European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available on-line at: www.oapub.org/edu

doi: 10.5281/zenodo.2604527 Volume 5 | Issue 12 | 2019

MULTIPLE-REPRESENTATION PHYSICS LESSON STUDY: ENHANCING PRE-SERVICE TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract:
This study probed the effects of the Multiple-Representation Lesson Study (MRLS) on the technological pedagogical content knowledge (TPCK) of pre-service Physics teachers using a pretest-posttest quasi-experimental design. The participants of the study were 18 fourth year BSED Physical Science majors who were randomly assigned to either experimental or comparison group. The experimental group composed of nine practice teachers was exposed to MRLS while the other nine participants from the comparison group implemented the Traditional Instructional Planning Approach (TIPA). Four knowledge domains of the TPCK framework were investigated – the technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), and the overall technological pedagogical content knowledge (TPCK). Data were gathered from multiple sources such as researcher-made written tests, teaching observations, pre-service teachers' outputs, interviews, journal entries, and field notes. The Mann-Whitney U test was applied to analyze statistical difference between the experimental and the comparison group. Results revealed significant differences between the two groups in certain knowledge domains. Findings indicate beneficial effects of the MRLS in instructional practices, particularly in developing pre-service teachers' TPCK. Based on the results, it is strongly recommended that MRLS be integrated in the pre-service teacher education and have its effects examined on other knowledge domains.

Keywords: lesson study, TPCK, TPACK, multiple representations, instructional planning, Physics teaching

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1. Introduction

The underpinnings of current educational practices are crafted by integration or superposition of various didactic principles. One prominent pillar of modern education is the establishment of the Pedagogical Content Knowledge (PCK) framework (Shulman, 1986). With the emerging developments in technology, education takes its new shape to adapt to inevitable changes. Indicative of such acclimatization is the introduction of the Technological Pedagogical Content Knowledge (TPCK) framework by Mishra & Koehler (2006). Founded on the educational constructs of PCK, the TPCK framework advocates that overall teacher performance is influenced by his integrated knowledge on educational technology, pedagogy and content (Koehler & Mishra, 2005; Cox, 2008; Koehler, Mishra, & Cain, 2013; Koehler, Mishra, Akcaoglu, & Rosenberg, 2013).

Why is there a need to improve pre-service teachers' TPCK? Scholars contend that reinforcing TPCK anticipates better learning assessment and allows the acquisition of essential competencies in instructional material design (Ervin, 2014; Tokmak, Yelken, & Konokman, 2013). Implications point out to the attainment of holistic professional competence by preparing prospective teachers not only to become technologically literate but to be effective technology users as well (Haley-Mize, 2011; Archambault & Crippen, 2009; Chew & Lim, 2013; Niess, 2005; Ozturk, 2012; Cavin, 2007; and Chai, Koh, & Tsai, 2010; Alev, Karal-Eyuboglu, & Yigit, 2012; Chang, Tsai, & Jang (2014). Embracing social changes, including technologies, must modify teaching practices to support a learning environment devoid of teacher dominance; rather, one that nurtures student discourse and critical thinking, without losing the essentials of education.

One predicament that confronts pre-service teachers is addressing learning difficulties with Physics which often stem from lack of concrete examples during instruction and involvement of mathematical manipulations or visualization (Erinosho, 2013; Alias & Ibrahim, 2013; De Cock, 2012; Kozhevnikov, Hegarty, & Mayer, 1999). A web of learning impediments is triggered by learners' failure to readily understand the connection among verbal, graphical, pictorial, and mathematical representations (Nguyen & Rebello, 2009; Soong, Mercer, & Er, 2009; Ogunleye, 2009; Snetinova & Koupilova, 2012; Gulkilik & Arikan, 2012; and Bal, 2015). Prevalent learning difficulties and misconceptions, particularly on dealing with multiple representations, may be a manifestation of teaching competence deficiency. Studies show that teachers' knowledge has a substantial influence on student learning (Tchoshanov, Lesser, & Salazar, 2008; Hightower, Delgado, Lloyd, Wittenstein, Sellers, & Swanson, 2011; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013). This implies that effective Physics teaching necessitates robust scaffolding of teachers' knowledge. Engaging in multi-representation-based instruction shows a promise to alleviate prevailing conceptual, procedural and mathematical difficulties (Akkus & Cakiroglu, 2009; Banerjee, 2010; Leigh, 2004; Bal, 2015; Gulkilik & Arikan, 2012; Ozmantar, Akkoc, Bingolbali, Demir, & Ergene, 2010).

A rich discourse on developing pre-service teacher multi-representation skills can be set when consideration is given to collaborative work such as what Lesson Study framework can provide. Lesson study, a professional development approach that originated from Japan, poses potential advances in attaining desirable learning outcomes through careful collaborative instructional planning (Fernandez, 2002; Lewis, 2002; Lewis, Perry, & Hurd, 2009). Integration of lesson study in pre-service teacher education provides an array of experiences that can improve skills, competencies, and habits (Elipane, 2012; Gurl, 2009), can successfully transfer Nature of Science (NOS) into classroom practice, and can deepen the NOS pedagogical content knowledge of preservice teachers (McDowell, 2010). Moreover, application of lesson study can have positive impact on student achievement and critical thinking (Lucenario, Yangco, Punzalan, & Espinosa, 2016; Barrett, Riggs, & Ray, 2013; Teele, Maynard, & Marcoulides, 2015; Quilario, 2014).

Taking into account the efforts to illuminate constructs of lesson study, multiple representations, and TPCK, a paucity of information sheds light on preservice Physics teacher education. To the knowledge of the researcher, no study has been conducted in the application of lesson study in practice teaching. Literature merely provides knowledge bases on classroom-based microteaching lesson study. A two-phase modified lesson study involving microteaching and practice teaching with the employment of technology-driven representations is yet unknown.

In light of the aforementioned inadequacies in the body of knowledge, the researchers deemed it necessary to examine the use of the multiple-representation approach employing a modified lesson study framework in the pre-service Physics teaching curriculum. This study endeavors to address "non-expertise" issue among pre-service teachers through collegial support inherent in the proposed instructional framework. Finally, the study aims to illuminate the Lesson Study framework through technology-driven and conventional multiple representations in the lens of practice teaching to elucidate influences on pre-service teachers' technological-pedagogical-content knowledge.

2. Related Literature

2.1. Technological Pedagogical Content Knowledge (TPCK)

Figure 1 is the representation of the three knowledge areas of the TPCK framework - technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) - and their interdependence. The area where technological knowledge and content knowledge overlap indicates technological content knowledge (TCK). Similarly, the junction between pedagogical knowledge and content knowledge denotes pedagogical content knowledge (PCK). The intersection between technological knowledge and pedagogical knowledge signifies the technological pedagogical knowledge (TPK). Finally, the core of the diagram where the three knowledge areas coincide represents the teacher's overall knowledge on instructional practice – the technological pedagogical content knowledge (TPCK).

The individual circles and the overlapping areas in the TPCK framework each represent a sub-domain. The proponents, Koehler, Mishra, Akcaoglu, & Rosenberg (2013) and Koehler, Mishra, & Cain, (2013) presented their descriptions of the seven knowledge domains of the TPCK as discussed in the following texts.

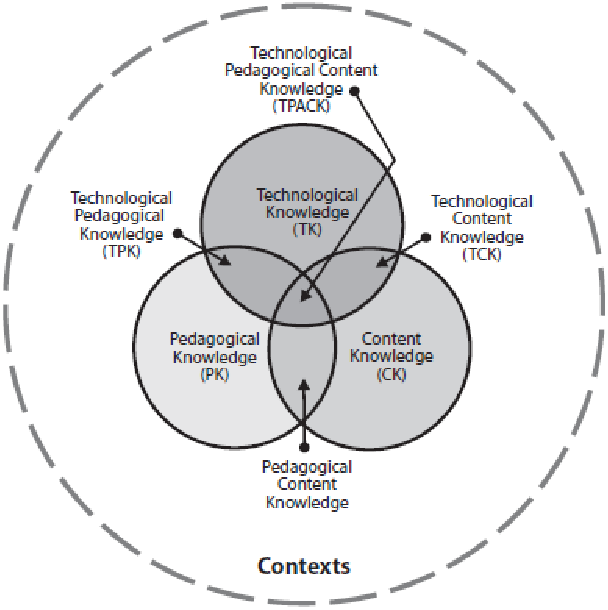

Figure 1: The TPCK framework.
(Koehler, Mishra, Akcaoglu, & Rosenberg, 2013, p.3)

1) Technological Knowledge (TK) refers to the teacher's understanding and continuous adaptation to changes on the use and functions of various technological tools such as computer units, programs and applications, and other educational technologies. In this study, it includes the development and understanding of other conventional educational technologies such as models, replica, visual materials, and so forth.
2) Pedagogical Knowledge (PK) denotes the teacher's knowledge on the different methods, strategies, and techniques that are applied to attain the desired learning outcomes. It also covers the classroom management style, assessment methods, and other instructional planning practices.
3) Content Knowledge (CK) refers to the breadth and depth of the teacher's understanding of the concepts and the required skills of the discipline he/she teaches.
4) Technological Pedagogical Knowledge (TPK) is an interplay between knowledge of technology and pedagogy. This includes, but is not limited to, selecting and utilizing appropriate educational technologies in the varied stages of instruction that suit to learners' needs and teaching objectives.
5) Technological Content Knowledge (TCK) is the interaction between technological knowledge and content knowledge. It is about knowing the specific instructional materials to use to teach best a particular subject matter.

6) Pedagogical Content Knowledge (PCK) refers to the teacher's knowledge of the different teaching strategies that are appropriate for a specific subject matter and the application of suitable assessment techniques or procedures relevant to the teaching objectives.
7) Technological Pedagogical Content Knowledge (TPCK or TPaCK) denotes the integrated knowledge of each component previously described. It is the synthesized knowledge of the teacher on the use of appropriate educational technologies befitting the methods and strategies applied in teaching a particular content or subject matter as opposed to a separate knowledge of technology, pedagogy, and content.

Assessing TPCK can be done in two ways according to literature. The quantitative method requires a survey instrument to solicit either a single or multiple responses. Dominant in TPCK studies is the self-assessment survey which may be administered either face-to-face or online (Schmidt, Baran, Thompson, Koehler, Mishra, & Shin, 2009; Chew & Lim, 2013; and Behar-Horenstein & Niu, 2011). The practicality of online survey administration allows researchers to gather as much information as needed from a large part of the target population and in a wide geographical location. Archambault & Crippen (2009) applied this strategy to examine TPACK among K-12 online distance educators in the United States. Chai, Koh, & Tsai (2010) applied the same strategy in examining Singapore secondary pre-service teachers' TPACK. Assessment of TPCK may also be done qualitatively. Cavin (2007), Mudzimiri (2012), Ozturk (2012), Terpstra (2009), and Niess (2005) utilized observation reports, field notes, interviews, audio and video recordings, student outputs, and other written documents in analyzing TPCK levels and changes among pre-service teachers.

While the use of self-report instruments gains popularity in many quantitative types of research, scholars express caution for its proper utilization. Podsakoff & Organ (1986) identified some problems with the use of self-report measures. Though they focused on organizational research, the underpinnings are relevant to the educational milieu. They contend that one problem is caused by the consistency motif explaining that many people often hold lay theories about the interdependence of many human dimensions like behavior, personality, psychological states and organizational environments. Self-report studies frequently ask for a summary of judgments and respondents often provide a collection of perceptions consistent with their prevalent lay theories. Another problem lies in the dependence of the response to the mood of the research participant. Current condition or timing of stimuli may influence responses on the self-report instrument. Also crucial to handling self-report data is the social desirability problem. Podsakoff & Organ (1986) asserted that people have the tendency to respond in a socially-accepted manner or to make them appear socially favorable, thus, a threat of adding bias to the data.

The use of single-measure self-report data in measuring pre-service teachers' TPCK poses a non-holistic view of the TPCK framework. This may be compensated through the use of multiple data sources, multiple data methods, and the use of learning outcomes indicative of pre-service teachers' TPCK (Agyei & Keengwe, 2014).

In this light, this study used multiple data points in describing the pre-service Physics teachers' TPCK such as an objective-type test, teaching observations, learning outputs like lesson plans and instructional materials, interviews, audio-video recordings, and journal entries. Moreover, two external evaluators were involved in assessing the teaching performance of the pre-service teachers aside from the researcher.

Scholars aimed at enhancing the TPCK of pre-service teachers. Chai, Koh, & Tsai (2010) disclosed that an ICT program, the ICT for Meaningful Learning, can significantly increase the pre-service teachers' TK, PK, CK and TPACK, with moderately large effect sizes. Additionally, results showed that PK has the largest impact on pre-service teachers' TPACK. Terpstra (2009) also reported that pre-service teachers exhibited more TK than TPK and TPCK, and exhibited more TPK than TPCK when she examined their perceptions on how they learn to use educational technology in teaching. Her findings, however, were limited to technology-bound domains like TK, TPK, TCK, and TPCK because other domains were irrelevant in the "use of technology" context of the study.

Meanwhile, Cavin (2007) adapted the microteaching lesson study (MLS) in developing the technological pedagogical content knowledge of six pre-service teachers who utilized the graphing calculator and Excel. The study revealed that MLS and the educational technologies provided an opportunity for pre-service teachers to appreciate the role of technology integration into a learner-centered teaching through collaborative instructional planning activities. It also opened their minds that traditional "methods" of teaching such as sequencing, pacing, and written directions change in context when there is involvement of technology.

With the positive effects of technology-based interventions on pre-service teachers' TPCK, factors having a potential impact on TPCK development have gained attention from scholars and educators. Holland (2014) found out that intrinsic motivation (IM) had a higher significant positive correlation than extrinsic motivation (EM) with TK, PCK, and TPK. Meanwhile, EM had a higher significant correlation than IM with CK, PK, TCK, and PCK. Similarly, Nathan (2009) devoted his work on examining and identifying the relationship between preservice teachers' level of technology integration self-efficacy (TISE) and their level of technological pedagogical content knowledge (TPACK). It was revealed that pre-service teachers' TISE is moderately related to TPACK. It can be noted that both correlational studies used a survey method adapting the TPCK survey instrument developed by Schmidt, et al. (2009).

2.1 Lesson Study

Lesson study is a popular teacher development approach widely practiced in Japan. It is a literal translation for the Japanese word jugyokenkyu – jugyo means lesson and kenkyu means study or research. The lessons are known as kenkyujugyo which means study or research lessons (Fernandez, 2002). Lesson study consists of a detailed study or examination of the practice of teaching (Department for Children, Schools, and Families, 2009).

Different researchers and educators who utilized the Lesson Study exhibited the following features in their process: (1) goal setting, (2) instructional planning, (3) designing the study, (4) implementing the instructional plan, (5) discussing the implementation, (6) revising the instructional plan, (7) teaching the new version of the instructional plan, (8) documenting results, and (9) discussing the implementation of the new version of the instructional plan (Fernandez, 2002; Cerbin & Kopp, 2006; Cavin, 2007; and Chew & Lim, 2013).

Meanwhile, Cerbin & Kopp (2006) emphasized that lesson studies are primarily conducted *not* to evaluate what the students have learned, rather, to find out *how* the students learn the lessons. They stressed:

> "*A common misconception about lesson study is that the study is intended to determine the lesson's effectiveness (e.g., whether students learn what they are supposed to learn and achieve the lesson's goals). Of course this is an important question, and one that most teachers want to answer. However, the primary focus of lesson study is not what students learn, but rather how students learn from the lesson. To investigate how students learn, teams focus on student thinking during the lesson, how they make sense of the material, what kinds of difficulties they have, how they answer questions, how their thinking changes during the lesson and so forth*". (p. 251)

As a professional development approach, Lesson Study poses potential advances in attaining desirable learning outcomes through careful collaborative instructional planning (Fernandez, 2002; Lewis, 2002; Lewis, Perry, & Hurd, 2009). Integration of lesson study in pre-service teacher education provides an array of experiences that can improve skills, competencies, and habits (Elipane, 2012; Gurl, 2009), can successfully transfer Nature of Science (NOS) into classroom practice, and can deepen the NOS pedagogical content knowledge of preservice teachers (McDowell, 2010). Moreover, application of lesson study can have positive impact on student achievement and critical thinking (Lucenario, Yangco, Punzalan, & Espinosa, 2016; Barrett, Riggs, & Ray, 2013; Teele, Maynard, & Marcoulides, 2015; Quilario, 2014).

The integration of technology into the lesson study framework shows another positive perspective. Cavin (2007) claimed that the microteaching lesson study (MLS) provides an opportunity for pre-service teachers to appreciate technology integration into a learner-centered teaching. Chew & Lim (2013) found that the use of Geometer's Sketchpad (GSP) in teaching mathematics through Lesson Study (LS) can enhance the technological pedagogical content knowledge of pre-service Mathematics teachers.

The lesson study may also be effectively utilized for curriculum design, implementation, and assessment. For instance, Gutierez (2015) applied the lesson study in identifying challenges of inquiry-based teaching in elementary science in the Philippines. Three major challenges were reported in engaging inquiry-based teaching among elementary Science teachers: (1) lack of support, training, and availability of inquiry-based materials; (2) overemphasis in assessing content learning rather than in learning through inquiry; and (3) the difficult and time-consuming nature of inquiry approaches. Meanwhile, some positive feedback was derived from the staff members who were involved in the Lesson Study for the implementation of Understanding by Design (UbD) curriculum in Neshaminy School District in Langhorne, Pennsylvania. These feedbacks include strengthening teaching confidence, elimination of isolationism, re-evaluation of teaching strategies through self-reflection, and empowerment of teachers (Kolenda, 2007).

Despite the growing number of studies involving lesson study, there still exist unexplained and less explored fields of its application in the instructional milieu. For instance, the literature shows many advantages of lesson study to Mathematics teachers and students. However, little is known about its application to other academic domains, especially in pre-service Physics teacher education. Moreover, a lesson study emphasizing the use of technology-driven multiple representations in Physics instruction is still unexplored. To the knowledge of the researchers, no research endeavor has devoted to scaffolding multiple representation skills of pre-service Physics teachers through collaborative instructional planning and implementation. Finally, no study has shown the application of lesson study in the practice teaching stage in the pre-service teacher education. Microteaching Lesson Study has been widely used but the employment of Lesson Study in practice teaching has not been undertaken to investigate its effects on pre-service Physics teachers and students.

The researchers aim to address the aforementioned gaps by employing the Multiple-Representation Lesson Study in the practice teaching stage of the pre-service teacher education curriculum.

3. Methodology

A mixed-method approach was utilized in the study which employed a pretest-posttest quasi-experimental design. Two groups were formed from the 18 randomly chosen fourth year BSED-Physical Science students of a state university in the Eastern Visayas Region of the Philippines. The Traditional Instructional Planning Approach (TIPA) was carried out by the comparison group while the Multiple-Representation Lesson Study (MRLS) was implemented by the experimental group during the first quarter period of their practice teaching.

The intervention lasted for six weeks in a large public high school in Eastern Visayas. A Posttest was administered after their practice teaching in the first quarter term of the Department of Education (DepEd). Four groups of secondary students were handled by the pre-service Physics teachers during their Practice teaching; each group was composed of three Grade 8 classes with approximately 50 students per class. One group was taught using the Traditional Instructional Planning Approach while the three groups were taught using the MRLS of different versions – the first version technology-driven MRLS, the second version technology-driven MRLS, and the conventional version MRLS.

3.1. The Sample

The sample of the study was composed of 18 fourth year BSED-Physical Science students of a state university in the Eastern Visayas Region, Philippines. They were randomly selected through a fishbowl technique from a class of 42 students who were eligible for Practice Teaching on the first semester of SY 2016-2017 (June - October 2016).

Participants of the TIPA group were from the ages 19 to 21 with an average age of 19.56 years. The MRLS group, on the other hand, has an age range of 18 to 20 with an average age of 19.00 years. Both TIPA and MRLS have three male participants who comprised 33.3% of the group sample, and both groups were composed of six female members who comprised 66.7% of the group sample. In terms of educational background, eight (88.9%) from the TIPA group came from public elementary schools while one (11.1%) graduated from a private elementary school. Meanwhile, all (100%) of the MRLS participants were products of public elementary schools. The MRLS and TIPA groups have the same profile in terms of high school background; seven (77.8%) graduated from public high schools while two (22.8%) came from private high schools. With respect to academic performance, the mean ratings in Science are almost the same for the two groups, 1.89 for TIPA and 1.88 for MRLS. The mean ratings in Mathematics are higher than in Science; the TIPA group has a slightly higher mean rating than the MRLS group which is 1.72 against 1.77.

3.2. The Instruments

A. Pre-service Physics Teacher Technological-Pedagogical-Content Knowledge Test (PPT-TPCKT)

The PPT-TPCKT was a researcher-made test composed of 15 scenarios with three questions each. It aimed to measure the Technological Knowledge, Pedagogical Knowledge, and Content Knowledge of the respondents. The questions in the instrument were patterned from the Mathematics Pedagogical Content Knowledge (MPCK) framework of the Teacher Education Study in Mathematics (TEDS-M). Adopting the framework in the Physics context, questions were framed to assess preservice teachers' Curricular Knowledge, Knowledge of Planning for Teaching and Learning, and Enacting Physics (International Association for the Evaluation of Educational Achievement (IEA), 2013).

B. Interview Schedules

Researcher-made interview schedules were utilized to gather data about the experiences in instructional planning approach and teaching demonstrations of the pre-service teachers from both experimental and comparison groups. The interview questions were primarily TPCK-based. The interview schedules were used at the end of each phase of the study – in May 2016 for Phase 1 and in August 2016 for Phase 2.

C. Journals

Each participant was asked to keep a journal and to record their experiences during the two phases of the study. Emphasis was placed on the challenges they have experienced with the instructional planning approach they were exposed to and their coping mechanisms in overcoming the challenges they had mentioned in their journal.

3.3. Data Collection Procedure

Permission to conduct the study with the participation of the fourth year BSED-Physical Science majors was sought from the university president and the university officials on March 17, 2016 through a letter signed by the researcher and noted by the research adviser. During the preliminaries of the study on April 11, 2016, the Informed Consent Form was administered to the research participants to seek their permission on their participation in the study. The pretest for TPCK and critical thinking were conducted shortly after the administration of the Informed Consent.

For the practice teaching stage, the researcher wrote a letter to seek permission from the DepEd Schools Division Superintendent of Tacloban City on June 28, 2016 and from the school principal of a large public high school on July 1, 2016. Similarly, permission was sought from the Science Cooperating Teacher Educators (CTEs) during the orientation on July 4, 2016 to observe classes, to videotape the teaching demonstrations, and to use certain student performance records for the analysis of the results of the study. The researcher discussed the flow of the study, the role of the CTEs, the schedule of activities, and the data needed for the analyses. Likewise, the risks and benefits of the study were explained. They were assured that the data will be handled with utmost care and will be used for research purposes only. The CTEs and their Department Head assisted the researcher to efficiently conduct the study.

A. MRLS in Practice Teaching

The MRLS group taught three classes – the first period for the first version of the technology-based lesson plan, the third period for the conventional version, and the fourth period for the second version of the technology-based lesson plan. Technology-based versions utilized two or more digital representations (i.e. verbal, pictorial, graphical, mathematical, or/and multimedia systems) while the conventional version used two or more traditional representations. The second-period class was handled by the TIPA members to give time for post-lesson discussions of the MRLS group. For every lesson, one member of the MRLS sub-group implemented the plan. The other group members observed and took down notes on the different aspects of teaching, both verbal and non-verbal, such as demonstrator responses, student responses, classroom management, and so forth. The observations highlighted students' responses in learning the topic.

After every implementation of the first version of the lesson plan, the sub-group members convened and reflected on the actual teaching. At times, they conducted the post-lesson discussion in the presence of the CTE and/or the researcher, but most of the times they did it on their own. The integrated observations, comments, and suggestions became the bases for the revised plan called the "second version". They, then, taught the conventional version to the third-period class. The second version of the technology-based lesson plan was taught to the fourth-period class which was followed by another post-lesson discussion. Lastly, they finalized the results including the lesson plan, instructional materials, and observation reports.

The same process was carried out on the succeeding lessons. All members of the sub-group had an approximately equal number of lesson implementations. At the end of the quarter term, a Posttest was conducted to measure the respondents' TPCK.

The lesson implementations of the participants were videotaped. A total of 194 videos were assessed for the entire practice teaching. Aside from the CTE and the researcher, an external evaluator was invited to assess the teaching performance of the pre-service teachers. She had been a high school Physics teacher for more than 10 years. She also served as a Cooperating Teacher Educator for Secondary Science majors at the university's Integrated Laboratory School for almost 10 years. Her expertise in Physics teaching was regarded as a vital factor in choosing her as the external evaluator, despite the overwhelming demands of her position. Her assessment method differed slightly as she relied fully on video recordings having had no chance for actual observations of the participants. She assessed the pre-service teachers' teaching performance using the same video recordings, scoring rubrics, and TPCK Observation Guide that were used by the CTEs and the researcher.

C. Traditional Instructional Planning Approach (TIPA) in Practice Teaching

After the orientation on the procedures, the researcher and the STC randomly assigned three TIPA members to each CTE to match the number of MRLS members before they were deployed to LNHS. For each topic taught by the MRLS group, there was one corresponding teaching demonstration from the TIPA group. They constantly taught the second-period class to give time for the MRLS members to conduct a post-lesson discussion on the first-period class. It should be noted that some topics were taught solely by the TIPA members to ensure an approximately equal number of lesson implementations among all participants.

The TIPA participants prepared individually the lesson plans on the topics assigned to them. The CTE collected and checked their plans and returned them at least a day prior to the demonstration schedule. The TIPA pre-service teachers revised their lesson plans based on the CTE's remarks, then proceeded to the construction of IMs. Then they proceeded to teach the approved lesson plan with the CTE assessing their teaching performance using the same instruments in assessing the MRLS group. The CTE gave feedback after implementing their lesson, either personally or in the presence of other practice teachers.

Although TIPA respondents were given the liberty to choose between conventional or technology-based instructional materials, seven out of nine preferred to prepare traditional IMs because of some drawbacks and justifications which include the lack of laptop or computer unit and the eagerness to master the lesson through manual preparation of instructional plans and materials.

The researcher spent time to observe the lesson implementations of the TIPA participants. Just like in the MRLS group, the researcher gave feedback after the lesson implementations of the TIPA members, done at times in the presence of the CTE.

Occasionally, a one-on-one discussion with the demonstrator was carried out. Table 1 summarizes the steps utilized in the experiment.

Table 1: Summary of the Experiment

MRLS Group	TIPA Group
• Pretest	• Pretest
• Orientation	• Orientation
• MRLS Practice Teaching ▪ Collaborative instructional planning ▪ Collaborative material preparation ▪ Lesson implementations (Tech-based 1st and 2nd Versions, Conventional) ▪ Post-lesson discussions	• Traditional Practice Teaching ▪ Individual instructional planning ▪ Individual material preparation ▪ Lesson implementations ▪ Individualized feedback
• Posttest	• Posttest

3.4. Data Analysis Procedure

The Mann-Whitney U Test was utilized to determine a significant difference in the scores of the MRLS group and TIPA group in the pretest of TPCK. The same statistical tool was applied to compare their posttest scores. All of these tests were set at α=.05 level of significance.

4. Findings and Discussions

4.1 Initial comparability in Academic Performance

The ratings of the research participants in the 13 Science and two Mathematics courses that were taken prior to the experiment were determined and analyzed to establish comparability in academic performance as provided by Table 2.

Table 2: Mann-Whitney U Test for the Ratings in Science and Mathematics

Subject/Group	N	Mean Rating	Mean Rank	Mann-Whitney U	p
Science					
MRLS	9	1.89	9.67	39.0	.894
TIPA	9	1.91	9.33		
Math					
MRLS	9	1.77	10.00	36.0	.690
TIPA	9	1.72	9.00		

Results of the statistical analysis suggest that the median rating in Science of the MRLS *(mean rank = 9.67)* group is not significantly different *(p = .894)* to that of the TIPA group *(mean rank = 9.33)*. Similarly, the median ratings in Mathematics between the two groups are not significantly different *(mean* $rank_{MRLS}$ *= 10.00, mean* $rank_{TIPA}$ *= 9.00, p=.690)*. These suggest that TIPA participants are comparable to MRLS participants in terms of academic performance in Science and Mathematics before their participation in the study.

4.2 Initial comparability in TPCK

Table 3 shows the results of the TPCK Pretest for both the comparison and the experimental group. Results revealed a better performance of the MRLS group *(Md = 98.00, Mn = 97.56, SD = 4.85)* than the TIPA group *(Md = 97.00, Mn = 95.22, SD = 5.56)*. Variability of the performance explained by instructional approach is 5.3% only.

Table 3: Pretest Results for the Technological-Pedagogical-Content Knowledge Test

Test/Group	N	Md (Max.=120)	Mn (Max.=120)	SD	$(SD)^2$	η	$η^2$
Pretest							
MRLS	9	98.0 (81.7%)	97.6 (81.3%)	4.85	23.5		
TIPA	9	97.0 (80.8%)	95.2 (79.3%)	5.56	30.9	.231	.053
Total	18	97.0 (80.8%)	96.4 (80.3%)	5.20	27.1		

Note: Max. Score=120; Md=median; Mn=mean; SD=standard deviation; $(SD)^2$=variance; and η and $η^2$=measures of association

Table 4 presents the results of the Mann-Whitney U test analysis for the TPCK pretest. Though the MRLS group scored higher *(Md = 98.0)* than the TIPA group *(Md = 97.0)*, results revealed a non-significant difference (*U* = 34.0, *p*=.562) between the Pretest scores of the two groups with a small effect size (*r* = .136). This suggests that the experimental group is comparable to the control group in terms of Technological-Pedagogical-Content Knowledge prior to the conduct of the experiment.

Table 4: Mann-Whitney U Test for the TPCK Pretest

Test/Group	N	Mean Rank	Mann-Whitney U	Z	p	r (ES)
Pretest						
MRLS	9	10.2	34.0	-.579	.562	.136
TIPA	9	8.78				

Note: *p<.05

4.3 After Practice Teaching

Table 5 provides the results of the TPCK Posttest. The MRLS group *(Md = 106, Mn = 105, SD = 4.30)* outperformed the TIPA group *(Md = 101, Mn = 100, SD = 2.01)* in the TPCK test after their practicum. Results indicate that the intervention accounts for 37.4% of the variability in the group scores.

Table 5: Posttest Results for the TPCK Test

Test/Group	N	Md (Max.=120)	Mn (Max.=120)	SD	$(SD)^2$	η	$η^2$
Posttest 2							
MRLS	9	106 (88.3%)	105 (87.5%)	4.30	18.5		
TIPA	9	101 (84.2%)	100 (83.3%)	2.01	4.03	.611	.374
Total	18	102 (85.0%)	103 (85.8%)	4.11	16.93		

Note: Max. Score=120; Md=median; Mn=mean; SD=standard deviation; $(SD)^2$=variance; and η and $η^2$=measures of association

The statistical analysis shown in Table 6 reveals that the median score of the MRLS group *(Md = 106)* is significantly higher than the median score of the TIPA group *(Md = 101), U = 13.0, p = .014*. Similarly, a large effect size *(r = .577)* was recorded for the TPCK Posttest.

Table 6: Mann-Whitney U Test for the TPCK Posttest

Test/Group	N	Mean Rank	Mann-Whitney U	Z	p	r (ES)
Posttest 2						
MRLS	9	12.6	13.0	-2.45	.014*	.577
TIPA	9	6.44				

Note: *p<.05

Results of this study affirm findings of previous studies conducted by Chew & Lim (2013), Chai, Koh, & Tsai (2010), and Haley-Mize (2011) that engaging in a technology-driven instructional design can increase the TPCK of pre-service teachers. These, however, do not support Ozturk's (2012) results that using Wikipedia as a teaching tool in History did not have a strong effect on the TPCK development of pre-service History teachers.

Similarly, these results conform with the findings of Chew & Lim (2013). The use of Geometer's Sketchpad (GSP) in teaching Mathematics improved the overall TPCK of the pre-service Mathematics teachers after engaging in microteaching lesson study. Likewise, results coincide with Cavin's (2007) claiming that technology-integration in microteaching lesson study can provide an array of benefits which can be manifested in pre-service teachers' instructional practice. The MRLS opened an opportunity to integrate and interact with technology through a series of activities that entailed collaboration and teamwork. Finally, the results of this study support the findings of Kolenda (2007), Quilario (2014), Hixon (2009) and Cajkler, Wood, Norton, Pedder, & Xu, (2015). They all expressed positive effects of the lesson study like reinforcing teaching confidence, strengthening self-efficacy, eradicating isolationism, ensuring a reflective teaching, and providing an opportunity for teamwork.

These results may be explained by Knowles' (1984) theory of adult learning. He proposed that creating a cooperative learning climate and establishing collaborative planning mechanisms can maximize learning. These conditions were existent in the MRLS, both in microteaching and in practice teaching experiences. Further, Knowles (1973) emphasized the role of experience in adult learning. He claimed that *"as an* *individual matures he accumulates an expanding reservoir of experience that causes him to become an increasingly rich resource for learning, and at the same time provides him with a broadening base to which to relate new learnings"* (p. 45-46). Providing a rich experiential collaborative environment set learning opportunities for MRLS participants apart from their TIPA counterparts.

These encouraging results propose various implications to science education and pre-service teacher education. The application of the MRLS in practice teaching is a potential curricular method endeavoring attainment of instructional competence. In light of this, pre-service teachers may be exposed to collaborative planning and teaching in their practicum to foster collegial support and to eliminate isolationism. Teaching in the actual field can challenge prospective teachers' technological, pedagogical, and content knowledge that having a support system may be especially relevant. Moreover, Cooperating Teacher Educators (CTEs) may uphold utmost guidance or close supervision on pre-service teachers through constant feedback and post-lesson discussions.

Giving feedback to pre-service teachers' performance should also be encouraged to affirm good practices and to rectify instructional lapses. Teachers and Cooperating Teacher Educators (CTEs) should constantly monitor the development of technological, pedagogical, and content knowledge of prospective teachers and notify them of their progress. Likewise, peer-assessment and peer-feedback should be promoted to foster collegial spirit and to fortify experiential learning.

Adequate preparation on the production and utilization of varied instructional resources, both conventional and technology-based, must be provided to pre-service teachers through educational technology courses, with the anticipation of the conditions of varied teaching fields. This may aid the pre-service teachers to plan for functional instructional materials at the onset of their practicum. They, too, must be supported with appropriate and sufficient equipment by their host schools through their CTE.

Teacher Education Institutions (TEIs) may carefully select partner laboratory schools for placement of pre-service teachers in their practicum. Competent Cooperating Teacher Educators and equitable educational resources must be highly-prized to support instructional competence of the pre-service teachers.

4.4 Effects of Instructional Planning Approach on Pre-service Physics Teachers' TK, PK, and CK. Further analysis was conducted to better understand the effects of the MRLS on pre-service Physics teachers. Table 7 summarizes the analyses on the scores obtained by the research participants in the TPCK Test per component.

Table 7: Summary Table for the Mann-Whitney U Test on TPCK Components

Test Statistics[b]					
	Mann-Whitney U	**Wilcoxon W**	**Z**	**Asymp. Sig. (2-tailed)**	**Exact Sig. [2*(1-tailed Sig.)]**
PreTK	39.500	84.500	-.090	.928	.931[a]
PostTK	5.000	50.000	-3.169	.002*	.001[a]
PrePK	16.000	61.000	-2.180	.029*	.031[a]
PostPK	37.000	82.000	-.316	.752	.796[a]
PreCK	36.000	81.000	-.401	.688	.730[a]
PostCK	29.500	74.500	-.980	.327	.340[a]
a. Not corrected for ties.					
b. Grouping Variable: Respondent					

TK. As shown in Table 8, the Posttest results of the TK component revealed a highly significant difference in the performance between the groups, with the MRLS *(Mn = 41.9)* group outperforming the TIPA group *(Mn = 38.8, U = 5.00, p=.002)*.

Table 8: Mann-Whitney U Test for the TK Component of the Posttest

TPCK Component	**Group**	**Posttest**			
		Mn	**Mean Rank**	**M-W U**	**p**
TK	MRLS	41.9 (93.1%)	13.4	5.00	.002**
(Max.= 45)	TIPA	38.8 (86.2%)	5.56		

Note: *p<.05; **p<.01

These encouraging results may be attributed to the experiences of the experimental group with the practice teaching MRLS. The intervention lasted for six weeks which allowed the MRLS participants to demonstrate at least four lessons. Since the participants had prior preparation of instructional plans and instructional materials in the microteaching MRLS, it opened an opportunity for them to explore and utilize more educational technologies, both modern and conventional, appropriate to the lessons assigned to them. Collaborative preparation and utilization of such instructional technologies may have appreciably developed their technological knowledge (Knowles, 1984; Knowles, 1973).

Results suggest that the MRLS group had a higher level of TK than the TIPA when their theoretical technological knowledge (TPCK test) was assessed. These results are consistent with the findings of other researchers. Chew & Lim (2013) also reported that engaging in lesson study can significantly improve the TK of pre-service secondary teachers. Likewise, Ceppi-Bussmann (2006) claimed an increased technological knowledge and competence of teachers who were involved in a lesson study program. Meanwhile, results of this study affirm Terpstra's (2009) and Chai, Koh, & Tsai's (2010) contention that technology-based instructional intervention can enhance the technological knowledge of the pre-service teachers. Utilization of multiple-representations generated by digital technologies and conventional materials in the MRLS process may have played a significant role in this development.

Apparently, results indicate that technological knowledge is influenced by the length of exposure to or utilization of educational technologies. More diverse resources may be explored when sufficient time is provided to experience use of technologies in instruction that can broaden technological knowledge of the pre-service teachers. In view of this, equitable curricular programs in pre-service teacher education, especially educational technology and professional education courses, must foster extended experiential and collaborative learning on the development and utilization of a host of educational technologies. Moreover, employment of multiple representations through multimedia systems should be encouraged for they can function as rich learning resources (Ozmantar, Akkoc, Bingolbali, Demir, & Ergene, 2010; Cairncross & Mannion, 2001). The Multiple-representation Lesson Study sets a teaching-learning environment that adheres to this provision.

PK. Table 9 provides that the MRLS group obtained a mean score of *Mn = 40.0* in the PK component of the TPCK written test. The TIPA group, on the other hand, acquired a mean score of *Mn = 39.6*. Statistical analysis revealed that the median scores of the two groups were, nevertheless, not significant ($U_2 = 37.0$, $p_2 = .752$). These results deviate from the findings of Chew & Lim (2013), Haley-Mize (2011), and Chai, Koh, & Tsai (2010) who reported significant increase in PK of pre-service secondary teachers after the conduct of technology-based interventions, including the microteaching lesson study. They, however, used a self-survey instrument in measuring participants' overall TPCK and its components. Similarly, these written test results indicate a seemingly divergence from the account of Lewis, Perry, & Hurd (2004) that lesson study can increase knowledge of instruction.

Table 9: Mann-Whitney U Test for PK Component of the Posttest

TPCK Component	Group	Posttest			
		Mn	Mean Rank	M-W U	p
PK (Max.=45)	MRLS	40.0 (88.9%)	9.89	37.0	.752
	TIPA	39.6 (88.0%)	9.11		

Note: *p<.05

The non-significant difference of the experimental and comparison group was probably due to a limited planning and teaching experience of the MRLS participants. The teaching experiences may have been inadequate to develop their pedagogical knowledge, especially the theoretical aspect of PK. In the same way, there can be inadequacies in the practice teaching MRLS that did not significantly advance pre-service teachers' pedagogical knowledge as measured by the written test. One can be that post-lesson discussions were not constantly conducted in the presence of their CTE. The MRLS participants were, oftentimes, left on their own to carry out informal post-lesson discussions. The lack of supervision may have insufficient impact to the theoretical aspect of their PK. Another inadequacy may be that the feedback from their CTE and the observations generated from the informal post-lesson discussions may have not highlighted pedagogical ideas, rather, may have emphasized other concerns not closely related to instructional practices (Gurl, 2009).

Furthermore, no significant differences may have been observed between the groups' performance in the Posttest for the reason that pedagogical knowledge cannot be measured completely by a written test. Some important data might be missing that necessitates further investigation from other data sources (Morrison & Luttenegger, 2015; Choy, Wong, Lim, & Chong, 2013). Cavin (2007) and Gurl (2009) conducted observations to determine PK levels and changes among pre-service teachers who have undergone lesson study. They provided apprehensible qualitative descriptions of the said construct that may have not been deduced from a written test or self-report survey instruments. Basing upon these grounds, this study included multiple data points for a broader PK assessment of the research participants.

Reckoning these statistical data, results imply that the MRLS can be an innovative approach to develop pre-service physics teachers' teaching performance. Metcalf, Hammer, & Kahlich (1996) noted that pedagogical skills can be strengthened through microteaching; the MRLS participants have undergone microteaching prior to their practice teaching. An effect of this endeavor was expressed by Participant E18 in her interview response:

> *"For me, Sir,* ***it was both awesome and at the same time back-breaking experience****. How come? Because* ***it paved a way to a lot of experiences****. I also believe that because of the lesson study,* ***it helped me build enough courage and enough confidence to face in front [of the class], especially during summer (Phase 1). I had a chance to have a demonstration teaching so I believe it helped me build my confidence,*** *that during my* ***first time to demonstrate in Leyte High I have that enough confidence to showcase what I have and what I can give to my students****… (E18; Interview, August 25, 2016) –* ***[strengthening teaching confidence]***

Morrison & Luttenegger (2015) contend that a single method of measuring PCK does not warrant a holistic insight of a teacher's PCK. They propose the use of multiple data sources such as written tests, observations of actual teaching, and interviews for this purpose. As such, measuring the pre-service physics teachers' TPCK in this study involved multiple data points, particularly TPCK Test, teaching observations, lesson plan assessment, instructional materials assessment, and interviews. It can be noted that there was no significant difference in the PK mean scores of the MRLS and the TIPA group in the written TPCK Posttest (p=.302 and p=.752, respectively). Interestingly, a significant difference was observed in their teaching performance (TP) when observation ratings were aggregated.

Kolenda (2007), Cavin (2007), and Gurl (2009) reported similar results. They all conveyed positive effects of lesson study to pre-service and in-service teachers in their instructional competence. Moreover, the MRLS have prompted the experimental group to utilize technology-driven multiple representations to exhibit pedagogical skills as identifying and addressing students' difficulties, designing curricular materials, and assessing student learning (Ozmantar, Akkoc, Bingolbali, Demir, & Ergene, 2010).

Because MRLS is a collaborative instructional approach, there had been opportunities in correcting misconceptions or unlocking difficulties through productive discussions in the MRLS group. They were also given a chance to rectify faults in delivering the lesson through a series of microteaching, demonstration teaching, peer-observation, and post-lesson discussions. Learnings from these experiences may have been tangible in their teaching performance (Knowles, 1973; Knowles, 1984).

In the same light, Rock & Wilson (2005) reported that teachers who participated in a lesson study professional development program *"experienced an increase in their professional confidence.* They also stressed that *"the peer collaboration was valuable to their professional development"* (p. 84). Furthermore, as a collaborative learning endeavor, participants in the MRLS group can select appropriate activities and can create better quality instructional materials, both conventional and technology-based, even with a limited preparation time. This defining characteristic of MRLS sets it apart from traditional instructional planning which is under the tenets of individualistic learning environment (Laal & Laal, 2012).

Findings of this study spell out certain implications to the teaching-learning process. Learning assessments may be carefully and appropriately undertaken especially when assessing instructional competence. It is necessary to employ explicit and multiple methods to apprehend the pedagogical knowledge of pre-service teachers. Essential elements may not be captured when measurement of PK is only centered on written test results. Pre-service teachers' outputs and actual teaching performance must be examined to inform different facets of their pedagogical knowledge.

Educators may provide rich collaborative learning experiences that champion collegial support among pre-service teachers such as engaging in small-group discussions, group-based projects, and group presentations. Individualistic learning may not be appropriate to many learners for it may create isolationism (Kolenda, 2007). Engaging in Multiple-representation Lesson Study offers opportunities to promote collegial spirit and to showcase and enhance varied pedagogical skills of prospective teachers.

CK. The MRLS group *(Mn = 23.4)* scored higher than the TIPA group *(Mn = 22.1)* in the CK component of the Posttest. The Mann-Whitney U test revealed a non-significant difference *(p = .327)* of the median scores between the two groups as shown in Table 10.

Table 10: Mann-Whitney U Test for CK Component of the Posttest

TPCK Component	Group	Posttest			
		Mn	Mean Rank	M-W U	p
CK (Max. = 30)	MRLS	23.4 (78.0%)	10.7	29.5	.327
	TIPA	22.1 (73.7%)	8.28		

Note: *p<.05

Results of this study do not conform with the findings of Chew & Lim (2013), Mitcheltree (2006) and Lewis, Perry, & Hurd (2004). They contend that improvement in the CK may be attained by those involved in the lesson study because *"teachers discuss the essential concepts and skills that their students need to learn, compare the concepts' treatment in existing curriculums, and consider what the students currently know and how they will respond to the planned lesson. As teachers engage in these activities, they naturally generate many questions about the subject matter. The group can often answer such questions; if not, the teachers look to outside resources"* (Lewis, Perry, & Hurd, 2004, p.19). Moreover, the collaborative lesson planning sessions and post-lesson discussions can offer an array of learning opportunities by looking into all aspects of the lesson and by engaging in conceptual discourse that may not happen if they were planning and teaching the lessons on their own (Mitcheltree, 2006). Apparently, these were not fully observed in the CK of the pre-service teachers. Although the experimental group outperformed the comparison group, the difference in the scores is not significant.

The non-significant difference in the median scores of the MRLS and TIPA group may be attributed to certain grounds. Unlike in microteaching where classmates can play the role of students, the pre-service teachers in the study taught the Grade 8 students in their practice teaching who were relatively "less mature" in terms of knowledge in content. The pre-service teachers exerted less effort in explaining the Physics concepts in their teaching and they relied heavily on the textbook; they rarely referenced any outside source (Gurl, 2009). Expectedly, they developed a shallow conceptual understanding on the topic they taught.

The insufficient contact time with the students during their practice teaching may have not prompted the pre-service teachers to delve deeper on the content of their teaching. They were compelled to focus on basic conceptual knowledge to accommodate all pre-planned classroom activities, leaving out relevant components of the topic. This may have not cultivated their knowledge on certain areas of Physics. Additionally, the absence of their CTE in a number of post-lesson discussions may have not addressed conceptual difficulties of the pre-service teachers nor have affirmed the accuracy of the content they taught. The lack of feedback from their CTE may have not promoted development of content knowledge among MRLS participants.

Furthermore, the post-lesson discussions may have not stressed content-related issues. Gurl (2009) stated that teachers and pre-service teachers oftentimes discuss a number of school-related concerns but there is less emphasis on content matters. *"When left to their own devices, student teachers and cooperating teachers discuss many important aspects of teaching secondary mathematics; however, explicating the mathematics content knowledge of teachers is not among the topics being discussed"* (p. 128). This has been observed among CTEs and pre-service teachers during the conduct of MRLS in practice teaching.

Establishing a robust content knowledge is a crucial step to attain high level of instructional competence. Apparently, interaction with the "more knowledgeable" creates a learning environment that influences CK positively. Thus, teachers ought to develop mastery of topics in their field of specialization. Varied teaching strategies must be employed to elicit existing knowledge of students and, to apprehend and rectify alternative conceptions.

Likewise, teachers should utilize various instructional technologies integrating multiple representations to transform concepts into different forms. This may deepen conceptual understanding considering that a number of processes are involved to grasp associations between multiple representations (Ainsworth, 2006; Mayer, n.d.).

4. Conclusion and Recommendations

Reckoning the results of the study, it can be surmised that MRLS can have substantial positive effects in developing the overall TPCK of pre-service teachers. Findings also suggest that with certain considerations, MRLS is potentially effective in developing TK, PK, and CK of pre-service Physics teachers.

Pre-service teachers and non-Physics major in-service teachers may undertake lesson study to enhance their confidence in carrying out instructional goals and to enhance their technological, pedagogical, and content knowledge. Likewise, the extensive use of technology-generated and conventional multiple representations in developing instructional materials in Physics is proposed to compensate the abstract nature of numerous concepts. Instructional material developers are enjoined to carry out expansive utilization of verbal, graphical, pictorial, and mathematical representations to tailor various learning needs.

Acknowledgement

The authors acknowledge the professional and financial support of the Leyte Normal University, Commission on Higher Education, University of the Philippines Open University, DepEd Tacloban City Division, Leyte National High School, Eastern Visayas State University, College of Education UP Diliman, and UP NISMED.

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