explain how the generator was able to induce electric current when what we only have here is a rotating magnet inside a loop? | Just like what Faraday did, the change in flux can either be due to moving magnets or varying orientation or size of the loop. |
| Good. When do we get maximum current induced? | If the magnetic flux is greatest. That occurs when the surface area of the loop is perpendicular to the magnetic field. |
| Correct. Likewise, that also means that a line drawn perpendicular to this loop is parallel to the magnetic field lines. This line represents the area vector. Lenz mentioned that we can also use the same generator as a motor. Then how would a motor work? | Faraday discovered that the process can be reversed. A motor will have current running along the rectangular loop that will make it magnetic. Due to this magnetic field, a magnetic force between the loop and the magnet inside the loop will interact, which will cause the loop to rotate. |
| Very good. | |
| Generalization:<br>What causes induction of electric current? | A changing magnetic flux causes electric current. |
| How does this change in flux affect magnitude and direction of induced electric current in a generator? | If the flux is increasing, the current induced increases as well. The direction of the flux can be used to determine the direction of the induced current using the right-hand-rule (RHR). The direction of rotation is due to the interaction of the magnetic fields from the loop and from the magnet. |
| Assessment: Administration of an RPSEI question.<br>How do motors and generators work using electromagnetic induction? | Students explain on an answer sheet. |
| Take home task:<br>Review the variables and the relationships existing between variables that explain EMI. | |

Appendix B

Days 1-2 Lesson Plan on EMI using MHRTA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics

Lesson: Electromagnetic Induction

Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- At the end of the lesson, the students will be able to realize how the idea of Electromagnetic induction has progressed using reconstructed historical experiments
- At the end of the lesson, the students should gain better conceptual understanding of on how magnetism can be induced by electricity
- During the lesson, the students should engage in scientific practice as they gather and share information from the reconstructed experiments
- At the end of the lesson, the students should be able to relate magnitudes and directions of magnetic field and force to electric current

Procedure/Discussion (employing the MHRTA)

**II. Observation and identification of the Electromagnetic induction phenomenon.**
- ✓ **Hans Christian Oersted's discovery**
- ✓ **Andre' Marie Ampere's verification**

III. Qualitative experimentation of induction current.
- ✓ Michael Faraday's experiment with a magnet and a primary coil

IV. Qualitative dependency: the change of flux through the coil
- ✓ Determining the common varying property from Faraday's experiment
- ✓ Creating the magnetic field line model
- ✓ Inferring Heinrich Lenz's law using magnetic flux and field lines

V. Model for measurement system and measurement.
- ✓ Quantifying the experiments-measuring the electric current in the primary coil and the induced voltage in the secondary coil as functions of time

VI. Representation of measurement results.
- ✓ Creating the graphical representations of the measurements
- ✓ Describing the relations from the graphs

VII. Interpretations.

- ✓ Expressing the mathematical form of the variables observed from the EMI phenomenon and interpreting this expression.

VIII. Extension of theory.

- ✓ Testing the theory's ability to explain the EMI phenomenon
- ✓ Using the theory to predict effects as the circumstances vary

Materials:

For discussion: laptop, television

For the setup per activity: Oersted's setup 1: compass, battery, wire, alligator clips

Ampere's setup 1: two parallel wires, batteries, alligator clips

Ampere's setup 2: circular wire, battery, alligator clips

Ampere's setup 3: Ampere's solenoid, a battery, alligator clips, compass

Guide

| Teacher's activity | Student's response/activity |
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| Motivation:<br><br>Students recall the use of the right hand rule for a moving charge in determining the directions of the magnetic force.<br><br>To prepare students on the historical journey and to give them an idea on the experiments, a simple generator will be shown to the students. The students' interests, prior ideas and beliefs about the generator will be explored (Hottecke, D. Henke, A. Riess, F. 2012).<br><br>What does a generator do?<br><br>What else do you know about generators?<br>What phenomenon can be observed in generators?<br><br>That's right. Generators convert mechanical energy to electricity via electromagnetic induction.<br><br>Do you know the scientist who made relevant contributions in the development of electromagnetic induction? | Students mention the following:<br><br>They make electricity by converting mechanical energy to electricity.<br>They contain magnets.<br>The Electromagnetic induction phenomenon can be observed in generators.<br><br>Hans Christian Oersted discovered that when a current-carrying wire was placed over a compass, the needle deflected.<br><br>Andre'-Marie Ampere also worked on current-carrying wires.<br><br>Michael Faraday investigated if a magnet can generate electricity in a coil of wire. |

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| | Heinrich Friedrich Emil Lenz discovered that the electric to magnetic phenomenon can be reversed. |
| Very good. How about we explore the development of electromagnetic induction as we trace these scientists' journey from the past. Are you ready? | |
| The arrangement:<br>Six round tables, with a maximum of 6 members per table/group. The replicas are placed on each table with the instructions and guide questions for reconstructing the experiments. Each group must have a journal where each member can record his/her observations. The students will be reminded of the safety precautions in the lab. | |
| Lesson Proper: employing a modified historical reconstructionist teaching approach. | |
| **Phase 1.** Observation and identification of the Electromagnetic induction phenomenon. | |
| In 1819, Oersted placed a current-carrying wire over a compass. He was surprised with what happened. | |
| | Oersted's setup and manipulating the setup. |
| Demonstration:<br>Connect the ends of the wire to a battery using alligator clips; observe the needle's deflection; change how the battery is connected to the wire; observe the needle's deflection; then, remove the battery. | |
| Discussion:<br>What did you observe? | What the students must observe and write on their journals: the turning of the needle violently perpendicular to the axis of the wire. Reversing the current's direction also reverses the needle's rotation. The current-carrying wire is a magnet. |
| Very good! We just rediscovered that electricity can induce magnetism. When Ampere heard about | |

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| this discovery, do you think, as a scientist, he believed it straightaway?<br><br>That's right! That's why in 1820, Ampere wanted to confirm Oersted's discovery using 2 current-carrying wires and various configurations of wires. He also experimented on determining how the strength of the magnetic force on the wire is related to the current that the wire carries.<br><br>Demonstration:<br>#1 two parallel wires where current flows in the same direction (battery is connected in the same manner for both) first, with the same voltage, second, increasing the voltage on both; observe the behaviors of the wire with respect to each other.<br>#2 two parallel wires where current flows in opposite direction (battery is connected in opposite manner) first, with the same voltage, second, increasing the voltage on both; observe the behaviors of the wire with respect to each other.<br>#3 do the same procedure with the two parallel wires but one is now half its original length; compare your findings with the first two.<br>#4 using Oersted's setup but twist the wire this time (figure shown in instructions); observe the needle's deflection.<br>#5 connect the free ends of Ampere's solenoid to a battery (figure shown); move the compass in a semi-circular arc around the coil; observe the deflections.<br><br>Discussion:<br>What did you observe in # 1 and 2? | Ampere's setups and Ampere's verifications<br><br>What the students must observe and write on their journal:<br>#1 and 2<br>a) The wires repelled when the directions of the currents are opposite and attracted each other when the directions of the currents are the same.<br>b) A stronger repulsion and attraction was observed when the voltages on both were increased.<br><br>It's force. The wires were exerting a force on each other. |

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| So it’s as if the wires pushed away each other or pulled one toward the other. In general, in Physics, what term describes this push or pull? | The attraction and repulsion is not as noticeable as before, maybe it has weakened too. This could be because the other wire is now shorter. |
| Since the wires were magnetic, we’ll call this magnetic force.  What about when the length of the wire has decreased (#3)? | |
| | It can be concluded that the magnetic force exerted is proportional to its length. |
| That’s correct. So what can be concluded about the magnetic force exerted by this wire and its length? | No deflections were observed; the twisting of the wire could’ve cancelled the effect. |
| | The deflections of the needle made a pattern. |
| Very good! What about your observations in #4? | The student draws. |
| That’s correct. Lastly for #5? | |
| Where does the needle point? Can you draw this pattern? | It’s the magnetic field surrounding the wire. |
| Good. Recall that the wire is now a magnet and this is a line visualizing the field surrounding the wire. Do you have any idea what this represent? | |
| | The current-carrying wires are magnets and that the currents directions affect the needle’s rotation or the magnetic fields directions. |
| Generalization:<br>What can generalize from Oersted’s and Amperes’ discoveries? | These are current, magnetic force, length of wire, and magnetic field. |
| Very good. Let’s review, what quantities have we dealt with so far? | As the current running along the same length of the wire increases, the magnetic field strength increases, so as the magnetic force. |
| What relationships can you share on any of these variables? | |
| Very good! | |

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| Assessment: Administration of RPSEI questions.<br>1. How do you determine the direction of the magnetic force and magnetic field given the direction of the current along the straight or coil of wire?<br>2. How does the strength of the current relate to the induced magnetic field strength and magnetic force?<br><br>Take home task:<br>Now that Ampere has confirmed that current-carrying conductors may induce magnetism, analyze your findings and observation further. The next question is can magnets produce currents? Can the process be reversed? Explore more about the causes and the effects of the electromagnetic induction phenomenon. | On an answer sheet, the students explain their answer the question. |

Days 3-4 Lesson Plan on EMI using MHRTA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics
Lesson: Electromagnetic Induction
Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- At the end of the lesson, the students will be able to realize how the idea of Electromagnetic induction has progressed using reconstructed historical experiments
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the students should engage in scientific practice as they gather and share information from the reconstructed experiments
- During the lesson, the generation of electricity by movement of a magnet through a coil shall be demonstrated by the students (*from K12 curriculum guide*)
- At the end of the lesson, the students should be able to relate magnetic flux and electromagnetic induction

Procedure/Discussion (employing the MHRTA)

IX. Observation and identification of the Electromagnetic induction phenomenon.
   - ✓ Hans Christian Oersted's discovery
   - ✓ Andre' Marie Ampere's verification

**X. Qualitative experimentation of induction current.**
   - ✓ **Michael Faraday's experiment with a magnet and a primary coil**

**XI. Qualitative dependency: the change of flux through the coil**
   - ✓ **Determining the common varying property from Faraday's experiment**
   - ✓ **Creating the magnetic field line model**
   - ✓ **Inferring Heinrich Lenz's law using magnetic flux and field lines**

XII. Model for measurement system and measurement.
   - ✓ Quantifying the experiments-measuring the electric current in the primary coil and the induced voltage in the secondary coil as functions of time

XIII. Representation of measurement results.

- ✓ Creating the graphical representations of the measurements
- ✓ Describing the relations from the graphs

XIV. Interpretations.

- ✓ Expressing the mathematical form of the variables observed from the EMI phenomenon and interpreting this expression.

XV. Extension of theory.

- ✓ Testing the theory's ability to explain the EMI phenomenon
- ✓ Using the theory to predict effects as the circumstances vary

Materials:
For discussion: laptop, television
For the setup per activity: bar magnet, a single coil of wire, N number of coils, 9V battery, galvanometer, alligator clips
Guide

| Teacher's activity | Student's response/activity |
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| Motivation:<br><br>The students will be shown diagrams of magnets and current-carrying wires.<br><br>Using the right hand rule, they will be asked to determine the direction of the magnetic field on the current-carrying conductor and compare it with the magnetic field lines of the magnet. | There is a similar magnetic field pattern for magnets and current-carrying conductors. |
| **Phase 2** Qualitative experimentation of induction current.<br><br>Ready for our next journey? | Yes! |
| Alright. Ampere figured out that electricity can induce magnetism. What do you think was going on in Faraday's mind after knowing this? | Maybe he wanted to see if magnetism can induce electricity. |
| That's right. In 1831, Michael Faraday tried to see if a current would be produced in a wire if it was placed in a magnetic field created by another current-carrying wire.<br><br>Demonstration: | |

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| Start with the magnet at rest; then, move the magnet towards the coil then hold it stationary at that position; next, move the magnet away from the coil and hold it stationary at that position; do the same thing with the coil moving; now with the magnet or the coil moving faster; finally, allowing current to run through a primary coil with the galvanometer connected to a separate secondary coil; observe the galvanometer readings. | Manipulation of Faraday's setup |
| Discussion:<br>What were your observations? | What the students must observe and write on their journals: the direction of the magnet's/coil's movement varies the needle's deflection; if the magnet /coil is held stationary, there is no deflection; and as the magnet/coil is moved faster, there will be greater induced emf/voltage in the coil. When the primary coil carries a current, the needle deflects with the galvanometer connected to the separate secondary coil, but just like the magnet, there were no deflections when the primary current carrying coil is stationary. |
| **Phase 3.** Qualitative dependency: the change of flux through the coil | |
| It was Faraday's observations that lead him to the discovery of electromagnetic induction. Share your observations, and let's see if we can figure out the electromagnetic phenomenon. Was there any deflection when the magnet/coil was held at the same position? | No, there was none. |
| Right. When did the deflections occur? | When the magnet/coil was moving constantly. |
| What does the deflection of the galvanometer's needle indicate? | It indicates the presence of an electric current. |
| Right, so that means that the magnet or the coil with a magnetic field can induce current, but remember, there wouldn't be a current if there is no voltage. So what does that mean and how do | |

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| they relate to each other from our experiment with Ampere earlier? | There was an induced voltage and an induced current. As the induced voltage increases, the induced current increases as well. |
| Correct. Now, what did you observer when you moved the magnet/coil faster? | There were more deflections in the galvanometer. |
| Does this mean that it is the speed (of the magnet or current-carrying coil) that is accountable for the induced voltage and induced current? To find out, let me introduce you to the magnetic lines of force. Recall that earlier we have seen a magnetic field line, more lines then we can also call them as magnetic lines of force. However, it is important to remember that these lines do not point in the direction of force. | |
| For the students to picture magnetic field lines, iron fillings, compasses, a magnet and a current-carrying wire and coil will be used. The pattern that the iron fillings and the compass needles make should give them a visual of the magnetic field lines. | |
| Then, using a circular cardboard, to represent the coil of wire, a magnet and a smaller conductor will be placed on opposite sides of the cardboard. With the magnet at the back of the cardboard and the conductor (such as a clip) is in front. | |
| Will the magnet be able to attract the clip even if there is a cardboard in between them? | Yes, it will.<br><br>The students will see that the clip followed every movement of the magnet. |
| Does this mean that the magnetic field lines from the magnet can pass through the cardboard's surface? | Yes, that's why the clip got attracted. |
| This is a representation of the magnetic flux. Can someone define or describe magnetic flux based on our example? | It is defined as the magnetic field lines passing through a surface. |
| Correct. Specifically the amount of magnetic field lines passing through a surface. What do you | |

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| think will happen if I vary the orientation of the cardboard, let's say at a certain angle with respect to the magnet?<br><br>That' right (will show it happens). Same thing will happen if it's the magnet that was slanting with respect to the surface of the cardboard.<br><br>Through a diagram, the students will further see magnetic flux representations at varying angles. What do you notice with the description of the magnetic flux and the variations of the angles?<br><br>That's correct. How does the orientation of either the field lines or the surface affect flux? | The clip might fall.<br><br>If more field lines pass through a surface, then there will be greater flux.<br><br>If the surface of the plane is parallel with the field lines, there are more field lines passing through it, creating more flux. As the surface becomes perpendicular to the field lines, the field lines passing through decreases, creating a smaller flux. |
| What if I move the magnet away from the surface, will the attraction be stronger or weaker? And will there be more or less field lines through the surface?<br><br>Very good. Recall that a pattern was seen earlier with the iron fillings and the compass needles with a current-carrying coil. The cardboard was analogous to a coil of wire. This means that the same thing occurs on the empty space bound by the coil of wire every time we move a magnet in or out of the coil. | It will be weaker because the amount of field lines passing through will become less. As you move the magnet closer, the attraction on the clip will be stronger, since more field lines pass through. |
| So, is it the speed (of the magnet or current-carrying coil) that is accountable for the induced voltage and induced current? | No. When the magnet was stationary, meaning speed is zero, there were no readings in the galvanometer. The deflections occurred mostly when the direction of movement varies, when you move the magnet towards or away from the coil. This means that the number of field lines passing through the coil varies. It is the variation in the magnetic flux that's responsible for the induced current. |

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| Very good! Now that Ampere has confirmed that current-carrying conductors may induce magnetism, and that we have confirmed that magnets or current-carrying wires or coils, since they are magnetic, can induce currents, do you think we can infer that the process can be reversed? To find out, let's take a closer look at Lenz's work. | |
| Let's review. So far, what variables have we dealt with? | These are current, magnetic force, length of wire, magnetic field, and magnetic flux. |
| Assessment: Administration of RPSEI question.<br>How does magnetic flux variation affect the magnitude and direction of the induced current in a coil of wire? | On an answer sheet, the students explain their answer to the question. |
| Take home task:<br>Now that Ampere has confirmed that current-carrying conductors may induce magnetism and Faraday discovered that the process can be reversed, recall and analyze which among the variables we have encountered can be accounted for the induction of electric current and voltage from a moving magnet.<br>Practice using the RHR in determining directions of induced current or voltage. | |

Days 5-6 Lesson Plan on EMI using MHRTA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics
Lesson: Electromagnetic Induction
Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- At the end of the lesson, the students will be able to realize how the idea of Electromagnetic induction has progressed using reconstructed historical experiments
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the students should engage in scientific practice as they gather information from the reconstructed experiments
- During the lesson, the should be able to create graphs of variables in control of the electromagnetic induction phenomenon
- At the end of the lesson, the students should be able to correlate induced electric current and voltage and the changing magnetic flux over time

Procedure/Discussion (employing the MHRTA)

I. Observation and identification of the Electromagnetic induction phenomenon.
   - ✓ Hans Christian Oersted's discovery
   - ✓ Andre' Marie Ampere's verification
II. Qualitative experimentation of induction current.
   - ✓ Michael Faraday's experiment with a magnet and a primary coil
III. Qualitative dependency: the change of flux through the coil
   - ✓ Determining the common varying property from Faraday's experiment
   - ✓ Creating the magnetic field line model
   - ✓ Inferring Heinrich Lenz's law using magnetic flux and field lines

**IV. Model for measurement system and measurement.**

- ✓ **Quantifying the experiments-measuring the electric current in the primary coil and the induced voltage in the secondary coil as functions of time**

V. **Representation of measurement results.**
- ✓ **Creating the graphical representations of the measurements**
- ✓ **Describing the relations from the graphs**

VI. Interpretations.
- ✓ Expressing the mathematical form of the variables observed from the EMI phenomenon and interpreting this expression.

VII. Extension of theory.
- ✓ Testing the theory's ability to explain the EMI phenomenon
- ✓ Using the theory to predict effects as the circumstances vary

Materials:
For discussion: laptop, television
For the setup per activity: small circular magnet, PVC pipe, copper pipe same length as the PVC, washer, string, cookie sheet
Guide

| Teacher's activity | Student's response/activity |
|---|---|
| Motivation:<br>Shown a rectangular loop of wire, identify the direction of the induced current in the wire as the flux changes.<br><br>This loop of wire can be found in motors and generators. To be able to explain how they work, we need to know certain variables affect the magnitude and direction of the induced voltage or current.<br><br>**Phase 4.** Model for measurement system and measurement.<br><br>This time, you will be using Faraday's setup to gather figures on electromagnetic induction. You will be using the setup with 2 coils- where one coil serves as your primary which is connected to a battery and multimeter, whilst the other is your secondary which is connected to a voltmeter. You must complete a table (included in the instruction) for us to compare the effects of the electric current on one coil to the induced voltage on the other. | Students practice using RHR on the rectangular loop of wire.<br><br>The students, knowing how and what to measure will gather data and write them on their journals. |

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| (The teacher observes and guides the students making sure that they're accurate)<br><br>**Phase 5.** Representation of measurement results.<br><br>Now that you have gathered the figures, you will be graphing these data and based on the graph, identify the relation between electric current and voltage. | Perform and record results of the experiment.<br><br>What the students must observe and write on their journal: from the graphs, the voltage correlates linearly with the electric current. |
| If we increase the electric current on the primary coil, what will happen to the induced voltage on the secondary coil? | It will also increase. |
| If a voltage is induced in the secondary coil, do you think an electric current is induced as well? There's one way to find out, use the multimeter to see if there is. | Students confirm. |
| Now, recall Ampere's setup earlier where you observed a stronger attraction and repulsion when 2 batteries were connected to the wires. How can you relate these findings with that? | Since voltage and current are proportional to each other, there was an increase in current when we increase the voltage by adding an extra battery. As the current increases, the magnetic forces the wires exerted on each other also increased, that's why the attraction and repulsion were more noticeable. |
| Right, now let's continue with our journey in history. Do you know that scientists have worked independently on the same investigations? Is it a good thing or a bad thing? | Students share their views on collaboration and working independently. |
| Well, working alone and working with a peer or a group have their own strengths and weaknesses; I'll leave the rest up to you. In 1832, Heinrich Friedrich Emil Lenz independently investigated the forces and magnetic action caused by a coil abruptly drawn away and brought towards a magnet. Yes, Faraday and Lenz were working on the same thing, however Lenz made another discovery. | |

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| Demonstration:<br>#1 the students will take the small magnet and drop it from about the height of the PVC pipe; then to the copper pipe.<br>#2 place the magnet on a cookie sheet ad tilt the sheet so the magnet slides off; observe the behavior of the magnet.<br>#3 tie the magnet to a string and swing it in a low circle so that it passes over a metal washer placed on a smooth surface; observe what happens to the washer; is this related to the previous observation? | Perform, observe, and record results of the experiment. |
| Discussion:<br>What have you observed? Starting with #1. | In #1, when you drop the magnet through the copper tube, it slowed down. Same thing when it slides down the cookie sheet in #2. The metal washer in #3 is nudged in the direction the magnet was spinning. |
| What do you think could've caused the washer to nudge? | The magnetic field of magnet. |
| Correct. What is common between the washer, the copper tube, and the cookie sheet? | They are all conductors. |
| Good. Just like the wires we used from Oersted to Ampere to Faraday. What happens when a magnet is moved towards or away from these conductors? | There will be induced voltage and induced electric current. |
| Correct! In #1 and #2 there was noticeable slowing down of the magnet. With the magnet moving through or on them, like what you said, a current is induced. However, these metals don't like having electric or magnetic field inside them, they resist them. This resistance is what slowed down the magnet, meaning there are opposing forces acting on the falling magnet due to this resistance. This is now known as Lenz's law. What connections or points of correspondence can you cite on the findings of Faraday and Lenz? | Faraday discovered that when you move a magnet towards or away from a coil or a wire or a washer, generally a conductor, a current will be induced |

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| That's correct. Independently, they agree that a magnet or a current-carrying conductor may induce an electric or magnetic field on another conductor. How were Lenz's findings different? | due to a change in magnetic flux. This seemed to be consistent with Lenz's investigations, despite their independent works. |
| | He pointed out that these conductors have resistance which tends to oppose the induced electric or magnetic field in them. |
| Very good. Let us deduce from these findings the combined mathematical form of the relationships we have discovered. Recalling from Faraday's findings, what causes an induced voltage or an induced current? | A change in magnetic flux induces voltage or current. |
| This change is actually measured as a function of time. Once again, what results if there is a change in flux at a time t? | It results to an induced voltage. |
| Since Lenz discovered that there is some sort of resistance in the conductor once an electric or magnetic field is induced in them, a negative sign was used to show this opposition.<br><br>(The mathematical form $\varepsilon = -\frac{\Delta\Phi_B}{\Delta t}$ will be shown)<br><br>The students will be asked to interpret the mathematical form of the law in their own words. They will also be asked to explain how this form summarizes the findings from the reconstructed experiments. We will continue with the use of the right-hand rule in determining directions of induced voltage and induced magnetic field. | |
| Assessment: Administration of an RPSEI question. The induced current in a coil of wire induces another magnetic field. How do you determine the direction of this induced magnetic field by the induced current in a coil of wire? | Students explain their answer on an answer sheet. |
| Take home task: | |

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| Read about how simple motors and generators work and relate what you learned about current-carrying wires, magnetic flux, and electromagnetic induction. | |

Days 7-8 Lesson Plan on EMI using MHRTA

Format adapted from the DO 70, s. 2012 - Guidelines on the Preparation of Daily Lessons

Subject Matter: Grade 10 Physics
Lesson: Electromagnetic Induction
Objectives: Adjusted to meet the grade 10 physics competencies based on the K12 curriculum guide

- At the end of the lesson, the students will be able to realize how the idea of Electromagnetic induction has progressed using reconstructed historical experiments
- At the end of the lesson, the students should gain better conceptual understanding of Electromagnetic Induction
- During the lesson, the students should engage in scientific practice as they gather and share information from the reconstructed experiments
- During the lesson, the students should be able to interpret all gathered information from the reconstructed experiments
- At the end of the lesson, the students should be able to explain the operation of a simple electric motor and generator using the variables in and the mathematical form of the theory (*from K12 curriculum guide*)

Procedure/Discussion (employing the MHRTA)

VIII. Observation and identification of the Electromagnetic induction phenomenon.
- ✓ Hans Christian Oersted's discovery
- ✓ Andre' Marie Ampere's verification

IX. Qualitative experimentation of induction current.
- ✓ Michael Faraday's experiment with a magnet and a primary coil

X. Qualitative dependency: the change of flux through the coil
- ✓ Determining the common varying property from Faraday's experiment

- ✓ Creating the magnetic field line model
- ✓ Inferring  Heinrich Lenz's law using magnetic flux and field lines

XI. Model for measurement system and measurement.

- ✓ Quantifying the experiments-measuring the electric current in the primary coil and the induced voltage in the secondary coil as functions of time

XII. Representation of measurement results.

- ✓ Creating the graphical representations of the measurements
- ✓ Describing the relations from the graphs

**XIII. Interpretations.**

- ✓ **Expressing the mathematical form of the variables observed from the EMI phenomenon and interpreting this expression.**

**XIV. Extension of theory.**

- ✓ **Testing the theory's ability to explain the EMI phenomenon**
- ✓ **Using the theory to predict effects as the circumstances vary**

Materials:
For discussion: laptop, television
For the setup per activity: a simple electric motor/generator, galvanometer

Guide

| Teacher's activity | Student's response/activity |
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| Motivation:<br><br>Let us take a look back.<br><br>The students will be shown the setups from previous activities starting with: | |
| Oersted – How did he discover magnetic induction? | When he placed a current-carrying wire over a compass, the needle deflected, which is a sign of a magnetic presence. |
| Ampere – How did Ampere respond after hearing Oersted's discovery? | He verified. He performed his own investigations and gathered more evidence of its existence. |
| What were the results of Ampere's investigations? | From his investigations, it was revealed that for two parallel wires with equal current strengths moving in opposite direction, the interaction is repulsive. This is an indication that a change in the current's direction has a corresponding effect on the direction of magnetic field too. Similarly, the variation of the strength of the current may result |

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| | to an increase or decrease I the magnetic field strength. |
| Faraday – What did Faraday wanted to prove? | He wanted to see if the process can be reversed, if magnets or magnetic fields can induce electricity or electric current. |
| What were his findings? | He discovered that it can be reversed. A moving magnet through a coil of wire induces electric current because of the change in magnetic flux or the number of magnetic field lines through the coil of wire. |
| Lenz – How were his findings different from Faraday's? | Though both of them were working on induction of electric current via magnetism, Lenz found out that non-magnetic conductors have resistance to the induction effects, so they react to cancel these effects. |
| Very good.<br><br>**Phase 6.** Interpretations and predictions.<br><br>This time, we'll use the law to explain the electromagnetic induction phenomenon from Oersted's discovery to Lenz's. | Oersted discovered that current-carrying wires can induce magnetic fields, or simply they are also magnets. Ampere verified this and found out that just like magnetic poles facing each other, parallel current-carrying wires exert magnetic forces on each other. An increase in the current will result to an increase in magnetic force exerted. Faraday investigated if magnets or current-carrying elements can induce electric fields, or if the process can be reversed. He used a magnet and a current-carrying coil or a primary coil and was able to determine that a voltage was induced in another/secondary coil. As the current on one coil increases, making it a stronger magnet, the voltage induced on the other also increases. Lenz discovered that this secondary coil, like the copper tube and the cookie sheet, resist these inductions. These laid the foundations for the law of electromagnetic induction. |

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| The students will use the law to create and explain the principles behind a simple motor and a generator. | Generators induce electricity by converting mechanical energy of the moving magnets which results to a change in flux.<br>Simple motors work in a reverse manner, where stored energy is converted to mechanical energy to perform work. The electromagnetic induction process is reversible, just like how generators and motors work. |
| **Phase 7.** Extension of theory.<br><br>The students will be given situations or conditions that would require the use of the law, the concept or the mathematical interpretation.<br><br>Example:<br>If a coil between two opposite magnetic poles is rotating and the magnetic flux on it is decreasing, | |
| a. Is there an induced electric and magnetic field in the coil? | Yes, there are. The magnets induce current in the coil since there is changing flux due to the rotation of the coil. Due to some sort of resistance, there will be an induced magnetic field in the coil. |
| b. Good. What is the sign for the change in flux vs time? | Since the flux is decreasing, the sign is negative. |
| c. Correct. What will be the sign for the induced voltage? And what does it mean if we're going to use the right hand rule? | It will be positive, this means that whatever directions we get using RHR, we leave it as it is, since induced voltage is positive. |
| d. With the directions of the magnetic field known using the opposite poles of the magnet, can we determine the direction of the induced magnetic field in the coil? | Yes, since we know the sign of the induced voltage and how to use the right hand rule. |
| Generalization:<br>What causes induction of electric current? | A changing magnetic flux causes electric current. |

| | |
|---|---|
| How does this change in flux affect magnitude and direction of induced electric current in a generator?<br><br>Assessment: Administration of an RPSEI question. How do motors and generators work using electromagnetic induction?<br><br>Take home task:<br>Review the variables and the relationships existing between variables that explain EMI. | If the flux is increasing, the current induced increases as well. The direction of the flux can be used to determine the direction of the induced current using the right-hand-rule (RHR). The direction of rotation is due to the interaction of the magnetic fields from the loop and from the magnet.<br><br>Students explain on an answer sheet. |

References for CATA and MHRTA:
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http://www.eti.kit.edu/english/1376.php
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http://www.education.com/pdf/copper-magnetic-affect-falling-magnet/

Appendix C

**Table of Specifications for 20-item Conceptual Survey in Electromagnetic Induction (CSEI)**

(Objectives adapted from DepEd-NSTIC Sci. Manual part 1 and DepEd Grade 10 Science Learner's Material. 2015. 1st ed.)

| Topics/Objectives | | Knowledge | Comprehension | Application | Analysis | Synthesis | Evaluation | **Total** |
|---|---|---|---|---|---|---|---|---|
| ***Magnetic fields in current-carrying conductors (straight and coiled)*** | ascertain the directions of the magnetic force of the induced magnetic field given the direction of current | | | #1 | #4, #6, #8 | | #3 | 5 |
| | identify factors affecting the strength of induced magnetic field or force in a conductor given certain conditions | | | | #2 | #5 | #7 | 3 |
| ***Magnetic flux*** | recognize how change in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or a magnetic substance | | | | #9, #16 | #11 | #12, #13 | 5 |
| ***Faraday's law*** | use the demonstration of generating electricity by moving a magnet or a magnetic substance through a coil in determining the factors affecting magnitude and direction of induced | | #10 | | | #14, #15 | | 3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | current through a conductor | | | | | | | |
| ***Simple electric motor and generator*** | explain the working principle of a simple electric motor and a generator using electromagnetic induction | | | | | #17, #20 | #18,#19 | 4 |
| **Total** | | 0 | 1 | 1 | 6 | 6 | 6 | **20** |

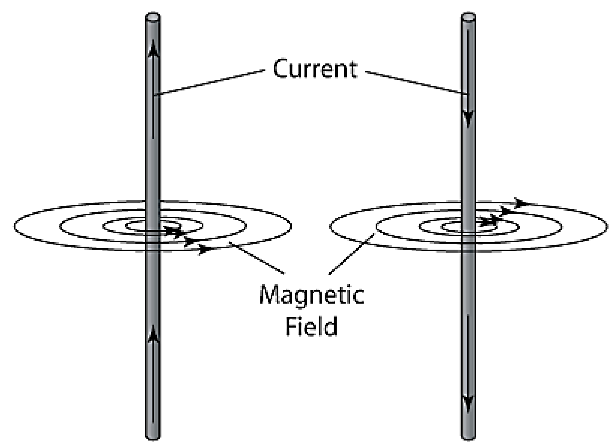
Appendix D

Conceptual Survey on Electromagnetic Induction (CSEI)

Name: ________________________________________ Section:________________

Direction: Read and analyze each item carefully. Write the letter of the correct answer.

1. On the right is a diagram showing two parallel current-carrying conductors. The current they carry are equal in magnitudes. How do the forces they exert with each other compare?
   A. The conductors exert repulsive forces with equal magnitudes on each other.
   B. The conductors exert attractive forces with equal magnitudes on each other.
   C. The conductors exert upward forces with equal magnitudes on each other.
   D. The conductors exert no forces on each other.

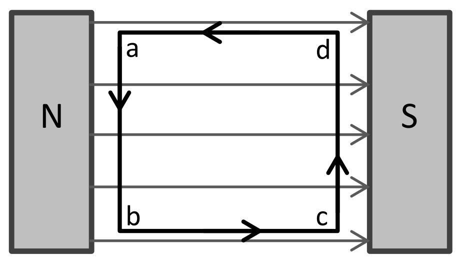



Field Pattern of Straight Wire

*Image from http://physics503.one-school.net/2008/06/magnetics-effects-of-current-carrying.html*

2. How can the magnetic field surrounding the same wires in the previous item increase without changing the length of the wire?
   A. It can be increased by decreasing the current.
   B. It can be increased by increasing the current.
   C. It can be increased by increasing the resistance of the wire.
   D. It can be increased by decreasing the resistance of the wire.

3. If a single wire is replaced by a current-carrying rectangular loop and placed between the poles of a magnet, then which of the following correctly explains the forces experienced by the sides of the loop causing the loop to rotate? Below is a top view of the loop in between the poles. The arrows on each side of the loop indicate the direction of current.




   I. Segment CD experiences an inward force.
   II. Segment AB experiences an inward force.
   III. Segment AB experiences an outward force.
   IV. Segment CD experiences an outward force.

   A. I and II only
   B. I and III only
   C. II and IV only
   D. III and IV only

4. After Ampere verified that a current-carrying conductor is a magnet, further investigations on electromagnetic induction were made. If a current-carrying wire is placed in between the poles of a magnet just like the diagram below, this wire experiences a force. The direction of the magnetic field is from the North to the South magnetic poles. The direction of the current on the wire is also shown. What is the direction of the force exerted on the wire?

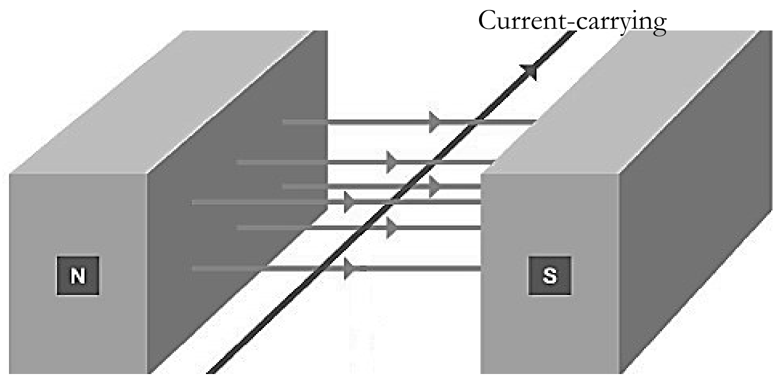


*Image from http://imgarcade.com/1/picture-of-*

A. The wire will be pushed by an upward force.
B. The wire will be pushed by a downward force.
C. The wire will be pushed by a force directed to the left.
D. The wire will be pushed by a force directed to the right.

5. Andre Marie Ampere investigated on how to determine the magnetic field inside a solenoid, a long coil of wire with many loops or turns. On the right is a current-carrying solenoid. Which of the following statements is true about the magnetic field inside this solenoid for the specified length?

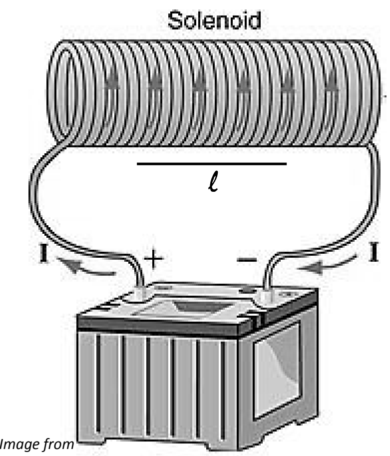


*Image from http://www.mystudyexpress.com/10%20th%20cbse/science/MAGNETIC%20EFFECT%20OF%20ELECTRIC%20CURR*

   I. As the number of turns is increased with the current held constant, the magnetic field inside the solenoid will also increase.
   II. As the current is increased with the same number of turns, the magnetic field inside the solenoid will also increase.
   III. As the current is doubled and the number of turns was halved, the magnetic field inside the solenoid will also increase.
   IV. As the current and the number of turns were increased, the magnetic field inside the solenoid will also increase.

   A. I and II only
   B. I, II, and III only
   C. I, II, and IV only
   D. All statements are true.

6. From the previous item, Ampere discovered that these current-carrying conductors induce magnetic fields so they are also magnets. What is the direction of the magnetic field induced in the solenoid in #5?

   A. ←
   B. →
   C. ↑
   D. ↓

7. How can the magnetic field surrounding the same solenoid in #5 be increased?
   A. It can be increased by decreasing the current and decreasing the number of turns.
   B. It can be increased by increasing the current and decreasing the number of turns.
   C. It can be increased by decreasing the current and increasing the number of turns.
   D. It can be increased by increasing the current and increasing the number of turns.

8. Recalling that current-carrying conductors are like magnets, by looking at the magnetic field lines on the plane holding the solenoid, where are the North and South magnetic poles of this current-carrying conductor?

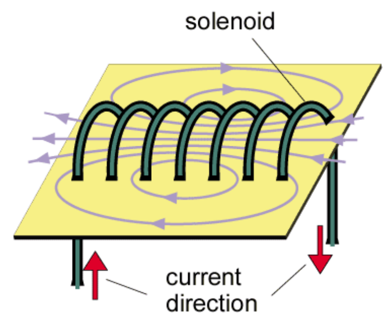
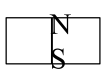
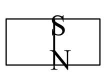
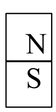
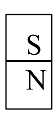


*Image from http://www.geocities.ws/motorac2002/solenoid_field_lines_e.gif*

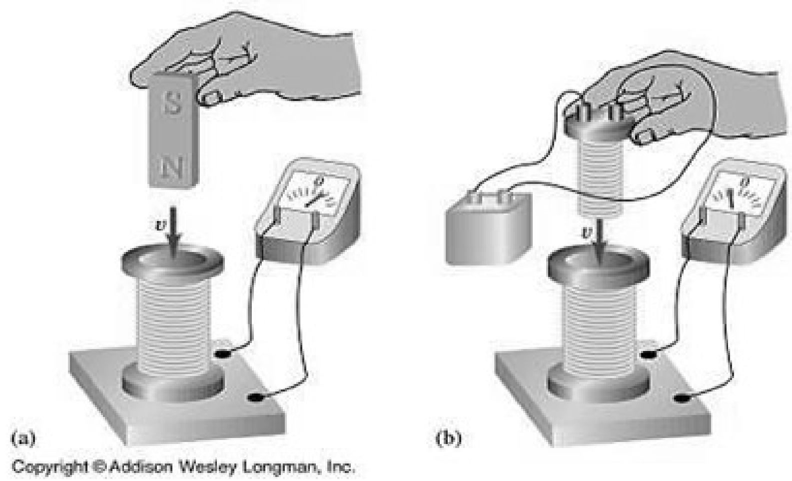
A. 


B. 


C. 


D. 

9. In Faraday's experiment, he deduced that a current can be induced by a magnet or a current-carrying coil. In the diagrams below, moving a magnet or a secondary current-carrying coil towards a primary coil which is connected to a galvanometer, a deflection occurs. v indicates the direction of the magnet's or coil's motion. If both magnets were moving towards the same primary coil and the magnitudes on the galvanometer's scale are the same, then, what can explain the difference in the deflections?




A. The magnetic flux in b is decreasing downward.
B. The magnetic flux in a is decreasing downward.
C. The magnetic flux in b is increasing downward.
D. The magnetic flux in a is increasing downward.

10. Magnetic field lines are visual representations of magnetic fields. These lines show direction and intensity of a magnetic field. They are also called magnetic flux and are given a Greek symbol Phi (Φ). What can be concluded from the diagram on the right?

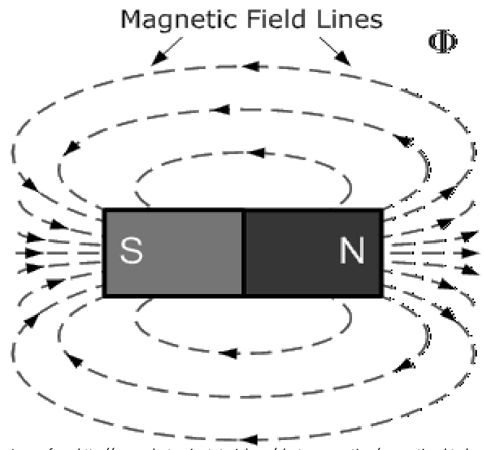



Image from http://www.electronics-tutorials.ws/electromagnetism/magnetism.html

A. The general path of magnetic flux is from the North to the South pole.
B. The magnetic field is strongest near the poles of the magnet where the lines of flux are more closely spaced.
C. Magnetic flux flow from the North to the South pole or anywhere.
D. A and B only.

11. Magnetic flux can be thought of as being the total number of field lines passing through the area enclosed by a loop. On the diagram below, n represents the normal line or a line that is perpendicular to the surface of the loop. The downward lines can be similar to pouring rain. The loop's orientation varies, resulting to a changing amount of rain (field lines) that passes through it. Which of the correctly shows the order of increasing magnetic flux?

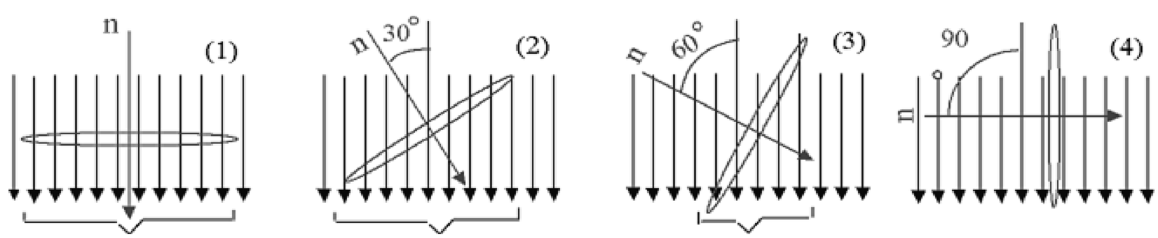



Image from http://www.pstcc.edu/departments/natural_behavioral_sciences/Web%20Physics/Chapter22.htm

A. 1,2,3,4
B. 2,3,4,1
C. 3,4,2,1
D. 4,3,2,1

12. Faraday used magnetic field lines to represent the magnetic field and found out that the induced emf in a loop is not simply proportional to the rate of change in the magnetic field. In the previous item, it is shown that the angle at which the loop is positioned with respect to the field lines affect the induced emf. Below shows a loop of wire that was stretched in a magnetic field B. The magnetic field lines are moving towards the loop. Which of the following statements is true?

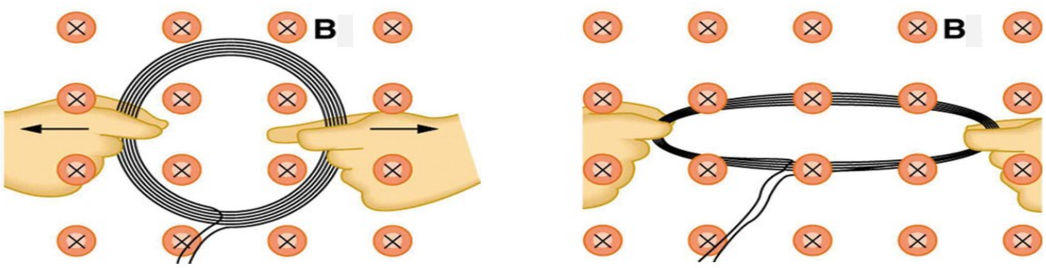
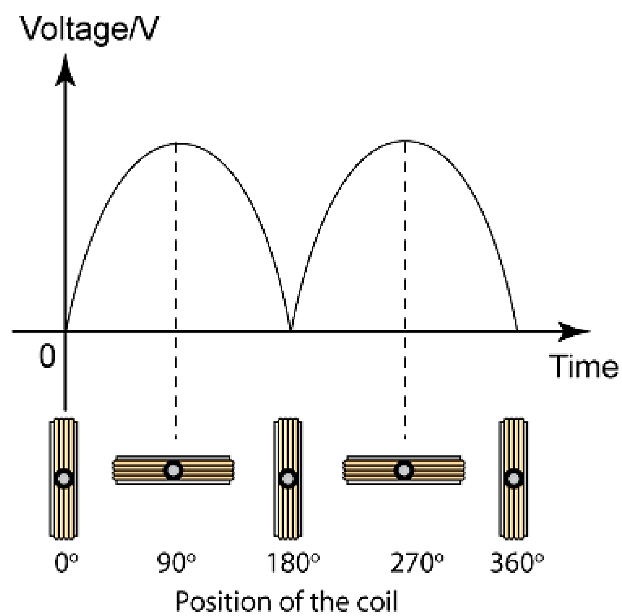



Image from https://voer.edu.vn/c/induced-emf-and-magnetic-

A. There is no induced emf in the loop when it was stretched.
B. There is an increased induced emf in the stretched loop.
C. The magnetic flux is zero when the loop was stretched.
D. There is an induced emf in the stretched loop.

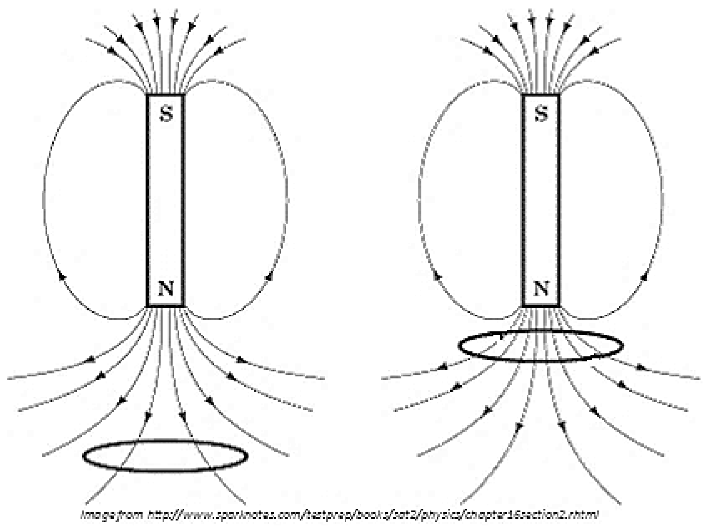
13. On the right is a voltage vs time graph at from a dc generator at varying orientations of its coil in between two opposite magnetic poles. At what orientations is the change in magnetic flux maximum?

A. At 0°, 180°, and 360°
B. At 90° and 270°
C. At 90° and 180°
D. At 360° only




Imagse from http://www.one-school.net/Malaysia/UniversityandCollege/SPM/revisioncard/physics/electromagnetism/induction.html

14. As the magnet moves closer to the loop, the flux, coming of the North magnetic pole, is in the downward direction. What can be concluded from the diagram?




1. There is an increasing downward flux through the loop.
2. There is an increasing upward flux through the loop.
3. The induced emf creates a clockwise current.
4. The induced emf creates a counter -clockwise current.

A. 1 and 3
B. 2 and 3
C. 1 and 4
D. 2 and 4

15. In Faraday's experiments, it was established that a change in flux results to an induced emf thereby producing a current. Applying Faraday's and Lenz's law, which of the following statements are correct?

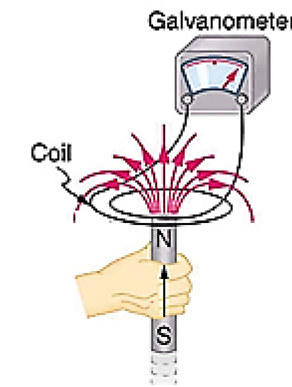


*Image from http://philschatz.com/physics-book/resources/Figure_24_01_02.jpg*

1. The induced emf is negative.
2. The induced emf is positive.
3. A clockwise current is induced in the coil.
4. A counterclockwise current is induced in the coil.
5. The induced current will setup a magnetic field in a downward direction.
6. The induced current will setup a magnetic field in an upward direction.

A. 2, 4, 6 only
B. 1, 3, 5 only
C. 1 and 5 only
D. 2 and 4 only

16. At the current position of the rectangular loop of wire, as the loop slowly rotates and aligns itself with the direction of the magnetic field between the poles of the magnets, which of the following statements is true about the magnetic flux as it turns in the said direction?

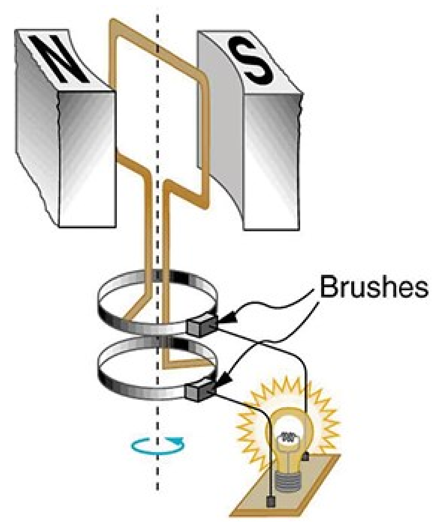


*Image from http://philschatz.com/physics-*

A. The magnetic flux in the loop is zero.
B. The magnetic flux in the loop is constant.
C. The magnetic flux in the loop is increasing.
D. The magnetic flux in the loop is decreasing.

17. On the right is a picture of an ac generator. It converts mechanical energy to electricity. Recalling Faraday's and Lenz's discoveries, with the coil rotating, a change in flux occurs and a current is induced in the coil. What happens then?

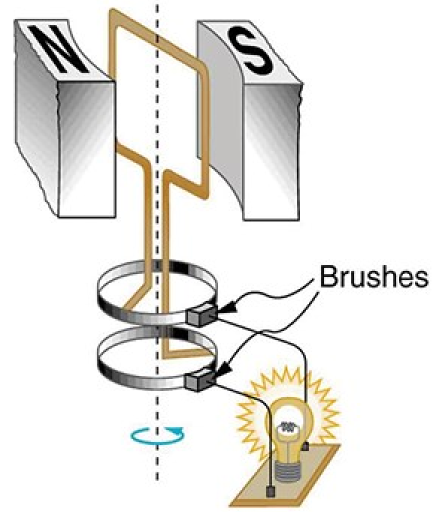



*Image from http://philschatz.com/physics-*

A. This induced current will oppose the original change in flux.
B. This induced current will succumb to the original magnetic field.
C. This induced current produces its own magnetic field that opposes the original change in flux.
D. This induced current produces its own magnetic field that will succumb to the original change in flux.

18. Using the right-hand-rule or the direction of the forces on the rectangular loop, what can be concluded on the force and torque (or the ability of a force to cause rotation) on the rectangular loop of the motor?

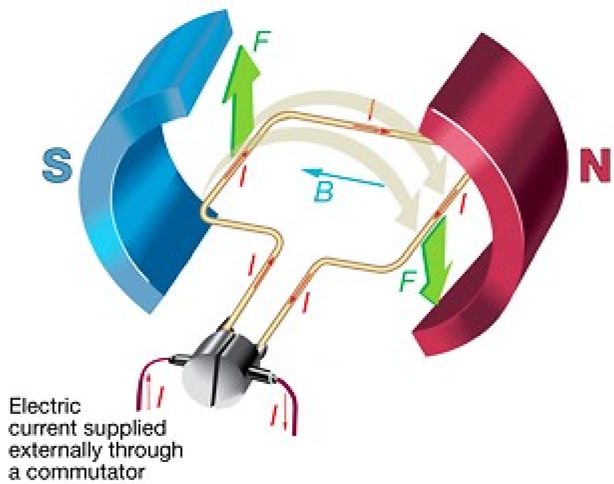
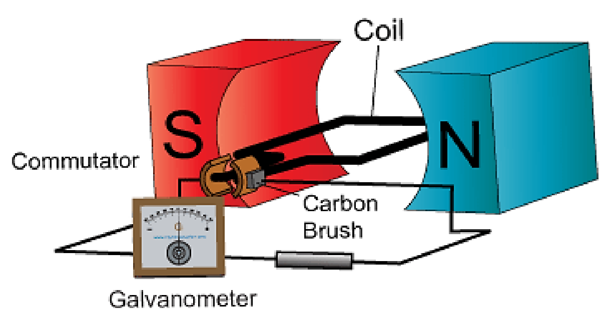


*Image from http://resource.rockyview.ab.ca/rvlc/physics30_BU/images/m4/p30_m4_108_l.jpg*

I. The net force is zero.
II. The net force is not zero.
III. The plane of the loop is parallel to the magnetic field, so torque is zero.
IV. The plane of the loop is perpendicular to the magnetic field, so torque is not zero.
V. The rectangular loop will not turn.

A. I and IV only.
B. I, III, and V only.
C. I, IV, and V only.
D. II, IV, and V only.

19. On the right is a picture of a dc generator. A dc generator is much like an ac generator, except the slip rings are replaced by split-ring commutator. At the current position of the coil, which of the following statements is true?



*Imagse from http://www.one-school.net/Malaysia/UniversityandCollege/SPM/revisioncard/physics/electromagnetism/induction.ht*

I. There is maximum magnetic flux.
II. There is zero magnetic flux.
III. There is a changing magnetic flux.
IV. There is no change in magnetic flux.
V. No current is induced in the coil.

A. II and V only
B. I, III, and V only
C. II, III, and V only
D. II, IV, and V only

20. Electric motors work similarly as generators, but they convert electricity to mechanical energy. The forces that make it turn are forces that a magnetic field exerts on a conductor carrying a current. The magnetic forces on the moving charges within the conductor, and the conductor as a whole experiences a force distributed along its length. This force creates a torque, which is the twisting or the turning effort of a force. What can be concluded on the picture?

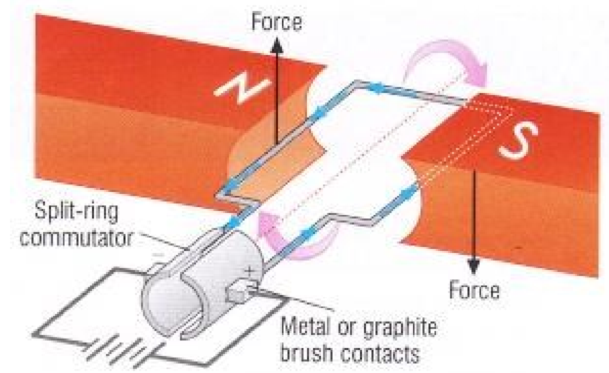


*Image from https://gcserevision101.files.wordpress.com/2009/02/0021.jpg?w=313&h=204*

A. The net torque is zero since the plane of the rectangular loop is parallel to the magnetic field, so the loop will not turn.
B. The net torque is zero since the plane of the rectangular loop is parallel to the magnetic field, so the loop will turn.
C. The net torque is not zero since the plane of the coil is perpendicular to the rectangular loop, so the loop will turn.
D. The net torque is zero, so the rectangular loop will not turn.

-END-

Appendix E

**CSEI Evaluation Checklist**

(Adapted from Morales, M.P.E. 2012. Development and Validation of a Concept Test in Introductory Physics for Biology Students. *The Manila Journal of Science*, 7:2, pp. 26-44, Appendix A.)

Please use the following scale for rating the conceptual survey in electromagnetic induction (CSEI).

| 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|
| I strongly agree with the statement. | I agree with the statement. | I am undecided. | I disagree with the statement. | I strongly disagree with the statement. |

| Criteria | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| 1. The items are congruent with the written objectives. | | | | | |
| 2. The question on each item is stated clearly. | | | | | |
| 3. The items include as much as possible information and do not include irrelevant materials. | | | | | |
| 4. The questions do not give away the correct answer and are free from clues. | | | | | |
| 5. The choices are stated or worded clearly and concisely. | | | | | |
| 6. The choices do not show any pattern as to which response is correct. | | | | | |
| 7. The grammar of each choice is consistent with the question. | | | | | |
| 8. Verbatim and textbook phrasing is avoided in stating the questions and the choices. | | | | | |
| 9. Almost all the choices in each of the items are reasonable. | | | | | |
| 10. In general, "all of the above" and "none of the above" were avoided as choices. | | | | | |
| 11. Each item includes one and only one correct or clearly best answer. | | | | | |
| 12. The choice of answer for each item is positioned in a random order, and is distributed approximately equal in number in the test. | | | | | |
| 13. Layout and format of the items are clear and in a consistent manner. | | | | | |
| 14. Proper use of grammar, punctuation, and spelling were observed. | | | | | |
| 15. Generally, difficult and unfamiliar terms were avoided. | | | | | |

General comments for the revision:

| |
|---|
| |

Evaluator: ________________________________ date: _________________________

(Signature over printed name)

To the Evaluator:

Please provide information for each of the six areas listed below. Attached to this profile is the evaluation checklist. This checklist is envisioned to determine the content validity of a test as gauged by test evaluators. It aims to support in the development of a valid multiple-choice conceptual survey in electromagnetic induction (CSEI) for grade 10 students.

Name: ______________________________________________

Contact information: _________________________

Highest Degree Earned:

______________________________________________________________________

______________________________________________________________________

___________

Current Office of Employment: __________________________________

Position: _______________________________

Professional Affiliations:

______________________________________________________________________

______________________________________________________________________

___________

Appendix F

**Table of Specifications for 5-item Reasoning Pattern Survey in Electromagnetic Induction (RPSEI)**

(Objectives adapted from DepEd-NSTIC Sci. Manual part 1 and DepEd Grade 10 Science Learner's Material. 2015. 1st ed.)

| Topics/Objectives | | Knowledge | Comprehension | Application | Analysis | Synthesis | Evaluation | **Total** |
|---|---|---|---|---|---|---|---|---|
| ***Magnetic fields in current-carrying conductors (straight and coiled)*** | ascertain the directions of the magnetic force of the induced magnetic field given the direction of current | | | | #1 | | | 1 |
| | identify factors affecting the strength of induced magnetic field or force in a conductor given certain conditions | | | | #2 | | | 1 |
| ***Magnetic flux*** | recognize how change in magnetic flux affect the magnitude and direction of induced voltage and current through a conductor based on the generation of electricity by a magnet or a magnetic substance | | | | | | #3 | 1 |
| ***Faraday's law*** | use the demonstration of generating electricity by moving a magnet or a magnetic substance through a coil in determining the factors affecting magnitude and direction of induced current through a conductor | | | | | | #4 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Simple electric motor and generator*** | explain the working principle of a simple electric motor and a generator using electromagnetic induction | | | #5 | | | | 1 |
| **Total** | | 0 | 0 | 1 | 2 | 0 | 2 | **5** |

Appendix G

Reasoning Pattern Survey in Electromagnetic Induction (RPSEI)

1. How do you determine the direction of the magnetic force and magnetic field given the direction of the current along the straight or coil of wire?

______________________________________________________________

______________________________________________________________

______________________________________________________________

2. How does the strength of the current relate to the induced magnetic field strength and magnetic force?

______________________________________________________________

______________________________________________________________

______________________________________________________________

3. How does magnetic flux variation affect the magnitude and direction of the induced current in a coil of wire?

______________________________________________________________

______________________________________________________________

______________________________________________________________

4. The induced current in a coil of wire induces another magnetic field. How do you determine the direction of this induced magnetic field by the induced current in a coil of wire?

______________________________________________________________

______________________________________________________________

______________________________________________________________

5. How do motors and generators work using electromagnetic induction?

______________________________________________________________

______________________________________________________________

______________________________________________________________

Appendix H

To the Evaluator:

Please provide information for each of the six areas listed below. Attached to this profile is the evaluation checklist. The checklist is envisioned to determine the level of acceptability of the lesson plans as gauged by physics Master Teachers. It aims to support the development of a valid lesson plan in electromagnetic induction employing the modified historical reconstructionist teaching approach (MHRTA) for grade 10 students.

Name: ______________________________________________

Contact information: __________________________

Highest Degree Earned:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Current Office of Employment: ___________________________________

Position: _________________________________

Professional Affiliations:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

To the Evaluator:

Please provide information for each of the six areas listed below. Attached to this profile is the evaluation checklist. The checklist is envisioned to determine the level of acceptability of the lesson plans as gauged by physics Master Teachers. It aims to support the development of a valid lesson plan in electromagnetic induction employing the conventional teaching approach (CATA) for grade 10 students.

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Name: ______________________________________________

Contact information: __________________________

Highest Degree Earned:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Current Office of Employment: ___________________________________

Position: _________________________________

Professional Affiliations:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Appendix I

**Lesson Plan Evaluation Checklist**

(Adapted from Pantig, R. (2013). The Effect of Ranking Tasks on Student Understanding of Electric Circuits)

Please use the following scale for rating the lesson plan using the modified historical reconstructionist teaching approach (MHRTA).

| 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|
| I strongly agree with the statement. | I agree with the statement. | I am undecided. | I disagree with the statement. | I strongly disagree with the statement. |

| Criteria | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| **OVERALL PLAN** | | | | | |
| 1. The overall plan is written in a clear and understandable manner. | | | | | |
| 2. The overall plan is practical (can be carried out in an actual school situation). | | | | | |
| 3. The overall plan is geared to the level of the students for which it is prepared. | | | | | |
| 4. The overall plan includes the use of supportive or illustrative audio or visual aids. | | | | | |
| **CONTENTS** | | | | | |
| 1. The contents are sufficient and appropriate to the level of the students and level of the subject. | | | | | |
| 2. The contents include information necessary for the achievement of the stated objectives. | | | | | |
| 3. The contents include all the essential parts of a lesson plan. | | | | | |
| **PRELIMINARY MATERIALS** | | | | | |
| 1. The preliminary materials include a clear title for the lesson that accurately reflects the lesson content. | | | | | |
| 2. The preliminary materials include resources and identification of prerequisite assignments designed to prepare students for class. | | | | | |
| 3. The preliminary materials include a complete list of all supplies and materials needed for the lesson. | | | | | |
| **OBJECTIVES** | | | | | |
| 1. The objectives ate stated in terms of student behavior. | | | | | |
| 2. The objectives are clear, concise, and can be easily understood. | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 3. The objectives are designed to support identified student "outcomes" for the entire physics subject as stated in the physics topic outline. | | | | | |
| **LESSON INTRODUCTION** | | | | | |
| 1. The lesson introduction provides students with a logical orientation to the content of the presentation. | | | | | |
| 2. The lesson introduction serves to involve students as active participants in the presentation to follow. | | | | | |
| 3. The lesson introduction motivates the students. | | | | | |
| **LESSON PRESENTATION** | | | | | |
| 1. The lesson presentation use methods, techniques, and learning experiences appropriate to the lesson objectives. | | | | | |
| 2. The lesson presentation provides students with opportunities to become actively engaged in the learning process. | | | | | |
| 3. The lesson presentation meets student needs, interests, and abilities. | | | | | |
| **CLOSURE** | | | | | |
| 1. The closure allows for "loose ends" to be pulled together. | | | | | |
| 2. The closure allows the students to draw conclusions consistent with the objectives of the lesson. | | | | | |
| 3. The closure enables students to actively participate in summarizing what they have learned. | | | | | |
| **ACTIVITIES** | | | | | |
| 1. The activities were aligned with the stated objectives and the type of performance appropriate to the desired student outcomes for the lesson. | | | | | |
| 2. The activities were aligned with the stated objectives and the type of performance appropriate to the desired student outcomes for physics subject. | | | | | |
| 3. The activities address student differences (visual, oral, diversity, SPED, ESL, etc.). | | | | | |

General comments for the revision:

| |
|---|
| |

Evaluator: ________________________________ Date: _________________________

(Signature over printed name)

**Lesson Plan Evaluation Checklist**

(Adapted from Pantig, R. (2013). The Effect of Ranking Tasks on Student Understanding of Electric Circuits)

Please use the following scale for rating the lesson plan using the conventional teaching approach (CTA).

| 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|
| I strongly agree with the statement. | I agree with the statement. | I am undecided. | I disagree with the statement. | I strongly disagree with the statement. |

| Criteria | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|
| **OVERALL PLAN** | | | | | |
| 5. The overall plan is written in a clear and understandable manner. | | | | | |
| 6. The overall plan is practical (can be carried out in an actual school situation). | | | | | |
| 7. The overall plan is geared to the level of the students for which it is prepared. | | | | | |
| 8. The overall plan includes the use of supportive or illustrative audio or visual aids. | | | | | |
| **CONTENTS** | | | | | |
| 4. The contents are sufficient and appropriate to the level of the students and level of the subject. | | | | | |
| 5. The contents include information necessary for the achievement of the stated objectives. | | | | | |
| 6. The contents include all the essential parts of a lesson plan. | | | | | |
| **PRELIMINARY MATERIALS** | | | | | |
| 4. The preliminary materials include a clear title for the lesson that accurately reflects the lesson content. | | | | | |
| 5. The preliminary materials include resources and identification of prerequisite assignments designed to prepare students for class. | | | | | |
| 6. The preliminary materials include a complete list of all supplies and materials needed for the lesson. | | | | | |
| **OBJECTIVES** | | | | | |
| 4. The objectives ate stated in terms of student behavior. | | | | | |
| 5. The objectives are clear, concise, and can be easily understood. | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 6. The objectives are designed to support identified student "outcomes" for the entire physics subject as stated in the physics topic outline. | | | | | |
| **LESSON INTRODUCTION** | | | | | |
| 4. The lesson introduction provides students with a logical orientation to the content of the presentation. | | | | | |
| 5. The lesson introduction serves to involve students as active participants in the presentation to follow. | | | | | |
| 6. The lesson introduction motivates the students. | | | | | |
| **LESSON PRESENTATION** | | | | | |
| 4. The lesson presentation use methods, techniques, and learning experiences appropriate to the lesson objectives. | | | | | |
| 5. The lesson presentation provides students with opportunities to become actively engaged in the learning process. | | | | | |
| 6. The lesson presentation meets student needs, interests, and abilities. | | | | | |
| **CLOSURE** | | | | | |
| 4. The closure allows for "loose ends" to be pulled together. | | | | | |
| 5. The closure allows the students to draw conclusions consistent with the objectives of the lesson. | | | | | |
| 6. The closure enables students to actively participate in summarizing what they have learned. | | | | | |
| **ACTIVITIES** | | | | | |
| 4. The activities were aligned with the stated objectives and the type of performance appropriate to the desired student outcomes for the lesson. | | | | | |
| 5. The activities were aligned with the stated objectives and the type of performance appropriate to the desired student outcomes for physics subject. | | | | | |
| 6. The activities address student differences (visual, oral, diversity, SPED, ESL, etc.). | | | | | |

General comments for the revision:

| |
|---|
| |

Evaluator: ________________________________ Date: ___________________________

(Signature over printed name)

Appendix J

July 9, 2015

Mr. Henry A. Sabidong
Principal
City of Mandaluyong Science High School

Sir,

I am a member of the Science and Technology faculty of Makati Science High School and I am currently working on my master's thesis entitled "*Effects of Modified Historical Reconstructionist Teaching Approach on Students' Conceptual Understanding and Reasoning Patterns.*" Electromagnetic induction is one of the major topics in grade 10 physics which was observed to be a challenge for most students. As a teacher, I must find means of making the topic (or any difficult topic) easier for my students to understand. I have been working on developing my research instrument entitled conceptual survey in electromagnetic induction (CSEI) to measure conceptual understanding of the topic.

In line with this, I would like to ask for your permission to allow me to pilot-test my instrument, CSEI, to one of the grade 10 classes from your school on July 15, 2015 at 2:00PM.

Any assistance regarding this matter will be highly appreciated. Thank you for your time.

Sincerely,

Michelle Z. Yakit

Noted by:

Mr. Brando C. Palomar
*Research Adviser*

Appendix K

July 10, 2015

Evangelina N. Apolinario
Principal II
Makati Science HS

Madame,

I, Michelle Z. Yakit, a member of the Science and Technology facultyof Makati Science High School, will be handling the grade 10 physics class for the second quarter for the SY 2015-2016. I am currently working on my graduate thesis entitled "*Effects of Modified Historical Reconstructionist Teaching Approach on Students' Conceptual Understanding and Reasoning Patterns.*" Electromagnetic induction is one of the major topics in grade 10 physics which was observed to be a challenge for most students. As a teacher, I must find means of making the topic (or any difficult topic) easier for my students to understand which is why I will be comparing the effects of two teaching approaches on students understanding of the topic and on their reasoning ability to find out which approach works best for them.

In line with this, I would like to inform you that I will be conducting the study to two sections of Grade 10 and I will be sending letters of consent to the parents whose child will take part in the study. All information gathered before, during, and after the conduct of the study will be held confidential.

Any assistance regarding this matter will be highly appreciated. Thank you for your time.

Sincerely,

Michelle Z. Yakit

Noted by:

Mr. Brando C. Palomar
*Research Adviser*

## Appendix L

To whom it may concern,

I, Michelle Z. Yakit, a member of the Science and Technology faculty of Makati Science High School, will be handling the grade 10 physics class for the second quarter for the SY 2015-2016. I am currently working on my graduate thesis entitled "*Effects of Modified Historical Reconstructionist Teaching Approach (MHRTA) on Students' Conceptual Understanding and Test-taking Confidence in Electromagnetic Induction.*" Electromagnetic induction is one of the major topics in grade 10 physics which was observed to be a challenge for most students. As a teacher, I must find means of making the topic (or any difficult topic) easier for my students to understand which is why I will be comparing the effects of two teaching approaches on students understanding of the topic and on their reasoning ability to find out which approach works best for them.

In line with this, I would like to ask for your consent to permit your child to take part in the study. Any information gathered before, during, and after the conduct of the study will be held confidential.

Sincerely,

Michelle Z. Yakit

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### PARENTAL CONSENT

To whom it may concern,

This letter is verification that I allow my son/daughter ____________________ of __________ to take part in the study.

I have considered the benefits of my son/daughter will derive from his/her participation in the conduct of the study and the school administration shall not be held responsible for any untoward incident beyond control during the conduct of the study.

______________________________
Parent's Signature over Printed Name

**MICHELLE ZAMORA YAKIT**
Int. 4, 210 E. Santos, Pantaleon St., Barangka Itaas, Mandaluyong City
(+63917) 801-7177
**mitchyakit@gmail.com; michelleyakit@makatiscience.edu.ph**

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## OBJECTIVE

To secure a position where my existing skills in the area of education can be utilized by a progressive and innovative institution.

## EDUCATIONAL BACKGROUND

| | | |
|---|---|---|
| **Graduate Study** | 2010-present | complete academic requirements<br>Philippine Normal University<br>Taft Avenue, cor. Ayala Boulevard, Manila<br>Master of Arts in Science Education major in Physics |
| **Tertiary** | 2004 - 2008 | Graduate<br>Philippine Normal University<br>Taft Avenue, cor. Ayala Boulevard, Manila<br>Bachelor of Secondary Education major in Physics |
| **Secondary** | 2000-2004 | Graduate<br>City of Mandaluyong Science High School<br>E. Pantaleon st., Hulo, Mandaluyong City<br>First year — Fourth year High school |
| **Elementary** | 1993- 2000 | Graduate<br>Ilaya Barangka Elementary School<br>Lion's Road, Brgy. Ilaya, Mandaluyong City<br>Kindergarten - Grade VI |

## JOB EXPERIENCES

**On the job training**

Philippine Normal University - CTL
Student Teacher – Observation and Participation with Community Immersion
(June 2007 –August 2007)

San Isidro Catholic School
Student Teacher – Observation and Participation with Community Immersion
(August 2007 –October 2007)

**Faculty Member**

Aquinas School, San Juan City
Physics and Integrated Science Teacher
Theater Arts Club Moderator
(S.Y. 2008-2009)

Aquinas School, San Juan City
Physics, Integrated Science, and Environmental Science Teacher
Science Club Moderator
(S.Y. 2009-2010)

Makati Science High School, Makati City
Chemistry Substitute Teacher
Trainer (Physics and Chemistry Competing students)
(S.Y. 2010-2011)

Makati Science High School, Makati City
Physics Teachers
Trainer
(S.Y. 2011-present)

**Other work**

SYKES, Ortigas
Collections and Loan Resolutions agent
April 2011-September 2011

## WORK QUALIFICATIONS

Computer literate that is more proficient in Microsoft Office
Have excellent communication skills
Facilitate session
Documenting and encoding data
Create and integrate technology based activities
Create activities integrating values formation

## AFFILIATIONS

**PNU LiThe** - Member (S.Y. 2004 – 2008)

**Society for the Advancement of Physics** - Member (S.Y. 2005 – 2008)

**Creative Educators Society** - Founding President (S.Y. 2006 – 2007)

**Aquinas School Faculty** - Member (S.Y. 2009 – 2010)

**Makati Science High School Faculty** - Member (S. Y. 20010-2011)

## SEMINARS AND TRAININGS ATTENDED

**INSET 2011- Classroom Management Skills**
June 2, 2011- June 3, 2011
Makati Science High School

**Teacher Induction Program**
May 23, 2011- May 28, 2011
University of Sto. Thomas

**Understanding by Design seminar**
November 2009
UP Prep

**Teaching Seminars**
April-May 2008
Aquinas School

- Designing and Implementing Articulation Activities inside the Classroom
- Promoting a Culture of Academic Excellence through Investigatory Research
- Effective Planning and Implementation of Classroom and School-based Enrichment

**Pre-Employment Seminar**
March 5-7, 2008
Philippine Normal University

**Educational Tour in Educational Technology Class**
2006
Philippine Normal University

**Educational Tour in Earth Science Class**
2005
Philippine Normal University

**National Service Training Program**
2005
Philippine Normal University

## PERSONAL PARTICULARS

| | |
|---|---|
| **Age** | 29 years old |
| **Birth Date** | 1 August 1987 |
| **Birthplace** | Cubao, Quezon City |
| **Nationality** | Filipino |
| **Religion** | Roman Catholic |
| **Languages Spoken** | Filipino and English |
| **Height** | 5'0” |
| **Weight** | 110 Lbs. |
| **Civil Status** | Single |
| **Gender** | Female |

## CHARACTER REFERENCE

**Prof. Brando C. Palomar**
Thesis Adviser
Department of Allied Sciences
Philippine Normal University

**Mr. Christian Jeff G. Cariaga**
Academic Head for Communication Arts
Aquinas School

**Mr. Nick Bunyi**
09993577177
Science and Technology Coordinator
Aquinas School

## CERTIFICATION

I certify the veracity of the above information.

__________________
**MICHELLE Z. YAKIT**