THE IMPACT OF SCIENCE TEACHERS' METACOGNITION ON THEIR PLANNING CHOICE OF TECHNOLOGY-MEDIATED INQUIRY-BASED ACTIVITIES

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Abstract

This study investigated the conditions for developing science teachers' Technological Pedagogical Content Knowledge (TPACK). It also explored the opportunities offered by two strategies to enhance science teachers' ability to design technology-based inquiry activities for science learning: Experiencing Inquiry Model (EIM) and Metacognitive Scaffolding (MS). These strategies were adopted to support the processing necessary for developing teachers' knowledge and for negotiating the integration of computer technology in science instruction. Situated Cognition Theory was used as a theoretical framework for learning, and TPACK was used as a conceptual framework for technology integration. 33 science teachers from four intermediate and high schools participated in the study. 17 and 16 teachers were conveniently assigned to EIM and MS, respectively. The study employed a mixed method of quantitative and qualitative evidence. As per the quantitative method, a quasi-experimental design that employed the 2 Teaching Strategy (EIM or MS) × 2 Time (pre- and post-intervention) of learning split-plot factorial design was applied in the study. Concurrently with the quantitative data collection, the qualitative evidence was collected from the researcher's logbook, participants' written documents, and interviews. The findings suggested that there were no significant differences between EIM and MS for developing the knowledge components embodied in TPACK. Nevertheless, the participants who learned through the MS strategy outperformed their counterparts in designing technology-based inquiry activities for science learning. The latter result suggested that teachers who received metacognitive scaffolding were more equipped to connect curriculum goals with technology and instruction.

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Dedicated to

my late mother (may rest in peace),

my wife Fatma,

my daughters and son,

my beloved father, and my extended family.

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CHAPTER 1. INTRODUCTION

1.1 Background

Computer technology has been regarded as a tool to support many aspects of science instruction. Many national standards of science emphasize the promise of technology in engaging students in scientific inquiry, problem solving, and critical thinking activities (International Society of Technology in Education [ISTE], 2008; National Research Council [NRC], 2001). Part of this promise is that technology makes it easier for students to conduct science experiments, interact with simulated phenomena, and receive feedback to refine their scientific understanding. The interactive features and multiple functions of new technologies can enhance the learning of science. For example, interactive computer simulation can reveal problems that are difficult to demonstrate in conventional science laboratories (Chien, Chang, Yeh, & Chang, 2012; Khan, 2008). With interactive computer technology, students are able to visualize physical phenomena several times, control variables, reduce the errors that are often associated with real laboratory experiments, and test their own hypotheses or models (Abdullah & Abbas, 2006; Kubicek, 2005). Such opportunities are expected to encourage science teachers to support student-centered learning environments, as well as providing incentives to students to participate in their own learning (Hofstien, 2004; Jonassen, 2004). Nevertheless, technologies enhance learning only when they are used appropriately. Therefore, science teachers must take advantage of the integration of computer technology in classrooms in order to facilitate and support students' learning, and to address the pedagogical needs for enhancing the learning of science.

Aligning with this vision, some studies suggest that science teachers should be offered opportunities to develop instructions that take advantage of the affordance for technology to enhance classroom instruction (e.g., Lubin & Ge, 2012). It is suggested that science teachers should develop decision-making abilities, reasoning skills, and critical thinking in relation to the integration of computer technology into science classrooms (Phelps & Ellis, 2002; Lubin & Ge, 2012; So & Kim, 2009). More importantly, to fully benefit from computer technology, teachers need to develop an understanding of the pedagogical and content uses of technology. This involves understanding the role of technology in the teaching of science, how technology can be beneficial for a science curriculum, the learning contexts in which technology is most useful and why, which technological features most support students' learning of science, and which technologies are appropriate for simulating particular scientific concepts and why. Unfortunately, many teachers lack an adequate understanding of such issues, and they often encounter problems in relation to the integration of technology in everyday teaching practices (Phelps & Ellis, 2002; Lubin & Ge, 2012; So & Kim, 2009).

Lubin and Ge (2012) have reported that new teachers often face challenges in designing technology-based activities for science learning. Many of them fail to choose technological features or functions suitable for their science teaching needs. Overall, they are often unable to recognize the dynamic interplay between the types of technology used, methods of teaching science, science content, and classroom context. Thus research findings suggest that the impact of computer technology in enhancing science instruction lags far behind what has been described by national standards of science (Chien et al., 2012; Lubin & Ge, 2012; Phelps & Ellis, 2002).

In searching for the reasons behind these challenges for technology integration, much attention has been paid to the quality of professional development programs, in particular educational technology training. Some studies connect the inappropriate integration of technology in classrooms to the methods utilized in educational technology training (So & Kim, 2009). Although the goal of such programs is to train teachers to use different technologies in classrooms, the training often does not focus on the alignment of technology with pedagogical objectives or classroom contexts (Lubin & Ge, 2012; Markauskaite, 2007). Therefore, this study responds to a body of researchers who calls for alternative methods of educational technology training that aim to clarify the relationship between technology, science pedagogy, and science content (Chien, 2012; Mishra & Koehler, 2006; Niess, 2005). One way to do this (as described below), is to use a framework that takes into account the pedagogical and content uses of technology for classroom instruction (Lim, 2007).

1.2 Training science teachers for technology integration

In order to understand technology integration within science education, it is necessary to overcome the idea of computers as additional tools, and move towards the notion of using technology to serve specific pedagogical purposes and to resolve content difficulties. With this goal in mind, Mishra and Koehler (2006) argue that “thoughtful pedagogical uses of technology require the development of a complex situated form of knowledge that we call Technological Pedagogical Content Knowledge (TPCK)” (p. 1017).

This framework builds on Shulman’s construct of Pedagogical Content Knowledge (PCK), describing how their PCK can improve teachers’ understanding of technology in order to develop more effective means of teaching with technology (Mishra & Koehler, 2006). At the 9^{th} Annual National Technology Leadership Summit, the acronym TPCK was substituted with TPACK (pronounced “tee-pack”) (Thompson & Mishra, 2007). The new term was chosen because it is easier to pronounce and remember, but most importantly because it emphasizes the idea that the three essential components (technology, pedagogy, and content) should be taken as one unit or “Total PACKage” (Thompson & Mishra, 2007). The general framework of TPCK

(Figure 1) consists of seven components: three primary components, three secondary components, and one that integrates the primary and secondary components. The primary components are defined as follows:

1. Technological knowledge (TK) refers to knowledge about various technologies, ranging from pencil and paper to digital technologies.

2. Content knowledge (CK) is "knowledge about actual subject matter that is to be learned or taught" (Mishra & Koehler, 2006, p. 1026).

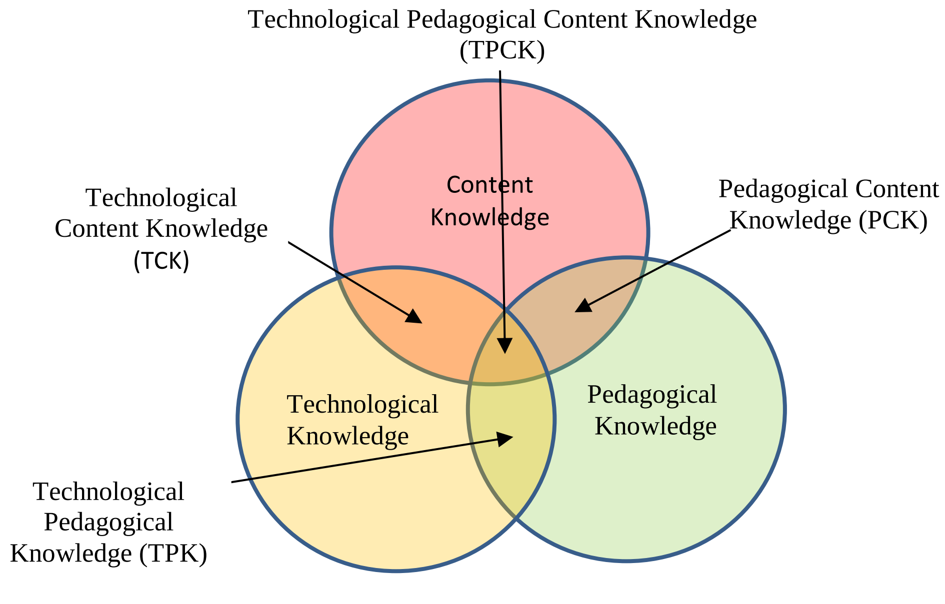


Figure 1. The components of the TPCK framework (Mishra, 2006)

3. Pedagogical knowledge (PK) refers to the methods and processes of teaching, including knowledge of classroom management, assessment, student context, curriculum objectives related to pedagogy, and activities development.

The secondary components are the intersections of the primary components. They are defined as follows:

4. *Pedagogical content knowledge (PCK)* refers to content knowledge that deals with the teaching process (Shulman, 1986). This blends both content and pedagogy, with the goal of developing better teaching practices in content areas. Evidence of PCK can be seen when, for instance, science teachers consider different strategies for teaching science as a process (e.g., inquiry, problem-based, discovery, etc.) as compared to the strategies used to teach science content (lecture, demonstration, etc.). This specialized knowledge allows science teachers to choose the most effective method for teaching specific science objective.

5. *Technological content knowledge (TCK)* refers to knowledge and skills that allow teachers to identify the best technology to support their students as they learn specific science content. For instance, as students learn to recognize and understand the sequence of steps leading up to Newton's second law of motion (content), teachers would look for technologies (such as interactive simulations or a microcomputer-based laboratory) that allow students to control and manipulate variables and plot graphs to help them understand the relationships between force, mass, and acceleration. A tutorial program or a YouTube clip may be useful to present various aspects of Newton's 2nd law, but such technologies may not engage students in testing hypotheses or encourage them to come up with their own explanations.

6. *Technological pedagogical knowledge (TPK)* refers to knowledge and skills related to the use of various technologies in teaching, and the understanding that using technology may change the way that teachers teach. For example, when engaging students to share their work or learn in collaborative groups (pedagogy), teachers might choose to have them communicate what they have learned through a wiki (a collaborative digital tool) or a multimodal presentation using, for example, PowerPoint or Prezi (digital tools that allow students to present what they

know). Choosing an interactive simulation, for example, might not be pedagogically useful to help students enhance their communication skills.

The central core, where all the primary components and their intersections overlap, is defined as follows:

7. Technological pedagogical content knowledge (TPCK or TPACK) refers to the knowledge required by teachers for integrating technology into their teaching in any content area. This includes an understanding of the complex relationships between content, methods of teaching this content, and the use of technology in teaching this content within classroom and school contexts. Teachers with good TPACK are expected to select effective technology for teaching specific content or subject matter, and to understand the rationale for this selection within a specific learning context. For example, a teacher might use a PowerPoint presentation (TK) to demonstrate (PK) the atomic structure of a Hydrogen atom (CK). While the demonstration aims to provide a scientific model of the Hydrogen atom (PCK), the PowerPoint would also help students visualize the distribution of electrons in the shells and around the nucleus (TPACK).

(Jimoyiannis, 2010; McCrory, 2008; Mishra & Koehler, 2006; Niess, 2005)

According to Mishra and Koehler (2008), the components of TPACK include (a) understanding of the representations of concepts using technologies, (b) pedagogical techniques that use technologies in constructive ways to teach content, (c) knowledge of what makes concepts difficult to learn and how technology can help redress some of the problems that students face, (d) knowledge about students such as how they learn and their prior conceptions, and (e) knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones.

In science education, researchers can use the concept of TPACK as a theoretical framework for understanding how science teachers develop the competencies needed to teach specific scientific topics in conjunction with particular technologies (McCrorry, 2008). Particular technologies have their own features and constraints that make them more suitable for certain tasks than others. This professional development should be curriculum-based to help science teachers achieve the goals of their particular subject area (The AACTE Committee on Innovation and Technology, 2008).

In 2007, the National Research Council (NRC) released a report, recommending a view of science not just as a body of knowledge but also as a process of evidence-based and model-building that continually extends, refines, and revises knowledge. In the report, the goals in order for students to be proficient in science include the following:

(a) Knowing, using and interpreting scientific explanations of the natural world, which includes acquiring facts and the conceptual structures that incorporate those facts.

(b) Generating and evaluating scientific evidence and explanations in order to develop the knowledge and skills needed to build and refine models. This includes designing and analyzing empirical investigations and using empirical evidence to construct and defend arguments.

(c) Understanding the nature of science and the development of scientific knowledge. This focuses on students' understanding of science as a way of knowing. Students who understand scientific knowledge recognize that predictions or explanations can be revised as a result of encountering new evidence or developing a new model.

(d) Participating productively in scientific practices and discourse, which includes students' understanding of the norms for participating in science as well as their own motivations and attitudes towards science. Students who engage productively in science understanding develop the ability to participate in scientific debates, adopt a critical stance, and ask productive questions.

To enable students to achieve science proficiency, teachers need to provide learning environments in which students can engage in these four areas (NRC, 2007). However, it was found that typical science curricula and instruction tend to treat science solely as a body of knowledge, such that the learning of science consists of solving problems and theories being transmitted to and memorized by students (Duschl & Grandy, 2008). Moreover, teachers often do not receive adequate guidance from teacher education or professional development programs in how to build on students' understanding so that they can learn science in depth. In fact, many new science teachers lack the knowledge and skills to guide their students in investigating problems in meaningful contexts, or in exploring complex ideas through authentic scientific practices (Kesidou & Roseman, 2002).

Research has suggested that teachers need more opportunities to learn how to teach science not only as an integrated body of knowledge but also as a process of investigation and evidence-based practice (Weiss & Pasley, 2004; Weiss, Pasley, Smith, Banilower, & Heck, 2003). More importantly, teachers need to recognize the role of technology in enhancing students' understanding of the nature of science and, crucially, in helping students to develop a sense of how scientists conduct science in their labs. The focus of scientific practice is on the process of building theories and models of natural phenomena, and the core of science learning is fundamentally about establishing lines of evidence and making use of that evidence to develop and refine explanations using theories, models, hypotheses, measurements, and observations (NRC, 2007). Thus the development of TPACK for science learning should focus on training teachers to integrate technology into the instruction of students in designing and conducting empirical investigations (Kuhn, Schauble, & Garcia-Mila, 1992; Metz, 2009). A body of researchers (Klahr & Nigam, 2004; Lee, 2011; Mayer, 2004) has proposed a training strategy called Experiencing Inquiry Model (EIM) to help teachers develop an understanding of technology integration in science instruction based on the TPACK framework.

1.3 Experiencing Inquiry Model (EIM)

The EIM strategy is based on Situated Cognition Theory (Brown, Collins, & Duguid, 1989) (described in details in section 3.1). EIM provides teachers with direct guidance in understanding how students learn with technology in a particular content area. Moreover, this strategy guides teachers through a sequence of learning tasks which can be used to help students conduct investigations using technology, rather than leaving teachers to figure out how to use technology to support student learning on their own. These learning tasks involve testing hypotheses, collecting and analyzing data, explaining events, and generating models. This strategy also provides teachers with opportunities to critically analyze the proposed learning tasks, and discuss the areas in which these tasks fail. The latter is a very important component of EIM because it advances teachers' understanding of how to design tasks that support student learning through inquiry. Consequently, when teachers design their own tasks for science learning using technology, they can adopt this pedagogical framework in order to plan a similar system of activities.

The main purpose of the EIM strategy is to provide opportunities for science teachers to recognize inquiry processes, events, and structures while integrating computer simulation in order to help students understand a natural phenomenon. This strategy provides teachers with explicit guidance to help them to not only assess the adequacy of particular inquiry activities for science learning, but also to consider the general parameters of what can be learned with technology, and why (Windschitl, Thompson, & Braaten, 2008). More importantly, the EIM strategy helps teachers in guiding students to generate models that can be examined using technology, supporting students to seek evidence using technology, and recognizing the challenges faced by students while conducting inquiry investigations (Windschitl et al., 2008). The EIM strategy has shown successes in guiding teachers to develop their understanding of inquiry instruction as a model for teaching science with technology (Radford & Ramsey, 1996). Nevertheless, EIM does not address the process through which teachers are able to develop technology-based inquiry activities effectively. It also seems to pay insufficient attention to providing teachers with opportunities to explore and discover where their knowledge falls short, which would allow them to work individually or collaboratively to bridge their knowledge gaps (Radford & Ramsey, 1996). As well, it falls short in helping teachers to negotiate their current knowledge structure in order to advance their instructional practices. For example, in their attempts to develop their own TPACK, teachers may struggle to translate this knowledge into instructional practices. Moreover, technology integration in science education is growing at a very fast pace, and teachers need to constantly monitor the status of their current knowledge to keep pace effectively. Without constant monitoring, reflecting, and adjusting of their own learning and thinking, teachers may have difficulty understanding the current, and future, value of technology in supporting students' learning of science. The results of the study suggest that teachers need more than an understanding of inquiry models and a recognition of the potential of computer technology within science instruction; equally important is the need to learn how to keep up with the accelerated pace of the development of technology that aids science proficiency. Teachers should also receive explicit guidance in how to more effectively translate their understanding of technology integration into instructional practices.

One way to achieve this goal is for teachers to be encouraged to plan for their own learning process, and reflect on their own experiences, while exploring the potential of new technologies for inquiry learning. Planning for and reflection on one's own learning is called metacognition (Phelps, Graham, & Kerr, 2004; Robson, 2006). Learning with metacognition is considered an effective strategy for developing teachers' knowledge (Phelps et al., 2004). This study was intended to investigate the impact of metacognition in developing science teachers' TPACK.

1.4 Learning with metacognition

The notion of metacognition, which was originally associated with the work of Flavell (1976), refers to learning about one's learning, or thinking about one's thinking (Flavell, Miller & Miller, 1993). Metacognition is commonly known as "knowledge concerning one's own cognitive processes, and the active monitoring and consequent regulation of these processes in the pursuit of goals or objectives" (Phelps et al., 2004, p. 51). It involves two components: metacognitive knowledge and metacognitive skills. Metacognitive knowledge refers to knowledge about the processes of one's own thinking and learning, including the processes of one's thinking about science and the process of science (Flavell, Miller & Miller, 1993; White & Mitchell, 1994). Metacognitive skills refer to abilities in utilizing metacognitive knowledge at different stages of learning, to adjust and readjust the course of learning in order to achieve the desired learning objectives (Phleps et al., 2004).

Given the fact that the use of computer technology in science education is growing exponentially, metacognition can help teachers to learn how to integrate technology more effectively (Phelps, Ellis, & Hase, 2001). Science teachers are continuously asked to incorporate new technologies (e.g., learning management systems, software programs, multimedia devices, etc.) in their instruction. Often, teachers have never used these technologies before, and hence they may lack the knowledge and skills necessary for effective integration. When developing metacognitive knowledge, teachers would not only be able to identify the areas in which their existing technological knowledge and skills fall short, but also to determine the learning course that should be taken to bridge these gaps in a more independent and flexible way. Aligning with this goal, TPACK can provide a framework to guide science teachers in recognizing the type of knowledge they require for technology integration. Consequently, teachers can continuously monitor, adjust, and readjust their learning processes in order to achieve a better understanding of technology integration as described in the TPACK framework. For example, when teachers are introduced to new technologies, they must not take these technologies for granted. They should raise questions (e.g., "How do I justify the use of this technology?"; "Why, and what for?") to examine the main features, strengths, and weaknesses of these technologies. When they reflect on what they have learned, they may come up with more comprehensive questions that could lead them to better understand how technology can address pedagogical goals or resolve content difficulties, and thus they can establish selection criteria for the appropriate integration of technology.

Teaching of science can be especially difficult for teachers who lack experience and understanding of authentic inquiry (Lynn & Eylon, 2006). This is because incorporating the inquiry process and teaching about the development of scientific knowledge are complex endeavors that require significant knowledge and experience (Hammer, 1999). As a result, science teachers tend to perpetuate the epistemic belief that scientific inquiry is generated in a single, fixed manner (i.e., questions, hypothesis, investigation, results, and conclusion). Consequently, students tend to believe that science is the absolute truth about nature rather than a dynamic entity that will continue to evolve over time (Ormrod, 2011). Although learning science through inquiry can promote students' awareness of how scientists do science, adopting a fixed idea of inquiry could send a misleading message that the scientific process is a "cookbook." Some studies suggest that when students think that the process of doing science is nothing but procedures and formulas in search of a single answer, they will continue to struggle to navigate the scientific process effectively (Kawalkar & Vijapurkar, 2015; Scherr & Hammer, 2007).

It is important that teachers become aware of their own thinking in order for them to understand the complex nature of the inquiry process. Teachers should not relax with the idea that scientific concepts do not evolve. Rather, inquiry learning is a multidirectional process that helps to understand and refine those concepts over time. Teachers must be able to help students decide which inquiry strategies to use during their scientific explorations. To increase the effectiveness of inquiry teaching, teachers should be aware of their own thinking processes, and be able to mirror the behaviors of professional scientists so they can translate these behaviors into effective instructional practices in classrooms. Such instructional practices should be designed to duplicate actual scientific investigation for the purpose of science learning. Learning with metacognition allows science teachers to develop this awareness, and an understanding of when to appropriately apply a particular inquiry strategy, and why (Schraw, Crippen, & Hartley, 2006). In addition to this awareness, there is an element of control (Flavell, 1976), which involves evaluating what one currently knows and determining what one needs to learn. For science teachers, this entails assessing the inquiry tasks at hand, evaluating whether students have the knowledge and skills necessary to accomplish these tasks, proposing various learning strategies, and reflecting on these proposed strategies, adjusting them as necessary (Ambrose, Bridges, DiPietero, Lovett, & Norman, 2010).

It can be concluded that the benefits of metacognition for science teachers are twofold. First, metacognition provides teachers with the opportunity to develop knowledge about their own learning and thinking with respect to the uses of computer technology in the science learning process. Second, metacognition provides teachers with strategies and skills with which they can monitor, adjust, and change their own learning paths in order to develop technological knowledge that brings science proficiency to the fore.

1.5 Purpose of the study

This study aims to understand the processing by which science teachers can be prepared to consider the pedagogical and content uses of technology in order to inform their designing of technology-based activities for science learning. The study will examine whether or not there is a difference in the effectiveness of Experiencing Inquiry Model (EIM) strategy, which guides teachers through the structured cognitive processing necessary to construct their own instructional practices pertaining to technology integration in classrooms, is more effective than the Metacognitive Scaffolding (MS) strategy. MS, in contrast, challenges teachers to exercise metacognitive strategies throughout instruction in order to be better equipped to construct technology-related instructional practices more independently. More specifically, the study will compare the impact of both strategies in advancing teachers' understanding of TPACK to inform their design of technology-based inquiry activities. The study hypothesizes that the MS strategy explicitly supports teachers' attempts to develop TPACK so that they can anticipate and plan for what will likely happen when technology is used in classroom instruction. Both strategies (EIM and MS) include processes aimed at identifying the technological features that will be pedagogically useful in teaching the subject matter, recognizing the areas in the curriculum that students might find difficult to understand, and exploring the effectiveness of computer technology in simplifying scientific concepts. However, MS explicitly guides teachers to constantly monitor their learning progress and adjust their learning course whenever necessary.

The research problem is addressed by comparing how well the EIM and MS strategies prepare in-service elementary/secondary science teachers by informing their planning choice of technology-mediated inquiry-based activities for their own students. The next section presents a historical review of the role of computer technology in science instruction, and discusses the effectiveness of different strategies in educational technology training, especially EIM and MS.

CHAPTER 2. LITERATURE REVIEW

This section reviews science education and educational technology literature in order to identify general trends, features, and characteristics of the teaching methods that are implemented in educational technology training. It also articulates how the role of computer technology in classroom instruction has been evolving, and how educational technology training is changing to support this role. Further, this section briefly reviews the development of the current notion of TPACK, and discusses the teaching methods used to develop teachers' TPACK.

2.1 The role of computer technology in science instruction: a historical review

The role of computer technology in science instruction has been changing since the 1970s, when educational computer technology was first introduced. This role has gone through different phases, depending on the type of technology present and on the methods used for training. Generally, the role of computer technology in classrooms is classified into two broad areas:

- Using microcomputers as a delivery system (from the mid-70s to the 80s); and
- Using Information and Communication Technology (ICT) as a cognitive tool (in the 90s and the new millennium)

The microcomputer as a delivery system

A microcomputer is a machine used for rapidly solving simple or complex calculations (Terry, Page, & Thomas, 1977). Microcomputers were introduced in science education in the late 1970s, and were utilized in classrooms as delivery systems. Yamashita and Anderson (1983) define a delivery system as a vehicle used to present science content, such as a text book. Delivery systems (such as drill-and-practice programs, tutorials, and instructional games) reflected the behavioral and cognitive learning theories that were popular at the time. They focused on direct instruction that grew out of these theories, delivering information to help students acquire and retain information and skills. Delivery systems also allowed teachers to explore strategies that usually required more time to execute.

Drill-and-practice programs, for example, are software applications used to engage students in extended practicing of their basic skills. These programs provide opportunities for students to work on problems or examples and then receive feedback on their performance. Tutorials play the role of a human tutor, providing all the information and instructional activities a learner needs to master a topic through information summaries, explanation, practice routines, feedback, or assessment. Instructional games, another type of delivery system, are computer programs that incorporate drills into games in order to make the drills more enjoyable. Although these programs have different characteristics and serve different instructional purposes, they are all based on behavioral learning theory. They were therefore used to reinforce previously learned information and develop students' problem solving skills, as with review questions in science textbooks (Ellis & Kuerbis, 1991; Joiner, Silverstein, & Ross, 1980; Milner, 1980). Later instructional software programs were designed to support the more constructivist aims of helping students explore topics and generate their own knowledge, as described in the next subsection (page 18).

Although the use of microcomputers in classrooms did not change overall teaching styles during the 1970s, teachers were required to develop new technical and operational skills. Primary attention was given to preparing science teachers to acquire the necessary operational skills and computational knowledge. To achieve this goal, many teacher professional development programs used strategies aimed at introducing the parts of the microcomputer, recognizing the logic of computing programs, and practicing how to execute computer programs

(Borchers, Shroyer, & Enochs, 1992; Ellis & Kuerbis, 1991; Sadowski, 1983). These strategies were implemented mainly through lectures, demonstrations and, to a lesser extent, hands-on activities (Ellis & Kuebis, 1991). In reality, however, the implementation of these training programs was not as simple as it might seem.

There were obstacles inhibiting the effectiveness of such kind of training, hence impeding teachers' ability to use microcomputer applications in classrooms instruction (Handler, 1993; Scrogan, 1992; Fulton, 1989). Some of these problems were related to the goals of the training courses, and others to the effectiveness of the training approaches. As for the goals, research studies have reported that educational technology courses often focus on presenting too many facts about computer processing and functions, without engaging teachers in activities that explain the benefits of microcomputer applications for teaching and learning (Ellis, 1984; Gelder & Maggs, 1983). Strategies used in professional development programs are often influenced by direct instruction methods. Lectures, demonstrations, and orientations are commonly used to present content related to the functions of microcomputers parts, as well as the computing processes involved. Although direct instruction is an effective teaching approach during the acquisition phase, professional development programs should be more focused on developing teachers' understanding of the benefits of technology for classroom instruction. Therefore, science teachers have been left to use technology in classrooms without adequate knowledge and understanding of how newer technologies could be integrated into their teaching (Bruder, 1989; Hurd, 1988; Misfeldt & Stahl, 1991).

In brief, during the 1970s and 1980s the use of microcomputer applications in classrooms reflected the behavioral learning theory that was popular at the time. Their primary role, enhancing teachers' direct instruction, grew out of the behaviorist paradigm. As a result, teacher professional development programs relating to technology integration have focused solely on the technical and operational aspects of technology and, hence, have failed to address the uses of technology in teaching and learning. However, training programs are not entirely to blame for this problem, since the types of technologies available during the 1970s and 1980s were not designed to consider pedagogical needs in science classrooms. This was no longer justified during the 1990s. More user-friendly computer programs emerged, introducing new roles for technology integration in science education, as described below.

ICT as a cognitive tool

In the late 1990s, new types of technology emerged that would become part of every aspect of modern life. These are known as Information and Communication Technology (ICT) or Technologies (ICTs). The term ICT stresses the role of unified communications and the integration of telecommunications (telephone lines and wireless signals), software programs, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information. This includes, but is not limited to: Windows®, Microsoft Office®, Apple Mac®, the Internet, and Multimedia systems. The expanding use of ICTs has provided incentive for software developers to produce applications that are specifically designed for educational purposes. Many of these applications go beyond simple representation of subject matter, offering new ways to enhance students’ learning. In terms of science education, research studies indicate that teachers should be encouraged to take up this opportunity and utilize ICTs as cognitive tools (Hofstien, 2004; Jonassen & Daneil, 2004). Jonassen (1996) refers to cognitive tools as those used to encourage students to be cognitively active. When students are cognitively active, they are able to organize prior knowledge, link new concepts to old, and use empirical evidence to come up with acceptable conclusions. Therefore, ICTs can be used to help students design investigations, conduct inquiries, and test hypotheses or models.

ICTs in science education can be classified into three types: interactive software programs, hypermedia applications, and microcomputer-based laboratories. First, interactive software programs, or computer simulations, are a type of technology that models natural phenomena via visualization. Visualization of phenomena helps students to understand physical events that are difficult to perform in a conventional laboratory setting (Hasenekoglu & Timuc, 2007). It also helps students to manipulate natural phenomena in order to test hypotheses (Khan, 2008, 2011), and promotes the integration of knowledge by connecting familiar objects with scientific concepts (Fernandez & Palacios, 2003). Second, hypermedia or World Wide Web refers to media that allows users to get direct access to audio, video, or text documents (Penn, Nedeff, & Gozdzik, 2000). Research studies have investigated the impact of various types of hypermedia in supporting different aspects of teaching and learning, such as:

- online homework (Penn, Nedeff, & Gozdzik, 2000)
- online formative assessment (Wang, 2008)
- online resources for inquiry (Hoffman, Wu, Krajcik, & Soloway, 2003)
- virtual reality (Sun, Lin, & Yu, 2008)
- online systems for project-based learning (ChanLin, 2008)

Finally, a microcomputer-based laboratory (MBL) is an example of a technological tool that integrates the benefits of conventional laboratory apparatuses with a wide range of computer technologies. A body of research describes MBLs as an approach that can improve students' graphing skills (e.g., Svec, 1995), analyze students' proficiency in dealing with discipline-specific content (e.g., Espinoza & Quarless, 2010), develop students' critical thinking skills (e.g., Espinoza & Quarless, 2010), encourage student control and interest in the laboratory (e.g, Thornton, 1989), and allow rapid transformation of data from a numerical format into a much more meaningful graphical form (e.g., Gagne & Glaser, 1987). What is significant about MBLs is not just their integration of physical environments with computer technology, but also the wide range of computer technologies that can be used within the MBL setup. For example, an MBL setup may include direct observation of a natural phenomenon in the science lab, multimedia devices (such as sensors) to collect data, data processing software to generate graphs, and interactive simulations to test outcomes. Although MBLs increase the level of control by students, some researchers (Beichner, 1990; Stuessy & Rowland, 1989) have examined the effects of microcomputer-based laboratory on students' interpretations of the graphs. These studies suggest that the maximum quality of student experience can be achieved through careful use of technology during instructional activities, and improved pedagogical materials. The aforementioned literature has examined various aspects of ICT implementation in educational settings that reflect the constructivist approach to learning. The findings indicate that ICTs are promising tools for enhancing students' conceptual understanding of science, supporting students' ability to generate their own knowledge, and encouraging students' control over their own learning. Although the findings indicate that these new technologies hold great promise to enhance students' learning and understanding of science, they also criticize teachers who use ICTs for teaching functions that do not coincide with the constructivist approach. Therefore teacher professional development programs are required to focus on developing teachers' abilities to: integrate computer technology for specific pedagogical uses (Espinoza & Quarless, 2010; Wang, 2008), utilize computer technology to resolve difficulties that are associated with specific subject matter (ChanLin, 2008), and facilitate students' learning with technology

(Abdullah & Merza, 2006). The next section discusses methods used for ICT training in professional development programs.

Methods of training

Increased access to ICTs has encouraged many professional development programs to move from direct instruction training approaches to training that activates teachers' critical thinking, decision-making, and self-reflection (Phelps et al. 2001). The primary reason for this shift is the growing perception among educators of the potential uses of ICTs for enhancing student-centered environments. A number of studies have explored the effectiveness of strategies that enhance teachers' critical thinking and decision-making skills related to the integration of ICTs into science classrooms (e.g., Arnold, Padilla, & Tunhikorn, 2009; Lee, 2011; Steketee, 2007). These studies suggest that such strategies need to be further developed in order to help science teachers to better understand the pedagogical uses of technology. Various strategies that adopt cognitive learning processes, such as learning-by-design (Koehler & Mishra, 2005), have been used to enhance teachers' computer knowledge and skills (Arnold et al., 2009). Although these strategies provide opportunities for teachers to learn how to use ICTs in classrooms (Sellen, 2002), new teachers are unable to utilize their newly acquired knowledge and skills effectively in their everyday teaching practices. Researchers have therefore suggested that simply implementing cognitive processes is not sufficient; metacognitive learning should be added in order to enhance teachers' ability to monitor and adjust their learning progress (e.g., Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005; Phelps et al., 2001; Vallance, 2007). Phelps and Graham (2008) further argue that metacognitive learning about ICT not only supports knowledge acquisition, but also offers strategies to help teachers identify their knowledge gaps and take the measures necessary to bridge these gaps. Different metacognitive strategies have been used within professional development programs to develop teachers’ knowledge relating to ICT use. For example, Prestridge (2014) has explored the role of reflective writing in shifting teachers’ pedagogical beliefs and practices towards the increased use of ICTs in classrooms. The findings of this research suggest that teachers’ reflective writing helped them to think critically about the means of actively transforming their practice in order to respond to changes brought about by the introduction of new ICTs. Liu (2013) has used teacher self-reflection to develop innovative teaching within teacher professional development programs for technology integration. The study concluded that teacher self-reflection was effective in sharing instructional information and providing practical pedagogical strategies using ICT. Finally, Gibson and Peacock (2006) used a think aloud strategy to investigate the views of faculty members about the effectiveness of a Web-based tool that aimed to support effective uses of learning technologies. Think aloud interviews helped the researcher to reveal rich information about the effectiveness of the technological tool. Much of this information was gathered during thoughtful moments when participants were able to recall and reflect on their own experiences.

Despite efforts to enhance teachers’ learning about ICT, more recent studies have criticized professional development programs for not being inclusive in connecting ICT learning with subject matter, classroom pedagogy, and classroom contexts. For example, most of these programs introduce educational technology in isolation from science content and methods courses. Instead, they focus on training that enhances teachers’ computer knowledge of specific technological tools, without developing a global understanding of technology integration within a wider context (Lubin & Ge, 2012; Markauskaite, 2007). As a result, many teachers fail to understand the dynamic interplay between technology, pedagogy, science content, and classroom context (Phelps & Ellis, 2002; Lubin & Ge, 2012; So & Kim, 2009).

Such obstacles not only impede technology integration in science education, but also prevent teachers from taking full advantage of the booming culture of technology among students**.** Today, students are more familiar with new technologies, and they are well-equipped to utilize new ICTs in every aspect of their lives, including learning. Therefore, professional development programs must train teachers in a way that takes advantage of students' experience with new technology, and promotes the current and future pedagogical value of ICTs. To do so, a body of research suggests that the integration of technology in classrooms can be better learned within a well-grounded framework such as TPACK.

2.2 Technological Pedagogical Content Knowledge (TPACK)

The utilization of technology in classrooms has grown exponentially. Successful integration of ICT in classrooms therefore requires teachers to develop a unique domain of knowledge that clarifies the relationship between technology, pedagogy, and content matter (Niess, 2005; Schwarz, Meyer, & Sharma, 2007; So & Kim, 2009). Mishra and Koehler (2006) have proposed TPACK as a conceptual framework to clarify the critical parameters related to technology integration in classrooms. This framework is built upon Shulman's work describing Pedagogical Content Knowledge (PCK) (Shulman, 1986). TPACK does not consider the above three key elements – content, pedagogy, and technology – in isolation, but rather as part of a complex system of relationships. The term TPACK is new, but its key concepts have existed in the literature for a while. As a precursor to TPACK, the triad of content, pedagogy, and technology has been briefly articulated within the context of educational software design under different labeling schemes, such as ICT-related to PCK (e.g., Angeli & Valanides, 2009), Technological Content Knowledge (Slough & Connell, 2006), and electronic PCK or e-PCK (e.g., Franklin, 2004; Irving, 2006). Other researchers have demonstrated a sensitivity to the relationships between content, pedagogy, and technology including Hughes (2005), McCrory (2008), Margerum-Leys and Marx (2002), Niess (2005), and Slough and Connell (2006).

Since its proposal in 2006, TPACK has been seen as a promising framework for conceptualizing the integration of computer technology in science education (Khan, 2011; McCorory, 2008; Susan, Curtis, & Karen, 2010). A number of issues concerning the approaches appropriate for developing science teachers' TPACK have dominated the initial and continuing discussions in educational technology training programs.

2.3 Developing science teachers' TPACK

To begin, McCrory (2008) suggests ways to expand teachers' TPACK. Fundamentally, these suggestions require science teachers to recognize the interplay of three factors: *where* in a science curriculum to use technology, *what* technology to use, and *how* to teach science using technology. To capture some key aspects of these questions, McCrory points out that technology should be used in areas of science curriculum where there are pedagogical difficulties to resolve, to represent topics or concepts that are difficult to teach, and in areas where technology is itself an integral part of the scientific concept being taught.

In line with the TPACK vision and within the context of science education, various training approaches have been implemented to enhance science teachers' TPACK (e.g., Lee, 2011; Ozturk, 2012; Ozmantar, Akkoc, Demir, & Ergene, 2010). Most of these approaches adopt designs that foster teachers' critical thinking and decision-making skills relating to technology integration, such as microteaching design (e.g., Cavin, 2007) and learning by design (e.g., Lee, 2011; Mishra & Koehler, 2006). Microteaching design is a process used to engage teachers in decision-making situations while developing technology-mediated lesson plans. In this process, teachers work collaboratively through repetitive cycles involving three stages: teaching a lesson, evaluating the effectiveness of the lesson in addressing a specific goal, and modifying the lesson as needed. This design is used as a process to test the effectiveness of a specific technological tool in enhancing a specific educational context. In contrast, learning by design engages teachers in designing learning tasks to solve challenging instructional issues that reflect real-life situations. When teachers learn to solve relevant problems as designers, they tend to find solutions through active engagement with familiar tools and ideas. This process of engagement provides a context for teachers to take into account the potential uses of technology in classroom instruction. Both design processes provide teachers with experience with real educational problems which can be addressed with technology. The findings of the aforementioned studies suggest that engaging teachers in authentic problem solving using technology can help them to develop the knowledge and skills embodied in TPACK. However, it is unclear to what extent teachers are able to apply their understanding of TPACK to inform their instructional practices.

2.4 Summary of the review

This historical review has been conducted in order to understand the pattern of training methods in educational technology courses, and the influence of this pattern on teachers' understanding of the integration of computer technology in science education. Since the 1970s, there has been rapid acceleration in the use of computer technology in science education and, consequently, a rapid development of various methods for educational technology training. Two factors influence how computer technologies are utilized: computer training approaches, and the types of computer technology used. The more sophisticated the technology innovations, the more complex their integration in classrooms has become. Despite this, science teachers are given few opportunities to understand the role of new technologies in the science classroom. Thus the impact of computer technology in enhancing science instruction lags behind what has been predicted.

Previous research outcomes have connected the ineffective integration of ICTs in classroom instruction to poor educational technology training. The literature reveals that training approaches do not focus on advancing teachers' understanding of the complex relationship between technology, pedagogy, and science content. Instead, the training has focused on the operational and technical aspects of specific technological tools**.** However, recent research has emerged that proposes TPACK as a framework to help understand the pedagogical uses of technology. Most of this research argues that teachers should be engaged in cognitive learning processes in order to better understand the uses of technology in classroom instruction (Cavin, 2007; Koehler et al., 2007; Lee, 2011; So & Kim, 2009). Unfortunately, within the context of educational technology training there has been little research (Gibson & Peacock, 2006; Liu, 2013; Prestridge, 2014) proposing think aloud and reflective writing as metacognitive strategies to engage teachers in tasks that can enhance their ability to integrate technology more independently and flexibly. As well, there have been no research studies proposing metacognition strategies to develop teachers' TPACK. This research attempts to fill this gap using specific metacognitive strategies (think aloud and reflective writing), which can be embedded in teachers' cognitive learning to help them develop technological pedagogical content knowledge (TPACK). These strategies will also be used to encourage science teachers to negotiate their understanding of TPACK in order to inform their design of technology-mediated activities for science learning. The next section situates teachers' cognitive and metacognitive learning within a sound theoretical framework.

CHAPTER 3. THEORETICAL FRAMEWORK

This section aims at situating the EIM and MS strategies within a sound theoretical framework in order to communicate the purpose, objectives, and anticipated results of this study. To do that, Situated Cognition Theory (Brown, Collins, & Duguid, 1989) will be used as a theoretical framework for the learning context, and the TPACK framework will be used to conceptualize technology integration (Jimoyiannis, 2010; McCrory, 2008; Niess, 2005). Two teaching strategies will be adopted: Experiencing Inquiry Model (EIM) (Windschitl, Thompson, & Braaten, 2008a) and Metacognitive Scaffolding (MS) (Kolencik & Hillwig, 2011; Phelps et al., 2001). Situated Cognition Theory, TPACK, and the two teaching strategies will be briefly discussed in the following sections.

3.1 Situated Cognition Theory

Situated Cognition Theory gained recognition within the field of educational psychology in the late twentieth century (Brown, Collins, & Duguid, 1989; Lave & Winger, 1991; Schell & Black, 1997). It posits learning as a process of constructing knowledge within a given educational context (Brown, Collins, & Duguid, 1989). It refers to the construction of knowledge as a process of interaction between individuals and groups in a learning environment (Barab & Roth, 2006). According to this theory, knowing is not seen as a matter of recognizing any self-contained or abstract concepts only, but also knowing emerges from the interaction between a learner and an environment (Barab & Roth, 2006). The learning environment is explained as a context in which knowledge can be constructed individually or socially while learners are explicitly guided through activities bound to this context. From this perspective, learning is a matter of an individual's increasingly effective performance across situations, or authentic contexts, rather than an accumulation of abstract knowledge, since what is known is codetermined by the individual and the context (Brown, Collins, & Duguid, 1989). Based on this theory, learning processes should reflect the way that knowledge and skills will be used in real life (Collins, 1998), so learners can be immersed in an environment that approximates as closely as possible the context in which their new ideas and behaviors will be applied (Schell & Black, 1997).

More recently, Situated Cognition Theory has gained recognition as a theoretical basis for developing teacher's knowledge and skills (Bergqvist, 2000; Grossman, 2008). A body of research suggests that the impact of teacher education programs on teacher behavior and learning tends to be minimal (Broekkamp & Van Hout-Wolters, 2007; Burkhardt & Schoenfeld, 2003). The researchers refer to this problem in terms of a divide between theory and practice. They argue that student teachers are normally overwhelmed when learning theories and definitions, even when the definitions are supported with exemplary sentences. Subsequently, student teachers are not fully engaged in activities that replicate real situations, such as those found in everyday teaching practice. As a result, teacher education graduates often face severe problems in trying to survive in the classroom, and trying to implement what they learned during their professional preparations (Burkhardt & Schoenfeld, 2003). This implies that, when teachers learn abstract knowledge in isolation from real teaching practice, they may lack the ability to apply their newly constructed knowledge in real situations. Thus, several researchers point out the importance of Situated Cognition Theory as a theoretical basis for learning in teacher education and professional development programs (Grossman, 2008; Korthagen, 2010), for multiple reasons. First, when teachers interact with real situations or contexts, they tend to apply new knowledge to real-life teaching practice. In this case, knowledge is not learned as a self-contained construct, but developed through a continuous interaction with authentic learning and teaching situations. Second, when teachers are engaged in complex negotiations of knowledge and skills in particular meaningful situations (e.g., classroom instruction), they often exercise various levels of invention and problem-solving. Third, teachers can recognize how their knowledge is relevant to their professional lives. And finally, teachers are supported in structuring their knowledge in ways that are appropriate to be used later in real educational contexts.

In the context of science education, science teachers can be engaged in authentic situations, related to the teaching and learning of science, to resolve pedagogical challenges similar to those encountered in real classroom instruction. For example, science teachers may act like apprentices and think like professionals in the field to resolve learning challenges associated with inquiry (Brown, Collins, & Duguid, 1989). In the context of this study, science teachers will be introduced to a scenario that models inquiry-based learning, and exposed to conditions in which technology can be used to enhance the teaching and learning of science through inquiry. This situated cognition is expected to help science teachers to recognize the pedagogical and science content uses of technology as articulated by TPACK and as implemented within the general framework of the inquiry model. To do this, science teachers need to acquire a number of skills pertaining to TPACK, as described below.

3.2 TPACK competencies

This section highlights some of the target competencies that characterize teachers with a good understanding of the pedagogical and content uses of technology. A teacher with good TPACK knowledge understands how to:

1. guide students in carrying out inquiry-based activities with computer technologies that make it easier for them to handle the process of investigation. Teachers with this ability would have acquired an adequate level of technological pedagogical knowledge (TPK).
2. evaluate educational software programs based on the content covered (TCK) and how well they comply with curriculum standards (TPK).
3. search for and access learning resources or curriculum materials in digital media such as the Internet (TK), evaluate websites based on content or pedagogical uses (PCK and TCK), and create digital content for future use (TK).
4. make complex decisions in planning the appropriate type of technology required for specific learning activities and specific content areas (TPACK), such as using computer-mediated tools (social media) to allow students to discuss the impact of climate change on the environment, or using an audio-video device interfaced with a software program to conduct an inquiry into the factors affecting the motion of an object on an inclined plane.
5. critique the role of technology in facilitating or supporting a specific learning approach in order to achieve a specific content objective (TPACK).

(Chien, 2012; Jimoyiannis, 2010; Niess, 2005).

From TPACK and Situated Cognition Theory perspectives, the study will comprise two strategies to guide science teachers to develop a deeper understanding of technology integration in science instruction: the EIM and MS strategies.

3.3 Experiencing Inquiry Model (EIM)

Windschitl et al. (2008) define EIM as a strategy to explicitly guide teachers to experience inquiry as an authentic model for the teaching and learning of science. Teachers are given opportunities to conduct an inquiry using technology for testing, revising, and generating ideas or models. Based on research evidence, EIM instruction uses situated cognition to explicitly guide teachers to develop relevant inquiry skills (e.g., postulating hypotheses, collecting and analyzing data, controlling and manipulating variables, organizing data, etc.) for conducting scientific investigations systematically using technology (De Jong & van Joolingen, 1998; Windschitl et al. 2008). EIM is proposed as a way to support teachers' cognitive processing while learning how to integrate technology into inquiry-based learning. For the purpose of this study, EIM consists of three parts. First, science teachers are expected to learn the key concepts involved (TPACK, inquiry model, electric circuits, and computer simulation). Second, science teachers are asked to conduct an inquiry into the properties of series and parallel circuits through situated cognition. The investigation is designed to duplicate a learning environment similar to that of real science classrooms. During this part, science teachers will utilize computer simulation to accomplish inquiry tasks that aim at investigating the properties of series and parallel circuits. Third, science teachers will focus their attention on analyzing different aspects of their precedent learning experiences, including: critiquing the role of technology in enhancing the inquiry tasks, analyzing the challenges encountered while conducting the inquiry investigation, and analyzing how technology could help (or not) in eliminating these challenges. These cognitive processes aim at clarifying the relationships between technology, pedagogy, and content matter (i.e., TPACK). Moreover, according to situated cognition theory, science teachers will be given opportunities to discuss and critically analyze how technology-based inquiry activities can be designed within the general framework of TPACK.

3.4 Metacognitive Scaffolding (MS)

MS is a metacognitive strategy that helps teachers become more independent learners. It provides teachers with explicit scaffolding techniques (organizing tasks in tables, presenting good examples, and posing questions) in order to facilitate their cognitive learning processes and improves their performance of new tasks on classroom instruction. It provides metacognitive strategies (i.e., setting goals, planning, and reflecting) so that teachers can take charge of their own learning, and brings awareness of how they learn through an evaluation of their learning needs (Hacker, 2009). Using MS, teachers can generate learning strategies to accomplish their cognitive tasks more independently, and then implement these strategies in their instructional practice. The scaffolding techniques and metacognitive strategies presented in MS aim to foster teachers' metacognitive skills and knowledge throughout their cognitive learning process (Phelps et al. 2001; Phelps et al. 2004; Phelps & Graham, 2008). In this study, and based in situated cognition theory, MS builds on the same cognitive activities presented in EIM. Besides, MS includes a number of the metacognitive strategies embedded within the EIM activities. These metacognitive strategies aim to assist teachers in monitoring and adjusting their understanding of the inquiry process (Phelps et al., 2001). With the MS strategy, science teachers will be guided to think about and reflect on their abilities, performances, and actions used to accomplish the various stages of the inquiry investigation.

To clarify, two aspects of metacognition will be emphasized: reflection-in-action and reflection-on-action (Schon, 1983). Both concepts were first explored by Schon (1983, 1987), and later extended by Ertmer and Newby (1996). Reflection-in-action is a process of managing, adjusting, and readjusting one's cognitive learning path as new knowledge or information is assimilated (Phelps et al., 2001). Consequently, science teachers will be assisted in monitoring their learning of inquiry processes in order to better understand how to implement these processes in real classrooms. Reflection-on-action, on the other hand, is an active process of making sense of past experience for the purpose of orienting oneself for future actions (Phelps et al., 2001). Science teachers will thereby be given the chance to think about their precedent experiences with inquiry tasks, and develop an awareness of how to design similar tasks for their students. Both reflection-in-action and reflection-on-action are key elements of metacognition because they underpin how teachers are able to apply their metacognitive knowledge in real learning situations (Barak, 2009). When teachers are guided to exercise self-reflection before, during, and after their learning, they will be able to recognize where their existing knowledge falls short and how to adjust their learning path to achieve the desired objectives (Barak, 2009). Nevertheless, learners need consistent scaffolding to reach acceptable fluency in metacognition, not only in understanding their own learning processes or the nature of the strategies that might be used to accomplish their tasks, but also in utilizing these strategies (reflection-in-action and reflection-on-action) to reinforce their cognitive learning (Barak, 2009; Kolencik & Hillwig, 2011). Within the context of this study, science teachers will use journal writing to learn about their own learning of TPACK through: responding to self-generated questions; recording their experiences or performances; questioning their actions or understanding; and connecting ideas to support their new understanding of the inquiry process. Journal writing will be used as a vehicle to assist science teachers in examining their thinking about the usefulness of learning science through inquiry and the role of technology in their particular context, and in recognizing how technology-based inquiry activities can be designed within the general framework of TPACK.

In brief, the theoretical framework is based on Situated Cognition Theory and the TPACK framework. The two strategies are adopted to assist science teachers to approach learning in two different ways: interacting with situated events as in EIM, and interacting with situated events and metacognition. The learning objectives aim to develop science teachers' TPACK, and in incorporate this knowledge in designing technology-based inquiry activities. The research questions and objectives are formulated accordingly, as shown below.

3.5 Research objectives and research questions

Research objectives

Primarily, the study would compare the implementation processes of two teaching strategies, and determine which strategy is more effective in developing science teachers' TPACK. The study will also examine science teachers' ability to incorporate their understanding of TPACK in planning for technology-based inquiry activities.

Research questions

1) What changes occur in science teachers' knowledge structure pertaining to the integration of computer technology (i.e., TPACK) as they learn through EIM and MS?
2) What aspects of both strategies (EIM and MS) are associated with these changes?
3) What aspects of the teaching strategies, or the participants' knowledge, afford opportunities to incorporate TPACK in designing technology-based inquiry activities?

Chapter 4. Teaching Strategies

The methodological design of this study was that two teaching strategies would be adopted to assist science teachers in developing TPACK. These strategies are: EIM and MS. Within the general framework of situated cognition, the proposed strategies are designed to help science teachers negotiate their newly constructed knowledge in real teaching practice. More specifically, the strategies aim to help teachers to develop an understanding of TPACK in order to inform their design of technology-based inquiry activities. This section describes the guidelines of the two strategies. A description of the overall teaching and learning expectations will be given first. Then, further description will be given of the contexts of the training, including descriptions of: science content, type of technology used, and pedagogical framework for inquiry approach.

4.1 Teaching and learning objectives

The overall learning objective was to provide opportunities for science teachers to develop the knowledge and skills that were necessary to teach science with technology at the elementary/secondary level. During the learning process, science teachers were expected to deepen their understanding of specific science content, teaching through inquiry, and the specific technology used to accomplish the inquiry tasks. Furthermore, science teachers were expected to recognize the dynamic interrelationships between science, pedagogy, and technology as pertaining to the TPACK framework. Understanding these relationships would help teachers to think strategically while engaged in planning, reflecting, and critiquing specific learning situations. By the end of this study, teachers were expected to:

- experience the teaching and learning of specific science content via a guided-inquiry approach;

- identify pedagogical necessities as a rationale for implementing computer technology in the classroom;
- critically evaluate the effectiveness of teaching science in a technology-rich guided inquiry environment;
- recognize the relationships between technology, pedagogy, and science content as related to the TPACK framework; and
- think critically and creatively in decision-making situations to inform the planning of technology-based learning activities for their students.

The teaching objectives were primarily designed to foster the learning objectives of the EIM and MS strategies. Thus to support these objectives, and in the role of instructor, I needed to:

- create a situated cognitive environment in which teachers would engage in learning situations that simulate a real classroom setting;
- implement the 5E Learning Cycle as a situated model for an inquiry approach (more details are given in the Context of Learning section);
- provide learners with the time, space, and resources needed for learning;
- implement various types of scaffolding techniques to guide learners to accomplish their learning tasks successfully; and
- utilize a range of assessment tools to evaluate the learning progress of individual learners and the class as a whole.

The teaching and learning objectives of EIM and MS will be further described in the form of an action plan. However, prior to describing how the teaching and learning objectives were addressed, a brief description of the learning context will be given.

4.2 Context of learning

The study aimed at providing opportunities to develop teachers' TPACK while experiencing learning situations similar to ones that occur in elementary/secondary schools. During the learning process, teachers were asked to utilize a Physics Educational Technology (PhET) computer simulation to complete an investigation into the construction of simple electric circuits. This section describes three areas that teachers were expected to develop knowledge related to:

1. the construction of simple electric circuits (CK);
2. the 5E learning cycle, which is the general framework for inquiry learning (PK); and
3. the PhET Circuit Construction Kit simulation (http://phet.colorado.edu/index.php) (TK).

Science content knowledge: Construction of electric circuits

For the purpose of this study, teachers were expected to conduct an investigation leading to the understanding of the construction and characteristics of series and parallel circuits. They would learn this content similar to the way Grade 6 students normally learn it in their schools. However, one may ask: Why the construction of electric circuits in particular? Many reasons constitute the answer to this question.

Initially, electric circuits are part of the Understanding Matter and Energy: Electricity and Electrical Devices strand of the Science and Technology Curriculum – Grade 6 (Ministry of Education, 2007). In this strand, students are expected to "investigate the characteristics of static and current electricity, and construct simple circuits" (Ministry of Education, 2007, p. 118). Also, Grade 6 students are expected to design and build series and parallel circuits, and use scientific inquiry or experimentation skills to investigate the properties of electric currents in series and parallel circuits (Ministry of Education, 2007). Thus teachers in this study were expected to gain first-hand experience in teaching and learning one of the fundamental concepts of dynamic electricity (Ates, 2005). By doing so, teachers would recognize the knowledge and skills necessary to understand the basic concepts of electricity. Consequently, they would be ready to prepare their students to construct a foundation for advanced topics in general science, physics, and chemistry courses at the secondary level. Moreover, elementary students often have alternative conceptions or misconceptions about electric energy, the flow of charges in electric circuits, and how total resistance differs in series and parallel circuits (Clement & Steinberg, 2002; Periago & Bohigas, 2005). This would be an opportunity for teachers to learn how students' misconceptions could be addressed, and what kinds of teaching approaches could be used to address students' alternative conceptions.

In the process, teachers were expected not only to deepen their science content knowledge, but also to simulate students' roles in the classroom and understand the optimum conditions by which students could enhance their learning. One of the instructional models used to conceptualize the teaching and learning of science is the 5E learning cycle, which can also be used as a pedagogical framework to guide teachers through inquiry investigation.

Pedagogical knowledge: The 5E learning cycle

Besides developing science content knowledge, teachers were expected to develop pedagogical knowledge while experiencing the 5E learning cycle, an instructional model that manifests the general framework of inquiry-based learning. It is part of a larger series of models such as Learning Cycle, 3E, 4E, and 7E (Atkin & Karplus 1962; Bybee et al., 2006; Eisenkraft, 2003; Karplus 1977). Although these models differ slightly in the number of phases, the basic ideas are collectively inspired by the Piagetian focus of construction of knowledge (Piaget, 1970) and the Vygotskian notion of scaffolded learning (Vygotsky, 1978).

For the purpose of this study, the 5E learning cycle (Figure 2) was preferred as a general framework for developing teachers' pedagogical knowledge for a number of reasons. First, 5E consists of a distinctive sequence of events that starts with recalling the learner's prior knowledge (engage phase), leading up to applying new knowledge in different situations

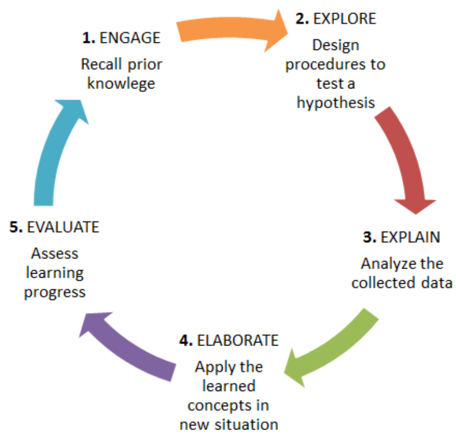


Figure 2. The 5E learning cycle

(elaborate phase). The purpose of the engage phase is to stimulate students' curiosity and get them involved in the investigation, while assessing their prior knowledge. During this phase, students first identify what they are expected to do, and then make connections between the current task and their prior knowledge and experiences. The explore phase aims to get students involved in the investigation, and provides them with the opportunity to build upon their initial understanding of the topic under investigation. In this phase, the students are guided through an inquiry process in which they postulate hypotheses, collect and organize data, and analyze data. In the explain phase, students are expected to negotiate what they have learned so far and try to come up with scientifically sound explanations for the results of their investigations. In the elaborate phase, students are given the opportunity to apply their new knowledge to real-life situations. They are expected to expand on the concepts they have learned and make connections with previously learned concepts. Finally, the evaluate phase allows students and teachers to determine whether the learning outcomes of the inquiry have been achieved. It involves ongoing diagnostic and assessment processes used throughout the 5E phases.

Such events provide learners with systemic guidance aimed at engaging their thinking in inquiry processes such as testing a hypothesis, collecting and analyzing data, and applying new knowledge in real-life situations. As well, the 5E learning cycle is commonly suggested by national standards (NRC, 2007). It has often been used in the teaching and learning of science, mainly because 5E is well grounded in a foundation of contemporary research on student learning (NRC, 2007). Finally, experiencing the 5E learning cycle provides teachers with opportunities to recognize students' skills that are needed for investigations, understand the challenges in the context of inquiry learning, understand the guidance needed to support students' learning, and more importantly, recognize the learning sequence that constitutes inquiry learning.

To sum up, teachers were expected to develop pedagogical knowledge while experiencing the 5E learning cycle. They would develop the knowledge and skills needed to facilitate inquiry learning, recognize the type of guidance needed to help students learn through inquiry, and be able to recognize what learning resources and logistics were needed within the context of inquiry learning. The latter included the utilization of information and communication technology such as PhET simulations.

Technological knowledge: Circuit construction kit simulation

The PhET Circuit Construction Kit (AC+DC) simulation (Adams et al., 2011) was selected so that teachers could develop their technological knowledge. The simulation was selected from among the ones that are available on the PhET website (http://phet.colorado.edu/index.php). They have been developed and tested by the PhET project, which has developed more than 60 free downloadable physics, chemistry, biology, earth science, and mathematics simulations that include many of the topics covered in elementary, middle, and secondary schools, as well as universities. The PhET Circuit Construction Kit simulation has the following features:

a) The simulation is interactive and allows the manipulation of different variables such as resistance, current, potentials, number of batteries, types of connecting wires, etc.

b) The simulation allows students to make observations as it runs. For example, students can observe the flow of charges in the connecting wires.

c) The layout of the simulation is simple and easy to manage.

d) The simulation contains tool kits that simulate a voltmeter and an ammeter, devices used to measure electric current and voltage, respectively.

For this study, the four abovementioned features were expected to enhance teachers' technological knowledge. For example, the simulation (Figure 3) would allow teachers to construct simple parallel and series circuits without being worried about technical issues, such as short circuit hazards or wiring problems. The teachers could test the effect of different variables (such as resistance) on the rate of flow of charges. Consequently, teachers could test the limitations of the simulation so they could be aware of possible failures, or the existence of unrealistic physical conditions.

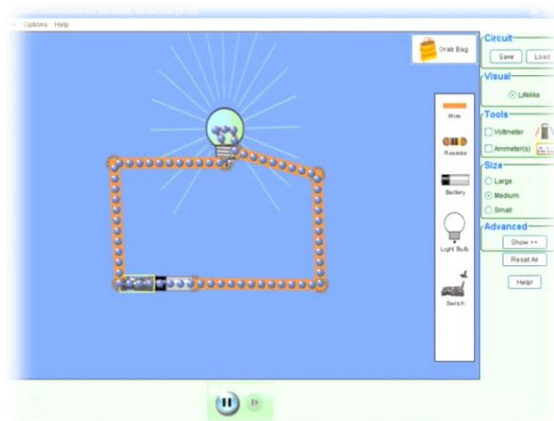


Figure 3. Main window of the PhET Circuit Construction Kit simulation (http://phet.colorado.edu/index.php)

In summary, teachers would be given opportunities to develop three types of knowledge related to: a) the construction of a simple electric circuit (CK), b) the principles of the 5E learning cycle (PK), and c) the PhET computer simulation (TK). Nevertheless, the main purpose of developing technological, pedagogical, and content knowledge is not only to learn these domains in isolation, but also to understand the dynamic interrelationships between them. Therefore, teachers would be given further opportunities to address questions like:

- What were the features of the PhET simulation that would support students' learning of series and parallel circuits?
- What made the 5E learning cycle appropriate (or not) to achieve the target objectives?
- How could PhET and the 5E learning cycle work together to support students' understanding of electric circuits?
- What were the possible failures of the PhET simulation that might happen during the inquiry investigation, and how could these failures be avoided in the future?

The two strategies (EIM and MS) would be used to address such issues as well as to assist teachers to inform the planning of technology-based inquiry activities. The next section describes the guidelines of these strategies.

4.3 Guidelines for the EIM and MS strategies

The EIM and MS strategies both aimed at engaging teachers in cognitive activities such as conducting inquiry investigation, interrelating technology pedagogy and science content, synthesizing TPACK components, and designing a learning sequence of instructions. While EIM would be confined to these cognitive activities, the MS strategy would adopt a metacognitive dimension, embedded within the EIM activities, so as to understand whether teachers' overall learning would progress differently. The following subsections describe the guidelines of both strategies.

Guidelines for the EIM strategy

The EIM strategy consisted of three main parts: a) learning the 5E cycle, the PhET simulation, and electric circuits, b) utilizing the PhET simulation to conduct an inquiry via 5E learning cycle, and c) analyzing the design of the inquiry process (Figure 4). The following guidelines describe what teachers were expected to do during these three parts.

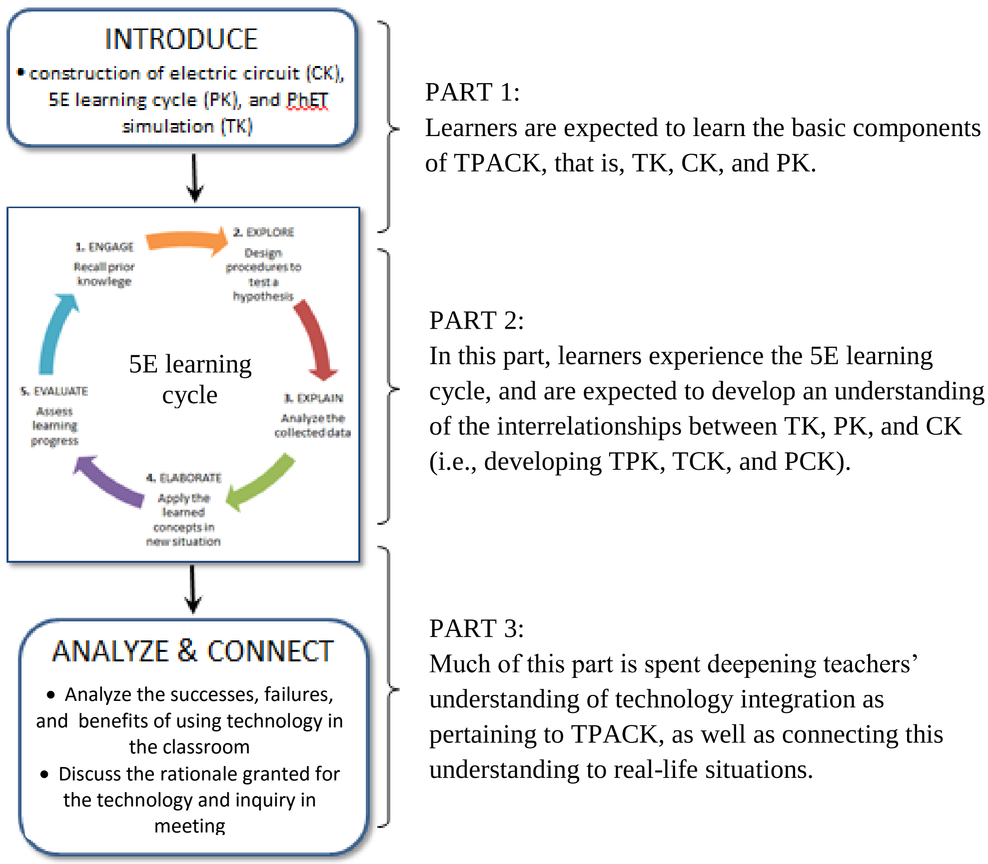


Figure 4. The EIM strategy and the rationale given for each of its components

To prepare teachers for the training, the instructor would first introduce the PhET Circuit Construction Kit simulation, the 5E learning cycle, and the basic concepts involved in electric circuits. Learners would be expected to recognize the language comprehension or formal discourse that would be used during the training. For example, learners would recognize the meanings of: computer simulation, inquiry learning, student-centered approach, electric charges, current, potential difference, etc. Then, learners would complete hands-on activities to practice how to use the PhET Circuit Construction Kit simulation, discuss how to implement the parts of the 5E learning cycle, and clarify the general concepts of electricity.

Next, teachers would be asked to conduct an inquiry into the characteristics of electric currents in series and parallel circuits using the PhET Circuit Construction Kit simulation and the 5E learning cycle. Learners would progress through the 5E phases: *engage, explore, explain, elaborate*, and *evaluate*. In the *engage* phase, learners were expected to recall their prior knowledge and discuss how the brightness of two bulbs differs if they were connected in series and parallel circuits. Then, in the *explore* phase, learners would be asked to make a hypothesis or hypotheses about the situation posed in the first phase. The instructor would guide learners in designing an investigation to test their hypotheses using the PhET Circuit Construction Kit simulation. Data would be gathered and organized in the *explore* phase. In the *explain* phase, learners would be expected to analyze their data and come up with scientifically acceptable explanations for their findings. Learners could use the computer simulation at any time if they needed to confirm/disconfirm their explanations. Learners would then *elaborate* and apply their newly constructed knowledge in new situations. Besides guidance, the instructor would monitor and *evaluate* learning progress throughout the investigation.

Next, after conducting the inquiry investigation, learners would be expected to critically analyze the learning activities to develop a deeper understanding of the effectiveness of technology integration. In this stage, learners would be guided to critique the design of the learning activities, but the intention would not be to encourage them to reflect on their own learning. Learners would: a) critique the ways in which the PhET Circuit Construction Kit was beneficial (or not) for the teaching and learning of the construction of an electric circuit, b) establish whether the 5E tasks provided an adequate inquiry model to challenge students' alternative conceptions, and c) if not, what their drawbacks were. Such questions would be posed to encourage learners to think critically and establish a rationale for using the PhET simulation in their classrooms, the 5E learning cycle, and the target concepts. Such direction was expected to lead learners to develop a better understanding of the pedagogical and content uses of technology in the classroom as pertaining to the TPACK framework.

In conclusion, the EIM strategy would allow teachers to experience the 5E learning cycle in an environment similar to real classrooms. Learners would be provided with opportunities to analyze their precedent experience in order to develop an understanding of the interrelationships between the use of technology, pedagogy, and science content. The MS strategy, however, was developed to scaffold teachers' engagement in metacognitive learning.

Guidelines for the MS strategy

Teachers would be prompted to consider their prior and current knowledge of the integration of computer technology in the classroom in order to articulate, pursue, and monitor personally relevant goals. In addition to the activities described in the EIM strategy, teachers following the MS strategy would be guided in planning for their learning course, and exercise reflective writing during and after the cognitive activities, as described below.

To prepare teachers for the training, the instructor would first introduce the PhET Circuit Construction Kit simulation, the 5E learning cycle, and the basic concepts involved in electric circuits. Learners would be expected to recognize the language comprehension or formal discourse that would be used during the training. Further, they would be expected to recall their prior knowledge of broader topics such as computer simulation, inquiry learning, and the concepts of electricity. The latter was expected to encourage learners to response to three questions: a) What would I like to learn today? b) Why do I want to learn it? and c) How would I learn it? In order to answer these questions, they would be asked to think aloud and plan for their learning. Their plan should include: a) personal or specific objectives they would like to achieve, b) relevant topics with which to deepen their understanding, c) a sequence of events or procedures to help them achieve their objectives, and d) learning resources. Finally, learners would be asked to execute their plan. To make learning more effective, the scaffolding strategy would be based on guiding learners through modeling tasks, coaching, and providing templates, compelling tasks, and resources. Therefore, learners would be expected to appropriately decode written texts, integrate new learning with prior knowledge, and monitor their learning process. Additional guidance might be needed to assist learners in achieving their learning goals. This guidance should: a) pose questions to clarify relevant concepts, procedures, or situations, b) facilitate the hands-on activities and help with journal entries, and c) assist learners in setting new relevant goals for the upcoming learning activity.

Similar to the EIM strategy, learners in MS (Figure 5) would be asked to conduct an inquiry into the construction and characteristics of series and parallel circuits using the PhET Circuit Construction Kit simulation. The 5E learning cycle would be used as a pedagogical framework. First, in the *engage* phase, learners were expected to recall their prior knowledge while discussing a relevant scenario (how the brightness of two bulbs differs if they are connected in series and parallel circuits). Second, in the *explore* phase, learners would be asked to postulate hypotheses about the situation posed in the first phase. Then, they would be expected to design an investigation to test their hypotheses using the PhET Circuit Construction Kit simulation. The gathered data would be analyzed in the *explain* phase. Learners would discuss their findings in small groups and try to come up with scientifically acceptable explanations. The PhET computer simulation could be used at any time, in case learners needed to confirm their explanations. Finally, in *elaborate*, learners would be expected to apply their newly constructed knowledge in real-life situations. The learning process would be evaluated at two levels: by the instructor throughout the 5E phases, and by the learners in the *evaluate* phase. During this part,

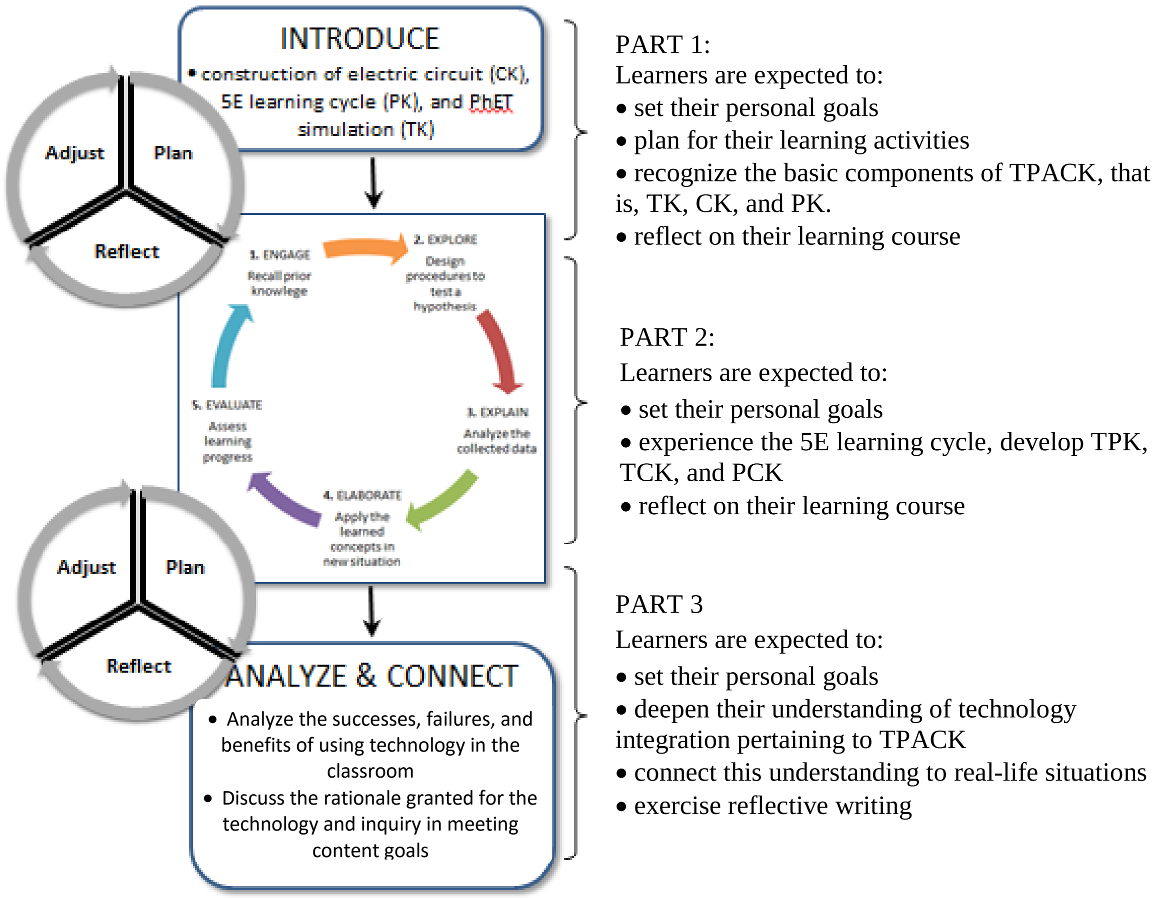


Figure 5. The MS strategy and the rationale given for each of its components

learners would be asked to reflect on their learning progress and respond to questions such as "Is my plan working? Am I progressing well? Am I achieving my learning goals?" A few open-ended questions would be posed at the end of the 5E tasks to encourage learners to reflect on their efforts, strengths, or weaknesses in their learning course. Also, learners would be asked to describe what they are still puzzled by. Thus, when they planned for their next learning task, they could propose learning goals aimed primarily at clarifying the concepts that were not fully understood.

Before analyzing the 5E learning activities, learners would be engaged in metacognitive tasks. In 2-member groups, learners would be expected to:

1. Recall their experience with the 5E learning cycle, looking for details that prompt problematic issues, challenges, advantages, or difficulties in relation to their efforts to accomplish the inquiry tasks
2. Spot successes or failures regarding their use of the PhET simulation in clarifying their understanding of the target concepts or their inquiry as whole
3. Identify their strategies used in the 5E tasks and discuss how they conceive these strategies, how they can utilize them to accomplish their personal goals, what their drawbacks or failures are during the implementation phase, what other goals are not accomplished, and what part of the strategies could have been performed better to improve their learning
4. Think about what they have learned so far and plan to tell their group partners their previous and current thinking about the pedagogical and content uses of the PhET simulation, and come up with a consensus about the best ways to learn about the integration of computer technology in the classroom
5. Use different methods to express the aforementioned in the journaling process, such as schematic diagrams, text, or graphic organizers

The aforementioned reflective writing would allow learners to manage their ongoing learning process and constantly adjust and readjust their objectives as new understanding is assimilated. This process would encourage them to think critically about their learning during the 5E tasks, and transfer what is learned to new situations. At this point, the instructor should provide consistent feedback or prompt questions (verbally or on worksheets) to all groups, so that they could monitor their work more effectively. Also, the instructor's role should be to provide all means of scaffolding to help learners in progressing through self-reflection and self-monitoring events.

Next, learners would be expected to critically analyze their 5E learning activities to develop a deeper understanding of the effectiveness of technology integration – more specifically, understanding how the PhET simulation, the 5E learning cycle, and the construction of electric circuits are interrelated. Learners would: a) critique the ways in which the PhET Circuit Construction Kit was beneficial (or not) in the teaching and learning of the construction of an electric circuit, b) establish whether the 5E tasks provide an adequate inquiry model to challenge students' alternative conceptions, and c) if not, describe what their drawbacks were. Such questions would be posed to encourage learners to think critically and establish a rationale for using the PhET simulation in the classroom, the 5E learning cycle, and the target concepts. This direction was expected to lead learners to develop better understanding of the pedagogical and content uses of technology in the classroom as pertaining to the TPACK framework.

The final metacognitive engagement would provide an opportunity for learners to use the final piece of their reflective writing. They would be expected to get ready for their next task: designing a technology-based inquiry activity for their own students. To do this, they would need to make sense of the whole learning experience for the purpose of orienting their learning toward creating better and more effective inquiry activities. Hence, they would be asked to generate:

1. Comprehension questions and sub-questions, such as: What was the activity all about? What were the pedagogical constraints? What technology would be suitable to help resolve the pedagogical constraints, and how? How would this technology help students understand the target concept?

2. Connection questions, such as: How was this activity different from, or similar to, the 5E tasks?
3. Reflection questions, such as: Did my choices make sense? Why were I stuck with this problem? and, What was missing?

The self-generated questions process was expected to foster learners' ability to comprehend and understand how technology, pedagogy, and science content were interrelated. More importantly, self-generated questions should guide learners to transfer their understanding of TPACK to inform their planning choice of technology-based inquiry activities. The instructor's role becomes essential to provide modeling and reinforcement in the skills of question generation.

In conclusion, in their attempts to develop technological pedagogical content knowledge, learners would start with exploring the basic principles of the PhET Circuit Construction tool kit simulation, the 5E learning cycle, and the construction of electric circuits. Then, they would conduct an inquiry into the construction of series and parallel circuits as well as critically analyze their 5E learning tasks in order to develop an adequate level of TPACK. Meanwhile, learners would exercise different metacognitive tasks before, during, and after their learning process. The learner's metacognition aims at monitoring, adjusting, and readjusting one's learning course.

The main distinction between EIM and MS is that learners in EIM experience an inquiry model while teachers in MS experience an inquiry model with metacognition (Table 1). At the end of the EIM and MS strategies, learners would be asked to apply their technological pedagogical content knowledge as they plan technology-based inquiry activities. They could use a technological tool of their choice to teach specific curriculum objectives. Also, the plan should include specific expectations, science concepts, teaching and learning procedures, types of technology used, and reason granted for technology and teaching procedures in meeting content objectives.

Table 1

Differences and Similarities of the Learning Sequences between the MS and EIM Strategies

	Learning sequence		Similarities/differences
	EIM teachers were expected to:	MS teachers were expected to:	
Part 1: Introduction	• be introduced to the basic concepts of electric circuits, the features of the PhET simulation, and the phases of the 5E learning cycle	• be briefly introduced to the basic concepts of electric circuits, the features of the PhET simulation, and the phases of the 5E learning cycle	EIM teachers would spend more time learning the basic concepts than MS teachers.
	• complete hands-on activities related to the electric circuits and the PhET simulation	• set specific learning goals, and select topic(s) that is/are interesting to learn • indicate why they would like to learn these topics • plan for their learning course	EIM teachers would be guided through structured hands-on activities to achieve specific learning goals set by the instructor, whereas MS teachers would set their own learning objectives and learning course, and then reflect on their learning outcomes.
		• implement their learning plan	
		• complete a reflective writing task	
Part 2: Experiencing inquiry	• conduct an investigation using the PhET simulation and the 5E learning cycle	• set specific learning goals to achieve • indicate why they would like to learn these topics	Prior to conduct the investigation, only MS teachers were asked to indicate what they want to learn from Part 2, and why. At the end, only MS teachers responded to questions about their own learning paths (failures and successes), and what they had learned and what they were still puzzled by.
		• conduct an investigation using the PhET simulation and the 5E learning cycle	
		• complete a reflective writing task	
Part 3: Analysis and Discussion	• critique the design of the 5E activities • analyze the successes, failures, and benefits of using technology in the classroom • discuss the rationale granted for the technology and inquiry in meeting content goals	• set specific learning goals and indicate why they would like to achieve them • set procedures and resources for the next task	Prior to the analysis and discussion, only MS teachers would be asked to indicate what they wanted to learn from Part 3, to set their procedures, and select their learning resources. While EIM teachers would discuss and analyze specific issues, MS teachers could have more open discussions. Both groups would be asked to critique the design of the inquiry model, but at the end, only the MS teachers would respond to reflective questions about their own learning paths (failures and successes), what they had learned, and what they were still puzzled by.
		• critique the design of the 5E activities • analyze the successes, failures, and benefits of using technology in the classroom • discuss the rationale granted for the technology and inquiry in meeting content goals	
		• complete the Reflective Journal Checklist task	

CHAPTER 5. METHODOLOGY

5.1 Context of the study

The main objective of this study was to compare the impact of the EIM and MS strategies on developing science teachers' TPACK. Based on situated cognition, the study also aimed at exploring the situated learning events, and the conditions of the two strategies that afforded the development of the participants' knowledge and the negotiation of their knowledge development in designing technology-mediated inquiry activities for science learning. Since TPACK is a framework that is developed for specific subject matter, a specific teaching method, and a specific classroom context (Niess, 2005), it would be meaningless to measure the development of science teachers' TPACK without considering their ability to apply this knowledge in a specific teaching context, such as planning a technology-based inquiry activity for science learning. In fact, developing TPACK is expected to help teachers make complex decisions in selecting the appropriate type of technology (depending on the appropriate features and functions of the technological tool) required for a specific pedagogical goal and a specific content objective (Chien, 2012; Jimoyiannis, 2010; Niess, 2005). Therefore, the study aimed to compare the impact of the EIM and MS strategies on developing science teachers' ability to incorporate their TPACK into the designing of technology-mediated inquiry-based activities. Considering that the study aimed to engage the participants in a dynamic interaction with sensitive and complex situated activities in order to address the outcome of a treatment, the study adopted a mixed methods approach. The qualitative data was used to describe the situated environment in which the participants interacted with one another and with the physical and representational systems (e.g., computer simulation, textbooks, and online resources). This description focused on the participants' performance and attitudes while interacting with the learning environment. It analyzed the real-world educational setting, reflecting the assumptions that knowledge is constructed within specific contexts. The quantitative variables were used to examine the impact of the strategies on the participants' TPACK throughout the process of implementing these strategies.

Mixed methods design

Mixed methods research has been established as a third methodological movement over the past twenty years, complementing the traditional quantitative and qualitative movements (Teddlie & Tashakkori, 2009). This development has been accompanied by the search for an appropriate paradigm to provide legitimacy for the use of mixed methods, comparable to the paradigms that have been widely accepted as justifying the use of quantitative or qualitative methods individually. The term mixed methods has come to be used to refer to the use of two or more methods in a research study yielding both qualitative and quantitative data (Cresswell & Clark, 2007). Strategies for the use of mixed methods design include expanding the understanding of each method, and converging or triangulating information from multiple data sources into one final data pool (Creswell, 2009). However, using mixed methods research does pose some challenges for the inquirer, who must be familiar with both quantitative and qualitative forms of research, collect extensive and varied data, and allow more time for the intensive analysis of textual and numerical data.

This study has adopted the concurrent embedded strategy of mixed methods (Figure 6). The advantage of this strategy is that it allows the "use of one data collection phase, during which both quantitative and qualitative data are collected simultaneously" (Creswell, 2009, p. 214). One method (quantitative or qualitative) guides the research and provides the primary source of data, and the other method plays a supporting role in the procedures.

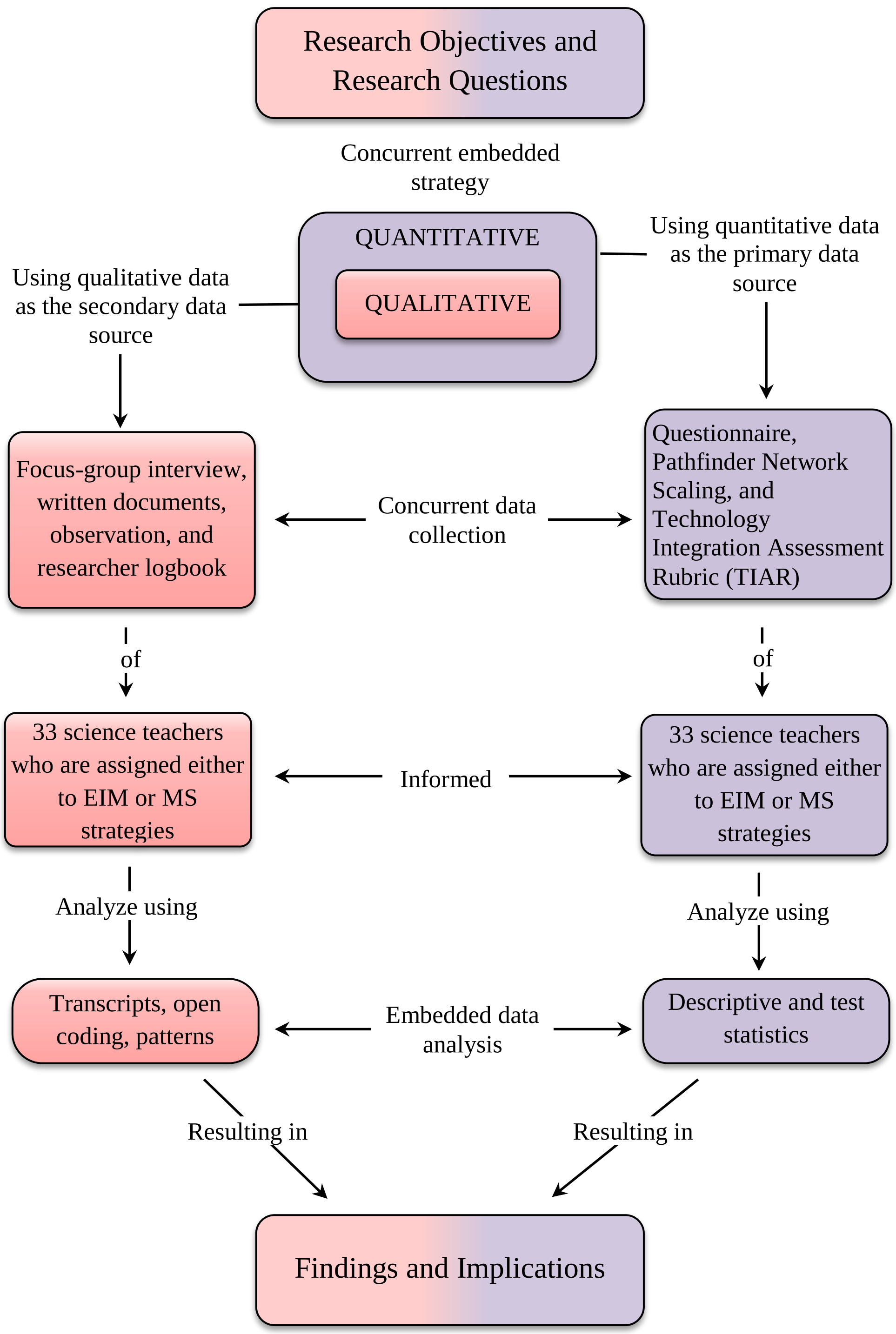


Figure 6. The mixed methods design

In this study, the quantitative data, as the primary source of data, was used to compare the effectiveness of the implementation of the teaching strategies on the development of science teachers' TPACK. The qualitative data, as a secondary source of data, was used to examine the learning events experienced by the participants to determine what part(s) of the situated activities best afford this development. The qualitative data therefore helped to describe the learning environment where the quasi-experimentation took place and the characteristics of the participants as they related to the design of the study and the anticipated outcomes. It was also used to study the influence of various factors that could be at play within this context, which would be difficult to measure quantitatively.

Participants

The participants were in-service science teachers at the elementary and secondary levels from the Sudan. Initially, an invitation letter was sent to the Sudanese Teacher Federation. For logistical reasons, the invitation was circulated to elementary and secondary teachers in Khartoum. Although there were no specific inclusion criteria (e.g., age group, gender, or ethnic background) for the participants to be involved in the study, only teachers who instructed in English would be selected. Based on this criterion, teachers from four international schools expressed their interest in participating in the study. The four schools' principals were approached and asked for permission to conduct the study in their schools. After receiving their approval, the science teachers who signed up for the training were grouped by school (a total of four groups), and the groups were randomly assigned to either the EIM strategy or the MS strategy (two groups for each strategy).

The participants assigned to the EIM strategy came from two international schools where English was the only language of instruction, though the participants did speak Arabic as a first language. 17 participants signed up in this group. 13 of them came from one school where they taught the national curriculum in English. The other four came from another school where they taught a home-made curriculum, so their students (girls only) were prepared to take the International General Certificate for Education (IGCSE) – Cambridge Board Examination by the time they enter Grade 11. 16 teachers were assigned to the MS strategy, nine of which came from one school and the other seven from another school, and they all spoke Arabic as a first language. Both schools teach all subjects, including sciences, in English and prepare their students to qualify for the IGCSE – Cambridge Board Examination.

5.2 Data collection

This section describes the data collection instruments, preparation of the site, and the data collection procedures.

Data collection instruments

Two sets of instruments were used for data collection procedures: quantitative instruments and qualitative instruments. The quantitative instruments were Pathfinder Network Scaling, Technology Integration Assessment Rubric, and demographic questionnaire, while the qualitative instruments included participants' written documents, the researcher's logbook, and focus group interviews.

Pathfinder Network Scaling

Pathfinder (Schvaneveldt, 1990) is a computer-based network scaling technique that offers a quantitative method for representing and evaluating structural knowledge (Azzarello, 2007; Trumpower & Goldsmith, 2004). The pathfinder network is generated by an algorithm from proximities from pairs of entities or concepts (DiCerbo, 2007). The network aims at representing the organization and conceptualization of knowledge involving understanding of facts, principles, and concepts, and most importantly, understanding how concepts of a particular knowledge domain are interrelated (Housner, Gomez, & Griffey, 1993). The proximities can be obtained from similarities, correlations, distances, conditional probabilities, or any other measure of the relationships among the concepts. In the pathfinder network, the concepts correspond to the nodes of the generated network, and the links in the network are determined by the patterns of proximities. The process of generating a pathfinder network involves three steps: knowledge elicitation, knowledge representation, and knowledge assessment. The most commonly reported method for conducting these three steps is as follows.

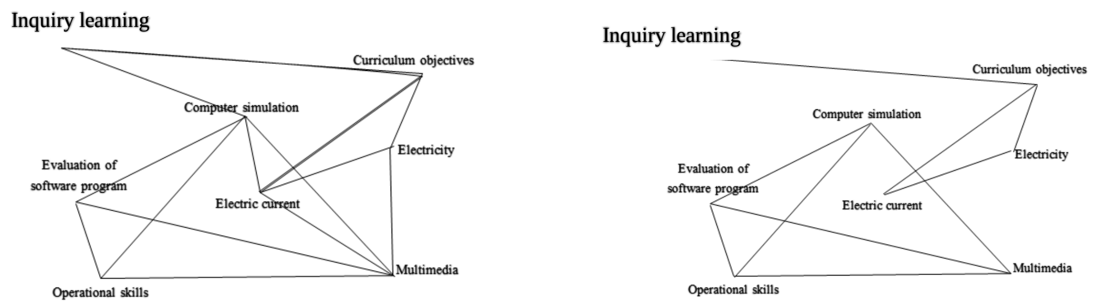
a) In the knowledge elicitation phase, an individual is expected to judge the relatedness of pairs of concepts from a certain domain on a Liker Scale from completely unrelated (a rating of 1) to strongly related (a rating of 5). Highly related concepts are connected by more links, and less related concepts are connected by fewer links or no links.
b) In the knowledge representation phase, the relatedness ratings are transformed into a structural representation of one's knowledge by the pathfinder scaling algorithm.
c) In the knowledge assessment phase, the structural network produced by an individual is evaluated by comparing it to the pathfinder network of an expert. Then, a similarity analysis between the expert's network and the individual's network is conducted in order to generate a relatedness coefficient called a similarity index. The similarity index is the ratio of the total number of common links to the total number of links that are in either network.

$$similarity\ index = \frac{total\ number\ of\ common\ links}{(total\ links - common\ links)}$$

More recently, knowledge networks are gaining more recognition as reliable tools for assessment and feedback instruction (Trumpower, Filiz, and Sarwar, 2014). In this study, Pathfinder Network Scaling was used to assess the participants' knowledge structure pertaining to TPACK. First, participants rated the relatedness of different pairs of concepts pertaining to the

TPACK framework. Appendix A illustrates the rating sheet and the concepts list that was generated from the integrated Technological Pedagogical Science Knowledge framework (Jimoyiannis, 2010). The participants judged the relatedness of each pair of concepts on a numerical scale from *completely unrelated* (a rating of 1) to *strongly related* (a rating of 5). Pathfinder Network Scaling would then transform the relatedness data into network representations via the Knowledge Network Organizing Tool (KNOT) software program, available online at www.conceptmapsforlearning.com (Goldsmith & Davenport, 1990). The KNOT software program is a tool built around the pathfinder network generation algorithms. The participants' networks were compared to a referent network to calculate the corresponding similarity index for each network. The referent network was created based on the average relatedness of the researcher and two TPACK experts who had recently conducted and published research works related to science teachers' TPACK. Ideally, the experts' pathfinder networks should relate the given pairs of knowledge components in a way that coincides with the TPACK framework. Therefore, the comparison between the participants' networks and the referent network would be expected to indicate the participants' relevant knowledge pertaining to the TPACK framework.

To put the process of pathfinder network scaling into perspective, suppose that electric currents are chosen as the focus content knowledge component in the referent network, as shown in Figure 7(a). The referent network shows that electric currents are directly related to four other knowledge components: electricity (CK), computer simulation (TK), multimedia (TK), and curriculum objectives (PK). Further, suppose that a teacher's network links electric currents with only two knowledge components: electricity and curriculum objectives (Figure 7(b)). Comparing both networks, the teacher's network indicates direct links between the concepts related to TK,



(a) Referent network (b) Teacher's network

Figure 7. Comparing the Pathfinder networks

and concepts related to TK and the concepts related to PCK. However, the teacher's network connects the concepts related to technology in isolation from the other concepts. Hence, he/she seems to lack TCK, TPK, and subsequently TPACK. This is a crucial point, because part of developing TPACK is understanding the interrelationships between technology, pedagogy, and content knowledge.

Technology Integration Assessment Rubric (TIAR)

The TIAR is outlined in Appendix B. It was used to evaluate teachers' ability to plan for technology integration. TIAR (Harris, Grandgenett, & Hofer, 2010) is an instrument to assess teachers' planning across three TPACK components – TPK, TCK, and TPACK – as well as the "fit" of the selected content, teaching strategies, and technologies, considered together. Construct and face validities and the reliability of TIAR have been examined. Expert reviewers have verified the construct validity of TIAR, which means they verified that the rubric actually measures technology integration as represented in educational activities. Further, experienced teachers have examined and verified the face validity of TIAR, which means they have verified that TIAR measures what it is supposed to measure (Harris et al., 2010). An inter-rater reliability was 0.857 (Harris et al., 2010). Hence, TIAR can be used as an appropriate instrument to measure the participants' ability to integrate computer technology in their activity planning.

Demographic questionnaire

The participants completed a short questionnaire to describe their academic background and teaching experience. In this questionnaire (Appendix C), the participants were asked to briefly describe their gender, age, teaching experience, academic qualifications, and subject background. Also, the participants were asked about their background or experience related to: teaching science through inquiry, uses of ICT in the classroom, and concepts of construction of electric circuits.

Participants' written documents and artifacts

The written documents, such as the Learner's Guide, were used to assess the participants' learning progress, and analyze their efforts to plan for and reflect on their own learning. Also, participants' artifacts (such as discussion posters) were used to analyze their ability to connect what they learned during the workshop to their everyday teaching practice, behavior and performance, and level of engagement throughout the intervention.

Researcher's Logbook

The logbook was used to maintain a record of activities and events occurring during the intervention. The logbook helped in creating descriptions of the learning process and analyzing the implementation of strategies as per the original guidelines, and provided more insight into the processes of teaching and learning throughout the study.

Focus group interviews

The interviews questions were prepared to gather information on how science teachers progress in their learning tasks throughout the intervention. Through interviews, it was also possible to understand the participants' perceptions of which part(s) of the proposed strategies influenced their understanding of TPACK, and the competencies necessary for technology integration in science instruction. Understanding of the latter concept is important in establishing the reason for incorporating TPACK components in activities planning. The participants' understanding of technology competencies would be cross checked with TIAR scores. All interviews questions were semi-structured with open-ended questions, which were modified from UNESCO (2008a) and Schmidt, Baran, Thompson, Koehler, Mishra, and Shin (2009). See Appendix D for the complete list of interviews questions.

Preparation of the sites

Prior to data collection, the participants were grouped by school (a total of four schools). Two groups were randomly assigned to each strategy (EIM or MS). The option of random assignment of individual participants was eliminated, mainly for logistical reasons and the mutual agreements with the schools' principals who agreed to host the study. 17 teachers were assigned to EIM and 16 were assigned to MS. The two strategies were implemented by the researcher and integrated within the general framework of professional development workshops. In addition to fulfilling the role of instructor, the researcher acted as an outsider in order to observe and document the implementation of the strategies. A research assistant was hired to assist (during the instruction) in recording the actual implementation of the teaching and learning events, setting up the workshop sites, distributing and collecting the hands-on activities, and managing the data collection procedures.

The participants were segregated into two workshops, both of which were supported by the same features and resources. The workshops were conducted in two separate schools. The amenities such as desktop computers, refreshments, and transportation were prepared by the schools. The researcher and research assistant made sure that all the desktop computers were in good working condition, and that the sites were air-conditioned and well-organized. The researcher prepared all learning and teaching materials such as Learner's Guides, electronic copies of the PhET simulation, data collection instruments, lesson plan templates, posters, and worksheets. The Learner's Guide (Appendix E and F for EIM and MS, respectively) includes a brief description of research objectives, the Pathfinder Network Scaling tool, specific expectations, instructional plans, and learning tasks.

Data collection procedures

The data were collected over four days, in August 2015. Based on the availability of the teachers and the readiness of the schools, the workshops were scheduled such that EIM was conducted over the first two days, and MS was conducted over another two days later on. The two workshops were separated by two days so that the researcher and the research assistant could make the necessary preparations.

Each of the workshops lasted for six hours, three hours a day for two days. The two-day workshops were conducted in the computer labs at the participating schools (Figure 8). In each workshop, every participant was assigned to a desktop computer. Although at times the participants worked without their computers, the computers were at their disposal at all times. In order to run PhET simulations offline, the Java program and the PhET Circuit Construction Kit

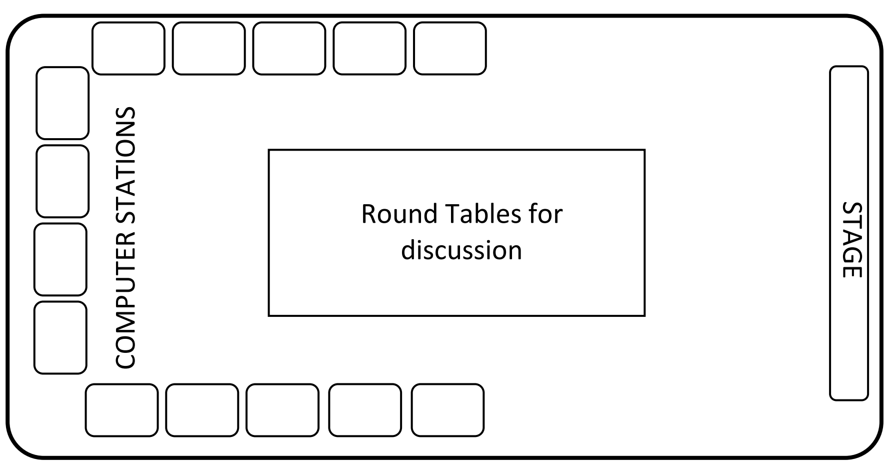


Figure 8. Illustration of the computer lab simulation were installed on all computers. The latter aimed to avoid any problems with technical issues, such as poor Internet connectivity, that might occur during the workshop.

The quantitative and qualitative data were collected simultaneously throughout the workshops. The procedures, in each of the two-day workshops, included six steps: a) introduction to the research objectives and procedures, b) completing the pre-intervention pathfinder network, c) the learning activities (the intervention), d) completing the post-intervention pathfinder network, e) designing technology-based inquiry activity, and f) focus group interviews.

a) Introduction

At the beginning of each workshop, the participants filled out the demographic questionnaire. Then, they were introduced to the basic principles of the assessment of knowledge structure via the Pathfinder Network Scaling (Azzarello, 2007). In this step, the participants were introduced to nine concepts pertaining to three knowledge domains (Table 2): a) Pedagogical

Table 2.
Description of the Knowledge Domains and Concepts

Knowledge domain	Concepts	Description
CK: knowledge related to Electric Circuits (Grade 8 science)	Electric current	The flow of electrons in a conductor
	Electric circuit	A switch, battery, and device (load) are connected by wires in a closed loop called an electric circuit
	Measurement of voltage	Determines the amount of electric energy released per unit charge
TK: knowledge related to computer simulation	Multimedia projector	A device used to display a computer screen on a larger screen
	PhET Circuit Construction Kit simulation	A software program that simulates the construction of electric circuits by means of visual representation
	Evaluation of PhET simulation	The method used to assess the effectiveness of the PhET simulation in representing the construction of electric circuits
PK: knowledge related to the 5E learning cycle	Curriculum expectations related to electricity	Specific expectations that learners are expected to achieve by the end of the unit on electricity
	Student's summative assessment	The method used by the teacher to assess students' learning at the end of the course or term
	Testing hypothesis	The process by which data are gathered and analyzed in order to test a previously postulated hypothesis

Knowledge (PK), b) Technological Knowledge (TK), and c) Content Knowledge (CK). The nine concepts were generated from the integrated Technological Pedagogical Science Knowledge framework (Jimoyiannis, 2010). However, only the participants assigned to MS were introduced to the metacognitive strategies (think aloud and reflective writing) that they were expected to use during the intervention.

b) Completing the pre-intervention pathfinder network

The participants were then asked to independently use Pathfinder Network Scaling to rate the relatedness of 36 pairs of concepts on a numerical scale from *completely unrelated* (a rating of 1) to *strongly related* (a rating of 5). The 36 pairs of concepts constitute all possible combinations of the nine concepts that were introduced in the first step. In the end, the participants' ratings sheets were gathered to generate the pre-intervention similarity indices. Table 3 shows a sample of the Pathfinder Network Scaling rating sheet. To avoid random ratings, the participants were instructed to justify their *related* and *strongly related* ratings (i.e., ratings of 4 and 5, respectively). If the participants could not justify their high ratings, the instructions were to select uncertain ratings such as *maybe related* (a rating of 2) or *somehow related* (a rating of 3) instead.

Table 3.
Sample of the Pathfinder Network Rating Sheet

Concept 1	Concept 2	Not related 1	Maybe related 2	Somehow related 3	Related 4	Strongly related 5	Rationale
Electric current	Electric circuit	☐	☐	☐	☐	☐	
Testing hypothesis	Measurement of voltage	☐	☐	☐	☐	☐	
PhET simulation	Multimedia projector	☐	☐	☐	☐	☐	

c) Learning activities (the intervention),

The participants engaged in learning activities following either the EIM or MS strategy. Although each participant was given a desktop computer to complete the learning activities, some of them brought their own laptops or smartphones. The participants assigned to the EIM strategy experienced the inquiry model only, while the participants assigned to the MS strategy experienced the inquiry model with metacognition. Appendices G and H contain an overview of the implementation protocol of the EIM and MS strategies, respectively. The implementation protocol includes the learning sequence and details about the time allotted for each task. The researcher designed a lesson plan for each strategy in order to guide its implementation. These lesson plans processes (Appendix I and J for EIM and MS, respectively) describe the main tasks, resources, instructional strategies, specific objectives, and learning and teaching procedures. During the workshops, the researcher used his logbook to describe the process of learning activities and all events that occurred, and to record the performance of the participants and their attitudes towards learning. The research assistant helped with this task when the researcher was busy with instruction. Presented here are the descriptions of the data collected during these sessions of the workshops.

First workshop: the EIM strategy

The first workshop was conducted in two days (three hours per day), and consisted of three sessions, including the septs described in sections a) and b). Table 4 shows the target knowledge components for each session, the implementation of the learning sequence, the timeline, and the remarks. The remarks section of the table indicates any procedures that were different from what had been planned. Presented here is the educational context of the EIM strategy.

Table 4

Actual Implementation of the EIM Strategy

Day	Session	Target knowledge component	Procedures / Tasks	Timeline	Remarks
Day 1	1. Introducing the target concepts	PK, CK, & TK	• Introducing research objectives and procedures	15 min.	
			• Introducing electric circuits, PhET simulation, and the 5E learning cycle: In this section, the participants were introduced to the key concepts and principles. They were then engaged in hands-on activities to explore the features of PhET simulations.	50 min.	
			Pre-intervention Pathfinder Network	35 min.	
	2. Experiencing inquiry model	PCK, TCK, TPK, & TPACK	• Experiencing the 5E learning cycle: The participants were expected to conduct an inquiry into the properties and characteristics of series and parallel circuits. They were expected to complete the 5E phases: engage, explore, explain, elaborate, and evaluate.	80 min.	The participants could not complete the explain and elaborate phases, though the instructor had gone over these two parts.
Day 2	3. Analyzing the 5E activities and closure of the training	PCK, TCK, TPK, & TPACK	• Exploring different inquiry-based methods • Exploring the potential of different types of technology in the teaching and learning of science	25 min.	
			• Analyzing the 5E learning cycle (group setting) • Whole class discussion	75 min.	
			Post-intervention Pathfinder Network	30 min.	
			Planning technology-based activities	35 min.	
			Focus-group interviews	15 min.	

First day (EIM)

The first day of the EIM workshop consisted of two sessions. In the first session, the participants went through the first two parts of the training: 1) introducing the target concepts (5E learning cycle, PhET simulations, and electric circuits), and 2) experiencing the inquiry model (conducting an inquiry via the 5E learning cycle). While the concepts of the 5E learning cycle and electric circuits were introduced via direct instruction, the participants were engaged in hands-on activities to explore the general features and functions of the PhET simulation. Although the participants learned about the PhET simulation, the hands-on activities allowed them on task and did not use the PhET simulation to learn the target content knowledge. Rather, they were asked to design a simple electric circuit that was made up of a battery, connecting wires, a switch, and a bulb. They tested the functions of each component of the circuit, but there were no attempts to construct series or parallel circuits (the target learning outcomes). At this stage of the workshop, the participants were introduced to the three knowledge domains (electric circuits – CK, the 5E learning cycle – PK, and the PhET simulation – TK).

In the second session, the participants conducted an inquiry into the properties and characteristics of series and parallel circuits. They used the PhET Circuit Construction Tool simulation and the 5E learning cycle to complete their investigation. Initially, the participants were asked to pair up and work in groups. Each group had two to three members. The instructor began with the first phase of 5E, the *engage* phase, and introduced a short scenario about a man who wants to decorate his community center with lights, but is puzzled by the type of connection he should use – parallel or series circuits. The objective of the scenario was to recall the participants' content knowledge. The participants were asked to respond to questions related to the scenario. They discussed these questions and worked in groups to come up with consensus answers. Overall, the answers were mixed. Regardless, the participants needed to focus on the process of inquiry investigation, such as formulating hypotheses, collecting and analyzing data, and coming up with acceptable explanations. The participants were instructed to manage their time wisely. In the *explore* phase, they were instructed to design a hypothesis and then design an investigation to test their hypothesis. They were then asked to conduct the investigation and write down their observations and conclusions (whether their hypotheses were accepted or rejected). Due to the time constraint, the participants could not complete the *explain* and *elaborate* phases, though the instructor had gone over these two parts.

By the end of the first day, the inquiry was complete. Then, the researcher and the research assistant met to discuss their observations and the logbook content in order to avoid any misinterpretation to the participants' behaviors, performances, or attitudes, and come up with a consistent observation on the logbook. All participants' written documents, including the Learner's Guides, were collected and safely stored for the uses of the second day.

Second day (EIM)

On the second day, the participants had one session left in their training, the third session: analyzing the 5E learning activities. The participants were asked to critically analyzing the design and the process of the 5E learning tasks. More specifically, the participants were asked to address the following issues:

- the effectiveness of the PhET simulation in achieving the learning objectives
- whether the selection of the PhET simulation and the 5E cycle fit together and in what way
- the rationale for choosing the 5E learning cycle as a pedagogical framework for inquiry learning

In order to develop such types of knowledge, different types of inquiry models were described. Based on the roles of teachers and students in the inquiry spectrum, the instructor described discovery learning, Predict-Observe-Explain (POE) (White & Gunstone, 1992), the 3-phase learning cycle, and the 5E learning cycle. The instructor drew a distinct line between these models in terms of teacher-student interaction and the degree to which students can take control of their own learning. Further, the instructor described different types of technology that are commonly used in science classrooms, such as computer simulations, hypermedia applications, multimedia devices, BBL or LMS, and Web-based learning.

At the beginning of the discussion period, the participants were organized into six groups (two to three members in each). Three issues were posted for discussion and each issue pertained to a TPACK component. Each group chose an issue for discussion, and they spent an average of 20 minutes addressing the issue. They were then asked to share their ideas and thoughts with the whole class via posters and short presentations. They used these posters to organize their main ideas and comments and then discuss them with the class. Each group was given 10 minutes to present their issue and 10 minutes to discuss it with the class. At the end of the third session, the participants took a short break before proceeding to the next step. The next step was to complete the post-intervention intervention pathfinder network. However, prior to describing this step, a description of the second workshop will be given.

Second workshop: the MS strategy

The second workshop was conducted in two days (three hours per day), and consisted of three sessions. Table 5 shows the implementation process of the MS strategy, including the target knowledge components for each session, the learning sequence designed to achieve the learning objectives, the timeline of the activities, and the remarks section. The remarks section of the table indicates any procedures that were different from what had been planned. The following is the educational context of the MS strategy.

First day (MS)

On the first day, the MS participants went through two sessions: 1) introducing the target concepts (5E learning cycle, PhET simulations, and electric circuits) and the metacognitive strategies, and 2) experiencing the inquiry model (conducting an inquiry via the 5E learning cycle). Meanwhile, the participants were asked to complete two sets of metacognitive tasks:

Table 5
Actual Implementation of the MS Strategy

Day	Session	Target knowledge component	Procedures / Tasks	Timeline	Remarks
Day 1	1. Introducing the target concepts and the metacognitive strategies	PK, CK, & TK	• Introduction of research objectives and procedures	15 min.	
			• Brief introduction of the concepts involved, including: Electric circuit, PhET simulation, 5E learning cycle, and metacognition	20 min.	
			• The participants were asked to complete a "Plan Learn & Reflect" task. In it, they were expected to set up a plan for the upcoming learning task, implement their plan, and reflect on their learning progress. By the end of this task, they were expected to have developed a better understanding of electric circuits, PhET simulation, and the 5E cycle. The participants were given various learning resources to be able to control their learning more fully.	30 min.	
			Pre-intervention Pathfinder Network	35 min.	
	2. Experiencing inquiry model	PCK, TCK, TPK, & TPACK	• Setting personal goal and planning for the upcoming task • Experiencing the 5E learning cycle: The participants were expected to conduct an inquiry into the properties and characteristics of series and parallel circuits. They were expected to complete the 5E phases: engage, explore, explain, elaborate, and evaluate. Also, they were expected to complete a reflective check list. • Complete a reflective journal checklist. This was aimed at reflecting on one's learning progress.	80 min.	• The participants could not complete the *explain* and *elaborate* phases, though the instructor had gone over these two parts. • The participants did not complete the Reflective Journal Checklist.
Day 2	3. Analyzing the 5E activities and closure of the training	PCK, TCK, TPK, & TPACK	• Exploring different inquiry-based methods • Exploring the potentials of different types of technology in the teaching and learning of science	25 min.	
			• Setting personal goal and planning for the upcoming task • Analyzing the 5E learning cycle (in groups) • Class discussion • Reflective journal checklist	75 min.	
			• Post-intervention Pathfinder Network	30 min.	
			• Planning technology-based activities		
			• Focus-group interviews		

Think Aloud, and Reflective Journal Checklist. While the Think Aloud task provided an opportunity for the participants to set up their learning goals and plan for their learning, the

Reflective Journal Checklist helped them to reflect on their learning progress during and after the main learning parts.

In the first session, the instructor introduced the two metacognitive strategies that would be used throughout the training: Think Aloud and Reflective Writing. Through Think Aloud, the participants were asked to:

- set specific objectives or topics that they would like to learn or explore
- decide the learning strategy (or procedures) that would help them in achieving their goals or objectives
- utilize the available resources in order to accomplish their learning task

The Reflective Writing journal, however, guided the participants through reflective thinking during and after learning. Then the participants were briefly introduced to the concepts of electric circuits, the 5E learning cycle, and the PhET simulation. They were given opportunity to pair up and think how they would like deepen their understanding of the key concepts demonstrated in the training. Therefore, they were asked to come up with objectives, or the topics they would like to learn, and the learning procedures while thinking aloud. They were also given the opportunity to choose to learn about all three concepts (5E, electric circuit, PhET simulation), or just the concepts in which they think their knowledge falls short. To help the participants in achieving their learning goals, various learning resources were available, including:

- Circuit construction tool kits: batteries, connecting wires, switches, battery holders, and light bulbs
- Science Textbook for elementary level
- https://phet.colorado.edu/en/simulations (PhET simulations)

- **{**Hyperlink ”http://youtu.be/BnlCQ45f7KM”**}** (5E learning cycle)
- **{**Hyperlink “https://www.youtube.com/watch?v=D2monVkCkX4”**}** (Electricity)
- **{**Hyperlink “www.mysciencesite.com”}
- {Hyperlink “https://phet.colorado.edu/forteacher”}
- “Constructing a Simple Circuit”, hands-on activity
- “PhET Circuit Construction”, hands-on activity

Next, the participants were asked to implement their plans and complete their first activities. After they had completed their first learning activity, the participants were asked to complete the Reflective Journal Checklist. By the end of the first session, the instructions were to write a short reflection in the following areas:

- What they have learned so far
- What they are still puzzled by
- The effectiveness of their learning plan and procedures
- Their strengths and weaknesses

In the second session, the participants conducted an inquiry into the properties and characteristics of series and parallel circuits. They used the PhET Circuit Construction Tool simulation and the 5E learning cycle to complete their investigation. Initially, they were asked to use the Think Aloud template to set learning goals for the upcoming learning events. Then, they were asked to pair up and work in groups. Each group had two to three members. Similar to the EIM group, the instructor began with the *engage* phase and presented a scenario followed by questions to answer. Then came the *explore* phase, where the participants were instructed to formulate a hypothesis and then design an investigation to test their hypothesis. Then, they were asked to conduct the investigation and write down their observations and conclusion (whether their hypothesis was accepted or rejected). The objective in conducting an inquiry via the 5E learning cycle was to develop an adequate understanding of how *computer* technology can be used to assist the learning of science through inquiry as perceived by students in an actual classroom setting. Thus they were expected to act like intermediate students, and hence became more conscious of the challenges that students often face in similar learning situations. However, due to the time constraints, the participants could not complete the *explain* and *elaborate* phases. Instead, the instructor described the typical learning sequence that embedded in the *explain* and *elaborate* phases. Then, the instructor discussed the findings and came up with scientifically acceptable explanations to the inquiry. That was the end of the first day.

Then, the researcher and the research assistant met to discuss their observations and the logbook content in order to avoid any misinterpretation to the participants' behaviors, performances, or attitudes, and come up with a consistent observation on the logbook. All participants' written documents, including the Learner's Guides, were collected and safely stored for the uses of the second day.

Second day (MS)

In the second day of the workshop, the participants were offered an opportunity to analyze their precedent experience and identify the learning challenges and successes, technology failures and potentials, effectiveness of 5E as an inquiry model, and required guidance. Following the implementation protocol, the participants needed another session to discuss all of these issues in order to come up with a consensus that could be applied in their teaching practice.

In third session, the participants were asked to set up their learning goals, and then come up with plans to achieve these goals. To do this, they completed the Think Aloud task, which enabled them to verbalize their objectives, the reasons for choosing them, their learning strategy, learning resources, and procedures. Individually, the participants worked out their plans, each of them laying down his/her learning course for the upcoming task.

During the session, the participants were organized into six groups (two to three members in each). Three issues were posted for discussion, and each issue pertained to a TPACK component. Each group chose an issue to articulate, and at the end of the group discussion they shared their ideas and thoughts with the whole class. The participants spent an average of 20 minutes in their small group discussion and presented their analysis on a poster. Each group was given 10 minutes to present their issue and 10 minutes to discuss it with the whole class. At the end of the third session, the participants were asked to complete their final reflective writing, which included questions about their current knowledge development and what they were still puzzled by. Then they took a short break before completing the post-intervention intervention pathfinder network. At the end of the intervention, the participants' written documents and artifacts were gathered as part of the data collection procedures. The Learner's Guides, however, were scanned and later on returned to the participants for their future uses.

d) Completing the post-intervention pathfinder network

The participants from both strategies were asked to independently rate the relatedness of the 36 pairs of concepts in order to assess their knowledge structure after the intervention. This assessment aimed at indicating any changes in the participants' networks that may have occurred during the intervention. Similar to the pre-intervention pathfinder networks, the participants were instructed to justify their *related* and *strongly related* ratings (i.e., ratings of 4 and 5, respectively), and if they could not justify their high ratings, they were asked to select a rating of either 3 or 2 instead. In the end, the participants' ratings sheets were gathered to generate the post-intervention similarity indices. Then the participants were asked to complete an assignment related to designing technology-based inquiry for science learning.

e) Designing technology-based inquiry activity

The participants from both strategies were asked to apply what they learned to inform the planning of technology-mediated inquiry-based activities for their own students. For this assignment, the participants were provided with a template (Appendix K) to help them focus on technology integration and describing the rationale for technology selection in meeting specific instructional and curriculum objectives. To complete the assignment, the participants were asked to include target objectives, instructional strategies, technological tools, and a brief description of learning sequences. The latter aimed to reveal the participants' ability to fit science content, technology, and pedagogy together in a smooth sequence of events. The participants' assignments were evaluated, by the research and two Ph.D. (Ed.) students, according to the Technology Integration Assessment Rubric (TIAR) (Harris, Grandgenett, & Hofer, 2010), which consists of four criteria pertaining to the TPACK framework: Curriculum Goals and Technology, Instructional Strategies and Technology, Technology Selection(s), and the Fit (i.e., technology, content matter, and pedagogy considered together). The participants' plans were rated in the four criteria from strongly aligned (a rating of 4) to not aligned (a rating of 1) (see Appendix B).

f) Focus group interviews

Finally, focus group interviews were conducted at the end of the second day of each workshop, when the all assignments and learning events had been completed. The participants in the EIM and MS groups were interviewed separately. For each interview session, they were organized into 3-4 groups (each group consisted of 4-5 members). The interviews were conducted to understand the participants' learning experiences and opinions of their assigned tasks, and their views of their understanding of the dynamic interrelationship between pedagogy, technology, and content matter. The interviews explored the participants' opinions on how aspects of the implementation of the EIM or MS strategies impacted their development of TPACK. As well, during the interviews, the participants were asked to bring some insights into their performances and on the part(s) of the strategies that influenced their learning the most, as well as their understanding of the competencies that are deemed necessary for technology integration. Appendix D contains the interviews questions. Figure 9 summarizes the research design and the timeline of the data collections procedures.

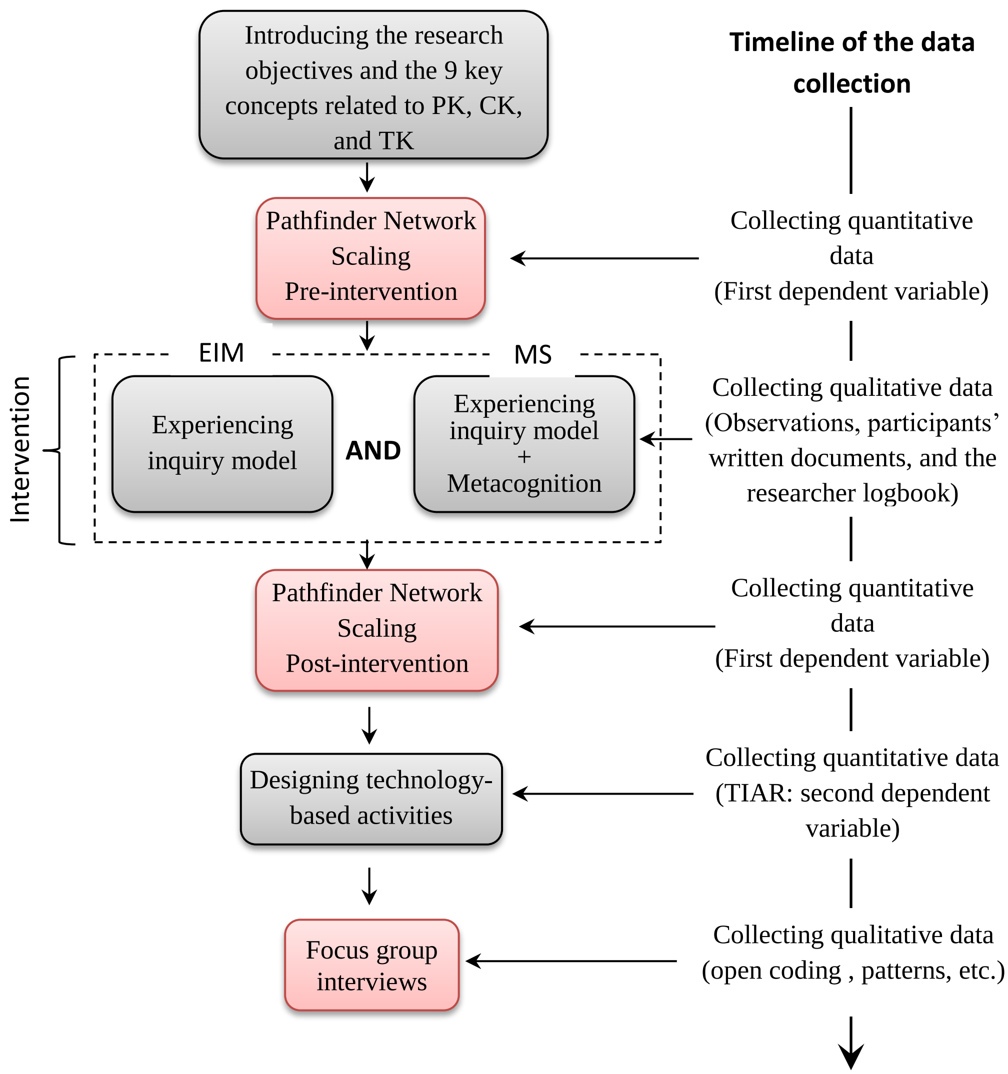


Figure 9. The research design and the timeline of the data collection

5.3 Data analysis

The data analysis section describes the pre-intervention data analysis and the data analysis procedures.

Pre-data analysis

Prior to the data analysis, a number of steps were taken to ensure that the quantitative data gathered via Pathfinder Network Scaling and TIAR, as well as the quantitative data gathered via observation, logbook, written documents, and interviews were adequately measured or collected.

Measurement of knowledge structure

The participants' responses on the ratings sheets were entered into a web-based tool (www.conceptmapsforlearning.com) for processing. This website utilizes Pathfinder Network Scaling in order to transform the relatedness data into network representations via the Knowledge Network Organizing Tool (KNOT) software program (Goldsmith & Davenport, 1990). In order to generate a referent network, three networks (Figure 10) were generated via

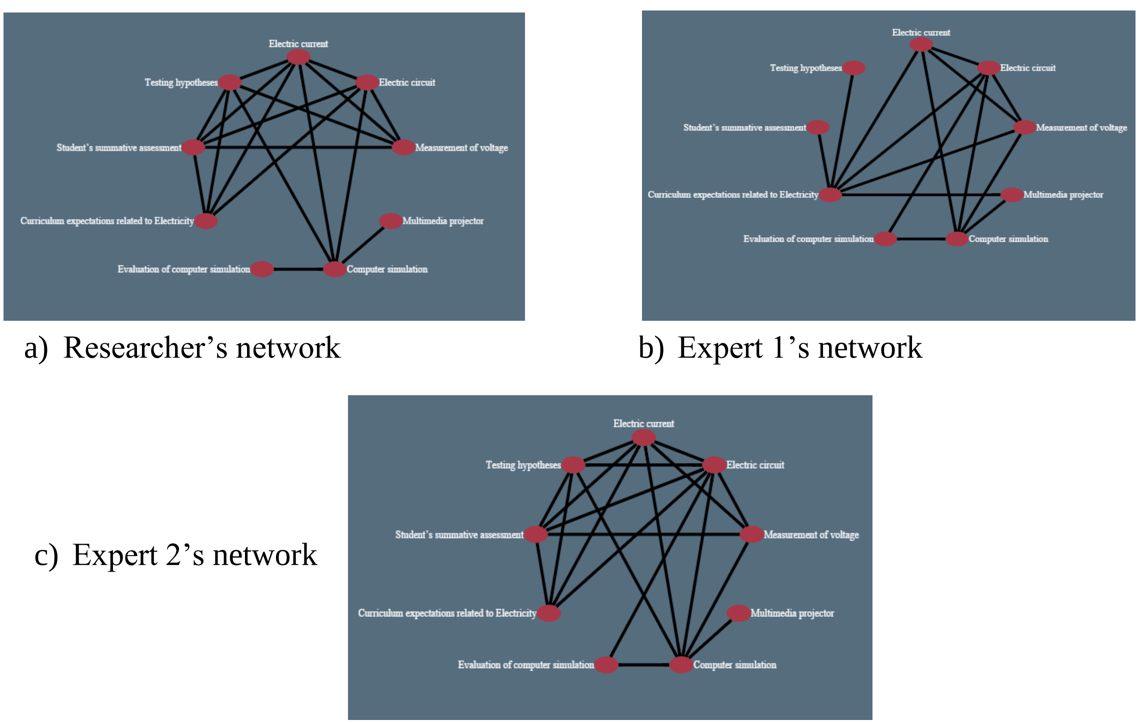


Figure 10. Three referent networks of a) researcher, b) first expert, and c) second expert

Pathfinder Network Scaling: one was generated by the researcher and the others were generated by two TPACK experts. Then, a correlation analysis was conducted to ensure that the three networks were consistent. Table 6 shows Pearson coefficients among the relatedness ratings of the two experts and the researcher, which indicated that the ratings were all significantly correlated with each other. Finally, a referent network (Figure 11) was generated by computing the average of the three relatedness ratings for each pair of concepts. Then the averages of the ratings were submitted to the Pathfinder scaling algorithm in order to generate the referent network.

Table 6
Correlation Analysis among the Relatedness Ratings of two Experts and the Researcher

		Researcher	Expert 1	Expert 2
Researcher	Pearson Correlation	1	.726**	.841**
	Sig. (2-tailed)		.000	.000
	N	36	36	36
Expert 1	Pearson Correlation	.726**	1	.698**
	Sig. (2-tailed)	.000		.000
	N	36	36	36
Expert 2	Pearson Correlation	.841**	.698**	1
	Sig. (2-tailed)	.000	.000	
	N	36	36	36

** Correlation is significant at the 0.01 level (2-tailed).

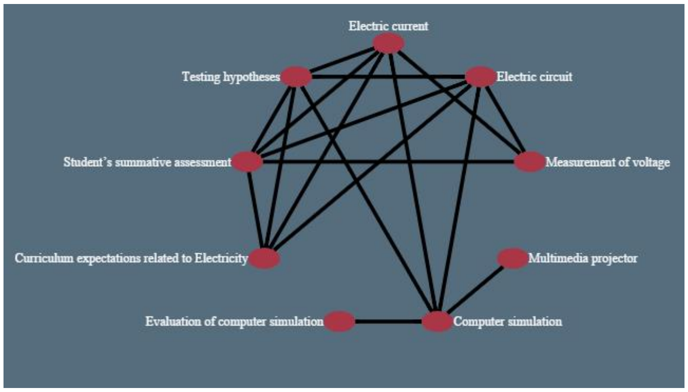


Figure 11. Referent network

The participants' networks were compared to the referent network and a similarity index was generated for each network. The similarity index indicates the similarities between each network and the referent network. If a participant's network has a similarity index closer to 1, this network is more similar to the referent network.

Measurement of TIAR scores

To begin with, TIAR is a rubric used to assess teachers' planning choice of technology integration pertaining to TPACK, though the rubric is not used to evaluate lesson planning in general. Therefore, other aspects of planning such as assessment tools, accommodations, and follow up tasks would not be evaluated by TIAR. To use TIAR appropriately, first, three inexperienced raters were asked to assess the participants' planning. Second, the raters set general guidelines for assessment, which included, but was not limited to, how to evaluate the participants' planning against each assessment criterion, listing key words or assessment indicators they should look for, and assessing three samples collectively and resolving any discrepant ratings. Third, each rater got a copy of all participants' lesson plans and marked them independently. Table 7 describes the mean and standard deviation of the TIAR scores for EIM and MS, as marked by each rater. Fourth, an interrater reliability test was computed to test the consistency of TIAR scores across the three raters. Table 8 shows that the

Table 7
Item Statistics of TIAR Scores for EIM and MS

		Mean*	Std. Deviation	N
EIM group	Rater 1	6.80	2.366	15
	Rater 2	8.47	2.800	15
	Rater 3	6.73	2.434	15
MS group	Rater 1	8.60	2.459	10
	Rater 2	10.70	2.869	10
	Rater 3	8.70	2.627	10

*TIAR maximum score is 16.0 pt.

reliability tests of the TIAR scores were 0.88 and 0.9 for EIM and MS, respectively. Consequently, the participants' TIAR scores, for both groups, were adequately measured. Finally, the participants' final scores were computed from the averaged values of the three scores.

Table 8
Interrater Correlation Coefficient for EIM and MS

		Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
			Lower Bound	Upper Bound	Value	df1	df2	Sig
EIM group	Single Measures	.887	.757	.957	24.575	14	28	.000*
	Average Measures	.959	.903	.985	24.575	14	28	.000*
MS group	Single Measures	.901[a]	.742	.972	28.254	9	18	.000*
	Average Measures	.965	.896	.990	28.254	9	18	.000*

* Intraclass correlation is significant at the 0.05 level

Qualitative data

Based on situated cognition, the qualitative data aimed at documenting the process of implementing the strategies, describing the dynamic interaction between the participants and the learning environment and helping to understand the conditions through which the participants could develop their TPACK knowledge. The qualitative data were collected via observation, the researcher's logbook, the participants' written documents, and interviews.

The observation took place within the learning environment during the implementation process. It involved the researcher (and the research assistant) taking lengthy and descriptive notes of the participants' performance, behavior, and attitudes during their interactions with the learning activities. To ensure the validity of the observation, the descriptive notes were regularly reviewed by the researcher and the assistant in order to come up with consensus notes that would reflect what actually happened during the implementation process. Further, the researchers' logbook was used to provide a detailed description of the implementation process.

The focus group interview was used to obtain information through collective discussion in order to understand the participants' opinions and perceptions about the implementation process, and to understand the participants' views of the conditions that best afforded their knowledge development. The interviews were conducted at the end of the workshops, and each session lasted for 15–20 minutes. The size of the sample group varied between 4–6 participants (3–4 interviews in each workshop). This setting allowed the researcher to facilitate the questioning more effectively. The semi-structured interviews began with open ended questions to provide opportunities for both the researcher and the interviewees to discuss their experience in more details. Then the open–ended questions were followed by more specific questions about the participants' understanding of the conditions provided by the EIM and MS strategies that afforded their development of TPACK. During the audiotaped interviews, the participants provided detailed information about the implementation process. All participants were able to interact and express their opinions freely, and all questions or issues were addressed and discussed.

Methods of data analysis

The mixed method approach aimed at responding to the research questions and objectives. Whereas the qualitative data was used to describe aspects of the implementation of the strategies, the quantitative data was used to compare the effectiveness of the EIM and MS strategies on developing science teachers' TPACK, as well as assessing science teachers' ability to inform their planning choice of technology integration in educational activities.

Considering the teaching strategy (EIM or MS) as the independent variable, and the participants' network (i.e., similarity indices) and TIAR scores as the dependent variables, the following analyses were conducted:

- A *t*-test was conducted on the mean differences between the participants' pre-intervention similarity indices.
- A 2 Teaching Strategy (EIM or MS) × 2 Time (pre- and post-intervention similarity indices) split-plot factorial design was conducted on the mean differences between the participants' pre- and post-intervention similarity indices.
- A *t*-test was conducted on the mean differences of TIAR scores between EIM and MS.
- A correlation analysis was conducted between TIAR scores and the similarity indices.

The Statistical Package for the Social Sciences (SPSS, version 23) was used for data analysis. All analyses were computed at the 0.05 level for statistical significance.

The qualitative data was analyzed simultaneously with the quantitative data. Although the quantitative data was considered the predominant method, the qualitative data was used to provide more insight and support to the statistical data. To do this, first, the observations and researcher's logbook were analyzed to come up with themes or patterns that could describe parts of the implementation of the strategies that could not be determined by the quantitative data, and to examine the participants' performance and behavior during the intervention. The following steps were conducted:

- summarizing what was observed by developing a chart that identified the site visit numbers, and how many participants were present during the observations, and describing the roles of the participants and the researcher;

- at the same time, using the researcher's logbook, which described the timeline of the implementation of the strategies, to examine the observations, and analyze the connections between the participants' performance and attitudes during the main events or activities;
- supporting all claims with specific examples from the observations;
- looking for behavior or attitudes that help in analyzing the way in which what was observed impacted the participants' learning;
- providing specific numbers to quantify patterns, repetitive behavior or attitudes, and durations;
- tabulating the observations and the researcher's logbook and organizing them in chronological order.

Second, content analysis was conducted on the participants' written documents. For analytical purposes, the participants' comments, responses, illustrations, and self-reflections were closely examined. Any writing that typically indicated the participants' understanding of the subject matter, such as their reflective writing, was considered part of their knowledge development. Any responses in the User's Guide were considered part of their level of learning engagement. However, irrelevant or poor responses do not necessary mean that a participant is interacting with the learning events.

Third, the interviews were recorded, transcribed, and analyzed using pattern coding techniques (Miles & Huberman, 1994) to shed more light on the participants' learning experiences and to help understand their perceptions of technology integration in science classrooms. The pattern coding techniques involved several steps:

- summarizing the interviews, including descriptive details such as the number of interview sessions, the number of interviewees in each session, and the duration of each session;

- using the notes taken during the interviews, providing a few sentences to summarize each interview, always keeping in mind the research questions (being sure to identify, specifically, who said what);
- looking for words or phrases used frequently in the various responses, in order to identify themes, ideas or language, and patterns that connect the participants to their own learning, learning objectives, or learning activities (Miles & Huberman, 1994);
- organizing these ideas or patterns into codes or categories following Miles and Huberman's (1994) coding system; and
- building over-arching themes for each category, and (if necessary) collapsing different categories under one main over-arching theme in order to focus the interview for the purpose of answering the research questions.

Finally, all qualitative data were combined very carefully, and organized in a table, in order to label the relevant themes, categories, or opinions. The labeling aimed to highlight the sections of the data relevant to the research questions, or relevant to the study in general. The next step was to decide which data sources were most reliable (and had the richest information) to support the findings from other sources. This triangulation process enhanced the validity of the findings, confirming them by multiple independent sources that measured the same thing.

5.4 Validity of the design

Essentially, validity means the correspondence between the intended purpose of the research design in terms of variables and conditions, and how these variables and conditions are implemented in reality. Experimental researchers need to identify potential threats to the validity and design of their experiments, so that these threats are less likely to arise or can be minimized.

In this study, three types of threats to validity were examined: statistical conclusion, internal, and external validities.

Statistical conclusion validity

Statistical conclusion validity emphasizes whether the statistical hypotheses are correct. The way to neutralize this threat is to increase the power of the design. The power is managed by calculating the appropriate sample size and maintaining a reliable dependent variable(s). For the purpose of this study, the sample size was calculated (at least 20 subjects) so that the power level was 0.95. Furthermore, extra measurements were taken to increase the reliability of the dependent variables. For examples, the participants' networks were compared to a referent network, which was generated from the average value of three referent networks. The three referent networks were significantly correlated (Table 3). Also, the TIAR scores (second dependent variable) were assessed by three raters, and the scores were computed from the average value of the three ratings. Interrater reliability showed that the raters' ratings were significantly reliable for single and average measures.

Internal validity

Internal validity is known as the third variable problem. There might be another unseen variable or variables responsible for the apparent relationship or lack of relationship between the teaching strategies (the independent variable) and the participants' networks (the dependent variable). Quality of training, the participants' prior knowledge and experience, gender, and inappropriate implementation of the strategies could all threaten the internal validity. A number of measures were adopted to reduce these threats. First, the learning environments in both groups were set up to be meticulously distinct (the lesson plans for the EIM and MS strategies are described in Appendices I and J, respectively). Second, the participants were given a training session and orientations to ensure appropriate implementation of the quantitative instruments (i.e., the pathfinder networks). Third, the researcher monitored and documented the implementation process to ensure everything was implemented as per the study design. Fourth, the researcher implemented both strategies to minimize the possible discrepancies in the quality of teaching. Finally, a *t*-test was conducted on the mean differences between the participants' pre-intervention similarity indices in order to understand whether the participants' prior knowledge pertaining to technology integration and the inquiry model were substantially different across the teaching strategies. The analysis of the *t*-test indicated that the groups were not significantly different in their TPACK knowledge. This analysis coincided with information gathered to examine the participants' backgrounds, education, ICT experience, and experience with inquiry.

External validity

External validity is the possibility of generalizing the findings to the entire population, time, and setting. The central concern is whether or not the sample is actually representing the entire population. In this study, the findings would not be generalizable to the entire population of science teachers. The findings would be restricted to the time, setting, and subjects of this study.

The next chapter provides an embedded data analysis of the qualitative and qualitative results in order to address the research questions and furnish a solid foundation for the final discussion. This means, the qualitative data will be examined in such a way that it provides more insight to the quantitative analysis.

CHAPTER 6. RESULTS AND ANALYSIS

The purpose of collecting the multiple data was to compare the impact of the EIM and MS strategies on developing science teachers' knowledge pertaining to TPACK, as well as to provide more insight into the conditions and situations of the learning events of the EIM and MS strategies that afford the development of science teachers' TPACK. Further, the analysis of part of the quantitative data aimed at comparing the participants' ability to apply their TPACK in planning technology-mediated inquiry-based activities. This chapter reports the results of the quantitative and qualitative data collected throughout the study, as described in the following order.

1. The results of the data collected prior to the intervention, including:
   a. the description of the demographic questionnaire
   b. the descriptive analysis of the participants' pre-intervention networks
   c. the inferential statistics of the pre-intervention similarity indices, and the *t*-test on the mean differences between the participants' pre-intervention similarity indices
2. The results of the data collected during the workshop, which includes the analysis of the implementation process and the learning events occurred during the workshops.
3. The results of the data collected post the intervention, including:
   a. the descriptive analysis of the participants' post-intervention networks
   b. the comparison between the participants' pre- and post-intervention networks
   c. the descriptive statistics of the post-intervention similarity indices, and the results of the 2 Teaching Strategy (EIM or MS) × 2 Time (pre- and post-intervention similarity indices) split-plot factorial design on the mean differences between the participants' pre- and post-intervention similarity indices (first dependent variable)

d. the analysis of the interviews transcripts

e. *t*-test on the mean differences of the participants' TIAR scores (second dependent variable)

f. correlation analysis between the dependent variables

The mixed methods data are explicated, in this chapter, in the order by which they were obtained.

6.1 Results of the data collected prior to the intervention

This section presents the results of the data gathered on the first day of the workshops and just before the beginning of the learning activities. The data were the demographic questionnaire and the participants' pre-intervention networks.

Participants' background

Before the beginning of each workshop, the participants filled out questionnaires to gather demographic information such as gender, teacher education, years of teaching experience, and grade level (Figure 12). Besides teaching sciences, a few participants were also teaching other subjects such as ESL and Math.

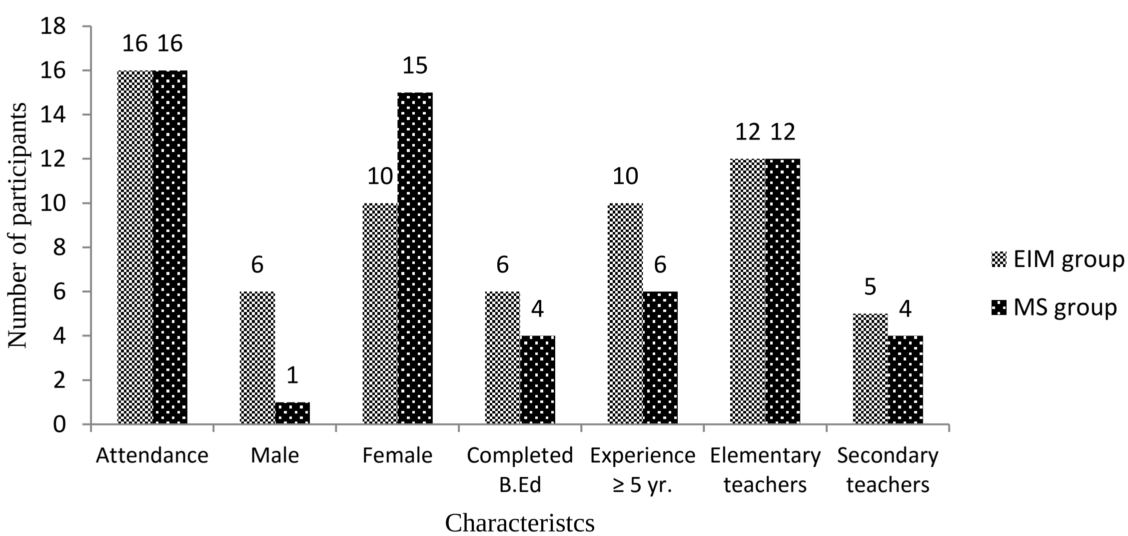


Figure 12. The characteristics of the participants in the EIM and MS groups

The participants' responses to the questionnaire indicated that their pedagogical knowledge was limited to knowledge related to a teacher-centered approach (lectures, demonstrations, and presentations). For example, when asked about inquiry learning, the vast majority of the participants, from both groups, responded that they did not use inquiry in their classrooms. They often used direct instruction, demonstration, or cookbook experiments through which students are asked to follow step-by-step procedures. Only two teachers, who learned in the EIM strategy, indicated that they had used some aspects of guided inquiry, such as asking students to investigate a problem or natural phenomenon without having the students take full control in their investigation. As well, none of the participants indicated that they had used the 5E learning cycle or PhET simulations during their teaching practice. Their technology integration was focused on Microsoft software. For example, they used Microsoft PowerPoint for demonstrations and Microsoft Excel for organizing and keeping their grade sheets. When the participants were asked whether they were familiar with the principles of electric circuits, the majority of the participants indicated that they felt comfortable with this content area. This response did not mean that they had a solid background in the principles of electricity or the construction of electric circuits. When further asked how they learned about construction of simple circuits, the participants answered differently. Some had learned about electricity from undergrad courses or formal schooling, others because it was part of their curriculum.

Participants' pre-intervention networks

The participants' pre-intervention networks were generated by the Knowledge Network Organizing Tool (KNOT) software program. There was a general trend among the participants' pre-intervention networks: The participants from both groups had fewer relevant links and more missing or irrelevant links compared to the referent network. As indicated, each network presents nine concepts related to three knowledge domains (electric circuit, 5E learning cycle, and PhET electric circuit construction simulation), and the links connect these concepts together. For example, Table 9 shows data computed from the selective pre-intervention networks of two participants, which were selected to represent this general trend. Both pre-intervention networks had seven links similar to those in the referent network, were missing 10 links, and had seven irrelevant links.

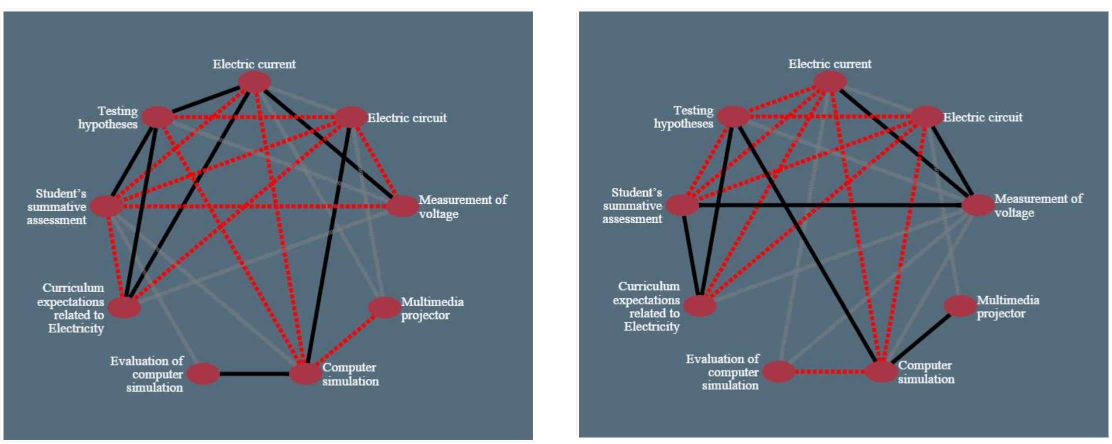
Table 9

The Data Computed from the Pre-intervention Networks of two Participants

Links relevant to the referent network	Participant # 13 (EIM group)	Participant # 15 (MS group)
	Pre-	Pre-
The number of relevant links	7	7
The number of missing links	10	10
The number of extraneous links	7	7
The similarity index	0.29	0.29

Computed from: www.conceptmapsforlearning.com

Figure 13 shows the actual representations of these pre-intervention networks. The links illustrated in red are the missing links, and those in black are links that are similar to the referent network. The links in white are irrelevant to the referent network. Although the aforementioned



a) Pre-intervention network of participant # 13 from EIM group with Similarity Index = 0.29

b) Pre-intervention network of participant # 15 from MS group with Similarity Index = 0.29

Figure 13. Pre-intervention networks of two participants with their respective similarity indices (Constructed from: www.conceptmapsforlearning.com) two pre-intervention networks were similar in terms of the number of missing and relevant links, these particular examples showed that the participants might possess different understandings of TPACK, or of TPACK subdomains. For instance, the pre-intervention network of participant # 13, who learned through EIM, had seven links related to PCK and TCK similar to those in the referent network, while participants # 15, who learned through MS, had seven links related to TPK and PCK similar to those in the referent network. This result coincided with the participants pre-intervention similarity indices, which indicated that the participants from both groups had no significant differences in their pre-intervention similarity indices.

Participants' pre-intervention similarity indices

The participants' pre-intervention networks were compared with a referent network and, accordingly, a similarity index was computed for each network. The participants' pre-intervention similarity indices were computed from the total number of common links and the total number of links in either network. Table 10 shows the mean and standard deviation of the participants' pre-intervention similarity indices, organized by groups. Table 8 shows that the participants from the EIM and MS groups, on average, had comparable pre-intervention similarity indices of (M = .29, SD = .12) and (M = .28, SD = .07) respectively. This result coincided with the *t*-test analysis of variance on the mean differences between the participants' pre-intervention similarity indices. The analysis of the independent sample t-test indicated that

Table 10
Pre-intervention Similarity Indices

	Pre-intervention Similarity Index	
	EIM	MS
Mean	.29	.28
Standard Deviation	.12	.07
N	14	13

there were no significant differences between the EIM and MS groups on the means of the pre-intervention similarity indices ($t(25) = 1.751$, $p > .05$).

6.2 Results of the data collected during the intervention

This section describes the analysis of the results of the learning processes of the EIM and MS strategies during the two days of training. The data was collected via the researcher's logbook, observation, and the participants' written documents. In the EIM strategy, these learning processes included the three sessions of the training: 1) introducing the target concepts, 2) experiencing the inquiry model (conducting an inquiry via the 5E learning cycle), and 3) analyzing the 5E activities and closure of the training. In the MS strategy, the learning process included the three parts of the EIM strategy plus metacognitive tasks (Think Aloud and Reflective Writing). Presented here are the results of the researcher's observations during these sessions of the training. These observations were gathered during the training or from the participants' written documents. The observations describe some of the participants' learning experiences, the researcher's perceptions about these experiences, the participants' written responses, and the general flow of the training.

Learning through EIM

The researcher's logbook (and the interview transcripts) indicated that the participants learned through three types of interactions without distinctive borders between them: during a) participants-instructor interaction, b) peer interaction, and c) interaction with the learning environment. However, a large portion of these learning interactions occurred during the 5E learning tasks and the discussion period. For example, the participants indicated that their interaction with the instructor was beneficial during the 5E learning activities as well as during group discussion. Although the participants had direct interaction with the instructor at the introduction phase (learning of TK, PK, and CK), they did not indicate that this was their richest moment of learning. Rather, they revealed the positive impact of experiencing the 5E learning cycle and the PhET simulation in developing their knowledge, and hence the development of their understanding of the relationship between technology, science content, and pedagogy.

During the inquiry investigation, when the participants were asked to postulate hypotheses and design their investigations, they expressed no obvious problems in completing these tasks. Upon closer observation of their work, however, the participants actually were not following the 5E phases accurately. In fact, they skipped crucial steps such as designing their own inquiry investigations. Figure 14 is a sample of participants' response before and after receiving feedback from the instructor. After receiving specific comments about how to complete the *explore* phase, the participants were able to review their works and complete the skipped steps.

A)

B)

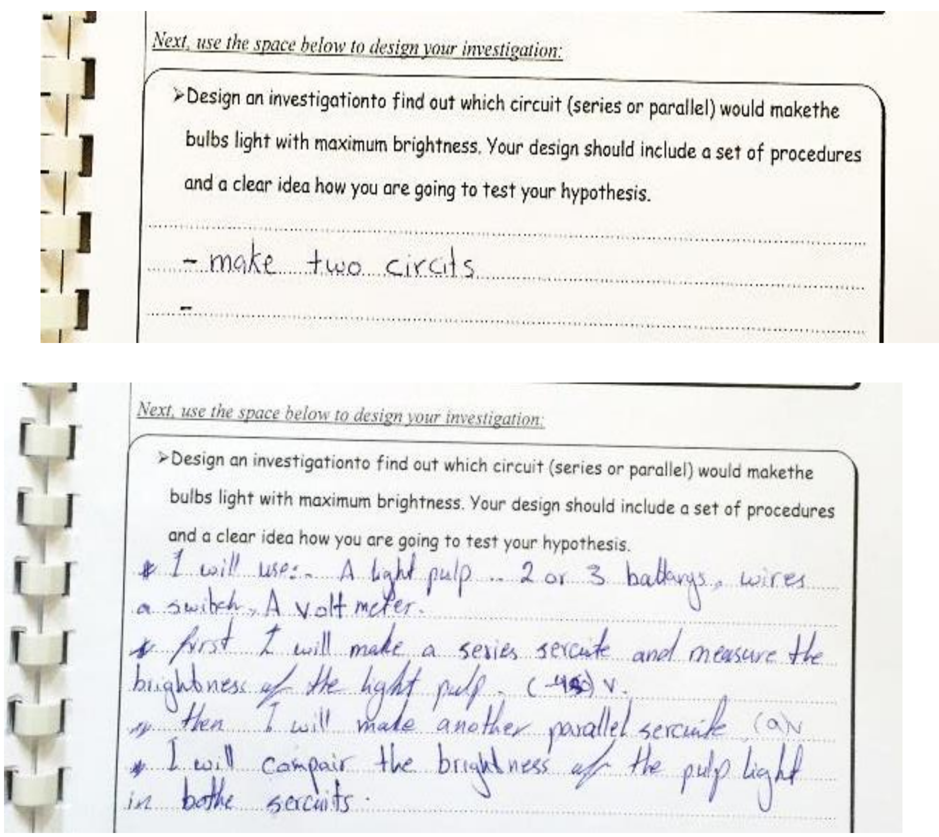


Figure 14. Sample of a participant's response: (A) before, and (B) after receiving feedback from the instructor

In this example, the participants were given opportunities to recognize not only how to accomplish pivotal aspects of inquiry tasks, but also how to guide their own students to accomplish inquiry investigations successfully. Besides, the participants showed great interest in the features of PhET simulations including, but not limited to: a) simulation of the flow of electric charges, b) replication of the brightness of the light bulbs, and c) ease of constructing the electric circuit. Some participants had gone even further in the PhET simulation and explored other features such as the use of a voltmeter and an ammeter in the circuit, the internal resistance of the battery, or changing the type of connecting wires. Learning the 5E cycle, on the other hand, raised many questions related to the five phases and how to incorporate them in science teaching. Some of these questions pertained to the possibility of shifting from a teacher-centered environment to student-centered learning. Although it was noted that the participants' pedagogical and technological knowledge sounded adequate, they seemed to have a basic understanding of the construction of electric circuits.

Further observations during the inquiry investigation revealed that some groups pushed the PhET simulation to the extreme limit and discovered some of the simulation drawbacks. Some participants were able to spot features and functions in the PhET simulation that were a disadvantage in relation to the representation of connecting wires, the flow of electrons in the circuit, and the layout of the main window (the size of the items being either too small or too big). The main concerns were related to the representation of the flow of electrons in the circuit. The simulation represents the electrons as spherical balls flowing from the negative terminal towards the positive terminal of the battery. Also, the speed of the electrons is dependent on the amount of potential applied by the battery (Figure 15).

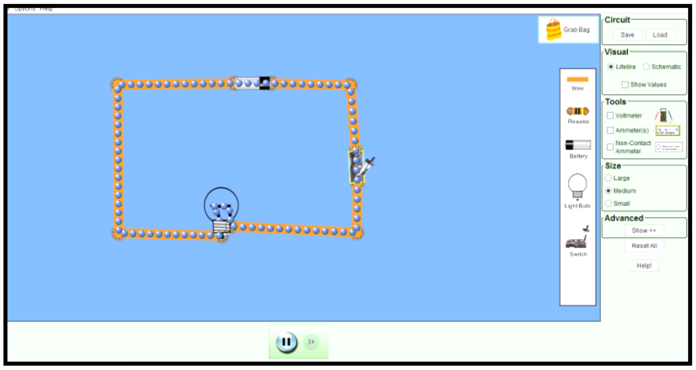


Figure 15. Screen shot of the PhET Circuit Construction Kit simulation (http://phet.colorado.edu)

During the discussion period, though, the participants indicated that the aforementioned drawbacks of the simulation would mislead the students by developing false concepts in their basic understanding of electric circuits. The participants discussed this problem and argued that the simulation should relate the potential difference to the amount of electric energy dissipated in the lamps rather than the speed of the electrons. Moreover, the representation of the electrons as spherical balls flowing at observable speeds would falsely represent the behavior of elementary particles at an atomic scale. Another group discussed their experience with the simulation. They argued that the brightness of the lamps remained the same regardless of the type of connection. When they discussed their findings with the class, they realized that during the experiment, they set the internal resistance of the battery to an infinitesimally small value. Thus the battery allowed very high current to flow. In this case, the lamps that were connected in series or parallel both lit with maximum brightness.

During group discussion, the participants discussed whether the PhET simulation is appropriate for teaching their own students within a 5E framework. The first group talked about the effectiveness of the PhET simulation for teachers and students. For teachers, they described the effectiveness of the simulation in facilitating the teaching process. For students, the simulation would support a student-centered environment. The group elaborated on the latter point and argued that their students would be able to learn science more actively while designing and conducting investigations, collecting and analyzing data, and testing hypotheses. Another group discussed the impact of the PhET simulation in developing students' operational skills. Consequently, at the end of the group discussion, the participants attempted to focus on the effectiveness of PhET in implementing the 5E learning cycle, as well as in enhancing students' understanding of electric circuits. The participants were able to spot the advantages and disadvantages of the PhET simulation.

Whether it was a failure or a success, the participants identified potential benefits and drawbacks of the PhET simulation, and analyzed these potential benefits and disadvantages in order to identify the lessons learned. They realized that technology is not always perfect. Therefore, teachers need to be very cautious before utilizing technologies in the classroom. They should present technologies that best serve the curriculum objectives and present scientific concepts as accurately as possible.

To conclude, the EIM strategy was implemented in a learning environment that emphasized a situated educational context (i.e., the 5E learning activities) through which the participants could construct their knowledge individually or socially. The participants were explicitly guided (by the instructor) to accomplish a sequence of activities bounded to the situated context. The next subsection describe the learning occurred in the MS strategy, as observed by the researcher.

Learning through MS

The participants in the MS strategy were explicitly guided to accomplish a sequence of metacognitive activities before and after the same cognitive tasks experienced by the participants in EIM strategy. Accordingly, it can be assumed that learning occurred during both cognitive and metacognitive activities.

At the beginning of any learning task, the participants were asked to complete the Think Aloud task in order to setup their learning goals and plan for their upcoming learning events. Although there were learning resources (i.e., the desktop computers, the online resources, and the hands-on activities) available at the participants' disposal, they were not obligated to use these resources. In fact they were able to choose whatever resources that they believe they would best help them to achieve their personal objectives. Through the observation, a number of participants brought their smart devices and had access to the Internet, therefore each of which had taken different approach to learnung. For example, in the first session (the Introduction), it was observed that there were participants who were interested in learning more about the 5E learning cycle. They posed questions about what the inquiry learning entails, what 5E consists of, how it works in the classroom, is it appropriate for their students or not, etc. These participants used different resources including their own cell phones to search for information related to 5E. They retrieved relevant articles and posed even more questions about the 5E phases and the lines that separate these phases from each other. More specifically, they asked the instructor about the difference between the *Explain* and *Elaborate* phases, and how the *Evaluate* phase was conducted. During this session, the participants received a few instructions regarding the key concepts of the training (the 5E learning cycle, the electric circuits, and the PhET simulation), but for the rest of the time they were learning in their own paces. Finally, before the end of the first session, the participants completed the Reflective Journal Checklist. They were asked to write a short reflection in each of the following areas:

- Now, I understand about…

- But, I am still puzzled by…
- How effective has my plan been in working and completing the previous task?
- My strengths / weaknesses are…

Table (11) shows some of the MS participants' reflective writing, noted from their Learner's Guides, page 11.

Table 11

A Sample of the Participants' Responses to their Reflective Writing

Participant's Code	Now, I understand about:	But, I am still puzzled by:	How effective has my plan been?	My strengths / weaknesses are:
A1	"The existence of computer simulation that aids in learning process [like that]"	"[the] 5E learning [cycle] is still ambiguous for me"	"I should have asked the instructor more questions about the 5E learning process"	"Strengths: quickly adapted to the PhET simulation. Weaknesses: I worked in the simulation more than in the 5E learning cycle"
A2	"The simulation, how easy it was, how many things students can experiment and learning with"	[no responses]	"not bad"	"My strength: I was able to utilize the simulation successfully. My weakness: I was unfamiliar with the computer"
A5	"The computer simulation of the PhET and I know how I can use it"	"[using] the simulation [with] my students, [and using it] without needing more lessons"	"The plan was effective"	"My strengths: now I know how to use the simulation, my weaknesses are: I need to know/decide how to design effective lessons with the simulation"

In the second session, the participants conducted an inquiry into the properties and characteristics of series and parallel circuits. They used the PhET Circuit Construction Tool simulation and the 5E learning cycle to complete their investigation. Initially, they were asked to use the Think Aloud template to set learning goals. It was observed that the majority of the participants were driven by the content. As indicated in their Learner's Guides, they showed more interest in developing scientific knowledge related to: a) the "difference between series and parallel connections" and how to construct them, b) "how electric current and voltage are related" in electric circuits, c) the effect of the internal resistance of the battery on the flow of current, and d) the "applications of series and parallel" circuits. A small number of the participants set their learning goals in another direction. There were goals to understand the interrelationships between two of the following domains: the PhET simulation and how it works, electric circuits and their applications, or the 5E learning cycle. For instance, a participant wrote in his/her Think Aloud chart, in the Learner's Guide (p.15), that they wanted to "learn how to use PhET simulation to connect an electric circuit using bulbs and connecting wires" because "it will help me in teaching." Furthermore, the participants' responses on their Learner's Guides showed that they were able to reflect on their own learning (after experiencing the inquiry model via the 5E learning cycle) independently. For example, a participant described her/his current understanding as: "[I learned about the] 5E learning cycle and how to engage students and let them guide themselves to [gain better] understanding." Also, she/he said: "[But, I am still puzzled by] how to apply it [5E] in each class with different topics and grades." Further, he/she reflected on her/his learning course as being effective because "in a short period of time, I obtained a plenty of information." So one of their strengths, she/he added, was "time management." By the end of the second session, the participants were required to analyze their experiences with the inquiry learning and exploring different avenues for science instruction.

In the third session and prior to analyzing the 5E learning activities, the participants were asked to set up their learning goals for the session. Table 12 shows a sample of the participants' responses when they were asked, during the discussion period: "What would I like to learn?" "Why do I want to learn it?" and "How would I learn it?" It is noted that, the participants set their plan not only for the upcoming discussion period and analysis, but also for their ongoing learning progress after the workshop. However, some participants could not set clear learning objectives, nor state the rationale for choosing these objectives.

Table 12

A Sample of the Participants' Responses to Think Aloud (Learner's Guide - MS, p.28)

Participant's Code	What would I like to learn from the discussion period?	Why do I want to learn it?	How will I learn it?
A1	"I would like to learn more about the 5E cycle"	"To facilitate communication with my students"	"Through more discussion with my instructor and peers" "I will use the resources provided"
A3	"I would like to learn how to apply 5E in its simplest way in order to make it easy for my students"	"I want to learn it to build up a certain framework for teaching science in order to facilitate [students'] learning"	"I will try to apply part of each stage in a simple way. (Making my own model)"
A6	"How to apply the 5E learning cycle"	"It's interesting to try a new method in classroom different than what we used to do"	"searching on the Internet…asking questions…discuss it with the teachers [to get] different point of views"
A8	"How to analyze the results"	"…to check how my plan works"	"use measurements, calibration, and observation"

During this discussion period, it is noted that the participants valued learning science through inquiry and with computer simulation. In particular, they were interested in the utilization of the PhET simulation for hypotheses testing, and experiencing the fact that their hypotheses could be accepted or rejected by the empirical evidence. Along with these positive impressions of PhET, some participants spotted potential drawbacks to the simulation. When they analyzed the potential disadvantages of the simulation, they found that some of the PhET features were less helpful. Such features included: the layout of the main window, more control buttons were needed like drag and drop, and that the simulation should include a Rheostat to vary the potential or resistance of the circuit. Despite this, 80% of the participants' responses of the post-intervention task reflective writing indicated that they were still unclear about what TPACK was all about. For instance, when asked: Do you understand what is meant by TPACK? a participant said: "I have a topic and I decide the technological method to explain it." Other participants were completely off in their understanding of TPACK, saying: “It is the use of technology on teaching,” or “How to learn by using technology.” There were, however, examples where the participants had good explanations of TPACK, such as: “It’s the relationship between science, technology and the tools for teaching science,” “It’s the connection between technology, teaching methods, and science,” or “It’s the framework that links the uses of technology to help in attaining high quality of teaching.” On the other hand, when the participants were asked to reflect on their understanding of simpler concepts (e.g., features of the PhET simulation, benefits of 5E learning cycle, and visual representation of electric circuits), they responded clearly and with appropriate terminologies. For example, they responded to the phrase: I understand the rationale for implementing technology to clarify scientific concepts as the abilities of technology to “make students visualizing concepts”.

Unlike their perception of TPACK, when they were asked to reflect on their instructional experience, they responded with more confidence. In fact, the reflective writing encouraged them to think about their students, class context, and consequently, their planning choice of technology-based activities. For example, when asked: What are the challenges in the planning you might face? a group of participants (five teachers) agreed on some common challenges such as:

- “where and when” in the science curriculum “technology becomes beneficial” to use
- “lack of resources such as the computers and Internet connection”
- “time constrain,” especially with their “busy yearly plan”

They addressed these issues in different ways. While some participants decided to “take more time to analyze the features of the technology” against the pedagogical goals, others said they would “use alternative resources” when technology fails. More interestingly, some participants thought about "checking all my [their] needs before planning for the lessons," giving "the students opportunities to work online if the school couldn't provide the required resources," or "considering the students' interests" as a selection criterion. Table 13 shows a sample of the

Table 13

A Sample of the Participants' Responses in their Final Reflective Writing

Code	What is your strategy for designing technology-mediated inquiry-based activities?	What challenges might there be in planning technology-based instruction?	What do you think your plan would be to overcome these challenges?
A1	"Use the [available] simulations, supported by designed questions, assignments, and guidelines	"…where and when during the school year I should present a plan to fill the gaps in my students' understanding or learning"	"use available simulations that are supported by questions, assignments, and guidance….Also, I have to run the simulation before the students and then make my decision"
A2	"look for simulations that come with their activities and learning objectives"	"Choosing the appropriate technology that make my teaching easier and clarify the subject matter"	"I have to learn more about different types of technologies…choose which one is better for me to implement…choose the one that motivate my students…select the one that best simulates the natural phenomena"
A4	"Plan, test, and choose which activity is suitable for which group and which topic"	"lack of resources (facilities, computers, Internet, etc.)…the complexity of the subject matter"	"if I can't find the suitable technology, I should look for what resources I have in my school. Try to use these resources to design activities that are suitable for my students and the science topic"
A9	"it depends on the students' backgrounds"	"Time constraints…culture of learning"	"during planning, consider students' background, interests, and expected actions or behavior"

participants' final reflective writing, when they were asked: What is your strategy for designing technology-mediated inquiry-based activities? What challenges might there be in planning technology-based instruction? and What do you think your plan would be to overcome these challenges? Thereby, the participants completed their three sessions of the training. The next section presents the results of the data collected after the third session and the last day of the training.

6.3 Results of the data collected after the intervention

This section presents the results of the data gathered on the last day of the workshops. The data were the participants' post-intervention networks and pre-intervention similarity indices, TIAR scores, and the focus group interviews. These results are given in the following subsections.

Participants' post-intervention networks

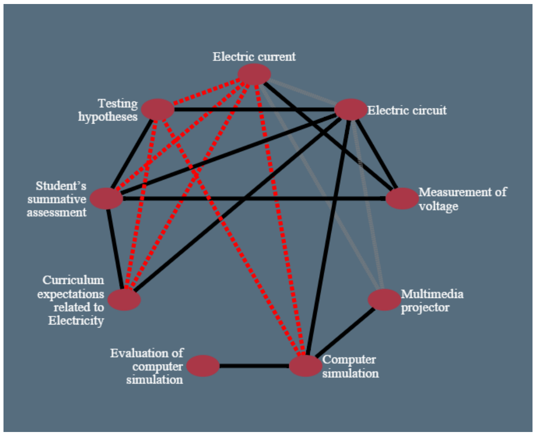
An examination of the participants' post-intervention networks indicated that there was a general trend. The participants who learned in EIM had more relevant links than their MS counterparts when compared to the referent network. Table 14 shows the data computed from two post-intervention networks to exemplify this trend.

Table 14
The Data Computed from the Post-intervention Networks of two Participants

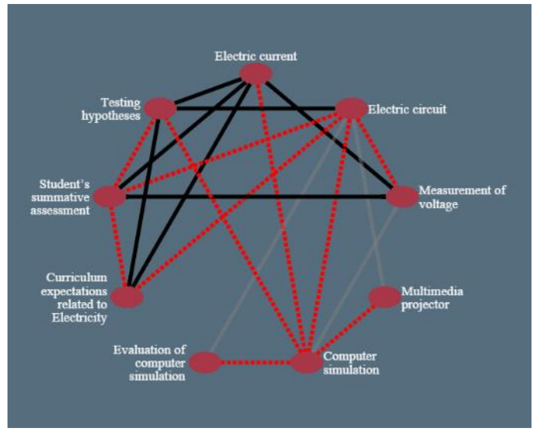
Links relevant to the referent network	Participant # 13 (EIM group)	Participant # 15 (MS group)
	Post-	Post-
The number of relevant links	11	7
The number of missing links	6	10
The number of extraneous links	3	3
The similarity index	0.55	0.35

Computed from: www.conceptmapsforlearning.com

After exposure to the EIM strategy, the post-intervention network of participant # 13 had 11 similar links, six missing links, and only three irrelevant links. Whereas the participant # 15, who learned through MS, had seven similar links, 10 missing links, and three irrelevant links. Figure 16 shows the actual representations of these post-intervention networks. The 11 relevant links in the post-intervention network of participant # 13 were related to PCK and TCK, while participants # 15 had seven relevant links related to PCK only. Although the post-intervention networks were similar in the number of irrelevant links, the participant who learned in MS had seven more missing links than the one who learned in EIM. These results also matched the descriptive statistics of the participants' post-intervention similarity indices.



a) Post-intervention network of participant # 13 from EIM group with Similarity Index = 0.55



b) Post-intervention network of participant # 15 from MS group with Similarity Index = 0.35

Figure 16. Post-intervention networks of two participants with their respective similarity indices (Constructed from: www.conceptmapsforlearning.com)

Comparison between the participants' pre- and post-intervention networks

The participants' networks, from both groups, showed that there was improvement in establishing direct links between various concepts related to 5E, the PhET simulation, and the construction of electricity. In fact, the participants' networks showed that there were specific direct links developed, and that these links described the participants' understanding of TPACK subdomains such as TPK, TCK, and PCK. Nevertheless, the direct links that would entail TPACK as a whole were missing. This trend was observed consistently throughout the data set from both groups. For example, Figure 17 shows the pre-intervention network of an EIM participant. The pre-intervention network shows the missing links describing the interrelationships between technology-pedagogy, technology-content matter, and pedagogy-content matter (as indicated in broken red lines). The post-intervention network of the same EIM participant (Figure 18) shows that these missing links are significantly reduced and replaced by

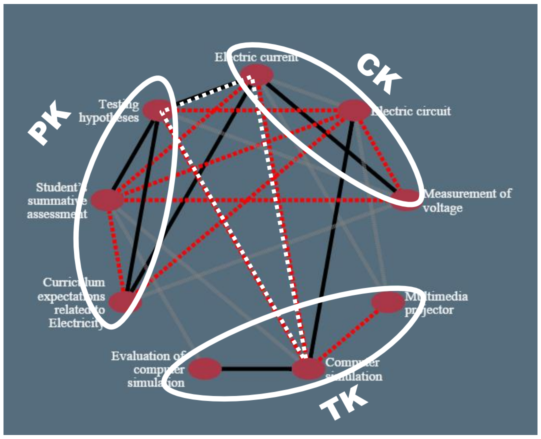


Figure 17. Pre-intervention network of an EIM participant indicating the missing links (broken red lines)

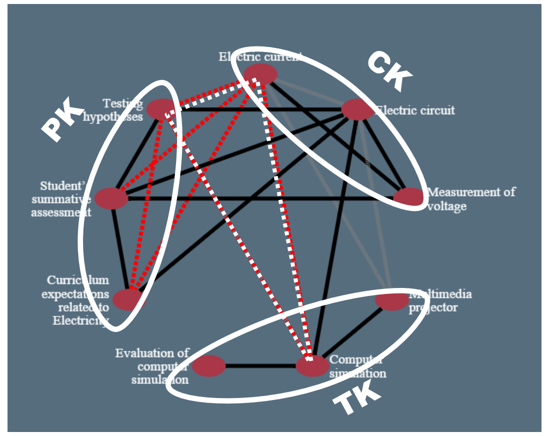


Figure 18. Post-intervention network of an EIM participant indicating the missing links (broken red lines)

direct links that describe the participant's TPK, TCK, and PCK only. However, the direct links that entail TPACK as a whole (as viewed by the white triangle) are still incomplete. The analysis of the pathfinder networks clearly showed the participants' knowledge gaps, but this analysis could not indicate whether there were any significant differences between the pre- and post-intervention networks. These findings bring the analysis of the participants' pre- and post-intervention similarity indices to the fore.

Comparison between the participants' pre- and post-intervention similarity indices

Table 15 shows the mean and standard deviation of the participants' post-intervention similarity indices, organized by group. It also shows that the participants from the EIM group, on average, had post-intervention similarity indices (M = .36, SD = .113) greater than those of the participants from the MS group (M = .32, SD = .114).

Table 15
Descriptive Statistics of the Post-intervention similarity Indices

	Post-intervention Similarity Index	
	EIM	MS
Mean	.36	.32
Standard Deviation	.113	.114
N	14	13

The descriptive statistics of the participants' pre- and post-intervention similarity indices indicated that the participants from both groups, on average, had post-intervention similarity indices higher than their indices before the intervention. Nevertheless, the participants who learned through EIM, on average, had higher post-intervention similarity indices (0.36) than their counterparts from MS (0.32). Although the pre-intervention networks of both participants looked similar in terms of the number of missing and relevant links, the post-intervention network of the participant who learned through EIM showed more relevant links than the participants who learned through the MS strategy. Consequently, as shown in Figure 19, the participants from the EIM group were able to improve their network structure, as compared to the experts' network, slightly better than the MS group. The descriptive statistics of the pre- and post-intervention similarity indices show that the participants from both the EIM and MS strategies improved their networks after the intervention. Although the participants who learned through the EIM strategy had post-intervention networks closely similar to the referent network than their counterparts from the MS strategy, this difference was not statistically significant.

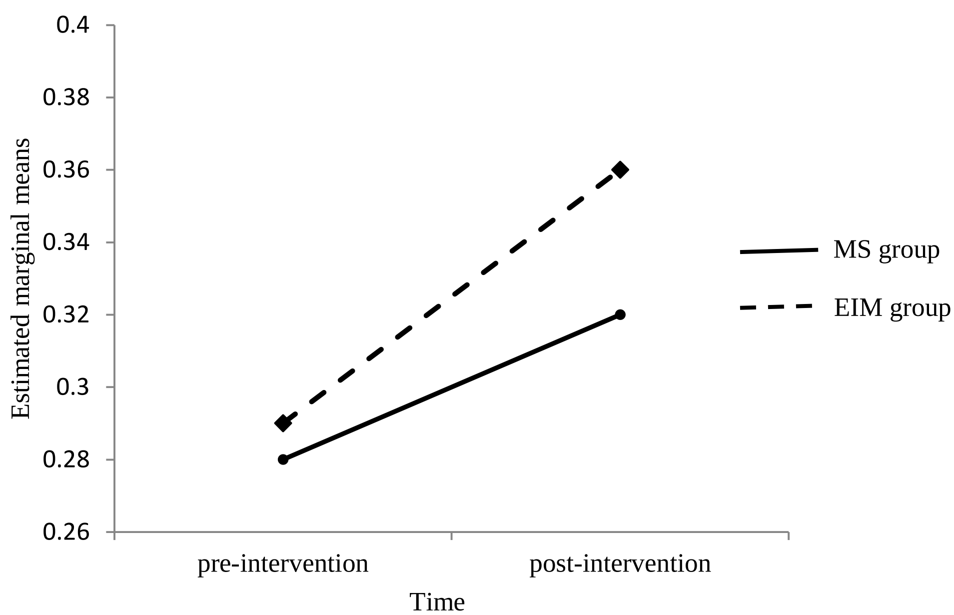


Figure 19. Estimated marginal means of pre- and post-intervention similarity indices for EIM and MS groups.

The 2 Teaching Strategy (EIM or MS) × 2 Time (pre- and post-intervention similarity indices) split-plot factorial design was conducted on the mean differences between the participants' pre- and post-intervention similarity indices, with participants' similarity indices (dependent variable) and teaching strategies (independent variable). The analysis of variance was conducted to study the interaction effect of the 2 Teaching Strategies (EIM and MS) × 2 Times (pre- and post-intervention similarity indices), and the main factor effect, that is, the effect of the variables independent from each other. The results, as shown in Table 16, indicate that there was no significant interaction, which means that the development of participants' TPACK was independent of the type of strategy used for the training ($F(1,24) = .496$, $p > .05$). Nevertheless, the inferential statistics show that the participants from both groups had significantly developed TPACK, as compared to the referent network between the pre- and post- intervention, ($F(1,24) = 24.669$, $p < .05$).

Table 16
Split-Plot Analysis of Variance on the Similarity Indices (the First Dependent Variable)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
		Between subjects			
Intercept	.166	1	.166	24.669	.000
Teaching Strategy	.003	1	.003	$.496^{*}$	.488
Error	.161	24	.007		
		Within subjects			
Time (pre- and post)	.166	1	.166	24.669^{**}	0.000
Teaching Strategy × Time	.003	1	.003	$.496^{***}$	.488
Error (time)	.161	24	.007		

$^{*}p < .05$, $^{**}p < .05$, $p^{***} < .05$

Focus group interviews

The analysis of the focus group interviews identified four categories that could be one of the ways to describe the implementation of the strategies, and understand the development of the participants' knowledge, performances, and behaviors during the intervention (e.g., answering the research questions). The categories are:

- the participants' general perceptions of the experiencing inquiry model
- the participants' general perceptions of metacognition (for MS strategy only)
- the impact of the interventions (EIM and MS) in developing of the participants' knowledge, and
- the participants' opinions on the teachers' competencies necessary for technology integration in science.

<u>Experiencing inquiry model</u>

In the interviews, the participants discussed the features of inquiry model, including the importance of: participating in scientific practices such as asking questions, deciding what to measure, developing measurements, collecting data from measures, structuring the data, interpreting and evaluating the data, and using the empirical results to develop and refine models. The participants also seemed to recognize the importance of helping students develop, test, and evaluate their ideas with technology.

When the participants, in the EIM strategy, were asked "Which part of the EIM strategy helped you learn the most?" their reactions were quite consistent. One participant said, "the 5E part of the workshop is the part where I learned the most." Another participant said, "The experiment [*explore* phase]…[it is] the time when we did the experiment. [It] was a learning curve for me." Similar comments were recorded. For example, when asked about why the participants think the 5E activities were meaningful to them, a participant said, "It is meaningful for me because I learned a method of teaching science…method of teaching electric circuit with computer simulation…this way is so effective." Another participant added: "I think 5E is effective for both, teachers and students….For example, students aren't told anything about electric circuit. They made their observations, conduct their experiment, and saw the results of their experiment in real time." When the participants were asked in what ways the 5E activities were beneficial for their learning, they responded in a similar way, such as the following response:

> I like the way how electric circuits were introduced and then allowed us to do some experiments to construct our own circuits using computer simulation. This is a good method of teaching electric circuits….At first when I did the pre-intervention test I said there is no relationship between electric circuit and measurement of voltage…but in the post-intervention test I changed my mind with regard to the relationship, and I have given some explanations to my choice.

In addition, the learning opportunities offered during the 5E activities were associated with effective guidance. The role of the instructor was acknowledged by the participants not only as enhancing their own learning, but also as a model for teaching. Along these lines, a participant appreciated the guidance he/she had, saying:

> I really benefited from the role of teacher [instructor]…especially the role of teacher as a facilitator [during the 5E tasks] this is more beneficial for me to learn how to run an inquiry with my students….Also, I agree with my colleagues regarding the fact that conducting an experiment [explore phase] is one of the most interesting part. Because in a normal science classroom we usually make demonstrations to natural phenomena and we ask our students to take notes or watch what we do.

Besides the guidance and 5E learning activities, other parts of the EIM strategy afforded opportunities to develop teachers' knowledge. A few participants (two participants) referred to the third part of the training (i.e., analyzing the 5E learning activities). For example, one participant said:

> I think the most important part of the workshop is analyzing the 5E tasks…and relating so many things that we have learned in the workshop to things we are already know and practice every day….So applying and analyzing what we have learned in the workshop is the most important part.

Similarly, when the participants in the MS strategy were asked: Which part of the MS strategy helped you learn the most? their reactions were also consistent. One participant said: "What I have learned the most actually is about the 5E learning cycle." Another participant said:

> I think the 5E cycle is very interesting…and get to know it through doing it and experiencing it is very helpful too. I could tell what are the challenges, advantages, ways to manage, and students' feelings, teacher loads and pressure, planning required for such methods…and every aspect of it….I mean experiencing the 5Es as such is way better than giving us a demonstration or a lecture about it.

Similar comments were received when the participants were asked: In what way were the 5E activities beneficial for your learning? Their responses included the following:

> Although I used some aspects of the learning cycle [in my teaching], but here I clarified my understanding of how teacher would facilitate the 5 stages and how students can progress through…this definitely will improve my way of teaching.

and

> I learned how to teach science through investigations [inquiry]…we made a hypothesis, and then we designed an experiment to test this hypothesis…and then we verified our findings….Actually, my hypothesis was rejected. And that was something new for me about the properties of series and parallel circuits.

Many participants referred to the fact that the MS strategy allowed them to learn in an environment that was very similar to a classroom context. They conducted an investigation similar to that conducted with Grade 6 students. Also, some participants valued the discussion period because they had opportunities to interact with experienced teachers for more clarification:

> The discussion part was very useful, because I learned from other discussant who are more experienced than me…so when I listen to them I immediately tail this to different things…and when it came to the reflecting part [Reflective Writing] I always think how I'm going to plan for my lesson…and how I prepare myself in case of failure…so I become aware of not only the uses of technology but also how to overcome any challenges associated with likely failure.

When asked: Which part of the MS strategy influenced your learning the most? one participant said: “Discussion period,” and when asked: In which way? he/she said:

> I have learned a lot and I connected what you have said about the TPACK. So what I learned today from other teachers and from you as an instructor of this training. So this is the most beneficial part for me.

Generally, there was a common agreement among all participants that the 5E learning activities were the most interesting part of the training. Figure 20 shows the perceptions of EIM and MS participants relevant to the parts of the training that influenced their learning the most.

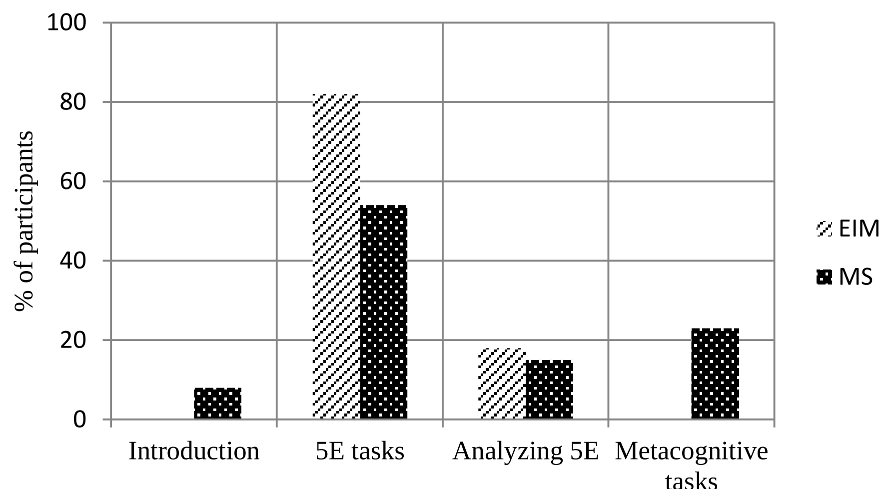


Figure 20. Participants' responses when asked: What part of the workshop influenced your learning the most?

<u>Learning through metacognition</u>

Further evidence showed that the participants, in the MS strategy, perceived learning through metacognition. A number of participants, in the MS strategy, acknowledged the fact that Think Aloud helped them in planning for learning. “In fact [during the training, my] planning for learning was always in my mind…whenever I’m up to something or a task I always tend to act in favor of my agenda. So, Think Aloud worked as guidance for me.” Other participants indicated that Think Aloud was helpful because it helped them to focus on their learning objectives, as well as to organize their learning course ahead of time. The participants "had to plan together as a group, and [they] had to make a learning strategy for the next tasks." Therefore, they could "analyze the information…and put it down on paper in that way…so we got to organize our learning ahead of time." Also, Think Aloud provided opportunity for them to develop an awareness of the advantages of utilizing computer technology for their students, not only in science classrooms but also in other subjects. "Due to my planning part…I realized how technology is useful for learning science and English as well." Nevertheless, some participants raised issues regarding the structure of the Think Aloud strategy, such as a) the whole idea of planning for learning was confusing, b) there were "so many details that were not included," and c) Think Aloud was not well-connected with the upcoming tasks. In this regard, a participant said:

> …until we talked about the planning [Think Aloud] the picture was not clear for me. I think we should have more time to clarify it and connect it to what is coming next…this way we haven't had complete planning, because our planning should include all the upcoming tasks. So anything we did during the task should be done according to our plan. But when we plan for our learning…still I believe my plan did not help me a lot….I think we should have worked with more detailed plan.

The participants acknowledged the fact that planning ahead was useful and helped them in setting clear objectives, but their plans were not effective because they lacked details about the next activities. Unlike Think Aloud, the second metacognitive task – Reflective Journal Checklist – was less controversial.

It is important to highlight that the participants, in the MS strategy, indicated that reflective writing helped them in "finding out whether we [they] are on track or need to adjust our [their] work for better achievement." Reflective writing also helped them to recognize where their learning fell short, which encouraged them to spend more time bridging these knowledge gaps.

> I believe reflective writing was important too….As I told you earlier, when we put our plans on the paper…things become more easier to monitor…and more organized….Now you can understand that

> sometimes there is a defect in my learning plan that I need to fix…so the reflection gives me a chance to fix these defects.

Another result of reflective writing was increased confidence and self-esteem. Indeed, a participant expressed her satisfaction when she had gone through the reflective writing successfully. As a consequence, she realized how much she learned from the precedent activities, saying:

> While doing the experiments [5E learning tasks] I thought I have done nothing and understood nothing…but in the reflection part…I realized how much knowledge I got and how much knowledge I need to know. …so the opinion here I believe I have something in my mind.

Reflective writing also gave opportunity for the participants to realize the potentials of PhET simulations not only in the present context, but they could also imagine how PhET could be useful for other subjects such as Biology. Here is what one participant said:

> Other things….I thought it [the workshop] is unrelated to my field….I'm a biology teacher. Later on I discovered that I can apply it….For example, I can apply it in demonstrating the respiratory system….I can use technology to simulate the mechanism of the respiratory system, so students can know how it works. When students visualize everything, they learn better than presenting a drawing or a diagram. I found the animation is helpful for teaching and learning of science. So I could make a connection between biology subject and computer simulation.

To conclude, the participants had different perceptions about the roles of the metacognitive tasks, especially the roles of the Think Aloud task. However, the reflective writing, according to the participants, was helpful in monitoring one's learning and increasing confidence and self-esteem. The next subsection describes the impact of the interventions (the EIM and MS strategies) on the participants' knowledge, as revealed by their interview responses.

<u>The development of the participants' knowledge</u>

The interview transcripts showed strong evidence that the participants developed an adequate understanding of the relationships between the 5E learning cycle (PK), the electric circuits (CK), and the PhET simulation (TK). Despite this the participants did not express a deeper understanding of the pedagogical necessities of technology as embodied by the TPACK framework.

Through the interviews of the participants in EIM, some evidence showed their understanding of some aspects of PCK. For example, a participant said: “When I teach science content, I have to look at the method of teaching this content….I can’t isolate these two things [domains] from each other.” As well, the participants indicated that the active engagement in the inquiry model allow students to develop a better understanding of science as compared to memorizing concepts and definitions and spending less time exploring science.

> This way [inquiry method], I don’t think students will forget what they have learned, unlike traditional teaching where students make notes while their teacher explain the concepts on the blackboard. This kind of teaching allows students to learn science more actively, rather than being passive.

When another participant was asked how one benefits from inquiry learning, s/he said:

> For both, teachers and students…(pause) in this experiment, learners aren’t told anything about electric circuit; they made their observations and saw the results of their experiment in real time.

Besides the evidence of developing PCK, therefore further evidence that indicated even richer learning opportunities that allowed the participants, in the EIM strategy, to develop other TPACK subdomains (i.e., TCK). For instance, when the participants utilized the PhET simulation to conduct the inquiry investigation, they developed a rationale for using the simulation to learn about the properties of series and parallel circuits. For example, one participant said, “I think PhET tool is very impressive….I made a hypothesis and when I tested it I got different answer….I think I learned something new about electric circuits. So I find PhET is a fast…simple…and easy to operate…you can run the simulation over and over.” In spite of some technical difficulties, the participants were able to use the PhET simulation to construct series and parallel connections, and find out what types of circuits would light all bulbs with maximum brightness, regardless of their number. The participants recognized the differences between the series and parallel circuits in different ways. Some groups hypothesized that lamps connected in series circuits would light brighter regardless of their number, and when they tested their hypothesis, they found it was not supported. This enterprise helped the participants in developing content knowledge related to the properties of series and parallel circuits as presented by the PhET computer simulation. A participant indicted that:

> In our formal schooling we learned about the electric circuits…we saw simple demonstration of the construction of electric circuit. That is connecting a wire with a battery…and then the bulb lit. But in today's experiment, it is so exciting to visualize the flow of electrons…even the electric bulb…the brightness of the electric bulb can be visualized.

The analysis of the interview transcripts indicated that the participants, in the MS strategy, appreciated the knowledge and experience gained during the 5E learning activities. Participants developed different knowledge domains including, but not limited to: content knowledge, pedagogical knowledge, pedagogical technological knowledge, and technological content knowledge. For example, when asked what they had learned from the workshop, a participant said:

> I think doing experiments in science is very important…but it needs lots of planning….I already have good understanding of electricity….I work on too many electrical things at home….So that was the practical part…here in this workshop….I learned more about the science of electric circuits and electricity.

Another participant said:

> What I have learned the most actually is about the 5E learning cycle. Although I used some aspects of the learning cycle, but here I clarified my understanding of how teacher would facilitate the 5 stages and how students can progress through…this definitely will improve my way of teaching.

In the above responses, the MS participants touched on their pedagogical knowledge (PK). They described how inquiry teaching is important for engaging their students in active learning. This seemed to be a major shift from their comfort zone, considering the fact that most of the participants did not use inquiry in their teaching. They had been much more comfortable with teacher-centered instruction. During the interviews, other participants expressed their understanding of the interrelationship between technology and pedagogy (TPK). For example, a participant responded as follows when asked about what he/she had learned during the workshop:

> I think when you applied the 5E learning cycle I understand that sometimes we need to hold back and let the students lead…because in our teaching we often don't offer opportunities to students to express their learning more fully….But know we learned that students should be given the chance to learn actively…and obviously…technology helps in this regard…same like what we did…each one of us had a chance to work on a computer and learn independently.

To summarize, the evidence gathered from the participants' interviews indicated that, in general, the participants from both strategies developed knowledge related to PCK, TPK, and TCK to various degrees. Despite this the participants did not express a deeper understanding of the dynamic interplay of the technological, pedagogical, content knowledge. The next subsection provides more insights into the participants' perceptions about the teacher's knowledge necessary for technology integration.

Teacher's knowledge necessary for technology integration

During the interviews, the participants were asked: what type of teacher's knowledge is deemed necessary for technology integration? The general perception of the participants was centered on technology-related knowledge (Figure 21). For example, 45% of the participants in MS referred to one of the basic components of TPACK (i.e., TK, PK, CK) as the most important knowledge. 27% referred to TPK and 28% referred to TCK as important subdomains domains for effective integration of ICT. No one indicated that PCK or TPACK are domains of

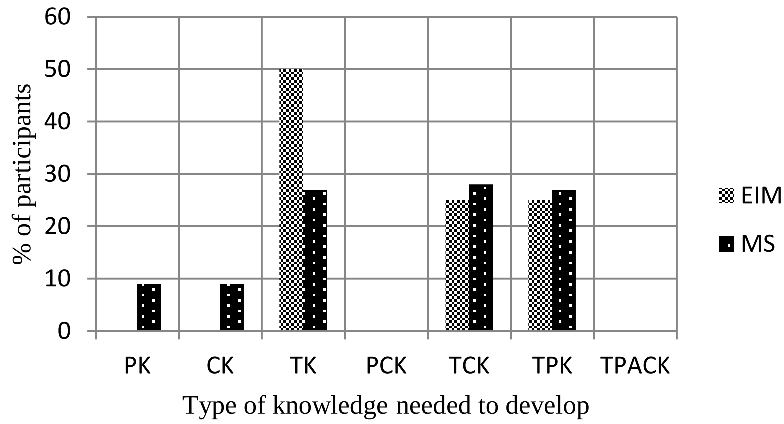


Figure 21. Participants' responses when asked: what types of teacher's knowledge deemed necessary for technology integration?

knowledge necessary for technology integration. In contrast, 50% of the participants in EIM acknowledged the importance of technological knowledge such as recognizing the features and functions of computer programs, being "able to cyber on the Internet", and being "able to operate computer software programs". 25% of participants in EIM referred to the knowledge that takes into account the content or pedagogical uses of technology (i.e., TCK or TPK, respectively). In this regard, the interviews responses suggested that there is a consensus among the participants to value specific subdomains (TK, TCK and TPK) as the knowledge deemed necessary for technology integration.

TIAR scores

As described in Chapter 5, the Technology Integrated Assessment Rubric (TIAR) was used to measure the participants' ability to take into account the pedagogical and content uses of technology to inform the planning of technology-mediated inquiry-based activities. The participants from EIM and MS completed a task of planning learning activities that focused on technology integration in four areas that are expected to indicate:

1. the selection of technology, instructional strategy, and target curriculum goals and objectives
2. the rationale for selecting technology to meet the curriculum objectives

3. the rationale for selecting technology to meet the instructional goals
4. the overall rationale for selecting technology and instructional strategy to meet the curriculum objectives

The descriptive and inferential statistics of the TIAR scores are described below.

Descriptive statistics of TIAR scores

The means of the participants' TIAR scores were 9.3 and 7.3 for MS and EIM, respectively. Figure 22 shows the breakdown of the scores as related to the assessment criteria, which are: curriculum goals and technology, instructional goals and technology, compatibility with curriculum goals and instruction, and the "fit" of technology pedagogy and content

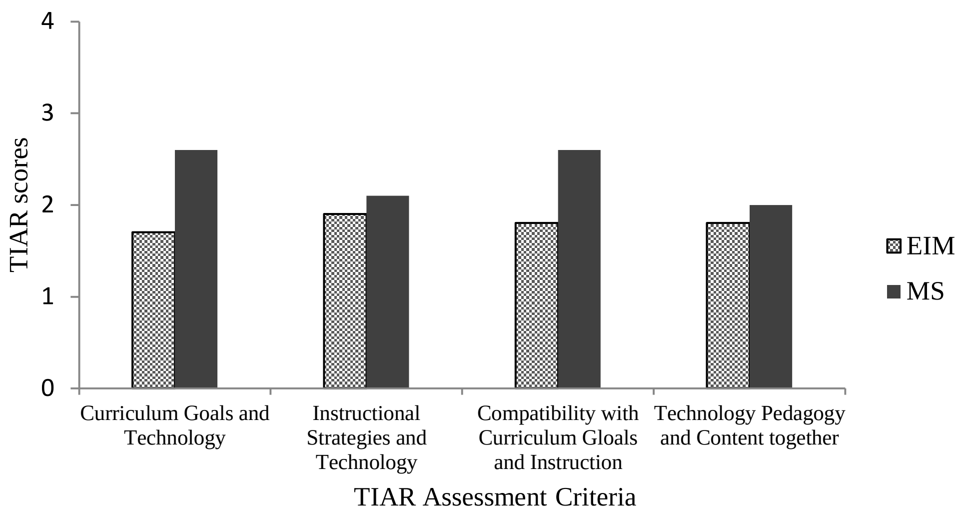


Figure 22. The TIAR mean scores across the four assessment areas

together. The descriptive statistics of the TIAR scores show that the participants who learned through the MS strategy, on average, had higher scores in the overall assessment (9.3) than the participants who learned through the EIM strategy (7.3). Furthermore, this result seems to be due to the differences in achievement between two assessment criteria: curriculum goals and technology, and compatibility with curriculum goals and instruction as shown in Figure 22.

Thus, the differences between the groups in the other two assessment areas (instructional strategies and technology and the "fit") did not contribute to the overall TIAR scores.

Figure 23 shows the frequency distribution of the overall TIAR scores of the EIM and MS groups. The graphs show that the MS participants, on average, had higher TIAR scores than the participants in the EIM group. The results showed that 53% of EIM participants scored 6.0 points, while 78% of the participants in the MS group had scores between 8.0 and 12.0.

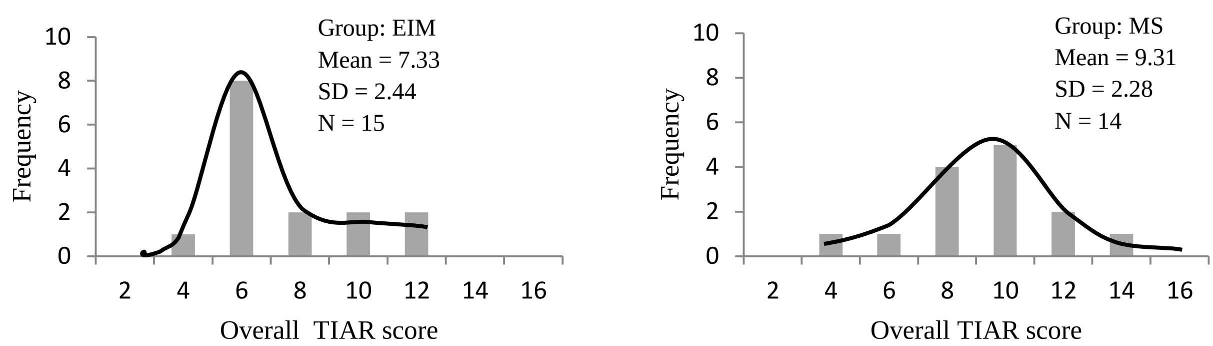


Figure 23. Distribution of the TIAR scores organized by group

In summary, the descriptive statistics of the TIAR scores show that the participants from the MS group outperformed their counterparts across all the assessment areas, especially in a) curriculum goals and technology, and b) compatibility with curriculum goals and instruction.

<u>Inferential statistics of TIAR scores</u>

A *t*-test (Equal variances assumed) was conducted on the participants' TIAR scores. The results, in Table 17, show that there are significant differences between EIM and MS on the TIAR overall scores ($t(27) = 2.247$, $p < .05$) as well as in two areas of assessment: curriculum goals and technology ($t(27) = 3.386$, $p < .05$) and compatibility with curriculum goals and instruction ($t(27) = 2.625$, $p < .05$). Consequently, the participants who learned through MS designed a technology-based inquiry activity better than those who learned through EIM. More specifically, the participants in MS were able to select the appropriate technology and instructional strategy for the target curriculum goals better than those who learned through EIM.

Table 17

t-test Analysis of TIAR Scores (the Second Dependent Variable)

	t-Test for Equality of Means		
	t	df	Sig. (2-tailed)
Overall TPACK-based Assessment	2.247	27	.033*
Curriculum Goals and Technology	3.386	27	.002*
Instructional Strategies and Technology	.515	27	.611
Compatibility with Curriculum Goals and Instruction	2.625	27	.014*
Fit technology pedagogy and content together	.570	27	.573

*p < .05

Correlation analysis between the participants' similarity indices and TIAR scores

A correlation between the change in the participants' similarity indices and TIAR scores was conducted in order to understand whether the participants' ability to plan technology-mediated inquiry activities are correlated to the development of their TPACK knowledge. The result (Table 18) indicates that there is no correlation between the variables, which mean that the participants' ability to plan technology-based activities does not necessarily depend on their levels of TPACK, instead it may depend on the strategy through which they have learned.

Table 18

Correlations between the Dependent Variables

		Change in Similarity Indices (First Dependent Variable)	TIAR scores (Second Dependent Variable)
TIAR scores (DV2)	Pearson Correlation	.007	1
	Sig. (2-tailed)	.972*	
	N	26	27
Change in Similarity Indices (DV1)	Pearson Correlation	1	.007
	Sig. (2-tailed)		.972*
	N	27	26

*p < .05

Overall, the findings of the mixed methods data are twofold. First, the statistical analysis indicated that the participants from both groups (EIM and MS) have significantly developed their knowledge structure pertaining to the TPACK framework. This finding was indicated by the quantitative analysis of the participants' pre- and post-intervention similarity indices. The qualitative data, however, was more conclusive, suggesting that the participants did not develop TPACK as whole, but rather they developed TPACK subdomains. This outcome is also evident in the participants' pathfinder networks. Nevertheless, these findings do not necessarily mean that the participants from both groups are able to incorporate their newly constructed TPACK in their instructional practices. So, the second finding reveals that the participants who learned through MS have designed technology-based activities significantly more than those who learned through EIM, as indicted by the inferential statistics of the participants' TIAR scores. This means that science teachers' planning choice of technology for science instruction may not necessarily depend on their TPACK level, but rather, it may depend on whether or not there have learned through metacognition. The next chapter discusses the mixed methods analysis to provide a firm conclusion with respect to the research objectives as well as to situate this research within the research literature.

CHAPTER 7. DISCUSSION AND IMPLICATIONS

This chapter presents a comprehensive discussion of the outcomes of the mixed methods analyses as they are related to the research questions and previous research studies. The qualitative evidence was compared with the quantitative data across three categories: development of the participants' TPACK, the learning opportunities offered by the strategies to assist in this development, and the impact of the strategies on the participants' planning choice in designing a technology-mediated inquiry activity. The objectives of this examination are twofold. First, it aims to answer the research questions, which are:

1. *What changes occur in science teachers' knowledge structure pertaining to the integration of computer technology (i.e., TPACK) as they learn through EIM and MS?*
2. *What aspects of both strategies (EIM and MS) afford opportunities for these changes to occur?*
3. *What aspects of the teaching strategies, or the participants' knowledge, afford opportunities to incorporate TPACK in designing technology-based inquiry activities?*

Second, it reflects on the designs of the EIM and MS strategies, indicating their strengths, weaknesses, failures, challenges, and areas for improvement. Throughout the discussion, different inferences will be drawn and connected to the research outcomes as well as to previous research studies.

7.1 Development of the participants' knowledge

This section discusses the development of the participants' TPACK as they learned through the EIM and MS strategies, which will address the first research question. To begin with, the quantitative results of this study indicated that the participants from both groups, on average, developed post-intervention networks significantly better than their pre-intervention networks.

Also, the descriptive analysis of the participants' post-intervention similarity indices showed that, on average, the participants who learned with EIM developed knowledge slightly better than their counterparts from MS. Consequently, the participants from the EIM group were able to improve their TPACK network structure (as compared to the experts' TPACK network) slightly better than the MS group, though it was not a significant improvement. The statistical analysis was not conclusive in determining the TPACK subdomains that the participants developed the most. However, the analysis of the participants' pathfinder networks, interview transcripts, the participants' written documents and artifacts, and the researcher's logbook provided more insight into the types of TPACK subdomains that were developed during the interventions. The mixed methods analysis suggested that the participants from both groups had developed three TPACK subdomains (TCK, TPK, and PCK) to various degrees. However, it cannot be concluded to what level or depth these subdomains were developed. The mixed methods analysis also did not show any indication that the participants from both groups developed TPACK as a whole.

This result echoes the results of researchers who have investigated the development of science teachers' TPACK and found that TPACK cannot be developed in short-term training sessions, or without having development reinforced by meaningful experience in the classroom. Rather, TPACK is often developed by teachers' cumulative experiences of technology integration and TPACK-specific training (Tokmak, Surmeli, & Ozgelen, 2014). Jang and Tsai (2012) further argue that developing science teachers' TPACK becomes more successful with experienced teachers. Teachers who have experience teaching different areas of science content are more confident in recognizing the role of computer technology in resolving content difficulties than novice teachers. Furthermore, teachers who have experience implementing different strategies for teaching science are more flexible in developing an understanding of the pedagogical uses of technology (Jang & Tsai, 2012). This may provide a possible explanation for the findings that EIM participants developed TPACK subdomains slightly better than their counterparts. According to the survey of the participants' background, 56% of EIM participants had accumulated more than five years of teaching experience, while only 37% of MS participants had the same degree of teaching experience. Although the EIM group contained more experienced teachers than the MS group, this factor did not significantly contribute to the development of the participants' TPACK. Participants from both groups did not develop TPACK as a whole. This dilemma brings the time factor to the fore.

The participants from both groups experienced six hours of training. They needed more time for training and instructional practice to fully conceptualize TPACK as whole. In order to do this, they would have had to conceive TPACK as a dynamic body of knowledge and not as static relationships between three domains (technology, pedagogy, and content matter). Therefore, understanding the dynamic interrelationships between the PhET simulation, 5E, and the construction of electric circuits requires a significant number of hours of classroom instruction. Science teachers would thereby be able to contextualize their TPACK-specific training, and hence develop a more sophisticated level of TPACK.

A number of TPACK researchers argue that TPACK should be developed within educational contexts that make sense to teachers (Kelly, 2008; Mishra & Koehler, 2006; Niess, 2005). Kelly (2008) describes the TPACK context as one of the most important, complex, and least tangible components of the TPACK framework. This context consists of a number of factors beyond TPACK subdomains, including but not limited to: students' learning needs, school philosophy, physical and technological features of the classroom, demographic characteristics of the students, and students' language proficiency levels. In addition, Kelly

(2008) highlights the importance of the interaction of these factors with each other, and with other elements, depending on the subject area.

As for this study, and from a science teaching perspective, it was extremely important to include in the strategies different educational contexts that make sense to the participants, such as their understanding of the nature of science, their teaching philosophy, their students' perceptions of learning of science, their understanding of technology integration in inquiry investigations, and technology affordances. Although the participants from both groups raised issues regarding their philosophy of teaching science and school budgets for technology, they apparently were not given enough time to effectively connect these issues to their overall development of TPACK. One way to explain this failure is the fact that the strategies did not consider the participants' limited experience with inquiry models prior the training. In fact, only two participants (from the EIM group) indicated that they used some form of inquiry in their instruction. Studies of science teachers' instructional applications of educational technologies suggest that developing a sophisticated level of TPACK requires an adequate understanding of boundaries, challenges, constraints, and issues pertaining to inquiry models (Earle, 2002; McCrory, 2008; McCrory-Wallace, 2004). Thereby, teachers would be able to identify the features and properties of technology that would help resolve these challenges or constraints to make science learning more accessible to students (Kirschner, Sweller, & Clark, 2006).

All in all, considering their limited experience with inquiry teaching and the time allotted for the training, the EIM and MS participants could only develop content- and technology-related domains of knowledge. They developed an adequate understanding of TPACK subdomains (TK, PK, TCK, PCK and to a lesser extend TPK), but they could not develop TPACK as a whole. This can be attributed to three possible explanations. First, both strategies did not bring a variety of educational contexts through which TPACK could be developed. Second, the strategies did not consider the participants' limited experience with inquiry teaching, which impeded their attempts to develop more sophisticated levels of TPACK. Third, the participants' general perceptions about technology integration focused on the technology itself and its content uses, without placing more attention on pedagogical knowledge. One way to explain this is the participants' epistemological positions. They needed to shift their epistemic stance about the teaching of science towards a more progressive position that embraces inquiry as an authentic model for the learning of science (Chien et al., 2012; Lubin & Ge, 2012; Phelps & Graham, 2008).

This section discussed the development of the participants' TPACK that occurred during the EIM and MS interventions. It explained some challenges with respect to the design of the strategies that led the participants to develop patterns of TPACK subdomains. However, within these limitations, this section did not explain why the conditions offered by EIM or MS did not make the participants' knowledge significantly different between the two groups. The next section discusses the parts of the EIM and MS strategies that afforded the development of the participants' knowledge (the second research question).

7.2 Learning conditions required for the development of TPACK

This section aims to address the second research question in order to identify and compare the situations and conditions in EIM and MS that offer the development of the participants' TPACK. The comparison is based on the mixed methods analysis and elaborated by previous research studies. Prior to the discussion, it is worth mentioning what constitute the EIM and MS strategies, and what makes them different. Fundamentally, both strategies aimed at providing the participants with opportunities to experience the 5E learning cycle as an inquiry model. Also, both strategies allowed the participants to analyze the designs of the 5E tasks to develop a better understanding of the pedagogical and content uses of technology related to the TPACK framework. While the EIM participants did go through their training with a more structured framework, the MS participants had opportunities to plan for their learning and constantly reflect on their own learning via two metacognitive strategies (Think Aloud and Reflective Writing).

To begin with, it was found that there were no significant differences between the groups of teachers in the quality of the TPACK components that they developed through the training. After experiencing the inquiry model with the PhET simulation, and analyzing the rationale of the technology integration within the inquiry learning, the participants could develop an understanding of how students could learn science with this technology. Further, the participants could recognize the importance of helping students develop, test, and evaluate their ideas. They also recognized the importance of participating in scientific practices including asking questions, deciding what to measure, developing measurements, collecting data from measures, structuring the data, interpreting and evaluating the data, and using the empirical results to develop and refine models. Despite this, the participants could not express a deeper understanding of the pedagogical necessities of technology as embodied by the TPACK framework. One way to explain this is the participants' epistemological positions. They needed to shift their epistemic stance about the teaching of science towards a more progressive position that embraces inquiry as an authentic model for the learning of science.

During the discussion period, the participants were asked to analyze different issues of the 5E activities pertaining to TPACK. Most of the participants discussed the potentials and failures of the PhET simulation in clarifying the construction of electric circuits. They also discussed the advantages of computer simulation in accomplishing the phases of 5E successfully, as compared to the concrete objects in science labs. Nevertheless, the participants could not interpret the rationale for selecting the PhET simulation and 5E activities together in meeting the content objectives. Although they analyzed the features of the 5E activities in learning about content, they did not discuss the advantages and constraints of the PhET simulation and the 5E learning cycle together for the teaching of electricity. This triangulation or negotiation of technology pedagogy and content knowledge is crucial in transforming teachers' knowledge to a more complex and unique TPACK (Mishra and Koehler, 2006; Jimoyiannis, 2010). Therefore, the mixed methods analysis suggested that the EIM and MS participants could not develop a deeper level of TPACK. Rather, they developed the TPACK subdomains to various degrees. This finding raises a question: Why did metacognition not help the MS participants develop TPACK differently than their counterparts?

The participants' learning experience in the MS group was slightly different from that in EIM. The MS participants' interactions with the 5E activities and the discussion period were derived not only from the course structure, but also from their personal learning objectives and self-reflections. The participants were given opportunities to develop personal objectives, monitor their learning process, reflect on what they know, and make the necessary changes to achieve their overall learning goals. Although the metacognitive activities were expected to help them in monitoring their knowledge development, the participants took a more pragmatic approach by prioritizing their personal goals for gaining instructional experience rather than knowledge acquisition. For example, during the Think Aloud activities, the participants set their personal learning objectives to practical aspects such as how to enhance their students' learning with technology, how to plan activities similar to the 5E tasks, and how to introduce new technology to their students. Further, at the end of the training, the MS participants were asked to reflect on their current knowledge development and elaborate on what they were still puzzled by.

80% of MS participants indicated that they were still unclear about what TPACK is all about. Unlike their perception of TPACK, when they were asked to reflect on their instructional experience, they responded with more confidence.

Both the EIM and MS strategies afforded opportunities to develop some aspects of TPACK, mainly TK, CK, PK, and TCK. These opportunities were centered on experiencing the 5E learning activities and, to a lesser extent, analyzing and interpreting these activities. The participants from both groups needed to establish a progressive epistemological position about the teaching of science through inquiry, so they could develop a deeper understanding of technology integration that brings scientific inquiry in to the fore. Through metacognition, the MS participants had an advantage in controlling their learning path. They were more interested in gaining instructional experience than knowledge acquisition. It can be concluded that both MS and EIM offered similar opportunities to develop TPACK. Therefore, the use of metacognition in the MS group enhanced the participants' ability to design technology-mediated learning activities rather than to develop a deeper level of TPACK.

To conclude, the majority of the participants, in the EIM and MS strategies, acknowledged the opportunities offered by the 5E learning activities. These activities (Table 19) provided opportunity for the participants to develop first-hand experience not only in learning science through inquiry, but also in exploring different guiding methods to facilitate learning. Through metacognition, the MS participants had an advantage in controlling their learning path. Nevertheless, they were more interested in gaining instructional experience than knowledge acquisition. It can be concluded that both MS and EIM offered similar opportunities to develop TPACK. Therefore, the use of metacognition in the MS group enhanced the participants' ability to design technology-mediated learning activities rather than to develop a deeper level of

TPACK. This may answer the question, why did metacognition not help the MS participants develop TPACK differently than their counterparts?

Table 19

Summary of the Impact of the EIM and Metacognitive Activities

Impact of cognitive activities in the EIM and MS strategies	Impact of metacognitive activities in the MS strategy
5E learning activities • Recognizing the challenges pertaining to the teaching and learning of science though inquiry • Understanding the role of the teacher as a facilitator • Understanding the role of technology in supporting students' understanding of science	*Think Aloud* • Setting clear objectives for one's own learning • Organizing and monitoring one's own learning course
Discussion period • Recognizing the rationale for selecting computer technology in meeting learning objectives • Assessing the impact of computer technology in supporting pedagogical necessities • Exchanging thoughts and ideas with more capable peers	*Reflective Journal Checklist* • Raising the awareness of one's understanding of TPACK • Monitoring and adjusting learning course • Raising self-confidence and self-steam • Being aware of classroom context while designing for technology-mediated activities

The next section discusses the parts of the EIM and MS strategies, or the participants' knowledge, that afforded the opportunities to incorporate TPACK in designing technology-based inquiry activities (the third research question).

7.3 Opportunities offered for the design of technology-based activities

This question is addressed by the quantitative and qualitative analyses. The quantitative analysis concluded that the participants in the MS strategy obtained significantly higher TIAR scores than the EIM participants. The qualitative analysis, though, provided more insight into the situations afforded by the MS strategy to help the participants in designing technology-mediated inquiry activities.

The participants in the MS strategy were constructively guided through metacognitive activities (Think Aloud and Reflective Journal Checklist), which allowed them to develop personal objectives related to what they wanted to learn, why they wanted to learn it, and how they would like to achieve their learning goals. Further, the metacognitive activities allowed the participants to constantly monitor their learning progress and overall learning achievement. This process made them wonder while conducting the 5E learning activities and, hence, pose meaningful questions during the discussion period. Posing meaningful questions during and after the inquiry model helped the MS participants not only in maximizing their learning experience, but also in orienting this experience toward supporting their instructional practice. Therefore, while doing Think Aloud and the Reflective Writing Checklist, the MS participants thought carefully about their professional development, including the general parameters of: guiding students through the hypothesis testing process, helping students gather data and come up with acceptable explanations, encouraging students to seek evidence with computer technology, anticipating pedagogical and content challenges, selecting appropriate technology, and designing alternative instruction when the initial plan fails. As the MS participants planned and reflected on their learning progress, they actually focused on informing the designing of activities for their students. More importantly, the MS strategy provided the participants with concrete examples and thoughtful processes to reflect upon. This encouraged them to think about adopting the instructional framework that they had experienced (or other similar inquiry models) to plan a system of learning activities and provide specific teaching strategies for supporting student learning with technology.

Along these lines, the qualitative data of this study suggested that the participants in the MS strategy shared a number of similarities in their ability to apply the components of TPACK in designing technology-based activities. This interpretation coincides with the statistical descriptive of the TIAR scores. The TIAR scores showed that the MS participants achieved higher scores than those who learned through the EIM strategy in two areas: curriculum goals and technology, and compatibility with curriculum goals and instruction. These two components specifically target teachers' ability to take into account the content uses of technology while planning for learning activities, as well as to consider the appropriateness of the pedagogical framework in meeting the curriculum goals. These particular areas of TPACK were articulated by the MS participants in two ways: During the Think Aloud activities when they were guided in planning for their own learning, and during their discussion periods. In both cases, the participants were engaged in thoughtful discussion about the effectiveness of PhET simulations for students' learning about electricity as compared to conducting actual experiments in science labs, their schools' budgets for technology-enhanced classrooms and how this impacts students' learning, and the challenges involved in designing technology-based learning activities. Furthermore, the MS participants thought carefully about their professional development plans for the future. They discussed the importance of systematic professional development plans specifically designed to enhance their ability to teach science through inquiry and to teach science with technology.

In contrast, the EIM participants' attempts to design technology-based inquiry activities focused solely on one model of inquiry (the 5E learning cycle) and one type of technology (PhET simulations). After experiencing the 5E activities, many of the EIM participants developed an adequate level of understanding of how 5E activities were implemented and facilitated, without recognizing the importance of contextualizing these activities within their instructional practices. The EIM participants recognized different aspects of inquiry such as testing hypotheses and making systematic observations, but they were unable to design inquiry-based activities that would account for their school and student contexts. This finding was supported by the descriptive statistics of the TIAR scores, which indicated that the EIM participants' mean scores were lowest in two specific TPACK-assessment criteria: the compatibility with curriculum goals and instructional strategy, and learning objectives and technology. On the other hand, the EIM participants could not negotiate their understanding of TPACK in designing technology-based activities. This finding suggests that the EIM participants needed to think more flexibly and be less attached to the content of TPACK. They should have thought carefully about how to construct TPACK knowledge within their current thinking. For example, the classroom observation indicated that the participants were very keen to respond to small or irrelevant details that were not crucial to the main objective of the training. Consequently, many of the EIM participants were strongly bound to the structure of the training without fully connecting their learning with their teaching practice. As a result, the participants were able to develop TPACK in isolation from their school or student contexts. This outcome is not surprising. In relation to this, Niess (2005) brought clarity to TPACK as a way of thinking strategically while planning, organizing, and critiquing for specific student needs, specific content, and specific classroom situations. He added that developing an understanding of the relationships between technology, pedagogy, and content matter is not sufficient to support teachers' ability to plan for a sound technology-based learning activity. In addition to this, teachers need to develop pedagogical and technological reasoning that integrates what they know about when, where, and how to integrate technology into a series of learning events (McCrory, 2008). This reasoning process is essential in the development of strategic thinking – the thinking that is developed during the continuous reflection on one's learning experience.

To sum up, the MS participants outperformed their counterparts in some aspects of designing technology-mediated inquiry activities despite the fact that the participants from both groups developed similar levels of TPACK knowledge. In fact, the MS strategy afforded different opportunities to help the participants apply their understanding of TPACK in designing technology-based inquiry activities. Mainly, MS's metacognitive strategies allowed the participants to take control of their own learning and develop strategic thinking that bound learning to their prior and future instructional experiences. Unlike the MS group, the participants in the EIM strategy focused on the content of the training without seeking to achieve consistency between the training content and their prior knowledge and experience. Therefore, developing teachers' TPACK does not mean that teachers would subsequently be able to apply this knowledge in different instructional situations, such as designing technology-mediated activities. Teachers need to take control of their own learning (through planning and reflection) in order to be able to transform their learning experience into a sequence of learning events that are accessible to their students.

7.4 Reflection on the Metacognitive Scaffolding strategy

It was found that there were no significant differences between the participants who learned through MS and EIM in the quality of the TPACK components that they developed through the training. Nevertheless, there were significant differences between the MS and EIM groups in how the TPACK components were negotiated in planning for technology-mediated inquiry activities. To understand the lessons learned from these two findings, this section presents explicit reflections on the design and implementation of the MS strategy and an exploration of its influence on instructional design for science learning with technology. Here, the strengths, weaknesses, failures, and challenges of metacognitive scaffolding will be discussed. Further, this section suggests different areas in which to improve the intended objectives of the MS strategy.

By analyzing the key components of the MS strategy, it has been found that when preparing teachers to learn with metacognition, there is a need to provide them with direct guidance in the principles of planning for their own course of learning. As indicated in the focus group interviews and the researcher's diary, experience in planning one's learning course requires deep understanding of the overall objectives of the training as well as the specific objectives of the upcoming learning events. The teachers' experiences with the Think Aloud strategy indicated that MS teachers missed essential information that they needed for developing a sense of learning ownership – an awareness of controlling one's own learning. Therefore, teachers without an adequate level of metacognitive skills and relevant background knowledge of metacognitive strategies generally lacked a substantive understanding of the principle of designing a detailed plan for their own learning course.

This finding is in line with research studies that investigated the role of metacognition in developing one's thought processes as related to instructional planning. For example, Doganay and Ozturk (2011) pointed out that when teachers are competent in utilizing metacognitive strategies within the context of professional development, they are better at observation, organization, and planning. The study also concluded that when teachers are engaged in metacognitive activities, they become less attached to the content of the training objectives. Rather, they become more independent and flexible to achieve their own learning goals that go beyond training-specific outcomes, towards goals that enhance their long-term instructional practice (Phelps, Ellis, & Hase, 2001).

Apparently, leaving the MS participants to gather essential information for their learning course while they barely knew about the upcoming learning events undermined the potential of the Think Aloud strategy. Nevertheless, the MS participants' understanding of the overall objectives of the training and the clear instructions about how to plan for their learning course helped them in connecting the training with their school and classroom contexts. Therefore, due to the lack of a deep understanding of the specific goals of the learning activities, some of the MS participants were confused about whether they should pursue an independent plan or follow the learning activities presented in their Learner's Guides. When Think Aloud is proposed as a metacognitive strategy, it should be presented to teachers with an adequate understanding of metacognition and metacognitive strategies. Also, a platform of rich resources should be available to help teachers design a flexible learning plan to support their learning needs. Finally, Think Aloud might not be an appropriate choice to engage teachers with novice metacognitive knowledge and skills in a process of detailed planning. Rather, a detailed planning process can be embedded at the end of the training in a final reflective writing activity to encourage teachers to plan for their upcoming professional development course. This finding suggests that providing teachers with clear guidance would beef up their metacognitive skills for essential planning in a way that makes these skills consistent with the overall goals of the training.

The MS participants followed specific procedures for reflection and monitoring their own learning, which was accompanied by scaffolding aimed at testing, revising, and generating their ideas. The results showed that the Reflective Writing Checklist allowed the participants to gain a better understanding of their own learning about technology. For examples, reflective writing raised the participants' awareness of their understanding of TPACK. It also allowed them to recognize what they had learned during the workshop, what they were still puzzled by, and what their plans for the future should be in order to continue developing their technological pedagogical content knowledge. More importantly, the participants gained awareness of their students' potential learning difficulties, such as making inappropriate hypotheses, designing inadequate experiments, and misinterpreting representations. The latter was actually discovered through two distinct learning processes. First, experiencing the 5E activities provided the participants with rich opportunities to understand the teaching strategies needed to help students learn science with technology. This was followed by a critical analysis of these activities to better understand the challenges, failures, weaknesses, and successes of technology integration within the general framework of inquiry-based learning. Second, the MS strategy engaged the participants in continuous reflective thinking during and after the 5E activities. This engagement helped them to concentrate on essential information for developing their TPACK and to negotiate their understanding of TPACK in order to design tasks to help students use computer technology to learn science through inquiry. However, the implementation of metacognition in educational technology training should not be at the expense of cognition.

Initially, metacognition is often implemented within or around cognitive activities. While cognitive activities offer learning opportunities to acquire essential information or content areas to develop one's knowledge, metacognition helps learners to gain full oversight of their cognitive processes. It is very critical to understand the rationale by which cognitive learning and metacognition maintain a coherent portrait of one's learning process. Most importantly, learners should be able to utilize their metacognitive skills and knowledge to better understand their knowledge gaps and direct or redirect their cognitive learning process accordingly. Thus, metacognition can be affirmed as a driving force to help learners not only control their own learning, but also monitor and adjust their learning course in a way that enhances their experiences and bridges their knowledge gaps.

In this study, the metacognitive activities of the MS strategy were basically organized to support teachers' experiences of the inquiry model in a way that connects with their understanding of TPACK to enhance their students' learning of science. The teachers who were not exposed to metacognitive scaffolding had difficulties in making strategic decisions to design inquiry tasks that could support student learning with technology, even though they had developed an adequate understanding of TPACK. In fact, EIM teachers focused solely on developing TPACK knowledge without linking this knowledge to their teaching practice. Their lack of understanding of the overall purpose for the training impeded their ability to line up their learning about technology integration with their school and student contexts. As an example, the EIM teachers were unable to match the anticipated learning needs with appropriate technology to support student learning.

On the other hand, the MS teachers used 20% of their training for metacognition and 80% for developing TPACK knowledge. This means that for every four minutes of cognitive learning there was one minute for metacognition. Consequently, the MS teachers spent less time in cognitive activities compared to the EIM teachers. This fact coincided with the descriptive statistics of the teachers' Pathfinder networks. It showed that EIM teachers developed better a understanding of TPACK than MS teachers. This finding suggested that any overemphasis on metacognition would come at the expense of cognitive learning.

To sum up, the metacognitive strategies implemented in this study supported a viable way to help teachers negotiate their newly constructed knowledge to enhance their instructional planning. The scaffolding offered by the MS strategy aimed at helping the teachers to develop metacognitive skills and knowledge to aid them in enhancing their own learning, and line this up with student learning. These metacognitive strategies offered opportunities to apply TPACK in order to create appropriate technologically inclusive learning plans that aimed at supporting students' learning of scientific concepts with context-specific pedagogical techniques.

Chapter 8. Conclusion

This study was conducted in to the need to understand how to prepare science teachers to appropriately integrate technology into teaching and learning of science. This final chapter reviews the main findings of the study, identifies potential research opportunities, and identifies the limitations of the study.

8.1 Overview of the study

This study was conducted because of the need to understand how to prepare teachers to appropriately integrate technology into teaching and learning. The purpose of this study was to determine how to prepare teachers to take into account the pedagogical and content uses of technology in order to inform their design of inquiry-based learning activities. This study utilized the theoretical lens of Situated Cognition Theory to analyze the learning context, and the TPACK framework to analyze the knowledge components that teachers developed. The MS and EIM strategies were implemented to find out the effect of metacognition on the development of science teachers' TPACK. The study also explored the conditions of the EIM and MS strategies through which teachers advanced their understanding of the pedagogical uses of technology and ways to support students in learning the subject matter.

This study was undertaken in response to the growing calls from the educational technology community for more research to define how metacognition can help in examining ways to help teachers develop TPACK so that they can integrate technology into teaching and learning in a particular area of science. A gap had emerged in the community's understanding of this area because the vast majority of educational technology training has been focused on introducing teachers to technology within the context of cognitive activities. Therefore, this study sought to begin addressing this gap by utilizing metacognitive activities to examine how to support teachers' pedagogical reasoning and decision-making in the process of integrating technology into the science classroom. Understanding how teachers develop knowledge that influences their instructional practice is crucial because there is a strong relationship between how teachers think and how they teach science. Teachers need to understand that this link has strong implications not only for their professional development, but also for students' learning of science as well.

Results

The results of the study showed that teachers who learned with metacognition developed aspects of TPACK and applied their newly constructed knowledge in designing technology-mediated inquiry-based learning activities in science. The findings suggested that experience in teaching science as inquiry may help teachers to gain a more robust understanding of TPACK components. However, developing TPACK per se is not sufficient for understanding the principles involved in supporting student learning. Guiding teachers through continuous reflective writing provides opportunities to negotiate TPACK components in order to anticipate and plan for what would likely happen during a technology-based sequence of learning events.

The results showed that science teachers need special guidance and support to plan and reflect for their learning course. Their limited knowledge of metacognition would impede their ability to think independently and flexibly about their own learning. Nevertheless, it is difficult for science teachers to adapt to metacognition, for multiple reasons. The results showed that MS teachers were unable to formulate specific learning goals, and decide appropriate strategies to achieve these goals. However, they were able to understand the overall learning objectives and continuously reflect on their cognitive learning process. Therefore, the findings of this study highlight the importance of supporting science teachers' metacognitive process concurrently with learning the pedagogical and content uses of technology. This system of support should ultimately aim at developing science teachers' consciousness not only of their own learning, but also of their instructional practice.

8.2 Limitations

First, this study, inevitably, was bounded by the quality and context of the research. The quasi-experimental design of this study aimed at evaluating the effectiveness of two strategies, EIM (control group) and MS (treatment group), on the development of the participants' TPACK. Since quasi-experiments do not utilize random assignment of participants to groups, there is greater likelihood that individual differences (such as prior knowledge, gender, age, experience, education, and motivation or interests) may impact the study's findings (Slavin, 2007). Further, in such cases of nonequivalent group design, the participants' characteristics may not be balanced equally among the control and treatment groups. This means that the participants' experiences during the study may differ, which may influence the statistical findings. Although these are real limitations, a number of measures were taken to minimize their impacts on the findings:

- Random assignment of the treatment: Although the participants were conveniently selected and grouped based on their natural settings, they did not choose which strategy (EIM or MS) they would be assigned during the experiment. Rather, the strategies were randomly assigned to the groups. Research suggests that while random selection (which does not occur in quasi-experiments) often leads to different study findings compared to true experimental design these differences in findings are even more pronounced in quasi-experiments in which participants are allowed to self-select the group to which they will belong (either the control or treatment group) (Cohen, Manion, & Morrison, 2007; Shadish, Matt, Navarro, & Phillips, 2000; Slavin, 2007).

- Both the EIM and MS groups completed pre-intervention networks to assess whether there were significant differences in their prior knowledge. The *t*-test indicated that there were no significant differences in the participants' pre-intervention networks, which suggested that the participants had had similar knowledge prior the intervention. This result ruled out a possible influence of the participants' prior knowledge on their TPACK development.
- The findings of the study were not interpreted by simply studying the differences in the descriptive or inferential statistics of the dependent variables (Pathfinder similarity indices and TIAR scores), because such differences could be attributed to differences in the participants' characteristics and /or differences in their experiences during the experiment. Instead, the results were interpreted by comparing the differences between each group's scores and their performance and attitudes, description of the learning process, and description of the implementation process during the experiment. The latter data were gathered through different qualitative sources such as observation, researcher's logbook, and interviews and provided rich information that helped in exploring the processes experienced by the participants as compared to their TIAR scores and Pathfinder similarity indices. This mixing of data integrated the information gathered from both sources and compared one data with the other in order to address the research questions.

However, with the uses of stringent criteria for data analysis to strengthen the quality of the study and limited concerns about the issue of individual differences, one must accept that quasi-experimental studies are always limited by their contextual nature. In this study, the data collection and data analysis procedures were designed to minimize the influence of individual differences on the findings. Yet, the participants' prior knowledge and skills, gender, English proficiency levels, ethnic background, and intellectual capacities and interests might have influenced the findings, and hence, might limit the conclusiveness of the final statements.

Second, there were other factors that may have impacted the effectiveness of the implementation of the proposed strategies, including:

- the participants' lack of familiarity with the PhET computer simulation
- the researcher's effectiveness in the classroom
- the participants' lack of prior knowledge related to particular concepts (e.g., TPACK, inquiry learning, the 5E learning cycle, or electric circuits)
- the participants feeling overwhelmed due to the intensive nature of the intervention

Third, the EIM strategy was geared toward cognitive learning activities only, but participants in this group may have exercised some aspects of metacognition, especially during the discussion periods.

Fourth, the practical disadvantages of implementing metacognitive tasks should be considered. In the MS group, the participants were asked to setup their learning plans, reflect on their learning and performance, respond to teacher-generated questions, and document their work. Some of these tasks demand much time and effort.

Finally, due to the small sample size, the study could not breakdown the variables into more levels in order to come up with more statistically inclusive results. For example, the study did not explicitly evaluate the effectiveness of some pivotal parts of the EIM and MS strategies, such as the inquiry investigation. The participants from both groups (EIM and MS) engaged in inquiry while conducting the 5E activities, but the study could not examine the possible learning that may have occurred in this situation.

8.3 Future research opportunities

This study demonstrated that the MS strategy provides ways of helping science teachers to apply their understanding of the pedagogical uses of technology in new situations more effectively than the EIM strategy. The unique aspect of this study is that it examined the complexities of teachers' metacognition in developing a technology-related domain of knowledge, as well as in applying this knowledge to the design of technology-mediated inquiry-based activities. This study was undertaken to offer other researchers an opportunity to consider how metacognition can be utilized in action within the context of TPACK-specific training. Further investigations are needed to examine teachers' metacognition in developing TPACK as part of a longer professional development plan, including lesson execution and determining how TPACK knowledge influences students' learning of science, and how teachers' metacognitive skills and knowledge influence student learning.

Along these lines, more research should be conducted to explore the effectiveness of metacognition within the context of educational technology training. More specifically, researchers should investigate ways to reach the optimum balance between cognitive and metacognitive activities. It is important to study how to support teachers' metacognition when they have different learning needs.

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Appendix A: **Pathfinder Network Scaling – Rating Sheet and Concepts**

What is Pathfinder Network Scaling?

Pathfinder Network Scaling is an assessment tool, and it is commonly used to map learner's structural knowledge. Structural knowledge refers to the way learners conceptualize or understand the interrelationships between concepts of a particular domain of knowledge.

Why am I using it?

You will use this Rating Sheet to rate the relatedness of pairs of concepts as pertaining to inquiry learning, science content, and technology; as well as to indicate the rational of your rating.

How does it work?

Each pair of concepts will be rated on a numeric scale from completely unrelated (a rating of 1) to highly related (a rate of 5). Pathfinder Network Scaling will then transform the relatedness data into network representations via Knowledge Network Organizing Tool (KNOT) software program. In the network representation, each concept is represented by a node, and each relationship between two concepts is represented by a link between nodes. The highly related concepts are separated by more links, and the less related concepts are separated by fewer links or may be no links.

What should I do?

1. Judge the relatedness of each pair of the concepts shown in the rating sheet (select a rating from 1 to 5).
2. Write a short sentence to justify the Related and Highly Related ratings (i.e., ratings 4 and 5).
3. You have 30 minutes to complete the rating.

What are the concepts that I am going to rate?

Knowledge related to Grade 8 Science:

1. *Electric current*: The flow of electrons in a conductor.
2. *Electric circuit*: A switch, battery, and device (load) are connected by connecting wires in a closed loop called electric circuit.
3. *Measurement of voltage*: Determines the amount of electric energy released per unit charge.

Knowledge related to technology:

4. *Multimedia projector*: A device used to display a computer screen on a larger screen.
5. *PhET Circuit Construction Kit simulation*: A software program that simulates the construction of electric circuits by means of visual representation.
6. *Evaluation of PhET Circuit Construction Kit simulation*: The method used to assess the effectiveness of the PhET simulation in representing the construction of electric circuits.

Knowledge related to classroom pedagogy:

7. *Curriculum expectations related to Electricity*: Specific expectations that learners are expected to achieve by the end of the unit on electricity.
8. *Student's summative assessment*: The method used by the teacher to assess students' learning at the end of the course or term.
9. *Testing hypotheses*: The process by which data are gathered and analyzed in order to test a previously postulated hypothesis.

Rating Sheet

Concept 1	Concept 2	Select between 1 (unrelated) and 5 (highly related)	Rational for Related and Highly Related ratings (i.e., ratings 4 &5)
Electric current	Electric circuit	Click here to select	Click here to enter comments.
Measurement of voltage	Multimedia projector	Click here to select	Click here to enter comments.
Multimedia projector	PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Electric circuit	Multimedia projector	Click here to select	Click here to enter comments.
Multimedia projector	Testing hypotheses	Click here to select	Click here to enter comments.
PhET Electric Circuit simulation	Evaluation of PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Electric current	Measurement of voltage	Click here to select	Click here to enter comments.
Curriculum expectations related to Electricity	Electric circuit	Click here to select	Click here to enter comments.
Measurement of voltage	PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Evaluation of PhET Electric Circuit simulation	Student's summative assessment	Click here to select	Click here to enter comments.
Measurement of voltage	Testing hypotheses	Click here to select	Click here to enter comments.

PhET Electric Circuit simulation	Student's summative assessment	Click here to select	Click here to enter comments.
Student's summative assessment	Testing hypotheses	Click here to select	Click here to enter comments.
Multimedia projector	Curriculum expectations related to Electricity	Click here to select	Click here to enter comments.
Student's summative assessment	Electric circuit	Click here to select	Click here to enter comments.
Measurement of voltage	Student's summative assessment	Click here to select	Click here to enter comments.
Measurement of voltage	Curriculum expectations related to Electricity	Click here to select	Click here to enter comments.
Electric current	Multimedia projector	Click here to select	Click here to enter comments.
Evaluation of PhET Electric Circuit simulation	Measurement of voltage	Click here to select	Click here to enter comments.
Testing hypotheses	Electric current	Click here to select	Click here to enter comments.
Curriculum expectations related to Electricity	Testing hypotheses	Click here to select	Click here to enter comments.
PhET Electric Circuit simulation	Electric circuit	Click here to select	Click here to enter comments.
Electric current	Curriculum expectations related to Electricity	Click here to select	Click here to enter comments.
Testing hypotheses	PhET Electric Circuit	Click here to select	Click here to enter comments.

	simulation		
Measurement of voltage	Electric circuit	Click here to select	Click here to enter comments.
Curriculum expectations related to Electricity	Student's summative assessment	Click here to select	Click here to enter comments.
Evaluation of PhET Electric Circuit simulation	Testing hypotheses	Click here to select	Click here to enter comments.
Electric current	Evaluation of PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Multimedia projector	Student's summative assessment	Click here to select	Click here to enter comments.
Electric current	PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Evaluation of PhET Electric Circuit simulation	Curriculum expectations related to Electricity	Click here to select	Click here to enter comments.
Electric current	Student's summative assessment	Click here to select	Click here to enter comments.
Multimedia projector	Evaluation of PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Electric circuit	Testing hypotheses	Click here to select	Click here to enter comments.
Curriculum expectations related to Electricity	PhET Electric Circuit simulation	Click here to select	Click here to enter comments.
Electric circuit	Evaluation of PhET Electric Circuit simulation	Click here to select	Click here to enter comments.

Appendix B: Technology Integration Assessment Rubric (TIAR)

Criteria	4	3	2	1
Curriculum Goals and Technologies (Curriculum-based technology use)	Technologies selected for use in the instructional plan are strongly aligned with one or more curriculum goals	Technologies selected for use in the instructional plan are aligned with one or more curriculum goals	Technologies selected for use in the instructional plan are partially aligned with one or more curriculum goals	Technologies selected for use in the instructional plan are not aligned with one or more curriculum goals
Instructional Strategies and Technologies (Using technology in teaching/ learning)	Technology use optimally supports instructional strategies	Technology use supports instructional strategies	Technology use minimally supports instructional strategies	Technology use does not support instructional strategies
Technology Selection(s) (Compatibility with curriculum goals and instructional strategies)	Technology use optimally supports instructional strategies	Technology selection(s) are appropriate, but not exemplary, given curriculum goal(s) and instructional strategies	Technology selection(s) are marginally appropriate, given curriculum goal(s) and instructional strategies	Technology selection(s) are inappropriate, given curriculum goal(s) and instructional strategies
"Fit" (Content, pedagogy and technology together)	Content, instructional strategies and technology fit together strongly within the instructional plan.	Content, instructional strategies and technology fit together within the instructional plan.	Content, instructional strategies and technology fit together somewhat within the instructional plan	Content, instructional strategies and technology do not fit together within the instructional plan

(Harris, Grandgenett, & Hofer, 2010)

Appendix C: **<u>Demographic Questionnaire</u>**

Purpose

This questionnaire is prepared to collect information concerning the participant's background, ICT use, and teaching experience. The information provided in this questionnaire will be used for reference only. All information will be treated with high confidentiality.

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1. Gender:
2. Age:
3. Did you complete teacher education program? (Yes/No) ______
4. What subjects are you trained to teach?
5. What grade(s) do you teach? _________
6. Years of teaching experience:
7. Have you done any educational technology training? If yes, what was the dominant training method? (e.g., Lecture, PowerPoint, Discussion, Hands-on, or Mixed Approach)
8. Are you familiar with the principles of electric circuit constructions? (Yes,/No)
9. Are you familiar with 5E Learning Cycle? (Yes/No)
10. Have you taught, or do you teach science through inquiry? (Yes/No) __
11. Are you familiar with PhET computer simulations? (Yes/No)
12. Have you used any one of the PhET simulations in your teaching?(Yes/No)

Appendix D: Interview Questions

1. As learner, what do you think are the key parts of the teaching strategy that make a good learning opportunity for you?
    a. In which way did this opportunity (or opportunities) enhance your learning of technology integration?
    b. What methods did you use to maximize your learning (if any)?
    c. What importance do you place on such strategies to enhance teaching science with technology?
2. What do you think are the important technological competencies (knowledge and skills) for you to properly use technology in classroom?
    a. How can you evaluate your own competencies in ICT integration in science teaching?
    b. Does this level of ICT integration competency you have, affects your motivation to use ICT in teaching?
    c. How do you engage your future students to learn by using ICT?
3. Based on your precedent experience, what do you know about TPACK framework?
    a. How do you establish a relationship between technology, pedagogy, and science content?
    b. To what extent do you think your understanding of TPACK can be a replica to teaching science with technology?
4. Do you use TPACK as a guide to your activities?
    a. In what ways do you use TPACK framework?
    b. How can you describe your competency level of on TPACK?
    c. What do you consider to be strength and or weaknesses of TPACK framework?
    d. To what extent do you think you will be able to use ICT in your teaching after graduation?
5. What is your future plan of enhancing technology integration for your students' class?

Appendix E: **Learner's Guide - EIM**

uOttawa

Faculty of Education
University of Ottawa

RESEARCH STUDY: THE IMPACT OF

Experiencing Inquiry Model

ON SCIENCE TEACHERS' PLANNING CHOICE OF TECHNOLOGY-MEDIATED INQUIRY-BASED LEARNING ACTIVITIES

CONDUCTED BY: MOHAMED IBRAHIM MUSTAFA

A Professional Development Workshop

Learner's Guide

Table of Content

Printed in Canada

1. Introduction

1.1 Overall of the Workshop

The purpose of this workshop is to investigate the impact of a teaching strategy, named Experiencing Inquiry Model (Windschitl et al., 2008a), on the participants' understanding of the integration of computer technology in classroom instruction. In it, the participants will have opportunities to learn science content, methods of teaching this content, and how to utilize computer technology in science instructions. Initially, the participants will be asked to conduct an inquiry investigation to explore the brightness of electric bulbs in series and parallel circuits, just like primary school students. 5E Learning Cycle will be used to manifest the general framework of inquiry–based learning, and PhET computer simulation will be utilized to execute the tasks of 5E Learning Cycle. Then, the participants will be asked to critically analyze different aspects of the inquiry investigation; and identify the challenges, failures, and successes of the integration of computer simulation in teaching and learning of electricity. Finally, the participants will be asked to apply their new knowledge in designing a technology-based inquiry learning activity. At the end of the workshop, the participants are expected to develop a unique domain of knowledge named: Technological Pedagogical Content Knowledge (TPACK). Developing such knowledge is expected to help science teachers to think strategically while integrating computer technology in science instruction.

1.2 Overall Expectations

Throughout this workshop, learners will:

A. demonstrate an understanding of the basic concepts of electric circuits, teaching science through inquiry, and computer simulation;
B. develop a unique domain of knowledge known as Technological Pedagogical Content Knowledge (TPACK); and
C. demonstrate skills (related to designing technology-based learning activities) in the four areas of Technological Pedagogical Content Knowledge (curriculum goals and technologies, instructional strategies and technologies, technology selections, and content pedagogy and technology fit).

1.3 Specific Expectations

A. Understanding the basic concepts

Throughout this workshop, learners will:

A.1 demonstrate basic understanding of the principles of construction of electric circuit (including the concepts of electric current and electric potential)

A.2 recognize and distinguish between the phases of 5E Learning Cycle: *Engage, Explore, Explain, Elaborate, and Evaluate*

A.3 describe the features and functions of *PhET Circuit Construction Kit simulation*

B. Developing TPACK

Throughout this workshop, learners will:

B.1 recognize the features of computer simulation that support teaching of science via 5E Learning Cycle

B2. identify the features of various types of computer technology in supporting specific curriculum objectives

B.3 discuss the pedagogical necessities as a rational to implement specific types of computer technology

B.4 critically analyze the effectiveness (or rational) of the 5E learning cycle and computer simulation in enhancing students' understanding of the characteristics of series and parallel circuits

C. Developing skills related to TPACK

Throughout this workshop, learners will:

C.1 use computer simulation to construct electric circuit in series and parallel

C.2 plan and conduct an inquiry into the examination of the characteristics of series and parallel circuits

C.3 design a technology-mediated inquiry-based learning activity

2. First Session

2.1 First Session Agenda

SESSION 1

TASKS

- Introduction
- Task 1: Electric circuits
- Task 2: PhET computer simulations
- Task 3: 5E Learning Cycle
- Task 4: Pre-test
- Task 5: Conducting an experiment via 5E learning cycle

RESOURCES

- ✓ Learner's Guide
- ✓ Science Textbook
- ✓ Science Curriculum
- ✓ PhET simulations
- ✓ Web resources
- ✓ Electric circuit tool kits

SESSION 2

TASKS

- Task 6: Discussion (1) - analyzing in what ways the computer simulation was helpful (or not) for the inquiry investigation
- Task 7: Discussion (2) - analyzing the role of technology as a rational of pedagogical and content objectives
- Task 8: Post-test
- Task 9: Designing technology-based learning activities
- Focus-group interview

Code: ....

2.2 *Tasks 1 – 5*

Task 1. Electric Circuits

Electrical appliances in your home such as bulbs, fans, and refrigerators should be connected or plugged into a circuit called an electric circuit. The electric circuit is a closed path for electricity, and it supplies electric appliances with energy. To understand how electric circuits work, you need to understand the basic principle of electricity. To do that, let's watch the following YouTube clip (https://www.youtube.com/watch?v=D2monVkCkX4).

Activity: Constructing a Simple Circuit

Materials:

- Wires
- Batteries (in battery holder)
- Light bulb
- Bulb holder
- Switch

Your task:

EXERCISE CAUTION

1. Use the materials listed above to construct a simple circuit.
2. Turn the switch ON, and check the status of the light bulb.
3. Once the light bulb is working, explore the function(s) of each part of the circuit
4. Draw and label a circuit diagram in the space below.

Task 2. PhET Simulations

PhET simulations are developed and tested by Physics Education Technology group, University of Colorado, Boulder. The PhET group has developed over 60 free downloadable physics, chemistry, and mathematics simulations. The content of the simulations includes most topics covered in a typical introductory science sequence in different grade levels (K – 12 and university). *PhET Circuit Construction Kit (DC)* is one of those simulations. It can be used to simulate the construction and operation of simple electric circuits, and electric circuits of different types of connections (e.g., parallel and series). The following activity is designed to walk you through the features and functions of the *PhET Circuit Construction Kit* simulation.

Activity: PhET Circuit Construction Kit (DC only)

Materials/Resources:

- Computer or laptop
- Internet connection
- Google: PhET Interactive Simulations

EXERCISE CAUTION

Your task is to:

1. From the PhET Interactive Simulations website, download *PhET Circuit Construction Kit (DC only)* simulation in your computer.
2. Once the simulation is lunched, click-and-drag the electric components to the center of the main window. Use these components to construct a simple electric circuit. Your circuit should include a switch, battery, light bulb, and connecting wires. After the electric circuit is completed, turn the switch ON and check the status of the light bulb.
3. Explore the functions of the simulation (e.g., use the voltmeter to measure the voltage).
4. Discuss some features or functions of the simulation that may be helpful (or NOT) in teaching and learning of electric circuits.

Task 3. 5E Learning Cycle

5E is an instructional model that manifests the general framework of inquiry-based learning. It is part of a larger series of models such as 3E, 4E, 5E, and 7E learning cycles. Although, these models are slightly different in the number of phases, the basic ideas are collectively inspired by the Piagetian focus of construction of knowledge and the Vygotskian notion of scaffolded learning. The following YouTube (http://youtu.be/BnlCQ45f7KM) will give you more insight on 5E Learning Cycle.

Task 4. Pathfinder Network Scaling (pre-test)

What is *Pathfinder Network Scaling*?

Pathfinder Network Scaling is an assessment tool used to map learner's structural knowledge. Structural knowledge refers to the way learners conceptualize the interrelationships between concepts of a particular domain(s) of knowledge.

Why am I using it?

You will use *Pathfinder Network Scaling* to draw a conceptual network as pertaining to your current technological, pedagogical content knowledge (pre-test). In doing so, you will be asked to rate the relatedness of 36 pairs of concepts relating to inquiry learning, concepts of electricity, and computer technology; as well as to indicate the rational of your rating.

How does it work?

Each pair of concepts will be rated on a numerical scale from completely unrelated (a rating of 1) to highly related (a rating of 5). Then, *Pathfinder Network Scaling* will transform the relatedness data into network representations via Knowledge Network Organizing Tool (KNOT) software program. In the network representation, each concept is represented by a node, and each relationship between two concepts is represented by a link between nodes. The highly related concepts are separated by more links, and the less related concepts are separated by fewer links or may be no links. Many of you may not be familiar with this type of assessment technique. Therefore, a simple example of the procedure involving non-study related concepts is presented in the following section.

Example: use the following Likert scale (Pathfinder Network Scaling) to rate the relatedness of each pair of words:

Word (1)	Word (2)	1	2	3	4	5	Justify your judgment
Ostrich	Reptile						
Bird	Ostrich						
Snake	Bird						
Bird	Reptile						
Snake	Reptile						
Ostrich	Snake						

<u>Now…… what concepts am I going to rate?</u>

Knowledge related to Grade 6 Science:

1. **Electric current**: is the flow of electrons in a conductor.
2. **Electric circuit**: a switch, battery, and load are connected by connecting wires in a closed loop called electric circuit.
3. **Measurement of voltage**: Voltmeter is used to measure the amount of electric energy released per unit charge.

Knowledge related to technology:

4. **Multimedia projector**: is a device that is used to display computer screen on a larger screen.

5. **PhET Circuit Construction Kit simulation**: it is a software program that simulates the construction of electric circuits by means of visual representation.
6. **Evaluation of computer simulation**: it is the methods of assessing the effectiveness of the simulation in representing the natural phenomena appropriately.

Knowledge related to classroom pedagogy:

7. **Curriculum expectations related to Electricity**: are the specific expectations that learners are expected to achieve by the end of the unit of Electricity.
8. **Student's summative assessment**: is the method used by the teacher to assess student's learning at the end of the course.
9. **Testing hypotheses**: it is a process by which data are gathered and analyzed in order to test a previously postulated hypothesis.

What should I do?

1. In your portable memory stick, open "Pre-test" document file. Judge the relatedness of each pair of the concepts shown in the questionnaire.
2. Briefly justify the "Related" and "Highly related" ratings (i.e., rating 4 or 5).
3. You have 35 minutes to complete the rating.
4. Save the questionnaire in the portable memory, and then exit the document.

GOOD LUCK

Task 5. Experiencing inquiry model: Brightness of light lamps in series and parallel circuits

The purpose of this task is to develop first-hand experience on the learning processes involved in technology-mediated inquiry investigation. You are expected to conduct an inquiry investigation in a primary school science lab. In it, 5E learning cycle will be implemented to investigate the brightness of light bulbs in series and parallel circuits. At the end of this task, you are expected to compare the characteristics of series and parallel circuits. You will be using *PhET Circuit Construction kit* simulation to conduct your investigation.

Within the 5E learning cycle, your task is to:

- read and then discuss a real-life scenario (*Engage*)
- make hypotheses, and then use PhET simulation to conduct an investigation and test your hypotheses (*Explore*)
- describe your findings and come up with scientifically acceptable explanations (*Explain*)
- apply your knowledge in new situations (*Elaborate*)
- evaluate your learning – part of this task will be completed by the researcher throughout the investigation (*Evaluate*)

ENGAGE: Recall, Get ready

In your group, read the following scenario and answer the subsequent questions.

<u>*Scenario:*</u>

It is summer holidays season. Your neighborhood is about to welcome some celebrities, and you and your neighbors want to show them a good time. To start, you want to decorate your community center with lights. You decided to go for shopping and checkout some lighting. Some shops say you should get series circuit, and other blocks say you should get parallel circuit. Which one should you get?

Brainstorming:

1. What is the difference between series and parallel circuits?

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2. Try your best to draw a series and parallel circuit. Each circuit should include a battery, two or three light bulbs, switch, and connecting wires.

3. Back to the above scenario. Does it matter if you use series or parallel circuit to decorate the community center? (Don't worry if you are not sure about your answer)

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4. Do you have any other reasons that make you in favor of one type of circuit?

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Code: ....

EXPLORE: Hypothesize, Organize, Experiment, Collect data

To be certain about which type of circuit that makes maximum brightness, you need to conduct an investigation to compare the brightness of light lamps in series and parallel circuits.

But first! You need to make a prediction (or a hypothesis):

- Which circuit (series or parallel) would make the electric bulbs light with maximum brightness, regardless of how many bulbs are connected? (you don't need to justify your choice, but you need to make a hypothesis)

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Next, use the space below to design your investigation:

- Design an investigation to find out which circuit (series or parallel) would make the bulbs light with maximum brightness. Your design should include a set of procedures and a clear idea how you are going to test your hypothesis.

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EXERCISE CAUTION

- Once you design your investigation, use *PhET Circuit Construction Kit* simulation to conduct your experiment. To do that, first, download the PhET Circuit Construction Kit (DC only) simulation in your computer. Use the electric components to construct a circuit, and then use the tools on the bottom to run your circuit.
- *Record* your observations

EXPLAIN: Describe, Analyze, Explain, Share

Now, your task is to analyze your data or observations and try to come up with scientifically acceptable explanations. In the end of the *Explain* phase, you are expected to share your ideas or findings with the class. You can always use the PhET simulation to confirm your answers.

The following questions are designed to help you understand your investigation more deeply.

- Do you think the circuits you built or the procedures you followed in *Explore* phase were effective, in which way?

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- Compare the brightness of the bulbs in series circuits for each of the following cases (and then repeat the same procedures for parallel circuits):

  I. if two bulbs were connected ?

………

………

  II. if three bulbs were connected ?

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………

  III. if four bulbs were connected ?

………

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- What does the information gathered (in I, II, and III) lead you to conclude about the flow of current in one path (series circuit), and the flow of current in more than one path (parallel circuit)?

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- In terms of the dissipation of electric energy, what possible scientific explanations you could make on the behavior of light bulbs in series and parallel circuits?

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- Share your thoughts and ideas with the class

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ELABORATE: Apply, Relate, Connect, Infer

This is the time to apply your knowledge in different situations. Your task is to elaborate the characteristics of series and parallel circuits in different situations. Remember, you can always use the *PhET Circuit Construction Kit* simulation to confirm or test your answers.

Apply your knowledge

- What is the connection between flow of current in a circuit, brightness of light bulbs, and transfer of electric energy?

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- Circuit A and circuit B (below) consist of the same electric components: a battery, two light bulbs, connecting wires, and three switches. However, the circuits are wired in different ways. In your group, examine circuits A and B, and then answer the following questions.

Circuit A:

I. What will happen to L_2 if L_1 is removed from the circuit? Does the brightness of L_2 change? Explain your answers.

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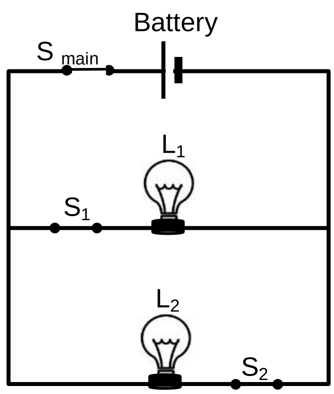

Circuit A

II. What will happen to the circuit if a wire is connected across the battery? Explain...

....

III. Using scientific terminologies, describe how electricity (electric current) will flow in the circuit when switch S_2 is open, while the other switches remain closed.

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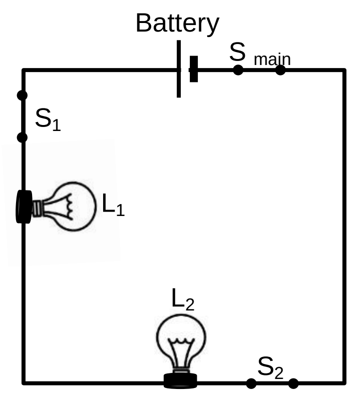
Circuit B:



Circuit B

I. What will happen to L_1 if L_2 burns out? Explain your answers.

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II. If you add a third bulb to the circuit, what would happen to the original light bulbs? Explain

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III. Light bulbs transfer electric energy in to light and heat energy. What does your answer to question II (above) lead you to conclude about the amount of light energy produced per bulb when too many bulbs are connected in series? ………………………………………………………

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- Compare the characteristics of series and parallel connections. Then decide how you are going to decorate your community center with lights. Share your thoughts and ideas with the class.

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Code: ....

EVALUATE: Assess, Observe, Evaluate

After you have gone through all of the previous excitements, it's the time to evaluate your understanding of the uses of series and parallel circuits in your daily life.

Assess your understanding

- Why do you think electrical appliances in our homes are connected in parallel?

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- Although home electricity is usually connected by parallel circuits, there are cases where lights are connected by series circuits. Discuss, with examples, some of these cases.

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- A "short circuit" is a term used to describe a condition when too much current passes through a circuit without significant resistance. Usually, it occurs when a metal wire is connected across an appliance or power supply. Different precautions are used in our homes to prevent short circuits from happening and, hence, causing damages to electric appliances or getting someone shocked. List some of these precautions, and discuss how they have made our homes safer.

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3. Second Session

3.1 Second Session Agenda

SESSION 1

TASKS

- Introduction
- Task 1: Electric circuits
- Task 2: PhET computer simulations
- Task 3: 5E Learning Cycle
- Task 4: Pre-test
- Task 5: Conducting an experiment via 5E learning cycle

SESSION 2

TASKS

- Task 6: Discussion (1) - analyzing in what ways the computer simulation was helpful (or not) for the inquiry investigation
- Task 7: Discussion (2) - analyzing the role of technology as a rational of pedagogical and content objectives
- Task 8: Post-test
- Task 9: Designing technology-based learning activities

RESOURCES

- ✓ Learner's Guide
- ✓ Science Curriculum
- ✓ Web resources
- ✓ PhET Circuit Construction simulation
- ✓ Electric circuit tool kits
- ✓ Science Textbook

3.2 Tasks 6 – 9

Task 6. Discussion (1)

After you have experienced a technology-based inquiry investigation, you are invited to analyze and reflect on the 5E learning activities. This task aims at critically analyzing the role of computer simulation in meeting the curriculum objectives. In doing so, you are asked to discuss the following issues, but also you are encouraged to bring other relevant issues, challenges, concerns, or point of views that are not explicated below.

Issues related to the 5E learning activities:

1. In the first session, you identified some features or functions of *PhET Circuit Construction Kit* simulation (see page 7 of this guide). Based on your precedent experience with the construction of parallel and series circuits, have you discovered other promising features or features that are less effective than what you thought?

2. Discuss the effectiveness (pros and cons) of the integration of PhET simulation in 5E learning cycle that have (or haven't) helped you learn the intended learning objectives (i.e., recognizing the characteristics of series and parallel circuits).

3. Based on your precedent experience, do you think the *PhET Circuit Construction Kit* simulation is an appropriate tool:
    a. for your students, in what way?
    b. to conduct 5E learning cycle, explain;
    c. for teaching and learning of electric circuits, justify

Task 7. Discussion (2)

This task aims at clarifying the role of computer technology in meeting pedagogical necessities. In doing so, you're asked to pair up and discuss the issues stated below. You are also encouraged to bring other relevant issues, challenges, concerns, or point of views that are not explicated below.

1. Identify parts of your science curriculum (e.g., primary level) where technology might help to overcome pedagogical or content difficulties.

2. With respect to your subject and students, in what ways computer technology could be useful in your teaching. You may think about the usefulness of a specific type of technology (e.g., Google Applications, Smart Boards, PhET simulations, or smart devices) in resolving cognitive problems or content difficulties. For example, when your students:
   - don't learn much from dissecting real animals; or
   - spend precious time in organizing and gathering data.

3. If you were asked to teach Electric Circuits to your students, what computer technology (or technologies) would you use, and how are you going to integrate this technology in your classroom teaching? Identify possible failure points in the computer technology, and develop alternate plans in case of a breakdown. If you decide not to use computer technology, justify your planning choice. (Note: make a draft or guidelines, no details are needed).

Task 8. Pathfinder Network Scaling (post-test)

Your task is to use Pathfinder Network Scaling a second time to relate the relatedness of the 9 concepts. You have done this test on the first session, but this time the test aims at examining the development of your Technological Pedagogical Content Knowledge (TPACK) that could have occur during the workshop.

To remind you how to complete the rating, you need to:

4. In your portable memory stick, open “Post-test” document file. Judge the relatedness of each pair of the concepts shown in the questionnaire.
5. Briefly justify the “Related” and “Highly related” ratings (i.e., rating 4 or 5).
6. You have 25 minutes to complete the rating.
7. Save the questionnaire in the portable memory, and then exit the document.

GOOD LUCK

Task 9. Planning and designing a technology-mediated inquiry-based learning activity

The purpose of this task is to incorporate your technological, pedagogical, and content knowledge in designing a technology-mediated inquiry activity (preferably working on a previously designed activity). You can choose any science content, technological tool, and inquiry approach. Your design, however, should include the following components:

1. the context: topic, target objectives, resources, teaching approach, and technological tool;
2. the rational of using technology in supporting specific content objectives
3. how technology would help in resolving students’ learning, teaching and learning procedures (pedagogical uses of technology);
4. layout instructional sequences or tasks (how you are going to teach your content with technology);
5. identify possible or likely failure points for the technology and develop an alternate plan in case of a breakdown.

Note: if you don’t want to choose computer technology in any part of your design, please justify.

3.3 Debriefing

First of all, thank you very much for your participation in this study.

What have Happened?

You have just completed a professional development workshop in educational technology. The workshop has provided you with opportunities to learn how science content, science pedagogy, and computer technology are interrelated. In doing so, you have completed different learning activities such as analyzing scenarios, conducting experiments, analyzing your learning experience, discussing relevant issues, and designing a technology-based inquiry activity.

What I am Investigating

The workshop aims at comparing the effectiveness of Experiencing Inquiry Model (EIM) in developing a unique domain of knowledge called, Technological Pedagogical Content Knowledge (TPACK); and examining how you would incorporate your new knowledge in designing a technology-mediated inquiry activity for junior/intermediate students.

What's Next?

The pre- and post- questionnaires will be used to determine the development of your TPACK knowledge that might have occurred during the workshop. Your design of technology based activity will be examined and cross-checked with your level of TPACK knowledge. Therefore, the findings of this study will inform the literature, science educators, and science teachers whether EIM strategy is equally effective in developing teachers' TPACK as compared to other strategies.

Overall

Your participation is highly appreciated and will help science educators and educational technologists in exploring effective strategies for developing science teachers' TPACK. I hope you have achieved your desired goals. If you could not achieve all of these goals, don't worry, teaching is a lifelong learning journey. We will continue to learn independently and flexibly in order to advance our knowledge and abilities.

Finally

This workshop received approvals from Research Ethics Board (REB) of the University of Ottawa, Ottawa - Canada. Accordingly, I did my best to follow the required ethics protocols and research guidelines at all times. All the information I collected in this workshop will be confidential, and there will be no way of identifying your responses or personal information in public. If I will quote any of your responses, I will seek your approval. You will have a copy of your learning materials two months from now. If there are questions about the study, please contact me or my supervisor.

THANK YOU AGAIN FOR YOUR PARTICIPATION

3.4 Recommended References

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McCrory, W.R. (2008). Science, technology, and teaching the topic-specific challenges of TPCK in science. In AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 193 - 206). New York: Routledge.

Online Resources and Websites

Teaching materials: www.mysciencesite.com

PhET website: www.phet.clorado.edu

Teaching materials at PhET website: https://phet.colorado.edu/forteacher

Teaching materials: https://wise.berkeley.eud/

Appendix F: <u>Learner's Guide - MS</u>

uOttawa

Faculty of Education

University of Ottawa

RESEARCH STUDY: THE IMPACT OF

Metacognitive Scaffolding

ON SCIENCE TEACHERS' PLANNING CHOICE OF TECHNOLOGY-MEDIATED INQUIRY-BASED LEARNING ACTIVITIES

CONDUCTED BY: MOHAMED IBRAHIM MUSTAFA

A Professional Development Workshop

Learner's Guide

Table of Content

Printed in Canada

1. Introduction

1.1 Overall of the Workshop

The purpose of this workshop is to investigate the impact of a teaching strategy, named Metacognitive Scaffolding (Kolencik and Hillwig, 2011), on the participants' understanding of the integration of computer technology in classroom instruction. In it, the participants will have opportunities to learn science content, methods of teaching this content, and how to utilize computer technology in science instruction. Initially, the participants will be asked to conduct an inquiry investigation to explore the brightness of electric bulbs in series and parallel circuits, just like primary school students. 5E Learning cycle will be used to manifest the general framework of inquiry–based learning, and PhET computer simulation will be utilized to execute the 5E Learning Cycle. Then, the participants will be asked to critically analyze different aspects of the inquiry investigation; and identify the challenges, failures, and successes of the integration of computer simulation in teaching and learning of electricity. Meanwhile, the participants will be asked to plan, monitor, and adjust their learning course using metacognitive strategies such as Thinking Aloud, and Reflective Journal. Finally, the participants will be asked to apply their new knowledge in designing of technology-based inquiry learning activity. At the end of the workshop, the participants are expected to develop a unique domain of knowledge named: Technological Pedagogical Content Knowledge (TPACK). Developing such knowledge is expected to help science teachers to think strategically while integrating computer technology in science instruction.

1.2 Overall Expectations

Throughout this workshop, teachers will:

A. demonstrate an understanding of the basic concepts of electric circuits, teaching science through inquiry, and computer simulation;
B. develop a unique domain of knowledge known as Technological Pedagogical Content Knowledge (TPACK); and
C. demonstrate skills (related to designing technology-based learning activities) in the four areas of Technological Pedagogical Content Knowledge (curriculum goals and technologies, instructional strategies and technologies, technology selections, and content pedagogy and technology fit).

1.3 Specific Expectations

A. Understanding the basic concepts

Throughout this workshop, learners will:

A.1 demonstrate basic understanding of the principles of construction of electric circuit (including the concepts of electric current and electric potential)

A.2 recognize and distinguish between the phases of 5E learning cycle: *Engage, Explore, Explain, Elaborate, and Evaluate*

A.3 describe the features and functions of *PhET Circuit Construction Kit simulation*

B. Developing TPACK

Throughout this workshop, learners will:

B.1 recognize the features of computer simulation that support teaching of science via 5E learning cycle

B2. identify the features of various types of computer technology in supporting specific curriculum objectives

B.3 discuss the pedagogical necessities as a rational to implement specific types of computer technology

B.4 critically analyze the effectiveness (or rational) of the 5E learning cycle and computer simulation in enhancing the understanding of the characteristics of series and parallel circuits

C. Developing skills related to TPACK

Throughout this workshop, learners will:

C.1 use computer simulation to construct electric circuit in series and parallel

C.2 plan and conduct an inquiry into the examination of the characteristics of series and parallel circuits

C.3 design a technology-mediated inquiry-based learning activity

2. First Session

2.1 First Session Agenda

SESSION 1

TASKS

- Introduction
- Introducing metacognitive strategies
- Introducing Electric circuits, computer simulations, & 5E Learning Cycle
- Task 1: Planning, Learning and Reflecting
- Task 2: Pre-test
- Task 3: Planning, Experiencing inquiry learning, and Reflecting

RESOURCES

- ✓ Learner's Guide
- ✓ Science Textbook
- ✓ Science Curriculum
- ✓ PhET simulations
- ✓ Web resources
- ✓ Electric circuit tool kits

SESSION 2

TASKS

- Task 4: Planning, Reflecting, and Analyzing in what ways the computer simulation was helpful (or not) for the inquiry investigation
- Task 5: Analyzing the role of technology in teaching and learning, and Writing reflective journal
- Task 6: Post-test
- Task 7: Planning, and Designing a technology-based learning activity
- Focus-group interview

Introduction to Electric Circuits, PhET Computer Simulations, and 5E Learning Cycle

A. Electric Circuits

Electrical appliances in your home such as bulbs, fans, and refrigerators should be connected or plugged into a circuit called an electric circuit. The electric circuit is a closed path for electricity, and it supplies electric appliances with energy. To understand how electric circuits work, you need to understand the basic principle of electricity. To do that, let's watch the YouTube following clip (https://www.youtube.com/watch?v=D2monVkCkX4).

B. PhET Simulations

PhET simulations are developed and tested by Physics Education Technology group, University of Colorado, Boulder. The PhET group has developed over 60 free downloadable physics, chemistry, and mathematics simulations. The content of the simulations includes most topics covered in a typical introductory science sequence in different levels (K – 12 and university). The *PhET Circuit Construction Kit (DC)* is one of those simulations. It can be used to simulate the construction and operation of simple electric circuits, and electric circuits of different types of connections (e.g., parallel and series).

C. 5E Learning Cycle

5E is an instructional model that manifests the general framework of inquiry-based learning. It is part of a larger series of models such as 3E, 4E, 5E, and 7E learning cycles. Although, these models are slightly different in the number of phases, the basic ideas are collectively inspired by the Piagetian focus of construction of knowledge and the Vygotskian notion of scaffolded learning. The following YouTube (http://youtu.be/BnlCQ45f7KM) will give you more insight on 5E Learning Cycle.

Before going into more details on the above three topics, you need to plan for your learning, and then use the learning resources, listed on page 8.

2.2 *Tasks 1 – 3*

Task 1. Planning, Learning, and Reflecting

A. <u>Planning</u>

The first part of this task is to set up a plan for developing deeper understanding of ***electricity and construction of electric circuits***, ***5E learning cycle***, and ***PhET computer simulation***. Your plan may focus on the three concepts or on the concepts where you think your knowledge falls short. Your plan, therefore, should include:

- personal or specific objectives you would like to achieve;
- specific topics that you would like to explore;
- a learning strategy (or procedures) that you think would help you in achieving your goals;
- appropriate learning resources;

You can use the learning resources listed on page 8.

The following tables are designed to help you set up your plan, but you can be more creative to design your own format. To make your plan absolutely effective, pair up and think aloud with your partner.

Think Aloud

i. Construction of Electric Circuits

What would I like to learn?	Why do I want to learn it?	How will I learn it?
Goals:		Strategy:
………………………………………………	………………………………………………	………………………………………………
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………………………………………………	………………………………………………	Resources:
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Topics:	………………………………………………	………………………………………………
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ii. *5E Learning Cycle*

What would I like to learn?	Why do I want to learn it?	How will I learn it?
Goals:		Strategy:
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iii. *PhET Computer Simulation*

What would I like to learn?	Why do I want to learn it?	How will I learn it?
Goals:		Strategy:
………………………………	………………………………	………………………………
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………………………………	………………………………	Resources:
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Topics:	………………………………	………………………………
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B. Learning

Once you plan for your learning path you can work with your group, or work independently in case your plan is fundamentally different from your group members. You are provided with learning resources. The learning resources listed below are of a wide range, including: cognitive tools, reading materials, Web resources, and hands-on activities. You are encouraged to use them, if needed.

Cognitive tools:

- Circuit construction tool kits: batteries, connecting wires, switches, battery holders, and light bulbs

Learning materials (books, articles, documents):

- Science Textbook
- Science Curriculum (Primary Level)

Web resources:

- https://phet.colorado.edu/en/simulations (PhET simulations)
- http://youtu.be/BnlCQ45f7KM (5E learning cycle)
- https://www.youtube.com/watch?v=D2monVkCkX4 (Electricity)
- www.mysciencesite.com
- https://phet.colorado.edu/forteacher

Activities:

- “Constructing a Simple Circuit” activity (page 9)
- “PhET Circuit Construction” activity (page 10)

Activity: Constructing a Simple Circuit

This activity aims at introducing the basic components of electric circuits, and how these components can be connected together to make a simple electric circuit.

Your task is to:

- Use the materials listed below to construct a simple circuit.
- Carefully use the connecting wires to join the components together.
- Make sure the switch remain open (OFF) until the circuit is complete
- Turn the switch ON, and make sure the electric bulb works.
- Explore the function(s) of each part of the circuit.
- Draw and label a circuit diagram in the space below.

EXERCISE CAUTION

Materials:

- Connecting wires
- Batteries (with battery holders)
- Light bulb
- Bulb holder
- Switch

Activity: PhET Circuit Construction Simulation

Materials/Resources:

- Computer or laptop
- Internet connection
- Google: PhET Interactive Simulations

EXERCISE CAUTION

Your task is to:

1. From the PhET Interactive Simulations website, download *PhET Circuit Construction Kit (DC only)* simulation in your computer.
2. Once the simulation is lunched, click-and-drag the electric components to the center of the main window. Use the components to construct a simple electric circuit. Your circuit should include a switch, battery, a light bulb, and connecting wires. After the electric circuit is completed, turn the switch ON and check the status of the light bulb.
3. Explore the function of the simulation (e.g., use the voltmeter to measure the voltage).
4. Discuss the main features or functions of the simulation that may be helpful (or NOT) in teaching and learning of electric circuits.
5. Explore other PhET simulations or the resources available for teachers.

C. ***Reflecting***

After-learning: Reflective Journal Checklist

Write short reflections in each of the following areas:

Now, I understand about ……………………………………………………………………………………………

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But, I am still puzzled by ……………………………………………………………………………………………

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How effective has my plan been in working and completing the previous tasks? ……………………………

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My strengths / weaknesses are. ……………………………………………………………………………………

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Task 2. Pathfinder Network Scaling (pre-test)

What is *Pathfinder Network Scaling*?

Pathfinder Network Scaling is an assessment tool used to map learner's structural knowledge. Structural knowledge refers to the way learners conceptualize the interrelationships between concepts of a particular domain(s) of knowledge.

Why am I using it?

You will use *Pathfinder Network Scaling* to draw a conceptual network as pertaining to your current technological, pedagogical content knowledge (pre-test). In doing so, you will be asked to rate the relatedness of 36 pairs of concepts relating to inquiry learning, concepts of electricity, and computer technology; as well as to indicate the rational of your rating.

How does it work?

Each pair of concepts will be rated on a numeric scale from completely unrelated (a rating of 1) to highly related (a rate of 5). Then, *Pathfinder Network Scaling* will transform the relatedness data into network representations via Knowledge Network Organizing Tool (KNOT) software program. In the network representation, each concept is represented by a node, and each relationship between two concepts is represented by a link between nodes. The highly related concepts are separated by more links, and the less related concepts are separated by fewer links or may be no links. Many of you may not be familiar with this type of assessment technique. Therefore, a simple example of the procedure involving non-study related concepts is presented in the following section.

Example: use the following Likert scale (or Pathfinder Network Scaling) to rate the relatedness of each pair of words:

Word (1)	Word (2)	1	2	3	4	5	Justify your judgment
Ostrich	Reptile						
Bird	Ostrich						
Snake	Bird						
Bird	Reptile						
Snake	Reptile						
Ostrich	Snake						

Now what concepts am I going to rate?

Knowledge related to Grade 6 Science:

1. **Electric current**: is the flow of electrons in a conductor.
2. **Electric circuit**: a switch, battery, and load are connected by connecting wires in a closed loop called electric circuit.
3. **Measurement of voltage**: Voltmeter is used to measure the amount of electric energy released per unit charge.

Knowledge related to technology:

4. **Multimedia projector**: is a device that is used to display computer screen on a larger screen.
5. **PhET Circuit Construction Kit simulation**: it is a software program that simulates the construction of electric circuits by means of visual representation.
6. **Evaluation of computer simulation**: it is the methods of assessing the effectiveness of the simulation in representing the natural phenomena appropriately.

Knowledge related to classroom pedagogy:

7. **Curriculum expectations related to Electricity**: are the specific expectations that learners are expected to achieve by the end of the unit of Electricity.
8. **Student's summative assessment**: is the method used by the teacher to assess student's learning at the end of the course.

9. **Testing hypotheses**: it is a process by which data are gathered and analyzed in order to test a previously postulated hypothesis.

What should I do?

1. In your portable memory stick, open "Pre-test" document file. Judge the relatedness of each pair of the concepts shown in the questionnaire.
2. Briefly justify the "Related" and "Highly related" ratings (i.e., rating 4 or 5).
3. You have 35 minutes to complete the rating.
4. Save the questionnaire in the portable memory, and then exit the document.

GOOD LUCK

Task 3. Planning, Experiencing, and Reflecting

<u>Brightness of light lamps in series and parallel circuits</u>

The purpose of this task is to develop first-hand experiences on the learning processes involved in technology-mediated inquiry investigation. You are expected to conduct an inquiry investigation in a primary school science lab. In it, 5E learning cycle will be implemented to investigate the brightness of light bulbs in series and parallel circuits. At the end of this task, you are expected to compare the characteristics of series and parallel circuits. You will be using *PhET Circuit Construction kit* simulation to conduct your investigation.

*A. **Planning***

Before experiencing the 5E learning activity, your task is to set personal learning objectives you would like to achieve, and explain why you would like to learn these objectives. Then, with your partner, lay out a strategy or a method that would like to use to help you progressing through the 5E learning activities.

Your plan should include:

- personal or specific objectives you would like to achieve, and why;
- a learning strategy (or strategies) that you think would help you in achieving your goals;
- appropriate learning resources;

You can fill up the following tables, or make your own design.

Think Aloud

What learning objectives would I like to achieve?	Why do I want to learn them?
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Code: ………………

A strategy that would help me in achieving my learning objectives:

Strategy: ……………………………………………………………………………………………………

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Resources: Experiencing Inquiry Model activity

Procedures: 5E learning cycle: engage, explore, explain, elaborate, and evaluate

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B. <u>Experiencing inquiry model</u>

Within the 5E learning cycle, your task is to:

- read and then discuss a real-life scenario (*Engage*)
- make hypotheses, and then use PhET simulation to conduct an investigation and test your hypotheses (*Explore*)
- describe your findings and come up with scientifically acceptable explanations (*Explain*)
- apply your knowledge in new situations (*Elaborate*)
- evaluate your knowledge – part of this task will be completed by the researcher throughout the investigation (*Evaluate*)

Engage: Recall your prior knowledge, Get ready

In your group, read the following scenario and answer the subsequent questions.

<u>*Scenario:*</u>

It is summer holidays season. Your neighborhood is about to welcome some celebrities, and you and your neighbors want to show them a good time. To start, you want to decorate your community center with lights. You decided to go for shopping and checkout some lighting. Some shops say you should get series circuit, and other blocks say you should get parallel circuit. Which one should you get?

Brainstorming:

1. What is the difference between series and parallel circuits?

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2. Try your best to draw a series and parallel circuit. Each circuit should include a battery, two or three light bulbs, switch, and connecting wires.

3. Back to the above scenario. Does it matter if you use series or parallel circuits to decorate the community center? (Don't worry if you're not sure about your answer)

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4. Do you have any other reasons that make you in favor of one type of circuit?

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Explore: Hypothesize, Organize, Experiment, Collect data

To be certain about which type of circuit that makes maximum brightness, you need to conduct an investigation to compare the brightness of light lamps in series and parallel circuits.

But first! You need to make a prediction (or a hypothesis):

- Which circuit (series or parallel) would make the electric bulbs light with maximum brightness regardless of how many bulbs are connected? (you don't need to justify your choice, but you need to make a hypothesis)

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Next, use the space below to design your investigation:

- Design an investigation to find out which circuit (series or parallel) would make the bulbs light with maximum brightness. Your design should include a set of procedures and a clear idea how you are going to test your hypothesis.

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EXERCISE CAUTION

- Once you design your investigation, use *PhET Circuit Construction Kit* simulation to conduct your experiment. To do that, first, download PhET Circuit Construction Kit (DC only) simulation in your computer. Then use the electric components to construct a circuit, and then use the tools at the bottom to run your circuit.
- *Record* your observations

Explain: Describe, Analyze, Explain, Share

Now, your task is to analyze your data or observations and try to come up with scientifically acceptable explanations. In the end of the *Explain* phase, you are expected to share your ideas or findings with the class. You can always use the PhET simulation to confirm your answers.

The following questions are designed to help you understand your investigation more deeply.

- Do you think the circuits you built or the procedures you followed in *Explore* phase were effective, in which way?

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- Compare the brightness of the bulbs in series circuits for each of the following cases (and then repeat the same procedures for parallel circuits):

  I. if two bulb was connected ?

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  II. if three bulbs were connected ?

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  III. if four bulbs were connected ?

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- What does the information gathered (in I, II, and III) lead you to conclude about the flow of current in one path (series circuit), and the flow of current in more than one path (parallel circuit)?

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- In terms of the dissipation of electric energy, what possible scientific explanations you could make on the behavior of light bulbs in series and parallel circuits?

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- Share your thoughts and ideas with the class

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Code: ……………….

5. ***Reflecting (during-learning)***

During-learning, you will be asked to reflect on the learning progress that you have accomplished so far, and make any necessary adjustment to your learning path, if needed.

Respond to the following questions:	YES	NO	If my answer is NO, what should I do next?
Is my plan working (strategies & learning procedures)?			……………………………………………………… ……………………………………………………… ……………………………………………………… ………………………………………………………
Am I progressing well?			……………………………………………………… ……………………………………………………… ……………………………………………………… ………………………………………………………
Am I achieving my learning goals?			……………………………………………………… ……………………………………………………… ……………………………………………………… ………………………………………………………

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Elaborate: Apply, Relate, Connect, Infer

This is the time to apply your knowledge in different situations. Your task is to elaborate the characteristics of series and parallel circuits in different situations. Remember, you can always use *PhET Circuit Construction Kit* simulation to confirm or test your answers.

Apply your knowledge

- What is the connection between flow of current in a circuit, brightness of light bulbs, and transfer of electric energy?

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- Circuit A and circuit B (below) consist of the same electric components: a battery, two light bulbs, connecting wires, and three switches. However, the circuits are wired in different ways. In your group, examine circuits A and B, and then answer the following questions.

Circuit A:

I. What will happen to L_2 if L_1 is removed from the circuit? Does the brightness of L_2 change? Explain your answers.

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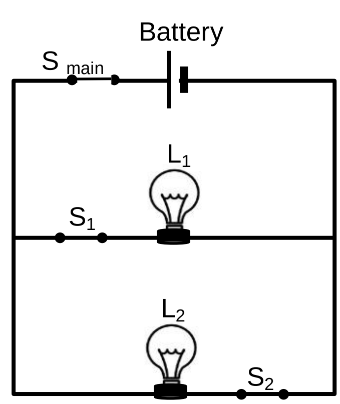

Circuit A

II. What will happen to the circuit if a wire is connected across the battery? Explain

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III. Using scientific terminologies, describe how electricity (electric current) will flow in the circuit when switch S_2 is open, while the other switches remain closed.

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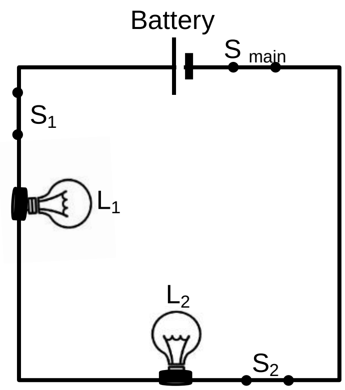
Circuit B:



Circuit B

I. What will happen to L_1 if L_2 burns out? Explain your answers.

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II. If you add a third bulb to the circuit, what would happen to the original light bulbs? Explain

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III. Light bulbs transfer electric energy in to light and heat energy. What does your answer to question II (above) lead you to conclude about the amount of light energy produced per bulb when too many bulbs are connected in series? ……………………………………………

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- Compare the characteristics of series and parallel connections. Then decide how you are going to decorate your community center with lights. Share your thoughts and ideas with the class.

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Evaluate: Assess, Observe, Evaluate

After you have gone through all of the previous excitements, it's the time to evaluate your understanding of the uses of series and parallel circuits in our daily life.

Assess your understanding

- Why do you think electrical appliances in our homes are wired in parallel?

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- Although home electricity is usually connected by parallel circuits, there are cases where lights are connected by series circuits. Discuss, with examples, some of these cases.

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- A "short circuit" is a term used to describe a condition when too much current passes through a circuit without significant resistance. Usually, it occurs when a metal wire is connected across an appliance or power supply. Different precautions are used in our homes to prevent short circuits from happening and, hence, causing damages to electric appliances or getting someone shocked. List some of these precautions, and discuss how they have made our homes safer.

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D. ***Reflecting (after-learning)***

After-learning, you will be asked to complete *Reflective Journal Checklist.*

Write short reflections in each of the following areas:

Now, I understand about ……………………………………………………………………………………

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But, I am still puzzled by ……………………………………………………………………………………

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How effective has my plan been in working and completing the previous tasks? ……………………………

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My strengths / weaknesses are. …………………………………………………………………………

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What I would change (in my plan) and do differently in the upcoming tasks. ……………………………

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3. Second Session

3.1 Second Session Agenda

SESSION 1

TASKS

- Introduction
- Introducing metacognitive strategies
- Introducing Electric circuits, computer simulations, & 5E Learning Cycle
- Task 1: Planning, Learning and Reflecting
- Task 2: Pre-test
- Task 3: Planning, Experiencing inquiry learning, and Reflecting

SESSION 2

TASKS

- Task 4: Planning, Reflecting, and Analyzing in what ways the computer simulation was helpful (or not) for the inquiry investigation
- Task 5: Analyzing the role of technology in teaching and learning, and Writing reflective journal
- Task 6: Post-test
- Task 7: Planning, and Designing a technology-based learning activity
- Focus-group interview

RESOURCES

- ✓ Learner's Guide
- ✓ Science Curriculum
- ✓ Science Textbook
- ✓ PhET simulations

  www.phet.clorado.edu
- ✓ Electric circuit tool kits

3.2 Tasks 4 – 7

Task 4. Planning, Analyzing, and Reflecting

A. <u>Planning</u>

After you have experienced a technology-based inquiry investigation, you are invited to analyze and reflect on the 5E learning activities. However, prior that, you are asked to set personal learning objectives you would like to achieve today. Your plan should include:

- personal or specific objectives you would like to achieve;
- a learning strategy (or strategies) that you think would help you in achieving your goals;
- appropriate learning resources;

You can fill up the following tables, or make your own design.

Think Aloud 

What would I like to learn?	Why do I want to learn it?
……………………………………………………	……………………………………………………
……………………………………………………	……………………………………………………
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How will I learn it?

Strategy: ……………………………………………………………………………………………

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Resources: …………………………………………………………………………………………

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Procedures: …………………………………………………………………………………………

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B. ***Analyzing the 5E learning activities***

Once you set up your learning objectives, your task aims at critically analyzing the role of computer simulation in understanding the construction of electric circuits. In doing that, you need to discuss the issues stated below. You are also encouraged to bring other relevant issues, challenges, concerns, or point of views that are not explicated below. The outcome of this analysis is expected to coincide with the learning objectives you are intending to achieve.

Issues related to the 5E learning activities:

1. In the first session, you might have identified some features or functions of *PhET Circuit Construction Kit* simulation (see page 13 of this guide). Based on your precedent experience with construction of parallel and series circuits, have you discovered other promising features or features that are less effective than what you thought?

2. Discuss the effectiveness (pros and cons) of the integration of PhET simulation in 5E learning cycle that have (or haven't) helped you learn the intended learning objectives.

3. Based on your precedent experience, do you think the *PhET Circuit Construction Kit* simulation is an appropriate tool:
    a. for your students, in what way?
    b. to conduct 5E learning cycle? Explain;
    c. for teaching and learning of electric circuits?

C. ***Reflecting (during-learning)***

During-learning, you will be asked to reflect on the learning progress that you have accomplished so far, and make any necessary adjustment to your learning path, if needed.

Respond to the following questions:	YES	NO	If my answer is NO, what should I do next?
Is my plan working (strategies & learning procedures)?			……………………………………………………………
Am I progressing well?			……………………………………………………………
Am I achieving my learning goals?			……………………………………………………………

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Task 5. Analyzing, and Reflecting

A. Analyzing the 5E learning activities (cont.)

This task aims at clarifying the role of computer technology in meeting pedagogical necessities. In doing that, you need to pair up and discuss the issues stated below. You are also encouraged to bring other relevant issues, challenges, concerns, or point of views that are not explicated below.

1. Identify parts of your science curriculum (e.g., primary level) where technology might help to overcome pedagogical or content difficulties.

2. With respect to your subject and students, in what ways computer technology could be useful in your teaching. You may think about the usefulness of a specific type of technology (e.g., Google Applications, Smart Boards, PhET simulations, or smart devices) in resolving cognitive problems or content difficulties. For example, when your students:
    - do not learn much from dissecting real animals; or
    - spend precious time in organizing and gathering data.

3. If you were asked to teach Electric Circuits to your students, what computer technology (or technologies) would you use, and how are you going to integrate this technology in your classroom teaching? Identify possible failure points in the computer technology, and develop alternate plans in case of a breakdown. If you decide not to use computer technology, justify your planning choice. (Note: make a draft or guidelines, no details are needed).

B. ***Reflective Journal Checklist***

Respond to the following questions:	YES	NO	If your answer is YES, briefly express your understanding or knowledge
Do I understand what does the pedagogical uses of technology mean?			………………………………………… ………………………………………… ………………………………………… …………………………………………
Do I know where, in science curriculum, technology might be very useful to use, and why?			………………………………………… ………………………………………… ………………………………………… …………………………………………
Do I understand the rational of implementing technology in clarifying scientific concepts?			………………………………………… ………………………………………… ………………………………………… …………………………………………
Do I understand what is meant by Technological Pedagogical Content Knowledge (TPACK)?			………………………………………… ………………………………………… ………………………………………… …………………………………………

If your answer is NO in any of the above questions, explain what are you puzzled by? ……………………

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What is my strategy for designing technology-mediated inquiry-based activities?……………………………

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What challenges in planning and designing such activities might be? ……………………………………

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How do I overcome these challenges? ………………………………………………………………

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Task 6. Pathfinder Network Scaling (post-test)

Your task is to use Pathfinder Network Scaling a second time to relate the relatedness of the 9 concepts. You have done this test on the first session, but this time the test aims at examining the development of your Technological Pedagogical Content Knowledge (TPACK) that could occur during the workshop.

To remind you how to complete the rating, you need to:

1. In your portable memory stick, open "Post-test" document file. Judge the relatedness of each pair of the concepts shown in the questionnaire.
2. Briefly justify the "Related" and "Highly related" ratings (i.e., rating 4 or 5).
3. You have 25 minutes to complete the rating.
4. Save the questionnaire in the portable memory, and then exit the document.

GOOD LUCK

Task 7. Planning and designing a technology-mediated inquiry-based learning activity

The purpose of this task is to help you incorporate your technological, pedagogical, and content knowledge in designing a technology-mediated inquiry activity (preferably working on a previously designed activity). You are free to choose the science content, technological tool, and inquiry approach. However, your design should include the following components:

1. the context: topic, target objectives, resources, teaching approach, and technological tool;
2. the rational of using technology in supporting specific content objectives
3. how technology would help in resolving students' learning, teaching and learning procedures (pedagogical uses of technology);
4. layout instructional sequences or tasks (how you are going to teach your content with technology);
5. identify possible or likely failure points for the technology and develop an alternate plan in case of a breakdown.

Note: if you don't want to choose computer technology in any part of your design, please justify.

3.3 Debriefing

First of all, thank you very much for your participation in this study.

What have Happened?

You have just completed a professional development workshop in educational technology. The workshop has provided you with opportunities to learn how science content, science pedagogy, and computer technology are interrelated. In doing so, you have completed different learning activities such as analyzing scenarios, conducting experiments, designing activities, and writing reflective journals.

What I am Investigating

The workshop aims at comparing the effectiveness of Metacognitive Scaffolding (MS) in developing a unique domain of knowledge called, Technological Pedagogical Content Knowledge (TPACK); and examining how you would incorporate your new knowledge in designing a technology-mediated inquiry activity for junior/intermediate students.

What's Next?

The pre- and post- questionnaires will be used to determine the development of your TPACK knowledge that might have occurred during the workshop. Your design of technology based activity will be examined and cross-checked with your level of TPACK knowledge. Therefore, the findings of this study will inform the literature, science educators, and science teachers whether MS strategy is equally effective in developing teachers' TPACK as compared to other strategies.

Overall

Your participation is highly appreciated and will help science educators and educational technologists explore effective strategies of developing science teachers' TPACK. I hope you have achieved your desired goals. If you could not achieve all of these goals, don't worry, teaching is a lifelong learning journey. We will continue to learn independently and flexibly in order to advance our knowledge and abilities.

Finally

This workshop received approvals from Research Ethics Board (REB) of the University of Ottawa, Ottawa - Canada. Accordingly, I did my best to follow the required ethics protocols and research guidelines at all times. All the information I collected in this workshop will be confidential, and there will be no way of identifying your responses or personal information in public. If I will quote any of your responses, I will seek your approval. You will have a copy of your learning materials two months from now. If there are questions about the study, please contact me or my supervisor.

THANK YOU AGAIN FOR YOUR PARTICIPATION

a. Recommended References

Chamberlain, K., & Crane, C. (2009). *Reading, writing, & inquiry in the science classroom Grades 6 – 12.* London, UK: SAGE.

Goldston, M., & Downey, L. (2013). *Your science classroom*. London, UK: SAGE.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technological Pedagogical Content Knowledge. *Teaching & Teacher Education, 21*(5), 509-523.

Mishra, P. & Koehler, M. (2006). Technological Pedagogical Content Knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

McCrory, W.R. (2008). Science, technology, and teaching the topic-specific challenges of TPCK in science. In AACTE Committee on Innovation and Technology (Eds.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 193 - 206). New York: Routledge.

Online Resources and Websites

Teaching materials: www.mysciencesite.com

PhET website: www.phet.clorado.edu

Teaching materials at PhET website: https://phet.colorado.edu/forteacher

Teaching materials: https://wise.berkeley.eud/

Appendix G: Implementation Protocol - EIM

Day 1

Date/Time	Task/Justification	Resources/Procedures	What could go wrong?	Contingency/Avoidance plan
15 min.	**Pre-Task (1):** • Introducing the research project • Distributing and signing the forms • Organizing the participants in small groups **Justification:** Inform the participants about the project and get their consent to go ahead on the data collection procedures	**Resources:** Learner's Guide, Information Letter, Consent Forms, Name tags **Procedures, I will:** 1. Use the information letter to describe the research objectives and procedures; in the description, **include the idea of recognizing the interrelationships between technology, pedagogy, and technology** 2. Ask the participants to hand in the Consent forms signed; 3. Remind the participants that **the main scope of this workshop is not intended to introduce something new**, rather it's aimed to provide you with opportunities to understand the interrelationships between **technology, pedagogy, and technology.**	• Some participants may come late or don't show up at all; • This task may take longer than anticipated	• Participants who are coming late, talk to them individually; • To avoid any delay, prepare all the materials, settings, resources, etc. ahead of time. To do that, arrive early, and prepare the classroom 30 min. prior the beginning of the session. Any paperwork should be done as early as possible. • To save more time, send the information letter out so we don't waste time in explicating the research procedures.
10 min.	**Pre-Task (2):** • Short introduction to educational technology **Justifications:** Leading-in	**Resources:** **PowerPoint presentation** **Procedures, I will:** 1. Elaborate on the basic components of TPACK and the interrelationship between these components. **(PP)** 2. Go through the overall expectations and the specific expectations **3. Go through Today's agenda** 4. Answer any question posed by the participants before the start 5. Ask the participants to create groups of 3 members.	• The speech may take longer time • The participants may pose more questions	• Discuss very limited points (e.g., IT, TPACK, and why developing TPACK)
20 min.	**Task 1:** Describe the basic	**Resources:** YouTube clip, Grade 6 Textbook, copies of science curriculum	• The participants may ask too many	• Prepare a YouTube clip that describes the concepts

	principles of electricity and electric circuit as required by the Ontario Science & Technology Curriculum – Grad 6. **Justification:** Prerequisite to complete *Pathfinder Network Scaling*	**Procedures, I will:** 1. Introduce the concepts of electricity. In it, I will ask the participants what do they know about electricity and whether they teach these concepts in their regular classes **(PP)** 2. Show a YouTube clip that describes the fundamental concepts of electric circuits 3. Ask the participants to complete **"Constructing a Simple Circuit" activity,** using concrete objects such as: batteries, bulb, connecting wires, switch, etc. 4. Summarize the basic idea of current, potential difference, and electric circuits (**use Grade 6 Textbook as a reference and PP**) *5. Organize the above documents in the guide*	questions. • Resources may not be available such as electric circuit tool kits.	the best. In it, there should be a verbal description of the topic as well as a visual aid activity. The clip should not take more than 5-8 min. • Connect the YouTube clip with the specific expectations of the curriculum. • Use Grade 6 Textbook to elaborate more on the topic or explain other concepts. • If the electric circuit tools kits is not available, blend task 1 and 2
20 min.	**Task 2:** Introducing PhET *Circuit Construction Kit* simulation **Justification:** Prerequisite to complete *Pathfinder Network Scaling*	**Resources:** Laptops or desktops, Internet connection, PhET Website **Procedures, I will:** 1. Briefly clarify what computer simulation is, and what PhET simulations are **(PP)**. 2. Ask the participants: are you using PhET simulations in your classroom teaching? 3. Ask the participants to login to their computers (or from the portable flash memory) and go to www.phet.clorado.edu 4. Go through the main sections of the PhET simulations website 5. With minimum guidance, ask the participants to complete **"PhET Circuit Construction" activity**, so they could be more familiar with electric circuits construction via PhET simulation	• Java software may not be installed in the computers. • Slow Internet connection, and hence unable to complete Task 2 in time • Difficulties to go about the simulation	• Make sure Java software is installed in the school's computers. Alternatively, as the participants to bring their laptops with Java installed. • Save the Circuit Construction simulation in a flash memory. Use this copy in case there are some difficulties in the Internet connection. • Walk the participants through the login process and how to locate the PhET simulations.
15 min.	**Task 3:** Introducing 5E learning	**Resources:** **PowerPoint presentation**, YouTube clip	• The participants may not so familiar	• Describe 5Es in a very simple manner. They are

	cycle **Justification:** Prerequisite to complete *Pathfinder Network Scaling*	**Procedures, I will:** 1. **Briefly**, discuss with the class the types of inquiry instructions used in schools. 2. Ask the participants if they have used 5E in their teaching? 3. Use PowerPoint slides to demonstrate the phases of 5E learning cycle, include in the PP a brief description of the 5 phases **(PP)** **4.** Show a YouTube clip, **if needed**	to 5E learning cycle • The participants may get confused or overwhelmed	going to learn about it any way.
10 min. 30 min.	**Task 4:** Introducing *Pathfinder Network Scaling* tool **Justification:** Inform the participants how their knowledge structure can be assessed; and hence, be able to make sense when they relate the concepts of electricity, 5E, and PhET simulation. Administering the pre-test **Justification:** The pre-test will illustrate the participants' knowledge structure prior the intervention. The pre-test will be considered as a covariate in order to normalize any differences between the groups.	**Resources:** *Pathfinder Network Scaling* (portable flash memory) **Procedures, I will:** 1. Briefly describe the concepts of knowledge structure and how it's assessed by Pathfinder Network Scaling **(PP)**. 2. Ask the participants to use **the Example** to rate the relatedness of familiar set of words such as: Ostrich, Reptile, Snake, and Bird 3. If there is enough time, let the participants use *Pathfinder Network Scaling* and view their knowledge structures as pertaining to these concepts/words (recommended). 4. Ask the participants to rate the relatedness of 36 pairs of concepts pertaining to Electricity, 5E, and computer simulation (pre-test)	• Unable to complete Task 3 in time • Technical issues related to Pathfinder tool	• Describe the concept of assessment of knowledge structure in a very simple way. • Be aware of the technical problems • In this training session, group the concepts in a questionnaire, and ask the participants to rate the relatedness of the concepts using a hard copy.
60 min.	**Task 5:** Conducting an inquiry experiment using 5E	**Resources:** Learner's Guide, Electric circuit tool kits (5 sets), PhET simulation	• The participant may skip the phases and don't	• Emphasize the fact that the participants are expected to act like Grade 6 students

	learning cycle: Engage, Explore, Explain, Elaborate, and Evaluate **Justification:** In order to experience inquiry model, the participants have to make hypotheses or predictions, collect and analyze data, provide scientific explanations, and make conclusions.	**<u>Procedures, I will:</u>** 1.Ask the participants to form their groups. 2. **Distribute learning activity # 5** (the participants should keep the hand outs in their folder). i) In ***Engage* phase**, ask the participants to <u>*discuss a scenario*</u> involving how the brightness of bulbs would be different in series and parallel connections. Present a real-life situation where bulbs are connected in series and parallel; ask questions, pose problems, and assess prior knowledge. (10 min.) ii) In ***Explore* phase**, ask the participants to predict (or make hypotheses) the level of brightness of light lamps in series and parallel circuits. The participants are expected to <u>*design and conduct an inquiry, collecting data via PhET simulation*</u>, organize and analyze the gathered data. (30min.) iii) In ***Explain* phase**, ask the participants to analyze the data and come up with scientifically acceptable explanations to their data; ask them <u>to share</u> their ideas and comments; <u>remind</u> the participants to go back to the simulation if they want to confirm or test their ideas; and <u>conclude</u> the findings. (20 min.) iv) In ***Elaborate* phase**, ask the participants <u>*to respond*</u> to the questions; at the end of this phase, ask the participants <u>to share</u> their ideas and comments with the class; <u>remind</u> the participants to go back to the simulation if they want to confirm their answers. v) In ***Evaluate* phase**, ask the participants to solve few questions to be able to evaluate their learning. In addition, the participants should be assessed throughout the experiment (15 min.).	follow the learning sequence as planned. •The participants may go directly to *Explain* phase without making predictions or hypotheses. •The participants may start acting as science teachers and forget to focus on completing the tasks	and they will be given another opportunity to act like science teachers. •Allow some kind of feedback between 5E phases. Thereby, make sure the participants are following the guidelines and on task. • Go around and respond to the participants' questions, difficulties, or inquiries. • Always remind the participants that we will analyze the 5E activities later on.

<u>Day 2</u>

70 min.???	**Task 6:** Discussing the role of technology as a rational of pedagogical and content objectives	**<u>Resources:</u>** Grade 6 Textbook, PhET simulations, Electric Circuit Tool kits **<u>Procedures, I will:</u>** 1. Ask the participants to <u>organize themselves in groups based on their grade levels (3 members in each group)</u>. 2. Briefly describe different models of inquiry learning; put more emphases on	• The participants may discuss some aspects of their own learning. •They may discuss how easy/difficult	•Emphasize the fact that this is the time to act like professional teachers. • Any discussion

	(Analysis and Assessment) **Justification:** The participants are expected to act like professionals and analyze the effectiveness of their precedent learning activities	teacher and student's roles **(PP)** 3. Briefly describe the types of technologies used for teaching and learning of science **(PP)** 4. Ask the participants to complete **Learning Task # 6**. In it, they <u>*are expected to act like science teachers*</u> and discuss their precedent experience. 5. Clarify the issues (1-3), if needed (read page 196 on McCrory) **(PP)**. 6. Ask the participants to *think about the PhET simulation, and whether it's effectiveness in completing the learning tasks*. They can also go back to the simulation to gain better understanding of the issues, if needed. 7. **Each group will be assigned to one topic, and in the end they discuss their topic with the class**. 8. At the end of the discussion period, summarize the participants' presentations; highlight any interesting points, critical issues, or relevant challenges to be addressed.	to perform the inquiry tasks; or • They may express some kind of satisfactions because they are able to finish the tasks in time.	about the activities should be related to 6 Graders and not themselves. • Ask the participants to analyze the effectiveness of the learning activities instead of discussing their own learning. • Learning Task 5 should be carefully designed to fulfill the points stated above.
30 min.	**Task 7:** critically analyzing the precedent learning activities **Justification:** This learning opportunity aims at engaging the participants in discussion to understand the interrelationships between 5Es (PK), computer simulation (TK), and electric circuit (CK). As a result, they should be able to develop TPACK.	<u>**Resources:**</u> Learner's Guide, Electric circuit tool kits (5 sets), PhET simulation, <u>**Procedures, I will:**</u> 1. Ask the participants to go back to their grade-based groups. 2. Ask the participants to complete Learning Task # 7. In it, the participants are expected to respond to specific questions and discuss the rational granted to the computer technology in meeting pedagogical goals and learning objectives (issues 1-3). 3. Walk around and observe the responses, questions, ideas, or comments on their tasks.	• The participants may focus on few relationships between PK, TK, and CK; and overlook other ones. • The participants may spend long time on talking/chatting without getting to solid conclusions.	• The Learning Task 6 should include leading questions. The leading questions should cover TPACK intersections (i.e., TPK, TCK, PCK, and TPACK). • I should facilitate the discussion in a way that helps the participants to much of their cognitive time more effectively. To do that, I should be firm on timing, finishing tasks in time, allowing specific questions, wrapping up discussions, writing the main points on the board, extracting themes and issues, and responding to 'what if' scenarios.
25 min.	**Task 8:** Administering the pre-test **Justification:** The post-test is expected to determine the changes in the participants'	<u>**Resources:**</u> *Pathfinder* Network *Scaling* (e-version), Participants' user names and passwords <u>**Procedures:**</u>	• Technical issues related to Pathfinder tool • The	• Be aware of the technical problems • Group the target concepts in a questionnaire, and ask the participants to rate the relatedness of the concepts using a hard copy.

	structure of knowledge that could have occurred during the intervention. The post-test should be conducted immediately after the intervention to avoid the influence of a third variable (internal validity).	1.Ask the participants to rate the relatedness of 9 concepts pertaining to Electricity, 5E, and computer simulation (pre-test) 2. Collect the consent forms.	participants may gain some kind of testing effect.	• Reorganize the concepts •Add the same pair of concepts more than once. Test the correlation effect among those particular concepts. In consistent ratings will be eliminated.
50 min.	**Task 9:** designing a technology-mediated inquiry-based learning activity **Justification:** This is an opportunity to apply the participants' understanding of TPACK in designing learning activities. It's important to examine the participants' abilities to incorporate their understanding of TPACK in one of their teaching practices. Simply because, developing TPACK doesn't necessarily lead to an effective integration of technology in science instruction.	**<u>Resources:</u>** Exercise Sheet **<u>Procedures:</u>** Ask the participants to complete the exercise. In it, they are expected to design a technology-based learning activity. They can work on a previously designed activity or design a new one. Their design **should integrate a technological tool or tools, or may be no technology at all.** Their design should include the following elements: Topic, target objectives, resources, teaching approach, cognitive tools (technology vs lab), assessment tools, procedures, and the rational granted to technology and teaching approach in meeting learning objectives.	•The participants may not be able to finish this task, or parts of it, in time.	• Ask the participants to bring to the class a previously designed activity to work on it. •The participants are not obliged to use a specific content, or specific teaching strategy. •Ask the participants to focus on the reasoning and decision-making parts. For example, what features make a specific technology the best choice for their design and why; etc. • In the Exercise Sheet, include templates, fill up the blanks, leading questions, etc.
15 min.	**Task:** Focus group interview and debriefing **Justification:** The interview session is expected to describe the parts of the intervention and post-intervention exercise that can't be examined by the quantitative analysis. Also, the interview will allow the researcher to examine the conditions of the strategy by which the learners could benefit the most.	**<u>Procedures, I will:</u>** 1. interview the participants for 15 minutes according to the following **protocol**: 2. debrief the participants and say THANK YOU	• No show case • The participants might be overwhelme d.	•Establish a protocol for the interview (timing, taping, Q & A, etc.) •The interview can be conducted at earlier stage (e.g., during the exercise). •Fire up the interview with leading questions. • Hear the participants' voices. • Allow equal opportunities for all members.

Appendix H: Implementation Protocol – MS

Day 1

Date/Time	Task/Justification	Resources/Procedures	What could go wrong?	Contingency/Avoidance plan
10 min.	**Pre-Task (1):** • Introducing the research project • Distributing and signing the forms • Organizing the participants in small groups **Justification:** Inform the participants about the project and get their consent to go ahead on the data collection procedures	**Resources:** Consent Forms, Learner's Folder **Procedures, I will :** 4. Use the information letter to describe the research objectives and procedures; **including the learning expectations (PP)** **Elaborate on the relationships between technology, pedagogy, and technology** 5. Distribute the Learner's Guide; and describe the content of the folder and what are they for; 6. Answer any question posed by the participants before the start 7. Remind the participants that **the main scope of this workshop is not intended to introduce something new**, rather it's aimed to provide you with opportunities to understand the interrelationships between **technology, pedagogy, and technology.** 8. Go through Today's agenda **(PP)**	• Some participants may come late or don't show up at all; • This task may take longer than anticipated	• Participants who come late, talk to them individually; • To avoid any delay, prepare all the materials, settings, resources, etc. ahead of time. To do that, arrive early, and prepare the classroom 15 min. prior the beginning of the session. Any paperwork should be done as early as possible. • To save more time, send the information letter out so we don't waste time in explicating the research procedures.
10 min.	**Pre-Task (2):** Introducing metacognitive strategies **Justification:** The participants will be using these strategies throughout the workshop. This task allows them to develop their metacognitive knowledge	**Resources:** **PowerPoint presentation or Prize** **Procedures, I will:** 1. Briefly, explain what metacognition means, and show some examples of learning with metacognition 2. Introduce ***Think Aloud*** strategy to: **(PP)** - Set personal goals - Plan for learning path - Monitor one's learning achievement 3. Introduce ***Reflective Journal*** as strategy to: **(PP)** - Reflect *on*, *in*, and *for* learning	• The task may take longer than anticipated • Participants may ask too many questions • Participants may misunderstand how to utilize the metacognitive correctly	• Make the strategies very clear and limited to the ones that will be used in the workshop • Show good examples of those strategies, and how they can be used • Ask the participants, whether they are familiar with these strategies, or whether they have ever

	and skills, and be able to respond to the metacognitive tasks or learning with metacognition more effectively.	- Monitor one's learning progress - Respond to self-generated questions 4. Show some examples of those strategies, and explain the context of each, and how it would be used **(PP)** 5. Beware of the metacognitive cycle: **Model, Engage, Transfer, and Assess**		used them before • Recall the participants' prior experience on metacognition
15 min. 10 min.	Describe the basic principles of electricity and electric circuit as required by the Ontario Science & Technology Curriculum – Grad 6; 5E learning cycle; and PhET simulations **Justification:** Prerequisite to complete *Pathfinder Network Scaling* **Task 1: Planning, Learning and Reflecting** **A. Planning (Think Aloud)** **Justification:** This is the first metacognitive process by which the participants will oversight their learning outcomes for this task **B. Learning:**	**<u>Resources:</u>** Laptop computers, Internet connection, YouTube clip, Grade 6 Textbook, and **PowerPoint presentation** **<u>Procedures, I will:</u>** 6. Ask the participants whether they are familiar with the target concepts, or they have used them in their classroom instruction 7. show a YouTube clip to describe the fundamental concepts of current, potential, and electric circuit 8. Introduce the main features and functions of PhET simulations **(PP)** 9. Introduce the main features of inquiry-based learning, **if needed.** 10. Demonstrate the phases of the 5E learning cycle **(PP)** 11. Ask the participants to pair up in groups (2-3 members in each group) 12. Ask the participants to set a plan (**ENGAGE**); their plan should include: - Specific objectives related to the understanding of electricity and circuit construction, 5Es, and PhET simulations (individually) - a plan that clarifies the learning course (what to learn, why, and how) – the W-W-H model - what resources they will need to use to achieve their goals (there are resources listed on page 8 on the Learner's Guide) - ask the participants to write their plans in the given <u>templates</u> **(PP)** 13. Ask the participants to use the necessary resources (page 8) that would help them to achieve their goals, including: - Concrete objects such as: batteries, bulb, connecting wires,	• The participants may ask too many questions. • Java software may not be installed in the computers. • Slow Internet connection, and hence unable to complete Task 2 in time • Difficulties to go about the simulation • The participants may not so familiar to 5E learning cycle • The participants may get confused or overwhelmed	• Prepare a YouTube clip that describes the concepts the best. In it, there should be a verbal description of the topic as well as a visual aid activity. The clip should not take more than 5-8 min. • Connect the YouTube clip with the specific expectations of the curriculum. • Use Grade 6 Textbook to elaborate more on the topic or explain other concepts. • Make sure Java software is installed in the school's computers. Alternatively, as the participants to bring their laptops with Java installed. • Save the Circuit Construction simulation in a flash memory. Use this copy in case there are some difficulties in the Internet connection.

25 min.	**C. Reflecting:** • Reviewing the achieved personal goals • Reflecting on the participants' own learning • Journal writing **Justification:** This task is another exercise; it will help the participants in monitoring and adjusting their learning path. Also, they are expected to recognize how to reflect on their learning.	switch, etc. - Grade 6 textbook - Online search engine - www.phet.clorado.edu - **"Constructing a Simple Circuit" activity** - **"PhET Circuit Construction" activity** 14. Ask the participants to execute their plan **(in a group setting or individually)** 15. Clarify the instructions on page 8 16. Monitor the participants' learning progress, and provide any necessary guidance or scaffolding 17. At the end of part B, ask the participants to reflect in their learning (use the templates provided in the guide) **(PP)** 18. Ask the participants to **ASSESS** their learning using the given template. In their assessment, the participants should **(PP)**: - Reflect on what they have learned so far and whether: ✓ They are satisfied on what they have learned ✓ They are satisfied on the strategies used to pursue their learning ✓ They want to change these strategies to better support their leaning ✓ They want to modify their personal plan (add, cancel, or change any of them) 19. Monitor the participants' progress 20. Receive feedback from the participants, and then summarize the basic concepts of electricity and construction of electric circuits; phases of 5E learning cycle; and PhET simulations	•The participants may not be able to complete the reflective journal • The participants' reflective journal may not describe their learning path precisely	• Walk through the login process and how to locate the PhET simulations. •Describe 5Es in a very simple manner. They are going to learn about it any way. •Finish this exercise before the end of the day • Guide the participants through this exercise (providing templates, responding to questions, tec.)
5 min.	**Task 2:** Introducing *Pathfinder*	**Resources:** *Pathfinder Network Scaling* (e-version), Participants' user names	• Unable to complete Task 4	•Describe the concept of assessment of knowledge

	Network Scaling tool **Justification:** Inform the participants how their knowledge structure can be assessed; and hence, be able to make sense when they relate the concepts of electricity, 5E, and PhET simulation.	and passwords **Procedures, I will:** 5. Briefly describe the concepts of knowledge structure and how it's assessed by Pathfinder Network Scaling **(PP)**. 6. Ask the participants to use **the Example** to rate the relatedness of familiar set of words such as: Ostrich, Reptile, Snake, and Bird 7. If there is enough time, let the participants use *Pathfinder Network Scaling* and view their knowledge structures as pertaining to these concepts/words (recommended).	in time • Technical issues related to Pathfinder tool	structure in a very simple way. • Be aware of the technical problems • In this training session, group the concepts in a questionnaire, and ask the participants to rate the relatedness of the concepts using a hard copy.
30 min.	**Task 2 continue:** Administering the pre-test **Justification:** The pre-test will illustrate the participants' knowledge structure prior the intervention. The pre-test will be considered as a covariate in order to normalize any differences between the groups.	**Resources:** *Pathfinder Network Scaling* (e-version) **Procedures, I will:** 1. Ask the participants to rate the relatedness of 9 concepts pertaining to Electricity, 5E, and computer simulation (pre-test)	• Technical issues related to Pathfinder tool	• Be aware of the technical problems • Group the target concepts in a questionnaire, and ask the participants to rate the relatedness of the concepts using a hard copy.
10 min.	**Task 6: Planning, Experiencing, & Reflecting** **6.1** • Setting personal goal for the day • Setting strategies to achieve personal goals • Clarifying how to proceed with these learning strategies	**Resources:** **PowerPoint presentation,** Learner's Guide, Electric circuit tool kits (5 sets), PhET simulation **Procedures, I will:** 1. Introduce the metacognitive tasks (planning) 2. Present a **MODEL** to help the participants setting their goals for the day **(PP)**. 3. **Clarify the specific objectives for task 6** 4. Ask the participants to **think a loud** with a partner and discuss **what you know**, **what they want to learn**, **and how they want to learn about** technology-mediated inquiry activities	• The participants may be engaged on side-talks • Confusions on the objectives of the task • Confusions on how to use the templates, or how to respond to the questions	• Use very simple and direct language/instructio n • Always allow room for the participants to utilize their own ideas/questions/, or add more items into the check list • Instruct the

	Justifications: This task would set the stage for Task (6). In order to achieve the desired learning goals, the participants need to clarify their goals for the task, select their learning strategies, decide how to monitor their learning progress, and learn how to adjust their learning course accordingly. **6.2** Conducting an inquiry experiment using 5E learning cycle: Engage, Explore, Explain, Elaborate, and Evaluate **Justification:** In order to experience inquiry model, the participants have to make hypotheses or predictions, collect and analyze data, provide scientific explanations, and make conclusions.	5. Ask the participants to set a plan (**ENGAGE**); their plan should include: - Specific objectives related to the understanding of electricity and circuit construction, 5Es, and PhET simulations (individually) - a plan that clarifies the learning course (what to learn, why, and how) – the W-W-H model - what resources they will need to use to achieve their goals - ask the participants to write their comments in the given templates **(PP)** - monitor the participants' progress and provide them with leading questions, samples, examples, etc. **(PP)** 6. Provide the participants with the 5E learning activities to complete their tasks 7. Ask the participants to go back to their groups. 8. **Distribute learning activity # 6-b** (the participants should keep the hand outs in their folder). vi) In ***Engage* phase**, ask the participants to *read a short story* (or graphic organizer) about circuit constructions in series and parallel. Home appliances are connected in parallel…..ask the participants to explain why? (10 min.) **Metacognitive task (PP)** Ask the participants to remain in their groups; and reflect on their precedent learning. vii) In ***Explore* phase**, ask the participants to *discuss a scenario* involving how the brightness of bulbs would be different in series and parallel connections. Present a real-life situation where bulbs are connected in series and parallel. Ask the participants to predict the level of brightness: similar brightness, brighter, or dimmer (15min.). viii) In ***Explain* phase**, ask the participants to *use PhET simulation* to construct electric circuit in parallel and series. Then connect two (or three) lamps in their circuits. Then test the brightness of the lamps in each connection. Finally, ask the participants to tabulate their observations, analyze them, and come up with a scientifically		participants to skip the questions that are not clear to them. But ask them to generate other questions that make sense to them. • Clarify the task with good examples, or even ask the participants to share their good examples

	6.3: • Reflecting on the precedent learning experience • Plan for the next learning activity **Justifications:** Before pursue to the next phase, the participants need to review their learning path (if necessary). Therefore, they should reflect on their learning progress and take the necessary measures that would assist them to achieve their ultimate goals.	acceptable conclusion (25 min.). ix) In ***Elaborate* phase**, ask the participants *to discuss* how target concepts can be applied in real life situations. Ask them to present few examples (10 min.). x) In ***Evaluate* phase**, the participants would be assessed throughout the experiment. 9. Ask the participants to reflect on their own learning and not on the learning activities. 10. As per the task, remind the participants to discuss what they should be learning in the next learning activity. 11. Monitor the participants' progress 12. Provide leading questions, examples, samples to help the participants in completing their tasks successfully **(PP)** Make sure the participants complete the task correctly		
10 min.		**Resources:** **PowerPoint presentation,** Learner's Guide, Electric circuit tool kits (5 sets), PhET simulation **Procedures, I will:** 13. Introduce the metacognitive tasks (planning) 14. Present a **MODEL** to help the participants setting their goals for the day **(PP)**. 15. **Clarify the specific objectives for task 6** 16. Ask the participants to **think a loud** with a partner and discuss **what you know**, **what they want to learn**, **and how they want to learn about** technology-mediated inquiry activities 17. Ask the participants to set a plan (**ENGAGE**); their plan should include: - Specific objectives related to the understanding of electricity and circuit construction, 5Es, and PhET simulations (individually) - a plan that clarifies the learning course (what to learn, why, and how) – the W-W-H model - what resources they will need to use to achieve their goals - ask the participants to write their comments in the given templates	• The participant may skip the phases and don't follow the learning sequence as planned. • The participants may go directly to *Explain* phase without making predictions or hypotheses.	• Emphasize the fact that the participants are expected to act like Grade 6 students and they will be given another opportunity to act like science teachers. • Allow some kind of feedback between

40 min.		**(PP)** - monitor the participants' progress and provide them with leading questions, samples, examples, etc. **(PP)** 18. Provide the participants with the 5E learning activities to complete their tasks 19. Ask the participants to go back to their groups. 20. **Distribute learning activity # 6-b** (the participants should keep the hand outs in their folder). xi) In ***Engage* phase**, ask the participants to *read a short story* (or graphic organizer) about circuit constructions in series and parallel. Home appliances are connected in parallel…..ask the participants to explain why? (10 min.)		5E phases. Thereby, make sure the participants are following the guidelines and on task. • Go around and respond to the participants' questions, difficulties, or inquiries.
10 min.		**Metacognitive task (PP)** Ask the participants to remain in their groups; and reflect on their precedent learning. xii) In ***Explore* phase**, ask the participants to *discuss a scenario* involving how the brightness of bulbs would be different in series and parallel connections. Present a real-life situation where bulbs are connected in series and parallel. Ask the participants to predict the level of brightness: similar brightness, brighter, or dimmer (15min.). xiii) In ***Explain* phase**, ask the participants to *use PhET simulation* to construct electric circuit in parallel and series. Then connect two (or three) lamps in their circuits. Then test the brightness of the lamps in each connection. Finally, ask the participants to tabulate their observations, analyze them, and come up with a scientifically acceptable conclusion (25 min.). xiv) In ***Elaborate* phase**, ask the participants *to discuss* how target concepts can be applied in real life situations. Ask them to present few examples (10 min.). xv) In ***Evaluate* phase**, the participants would be assessed throughout the experiment.	• The participants may reflect on the activities rather than their own learning path	• Make clear instruction that this is the time for self-reflections, and next phase you will reflect on the learning activities • Provide the participants with the tools that are deemed necessary to complete their tasks: - Templates - List of questions to respond - Check list • Emphasize the fact that this is the time to act like professional

		21. Ask the participants to reflect on their own learning and not on the learning activities. 22. As per the task, remind the participants to discuss what they should be learning in the next learning activity. 23. Monitor the participants' progress 24. Provide leading questions, examples, samples to help the participants in completing their tasks successfully **(PP)** 25. Make sure the participants complete the task correctly **Resources:** Grade 6 Textbook, Copies of Ontario Science & Technology overall expectation #2, pages 118 – 120 **Procedures, I will:** 1. Ask the participants to complete **Learning Task # 7**. In it, they *are expected to act like science teachers* and discuss their precedent experience. In it, ask the participants to *think about the design of the experiment, and whether it's effective in guiding them through the learning tasks*. **Next day**, the task is to recognize the interrelationships between electric circuits, 5Es, and PhET simulation. 2. Ask the participants to reflect on their own learning and not on the learning activities. In it they should: - Review their goals - check whether they have achieved their goals - complete the reflective writing journal 3. Monitor the participants' progress 4. Provide leading questions, examples, samples to help the participants in completing their tasks successfully **(PP)** 26. Make sure the participants complete the task correctly		teachers. • Any discussion about the activities should be related to 6 Graders and not themselves. • Ask the participants to analyze the effectiveness of the learning activities instead of discussing their own learning. • Learning Task 7 should be carefully designed to fulfill the points above.
				•

35 min. 15 min.	**Task 7: Analyzing and Reflecting** **7.1:** Discussing the role of technology as a rational of pedagogical and content objectives **Justification:** The participants are expected to act like professionals and analyze the effectiveness of their precedent learning activities **7.2:** • Reviewing the achieved personal goals • Reflecting on the participants' own learning • Journal writing **Justification:** This task is another exercise; it will help the participants in monitoring and adjusting their learning path. Also, they are expected to recognize how to master reflective journal writing.		• The participants may discuss some aspects of their own learning. • They may discuss how easy/difficult to perform the inquiry tasks; or • They may express some kind of satisfactions because they are able to finish the tasks in time. • The participants may not be able to complete the reflective journal • The participants' reflective journal may not describe their learning path precisely	• • Finish this exercise before the end of the day • Guide the participants through this exercise (providing templates, responding to questions, tec.)

Day 2

Date/Time	Task/Justification	Resources/Procedures	What could go wrong?	Contingency/Avoidance plan

7 min. 20 min.	**Task 8: Planning, Analyzing, & Reflecting** **8.1:** • Examining what has been achieved so far • Setting strategies and planning for the upcoming task **Justifications:** This task would set the stage for Task (8-a). In order to achieve the desired learning goals, the participants need to review their knowledge gaps, clarify their goals for the task, select their learning strategies, decide how to monitor their learning progress, and learn how to adjust their learning course accordingly. **8.2:** critically analyzing the precedent learning activities **Justification:** This learning opportunity aims at engaging the participants in discussion to understand the interrelationships between 5Es (PK), computer simulation (TK), and electric circuit (CK). As a result, they should be able to develop TPACK.	**Resources:** Learner's Folder, **PowerPoint presentation** **Procedures, I will:** 1. Introduce the metacognitive tasks, and what the participants are expected to learn 2. Provide the participants with the tools that are deemed necessary to complete their tasks: **(PP)** - Templates - List of questions to respond - Check list 3. Monitor the participants' progress 4. Make sure the participants complete the reflective journal writing correctly **Procedures, I will:** 4. Ask the participants to go back to their groups. 5. Ask the participants to respond to specific questions and discuss the rational granted to the computer simulation and 5E approach in meeting learning objectives. **(PP)** 6. Walk around and observe the responses, questions, ideas, or comments on the 5E learning activities.	• The participants may be engaged on side-talks • Confusions on the objectives of the task • Confusions on how to use the templates, or how to respond to the questions • The participants may focus on few relationships between PK, TK, and CK; and overlook other ones. • The participants may spend long time on talking/chatting without getting to solid conclusions.	• Use very simple and direct language/instruction • Always allow room for the participants to utilize their own ideas/questions/, or add more items into the check list • Instruct the participants to skip the questions that are not clear to them. But ask them to generate other questions that make sense to them. • Clarify the task with good examples, or even ask the participants to share their good examples • The Learning Task 6 should include leading questions. The leading questions should cover TPACK intersections (i.e., TPK, TCK, PCK, and TPACK). • I should facilitate the discussion in a way that helps the participants to much of their cognitive time more effectively. To do that, I should be firm on timing, finishing tasks in time, allowing specific questions, wrapping up discussions, writing the main points on the board, extracting themes and issues, and responding to 'what if' scenarios.
8 min.	**8.3:**	**Procedures, I will:** :	• Confusions on the	• Use very simple and direct

	•Reviewing personal goals •Recognizing whether the ultimate goals have been achieved. •Recognizing their knowledge gaps and what should be done next **Justifications:** This task would assist the participants in recognizing their successes, failures, and challenges through their learning course; and planning for future workshops.	1. Introduce the metacognitive tasks, and what the participants are expected to do; 2. Provide the participants with the tools that are deemed necessary to complete their tasks: **(PP)** - Templates - List of questions to respond - Check list 3. Monitor the participants' progress 4. Make sure the participants complete the reflective journal writing correctly	objectives of the task • Confusions on how to use the templates, or how to respond to the questions	language/instruction • Always allow room for the participants to utilize their own ideas/questions/, or add more items into the check list •Instruct the participants to skip the questions that are not clear to them. But ask them to generate other questions that make sense to them. • Clarify the task with good examples, or even ask the participants to share their good examples
25 min.	**Task 9:** Administering the pre-test **Justification:** The post-test is expected to determine the changes in the participants' structure of knowledge that could have occurred during the intervention. The post-test should be conducted immediately after the intervention to avoid the influence of a third variable (internal validity).	**<u>Resources:</u>** *Pathfinder* Network *Scaling* (e-version), Participants' user names and passwords **<u>Procedures, I will:</u>** 3.Ask the participants to rate the relatedness of 8 concepts pertaining to Electricity, 5E, and computer simulation (pre-test) 4. Collect the consent forms	• Technical issues related to Pathfinder tool • The participants may gain some kind of testing effect.	• Be aware of the technical problems • Group the target concepts in a questionnaire, and ask the participants to rate the relatedness of the concepts using a hard copy. • Reorganize the concepts •Add the same pair of concepts more than once. Test the correlation effect among those particular concepts. In consistent ratings will be eliminated.
45 min.	**Task 10:** Planning and designing a technology-mediated inquiry-based learning activity **Justification:** This is an opportunity to apply	**<u>Resources:</u>** Exercise Sheet, Google Applications (e.g., Google Classroom, Google Doc, etc.) **<u>Procedures, I will:</u>** Ask the participants to complete an exercise. In it, they are expected to design a technology-	•The participants may not be able to finish this task, or parts of it, in time.	• Ask the participants to bring to the class a previously designed activity to work on it. •The participants are not obliged to use a specific content, or specific teaching strategy. •Ask the participants to focus on

	the participants' understanding of TPACK in designing learning activities. It's important to examine the participants' abilities to incorporate their understanding of TPACK in one of their teaching practices. Simply because, developing TPACK doesn't necessarily lead to an effective integration of technology in science instruction.	based learning activity. They can work on a previously designed activity or design a new one. Their design should integrate a technological tool or tools, or may be no technology at all. Their design should include the following elements: Topic, target objectives, resources, teaching approach, cognitive tools (technology vs lab), assessment tools, procedures, and the rational granted to technology and teaching approach in meeting learning objectives.		the reasoning and decision-making parts. For example, what features make a specific technology the best choice for their design and why; etc. • In the Exercise Sheet, include templates, fill up the blanks, leading questions, etc.
10 min. 5 min.	**Task 11:** Focus group interview **Task 12:** debriefing **Justification:** The interview session is expected to describe the parts of the intervention and post-intervention exercise that can't be examined by the quantitative analysis. Also, the interview will allow the researcher to examine the conditions of the strategy by which the learners could benefit the most.	<u>**Procedures:**</u> The participants will be interviewed for 15 minutes according to the following protocol:	• No show case • The participants might be overwhelmed.	• Establish a protocol for the interview (timing, taping, Q & A, etc.) • The interview can be conducted at earlier stage (e.g., during the exercise). • Fire up the interview with leading questions. • Hear the participants' voices. • Allow equal opportunities for all members.

Appendix I: Lesson Plan – EIM

Session 1

<table>
<tr><td>Main task: Preparing the participants for the workshop</td><td>Time: 2 hours</td></tr>
<tr><td colspan="2">Resources:
• Letter of Information
• Consent Form
• Learner’s Guide
• Pathfinder Network Scaling tool
• PhET Circuit Construction Kit simulation
• Laptops
• Internet connection
• Lab equipment: Electric circuit tool kit
• Grade 6 Textbook
• YouTube clips</td></tr>
<tr><td colspan="2">Instructional Strategy:
Direct instruction, demonstration, group discussion, and guided-inquiry</td></tr>
<tr><td>Objectives:
At the end of this day, the participants should be able to:
• Recognize the research objectives and procedures
• Describe the main features and functions of the PhET Circuit Construction Kit simulation
• Develop necessary skills for constructing electric circuits with PhET simulations
• Demonstrate basic understand of the principles of electricity and electric circuits
• Recognize the main principles of 5E learning cycle
• Recognize the idea of representing one’s knowledge structure via Pathfinder Network Scaling
• Complete the pre-test</td><td>Procedures:
The researcher will:
• demonstrate the research objectives and procedures
• clarify the data collection procedures
• state the participants’ rights with regard to the protection of private information, and rights to withdraw from the study at any time
• organize the participants in small groups, and distribute the codes
• introduce the learning expectations
• describe the basic principles of electricity, construction of electric circuits, and basic concepts of computer simulation
• introduce the phases of 5E learning cycle as a manifest of inquiry-based learning
• guide the participants through a training session: illustrate one’s knowledge structure via Pathfinder Network Scaling
• clarify the TPACK concepts the participants are going to rate
• administer the pre-test (Pathfinder Network Scaling)</td></tr>
<tr><td colspan="2">Assessment:
The researcher will evaluate the participants’ learning progress using different assessment tools such as observation, feedback, and questioning.</td></tr>
</table>

Session 2

<table>
<tr><td colspan="2"><u>Main task:</u> Conducting 5E experiment</td><td><u>Time:</u> 1 hour</td></tr>
<tr><td colspan="3"><u>Resources:</u>
• Learner's Guide
• Lab equipment: Electric circuit tool kits
• PhET Circuit Construction Kit simulation
• Laptops (desk top, or participants' smart devices, etc.)
• Internet connection</td></tr>
<tr><td colspan="3"><u>Instructional Strategy:</u>
Guided-inquiry (5E learning cycle), Group Discussion</td></tr>
<tr><td><u>Objectives:</u>
At the end of this day, the participants should be able to:
• utilize the PhET Circuit Construction Tool Kit simulation to construct electric circuits
• identify the properties of electric current and potential difference in series and parallel circuits (the target concepts)
• experience 5E Learning Cycle
• critically analyze the effectiveness of 5E learning cycle in meeting the target objectives</td><td colspan="2"><u>Procedures:</u>
The researcher will:
• guide the participants throughout the 5E learning cycle; in it, they are expected to / to be:
i. Engaged in activity to recall their prior knowledge of electricity and electric circuits
ii. Explore the target concepts and postulate testable hypotheses and design an investigation using Circuit Construction Kit simulation to test their hypotheses
iii. Explain the collected data by tabulating and analyzing it, and come up with scientifically acceptable explanations to the phenomenon
iv. Elaborate and apply the newly constructed knowledge in real-life situations
v. Evaluate their learning exercise (answering questions)</td></tr>
<tr><td colspan="3"><u>Assessment:</u>
The researcher will evaluate the participants' learning progress using different assessment tools such as observation, feedback, and questioning.</td></tr>
</table>

Session 3:

<table>
<tr><td><u>Main task:</u> analyzing the pedagogical uses of technology</td><td><u>Time:</u> 2 hours</td></tr>
<tr><td colspan="2"><u>Resources:</u>
• Learner’s Guide
• Electric circuit tool kits
• PhET Circuit Construction Kit simulation
• Pathfinder Network Scaling tool
• Laptops
• Internet connection
• Lab equipment: Electric circuit tool kits</td></tr>
<tr><td colspan="2"><u>Instructional Strategy:</u> Group discussion</td></tr>
<tr><td><u>Objectives:</u>
At the end of this day, the participants should be able to:
• recognize different student-centered learning models
• recognize the benefits of using computer simulation in enhancing students’ understanding of the construction of electric circuits
• identify the challenges of teaching electricity through 5E and computer simulation
• recognize different technological tools that are commonly used in science instruction
• discuss the pedagogical necessity as a rational to implement computer technology
• discuss the challenges that might be encountered while teaching and learning with technology
• suggest how these challenges can be overcome
• design a technology-mediated inquiry-based learning activity</td><td><u>Procedures:</u>
The researcher will:
• briefly describe different inquiry learning models (e.g., POE, 3-face cycle, discovery learning) that are used in science instruction
• describe technological tools that are commonly used to facilitate inquiry learning models
• engage the participants in group discussion in order to analyze the role of technology as a rational in meeting the content objectives
• engage the participants in group discussion in order to analyze the role of technology, in their precedent 5E activities, as a rational in meeting the pedagogical objectives
• facilitate the discussion by posing questions like:
i. In what ways computer technology is beneficial to enhance learning and teaching through inquiry?
ii. What are the areas in which the computer technology is likely to fall short?
iii. What are the drawbacks of inquiry learning, if any, within the context of teaching and learning of science?
• administer the post-test (using Pathfinder Network Scaling)
• ask the participants to design inquiry-based activity (or work on a previously designed activity)</td></tr>
<tr><td colspan="2"><u>Assessment:</u>
The researcher will evaluate the participants’ learning progress using different assessment tools such as observation, feedback, and questioning.</td></tr>
</table>

Appendix J: <u>Lesson Plan – MS</u>

Session 1:

<u>Main task:</u> Preparing participants for the workshop

<u>Time:</u> 1 hours

<u>Resources:</u>

- Letter of Information and Consent Form
- Learner's Guide
- *Pathfinder Network Scaling* tool
- PhET *Circuit Construction Kit* simulation
- Laptops and Internet connection
- Lab equipment: Electric circuit tool kit
- Grade 6 Textbook
- YouTube clips

<u>Instructional Strategy:</u>

Direct instruction, demonstration, group discussion, guided-inquiry, and metacognitive scaffolding

<u>Objectives:</u>

At the end of this day, the participants should be able to:

- Recognize the research objectives and procedures
- Develop metacognitive knowledge and skills
- Utilize metacognitive strategies to monitor and adjust their learning course
- Describe the main features and functions of the *PhET Circuit Construction Kit* simulation
- Develop necessary skills for constructing electric circuits with PhET simulations
- Demonstrate basic understand of the principles of electricity and electric circuits
- Recognize the main principles of 5E learning cycle
- Recognize the idea of representing one's knowledge structure via *Pathfinder Network Scaling*
- Complete the pre-test

<u>Procedures:</u>

The researcher will:

- demonstrate the research objectives and procedures
- clarify the data collection procedures
- state the participants' rights with regard to the protection of private information, and rights to withdraw from the study at any time
- organize the participants in small groups, and distribute the codes
- introduce the learning expectations
- briefly describe the metacognitive strategies that would be used in this workshop, including:
  - i. *Think Aloud:* strategy used to plan for a learning course
  - ii. *Reflective Journal* checklists: for reflecting on, monitoring, and adjusting one's learning path
- recall the participants' prior knowledge of 5E learning model, PhET computer simulation, and construction of electric circuits
- describe the basic principles of the above three domains
- ask the participants to set their personal goals for the day; and plan for their learning course
- guide the participants through their learning plan by providing resources, strategies, and activities to do so
- guide the participants through a training session: exercise how to illustrate one's knowledge structure via *Pathfinder Network Scaling*
- clarify the 9 concepts that the participants are going to rate
- administer the pre-test (*Pathfinder Network Scaling*)
- ask the participants to reflect on their own learning and thinking

<u>Assessment:</u>

The researcher will evaluate the participants' learning progress using different assessment tools such as observation, feedback, and questioning.

Session2:

Conducting 5E experiment, reflecting on learning, and monitoring one's learning	**Time:** 2 hours
Resources: • Teacher's Guide and Learner's Guide • Lab equipment: Electric circuit tool kits • PhET *Circuit Construction Kit* simulation • Laptops (or desk top, smart devices, etc.) with Internet connection	
Instructional Strategy: Guided-inquiry, metacognitive scaffolding, group discussion	
Objectives: *At the end of this day, the participants should be able to:* • utilize the PhET *Circuit Construction Tool Kit* simulation to construct electric circuits • identify the properties of electric current and potential difference in series and parallel circuits • experience 5E Learning Cycle • Utilize metacognitive strategies to reflect, monitor, and adjust their learning path • critically analyze the effectiveness of 5E learning cycle in meeting the target objectives • recognize the benefits of using computer simulation in enhancing students' understanding of the construction of electric circuits • identify the challenges of teaching electricity through 5E and computer simulation	**Procedures:** *The researcher will:* • guide the participants to recall their prior knowledge • guiding the participants through the Planning, Experiencing, and Reflecting task; in it, the participants are expected to: i. set their learning goals using *Think Aloud* strategy ii. conduct 5E learning investigation; in it, they are expected to / to be: - *Engaged* in activity to recall their prior knowledge of electricity and electric circuit - *Explore* the target concepts and postulate testable hypotheses and design an investigation using *Circuit Construction Kit* simulation to test their hypotheses - *Explain* the collected data and come up with scientifically acceptable explanations to the phenomenon - *Elaborate* and apply the newly constructed knowledge in real-life situations - *Evaluate* their learning exercise (answering questions) *iii.* reflect on their learning path during and after the 5E learning activities • constantly guide the participants through their metacognitive tasks by posing sample questions or responses, providing templates, and clarifying meanings or terms • engage the participants in group discussion in order to analyze the role of technology as a rational in meeting the content objectives • guide the participants through reflective writing process
Assessment: The researcher will evaluate the participants' learning progress using different assessment tools such as observation, feedback, asking questions, etc.	

Session 3:

<table>
<tr><td colspan="2"><u>Day 3:</u> analyzing the pedagogical uses of technology, and reflecting and monitoring one’s learning</td><td><u>Time:</u> 2 hr.</td></tr>
<tr><td colspan="3"><u>Resources:</u>
• Learner’s Guide
• Electric circuit tool kits
• PhET Circuit Construction Kit simulation
• Pathfinder Network Scaling tool
• Laptops with Internet connection
• Lab equipment: Electric circuit tool kits</td></tr>
<tr><td colspan="3"><u>Instructional Strategy:</u> Group discussion, metacognitive scaffolding</td></tr>
<tr><td><u>Objectives:</u>
At the end of this day, the participants should be able to:
• recognize different student-centered learning models
• recognize different technological tools that are commonly used in science instruction
• discuss the pedagogical necessity as a rational to implement computer simulation
• discuss the challenges that might be encountered while teaching and learning with technology
• suggest how these challenges can be overcome
• design a technology-mediated inquiry-based learning activity
• develop metacognitive skills and knowledge to be able to accomplish learning task successfully</td><td colspan="2"><u>Procedures:</u>
The researcher will:
• briefly describe different inquiry learning models (e.g., POE, 3-face cycle, discovery learning) that are used in science instruction
• describe technological tools that are commonly used to facilitate inquiry learning models
• engage the participants in group discussion in order to analyze the role of technology, in the precedent 5E activities, as a rational in meeting the pedagogical objectives; in doing so, the participants are expected to:
i. use Think Aloud strategy to examine what has been learned so far, and what is expected to be learned next
ii. analyze the 5E activities
• facilitate the discussion period by posing questions like:
i. In what ways computer technology is beneficial to enhance learning and teaching through inquiry?
ii. What are the areas in which the computer technology is likely to fall short?
iii. What are the drawbacks of inquiry learning, if any, with the context of teaching and learning of science?
• use Reflective Journal checklist to examine the participants’ learning progress, and find out whether they’ve achieved the previously established personal goals
• administer the post-test (using Pathfinder Network Scaling)
• ask the participants to design inquiry-based activity (or work on a previously designed activity)</td></tr>
<tr><td colspan="3"><u>Assessment:</u>
The researcher will evaluate the participants’ learning progress using different assessment tools such as observation, feedback, and questioning.</td></tr>
</table>

Appendix K: <u>Lesson Plan Template</u>

Grade: Click here to enter text. **Strand/topic:**		
Length:		**Code:**
Target or Curriculum Objectives *(what will students be able to do/know by the end of the activity)*		**Teaching Method** *(Tick all that apply)* ☐ *Demonstration (Didactic)* ☐ *Guided Inquiry* ☐ *Open Inquiry* ☐ *Lecture* ☐ *Group discussion* ☐ *Others (specify):*

Resources *Equipment and materials (if needed)*	**Technology tools** *(click all that apply)*	**Describe the rational of using technology in meeting curriculum goals** *(if you are not planning to use technology, please justify your choice of resources)*

Brief description of the teaching/learning procedures (How you are going to teach the content with technology)	**Reason for using technology** *(click all that apply)*	**Describe the rational of using technology in meeting science content or/and pedagogical objectives**
	☐ science content ☐ pedagogical uses ☐ Other	
	☐ science content ☐ pedagogical uses ☐ Other	

	☐ science content ☐ pedagogical uses ☐ Other	

Explain what possible or likely failure points for the technology and suggest an alternate plan in case of a breakdown