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EFFECTS OF MICROTEACHING MULTIPLE-REPRESENTATION PHYSICS LESSON STUDY ON PRE-SERVICE TEACHERS' CRITICAL THINKING

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Abstract. *A research on the effects of the microteaching Multiple-Representation Lesson Study (MRLS) on pre-service Physics teachers' critical thinking was conducted using a pre-test-post-test quasi-experimental design. Eighteen fourth year Bachelor of Secondary Education-Physical Science majors participated in the research. The experimental group employed the microteaching MRLS while the control group implemented the Traditional Instructional Planning Approach (TIPA). Data were gathered from multiple sources such as researcher-made written tests, interviews, diaries, and field notes. The Mann-Whitney U test was utilized to ascertain statistical difference between the experimental and the control group. Results revealed significant differences in the scores between the two groups in the overall critical thinking and on its sub-domains. Findings indicate beneficial effects of the microteaching MRLS in developing pre-service teachers' critical thinking.*

Keywords: *critical thinking, lesson study, multiple representations, physics education, pre-service teachers, science education.*

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Introduction

The prevalent educational milieu is characterized by an amalgamation of various pedagogical principles and social dynamics involving the learners, teachers, and other stakeholders. Technological developments in the modern time inevitably shape educational paradigms, hence, instructional practices must adapt to these changes that essentially foster student discourse and critical thinking. Emphasizing critical thinking within teacher education anticipates a better response to societal issues by carrying out effective measures (Williams, 2005). Scholars have established an explicit relation of critical thinking and problem-solving (Buckley, 2012; Maebius, 1990; Sensibaugh, 2015; Tseng, 2008; Williams, 2005). Buckley (2012) has even asserted that critical thinking is a prerequisite to problem-solving.

With the overwhelming challenges faced by pre-service teachers each day, acquiring sound critical thinking is necessary for effective instructional planning, implementation, and reflection. Research, however, has shown a dismal state of pre-service teachers' critical thinking level (Akdere, 2012; Grosser & Nel, 2013; Qing, Jing, & Yan, 2010). Gashan (2015) has declared that pre-service teachers hold insufficient understanding of critical thinking skills, that they have uncertain knowledge about it despite their positive views about the place of critical thinking in the educative process. Furthermore, the pre-service teachers have struggled in substantiating their knowledge of their pupils' capacity to probe, integrate, and assess information (Meister, 2011). Initiatives to resolve these issues have been carried out but these revealed mixed impressions. Various approaches have not consistently ensued desirable results (Akyuz & Samsa, 2009; Behar-Horenstein & Niu, 2011; Goyak, 2009; Qing, Jing, & Yan, 2010; Sulaiman, 2013).

One major challenge that confronts pre-service teachers is addressing

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learning difficulties with Physics due to the numerous abstract concepts involved as well as the ubiquitous presence of mathematical symbols and processes (Alias & Ibrahim, 2013; De Cock, 2012; Erinosho, 2013; Kozhevnikov, Hegarty, & Mayer, 1999). Learners often struggle to discern connections among mathematical, graphical, verbal, and pictorial representations (Bal, 2015; Gulkilik & Arikan, 2012; Nguyen & Rebello, 2009; Ogunleye, 2009; Snetinova & Koupilova, 2012; Soong, Mercer, & Er, 2009).

A deficiency in teaching competence may be manifested in learners' misconceptions and difficulties associated with multiple representations. Literature has shown a close association of the teachers' knowledge and student learning (Hightower, Delgado, Lloyd, Wittenstein, Sellers, & Swanson, 2011; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013; Tchoshanov, Lesser, & Salazar, 2008). This connotes that a productive teaching entails a firm scaffolding of teachers' knowledge. Instructional practices maximizing the use of multiple representations can be a potential driver in alleviating perennial conceptual, procedural, and mathematical difficulties (Akkus & Cakiroglu, 2009; Bal, 2015; Banerjee, 2010; Gulkilik & Arikan, 2012; Leigh, 2004; Ozmantar, Akkoc, Bingolbali, Demir, & Ergene, 2010).

A collaborative instructional planning approach such as the Lesson Study (LS) may be considered in confronting these academic difficulties involving multiple representations. Lesson study is a cooperative educational approach employed by in-service Japanese educators that can pose potential advances in attaining desirable learning outcomes through careful collaborative instructional planning (Fernandez, 2002; Lewis, 2002; Lewis, Perry, & Hurd, 2009). Incorporating the Lesson Study in the pre-service teacher curriculum offers explicit benefits such as improving habits, competencies, and skills (Gurl, 2009; Elipane, 2012), transferring Nature of Science (NOS) into classroom practice, and deepening the NOS pedagogical content knowledge of prospective teachers (McDowell, 2010). Moreover, engaging in a lesson study can promote student achievement and critical thinking (Barrett, Riggs, & Ray, 2013; Lucenario, Yangco, Punzalan, & Espinosa, 2016; Quilario, 2014; and Teele, Maynard, & Marcoulides, 2015).

Reckoning the initiatives to cast light upon the constructs of lesson study, multiple representations, and critical thinking, a paucity of information sheds light on pre-service Physics teaching. A microteaching Physics Lesson Study employing technology-driven representations is yet unknown. Further, little is known of the effects of a multiple-representation-based collaborative instructional planning on the critical thinking of prospective Physics teachers, either as an overall competence, or as a specific proficiency.

Multiple Representations and Learning

Representations are vital elements of a good Physics instruction. When at least two representations are employed, either simultaneously or at some point during the entire duration of instruction, it is called a multi-representational system (Ainsworth, 2006). Kohl and Finkelstein (2006) categorized basic representations into four:

1. Verbal – spoken words, written text, phrases or sentences
2. Graphical – graphs, diagrams that have labeled axes
3. Pictorial – pictures, images, sketches, diagrams
4. Mathematical - numerical calculations, equations, formulae, or any quantitative reasoning

The evolving technological education offers a more advanced combination of representations which Ainsworth (2006) called a multi-media system. A regular multi-media system can present images, words, simulations, sound, mathematical symbols, and diagrams. Notably, this multi-media system contains basic representations defined by Kohl and Finkelstein (2006).

Learning with multiple representations can be a complicated task for learners due to the numerous information they contain. Ainsworth (2006) cited Palmer's (1977) five compositions of an external representation as shown in Figure 1. The Cognitive Theory of Multimedia Learning describes five intellectual processes associated with multiple representations and multimedia instruction. Mayer (n.d.) identified these processes which includes choosing words, choosing images, organizing words, organizing images, and amalgamating. The theory maintains that learning is established when learners systematically undergo these processes as they interact with representations.

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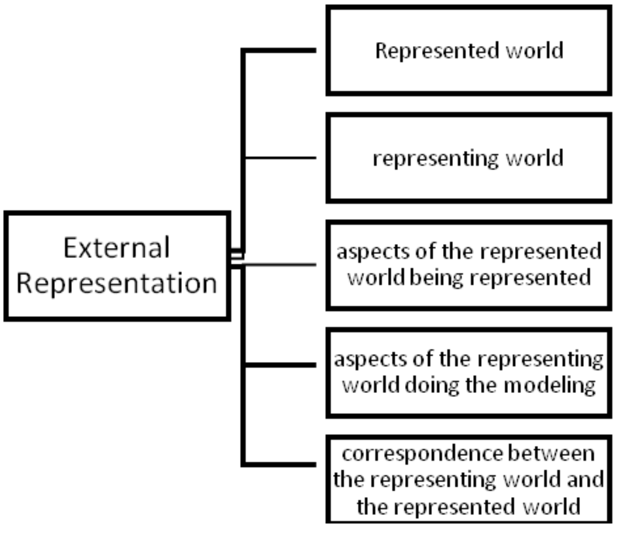

Figure 1. Compositions of external representation.

Kozhevnikov, Hegarty, and Mayer (1999) have reported that the use of images presents problem-solving impediments. This may be due to the ineffective use of representations or failure of the students to visualize problems in the form of illustrations or figures (Alias & Ibrahim, 2013; Kohl & Finkelstein, 2006).

Some scholars, however, have argued that instructional strategies utilizing representations pose beneficial effects to students such as improving achievement, conceptual understanding, problem-solving strategy, use of representations, and mathematics performance (Akkus & Cakiroglu, 2009; Banerjee, 2010; Kohl & Finkelstein, 2006; Kurnaz & Saglam Arslan, 2014; Lucas, 2014). Larkin and McDermott (1978) classified the representations used by the students into four stages as presented in the following figure.

Figure 2. Stages of utilization of representations.

Figure 2 connotes that problem-solving often allows students to undergo a transition from the lower stages of employing representations (i.e. literal and naive representations) to higher stages such (i.e. scientific and algebraic representations). It can be noted that the last two stages indicate a more abstract depiction of the problem.

Understanding students' representational skills and performance in Physics or in Mathematics in relation to multiple representations is essential for a better grasp of Science instruction. Nevertheless, probing pre-service teachers' multi-representational competence and the methods of developing it are equally important. What lacks in the literature is the initiative of scaffolding pre-service Physics teachers' proficiency in the didactic use of multiple representations, particularly the technology-driven ones.

Lesson Study

Lesson Study is a popular cooperative educational approach widely practiced in Japan. It comes from the Japanese word *jugyokenkyu*. In English, the word *jugyo* is translated as "lesson" while *kenkyu* is translated as "study or research". The reverse word *kenkyujugyo* is literally translated as "study or research lessons" (Fernandez, 2002).

Various researchers and educators who have utilized the Lesson Study have 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 revised instructional

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plan, (8) documenting results, and (9) discussing the implementation of the new version of the instructional plan (Fernandez, 2002; Cerbin & Kopp, 2006; Cavin, 2007; Chew & Lim, 2013).

Meanwhile, Cerbin, and Kopp (2006) have 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. Their interaction with each other, with the teacher, and with the instructional materials are the chief considerations in the Lesson Study framework.

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). The integration of the Lesson Study in the teacher education curriculum has provided 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 pre-service teachers (McDowell, 2010). Moreover, the application of lesson study can have positive impact on student achievement and critical thinking (Barrett, Riggs, & Ray, 2013; Lucenario, Yangco, Punzalan, & Espinosa, 2016; Quilario, 2014; Teele, Maynard, & Marcoulides, 2015).

The integration of technology into the Lesson Study framework has shown another positive perspective. Cavin (2007) has claimed that the microteaching Lesson Study (MLS) can create a learning environment leading to the appreciation of technology integration into a learner-centered teaching. Chew and Lim (2013) have found that employing Lesson Study (LS) with the use of Geometer's Sketchpad (GSP) in teaching mathematics can enhance the technological pedagogical content knowledge of the pre-service teachers.

The lesson study may also be effectively utilized for curriculum design, implementation, and assessment. For instance, Gutierez (2015) has applied the lesson study in identifying the issues associated with the implementation of inquiry-based instruction in elementary science in the Philippines. Three major challenges have been reported in engaging inquiry-based teaching among elementary Science teachers: (1) dearth in inquiry-based resources and professional support; (2) giving more importance to content learning than inquiry-learning; and (3) the long and laborious nature of inquiry-based didactic strategies. Meanwhile, some positive feedbacks have been derived from the staff members who participated 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 the pre-service Physics teaching curricula. Moreover, a Lesson Study emphasizing the use of technology-driven multiple representations in Physics instruction is still unexplored.

Critical Thinking

A major goal of science education around the globe is the attainment of critical thinking. The varying definitions of this construct by various scholars converge to the contention provided by the American Philosophical Association (APA) Delphi Consensus as the process of persistent, self-directing judgment (Insight Assessment, 2013). Therefore, critical thinking allows an individual to appraise a statement, problem, or issue by carefully examining given facts and by looking "beyond" the data at hand through constant reflections while considering various possibilities to construct a belief system, make a definite decision, or do appropriate action.

As an essential domain of education and employment, measuring students' critical thinking have propelled academicians to craft valid and reliable instruments. Behar-Horenstein and Niu (2011) have revealed a predominant use of single, quantitative measure of critical thinking, utilizing tests such as Watson-Glaser Critical Thinking Appraisal (WGCTA), California Critical Thinking Skills Test (CCTST), and Cornell Critical Thinking Tests (CCTT). They have asserted that qualitative measures are necessary in determining changes in students' critical thinking. Therefore, integrating open-ended questions to single-response items in a critical thinking test can enrich data that may provide a deeper understanding of the changes that may take place.

In an attempt to measure critical thinking qualitatively, Facione and Facione (2013) have developed an all-inclusive rubric internationally known for its applicability - The Holistic Critical Thinking Scoring Rubric (HCTSR). It is primarily intended to assess the quality of thinking displayed in verbal presentations or written reports to

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discriminate between strong and weak thinking which may be used in any training program or assessment process. Facione and Facione (2013) contended that "*its greatest value is obtained when used by trainees to assess the quality of their own or another's reasoning*" (n.p.). The instrument scores an item ranging from 1 to 4 depending on the quality of response.

Literature suggests the applicability of the WGCTA to measure pre-service teachers' critical thinking. It can be used to evaluate critical thinking ability of adult learners, trainees, and career-seekers (Akyuz & Samsa, 2009; Behar-Horenstein & Niu, 2011; Gadzella, Stacks, Stephens, & Masten, 2005; Watson & Glaser, 2008). The WGCTA has five components that test the examinees' critical thinking ability - (1) Inference, (2) Recognition of Assumptions, (3) Deduction, (4) Interpretation, and (5) Evaluation of Arguments.

The earlier versions of the WGCTA were composed of 100 items (Forms Ym and Zm) while the new versions contained 80 items (i.e. Forms A and B) and 40 items (i.e. WGCTA – Form S), respectively, which are suitable for one classroom period. These versions can be completed in a relatively shorter span of time (30 to 40 minutes) which makes it practical enough to administer without altering the fundamental elements of constructs appraised in the original forms (Watson & Glaser, 2008).

Efforts have been made to develop critical thinking among students by proposing and experimenting with varied instructional interventions (Peirce, 2004). Mundilarto and Ismoyo (2017) utilized the problem-based learning (PBL) while Barnett and Francis (2012) applied higher order thinking questions in classroom discourses. Desirable results have been found considering that these pedagogical strategies require employment of various mental processes.

In the higher education, most of the researches on critical thinking development have been directed to the investigation of instructional interventions employing quasi-experimental pretest-posttest design. However, these studies were chiefly geared towards medical education fields (Behar-Horenstein & Niu, 2011). It has been reported that certain instructional approaches can affect critical thinking skills of students such as inquiry-based learning, concept mapping, scenario-based course exercises, active learning techniques, computer-assisted instruction, structured web-based bulletin boards, guided instruction, and online instruction. Findings of the review revealed mixed results of the studies; the effectiveness of the instructional strategies has differed from one study to another.

Central to this research was the development of pre-service teachers' critical thinking. Studies in this area have reported varied research techniques and claimed different results. Akdere (2012) has investigated the critical thinking levels of Turkish pre-service teachers and other related constructs. It has been revealed that pre-service teachers have a dismal level of critical thinking regardless of their encouraging outlook towards it. Correspondingly, Qing, Jing, and Yan (2010) have disclosed that the effects of the inquiry-based and traditional approaches are not significantly different on developing pre-service teachers' critical thinking. They, however, concluded that the inquiry-based chemical experiment in teaching is an effective approach in enhancing pre-service chemistry teachers' critical thinking. Other methodologies that have positive effects on pre-service teachers' critical thinking are the Cognitive-Infusion Intervention (Lang, 2006), problem-based learning model (Jatmiko, Prahani, Munasir, Supardi, Wicaksono, Erlina, Pandiangan, Althaf, & Zainuddin, 2018), and reflective thinking-based teaching activities (Tican & Taspinar, 2015).

Literature has shown that despite the efforts to develop critical thinking among pre-service teachers, a solid understanding of this area has not yet been fully achieved. Majority of the studies employed a single measure or a purely quantitative approach in analyzing data which does not warrant a holistic assessment. There are aspects of critical thinking that are not easily captured by quantitative instruments (Behar-Horenstein & Niu, 2011); qualitative components of data need to be incorporated to meet such end. Likewise, there is a dearth of literature concerning the development of valid and reliable domain-specific critical thinking instrument, especially in Physics. Scholars often use existing general-content critical thinking tests, with the dominance of the WGCTA.

Problem of Research

Literature indicates a dismal level of critical thinking among pre-service teachers. Clearly, devising methods to enhance critical thinking of pre-service teachers is imperative for a better system of instructional practice in their future career. Hence, this research endeavored to determine if the microteaching Multiple-Representation Lesson Study (MRLS) have significantly better effects on critical thinking of the pre-service Physics teachers than the widely-used Traditional Instructional Planning Approach (TIPA). Further, this research was aimed to determine if there is a significantly different effect of the two instructional approaches on the critical thinking components: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments.

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One limitation of this research is the relatively small number of participants. This was mainly due to the limited number of the pre-service teachers taking Bachelor of Secondary Education Major in Physical Sciences in the university where the research was conducted. However, it was ensured that data were appropriately analyzed and findings were properly interpreted to answer the research problems.

Research Methodology

General Background

This research utilized a mixed method approach which employed a pre-test-post-test quasi-experimental design. The data were gathered last April-May, 2016 prior to the practice teaching of the pre-service Physics teachers in a state university of the Eastern Visayas Region of the Philippines. The intervention lasted for five weeks.

Permission to conduct the research 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 research on April 11, 2016, the Informed Consent Form was administered to the participants to seek their permission on their participation in the research. The pre-test for critical thinking were conducted shortly after the administration of the Informed Consent.

The 18 research participants were evenly divided into two by randomly assigning them to the experimental or control group through a fishbowl technique. The nine participants in the control group were exposed to the Traditional Instructional Planning Approach (TIPA) while the other nine were exposed to the experimental educational approach, the Multiple-Representation Lesson Study (MRLS). The MRLS group was further subdivided into three sub-groups with three members each.

A total of nine topics representing the different areas of Physics were identified as shown in the following list.

Topic 1: Forces and Motion (Law of Acceleration)
Topic 2: Work and Energy (What is Work?: Calculating Work)
Topic 3: Work, and Energy (Work is a Method of Transferring Energy)
Topic 4: Heat and Temperature (Defining Heat and Temperature)
Topic 5: Heat and Temperature (Phase Change)
Topic 6: Electricity (Electric Current, Voltage and Resistance)
Topic 7: Electricity (Series and Parallel Connections)
Topic 8: Sounds (Propagation and Characteristics of Sound)
Topic 9: Colors of Light (Refraction of Light)

All the TIPA members wrote the instructional plans and prepared the instructional materials individually for the nine topics. The three sub-groups in the MRLS group prepared the instructional plans and materials collaboratively for the three different topics. Microteachings were conducted for each topic and each sub-group shared the instructional plans and materials that they have prepared to other sub-groups.

The research culminated on May 18, 2016. A post-test for critical thinking was administered to all the research participants on the said date.

Participants

The participants of the research were 18 fourth year BSED-Physical Sciences students of a state university in Region VIII, Philippines. The nine members 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, had a mean age of 19.00 years, with age range of 18 to 20 years. Both TIPA and MRLS had 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. The MRLS and TIPA groups had 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 were almost the same for the two groups, 1.89 for TIPA and 1.88 for MRLS. The mean ratings in Mathematics were higher than in Science; the TIPA group had a slightly higher average rating than the MRLS group which was 1.72 against 1.77.

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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 the academic performance. Table 1 presents the data.

Table 1. 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 suggested that the median rating in Science of the MRLS (*mean rank* = 9.67) group was 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 were not significantly different ($mean\ rank_{MRLS}$ = 10.00, $mean\ rank_{TIPA}$ = 9.00, p = .690). These indicate that TIPA participants were comparable to MRLS participants in terms of academic performance in Science and Mathematics before their participation in the research.

Instrument and Procedures

A. Pre-service Teacher Critical Thinking Inventory in Physics (PTCTIP)

The PPTCTI was a 60-item researcher-made test composed of both objective-type and open-ended items. It aimed to assess the pre-service teachers' level of thinking based on the six components of the WGCTA Form-S. Each component comprised of twelve questions in the Physics context with the utilization of different representations. One point was given for every correct response on the objective-type items while no point was given to a wrong choice. Answers in the open-ended portion were given different credits ranging from one to four points based on The Holistic Critical Thinking Scoring Rubric (Facione & Facione, 2013). The said rubric was modified and adapted to rate participants' explanations to the option they chose per item.

The PTCTI was validated by seasoned educators in Science and Mathematics Education coming from the UPD College of Education and UP Open University. Their academic works involved researches on student Critical Thinking and production of instruments and materials that promote Critical Thinking Skills. The validated material was pilot-tested to 56 BSED-Physical Sciences students of two state universities in Region VIII. The Cronbach's alpha of the 60-item instrument was calculated to be .923. The subtests also had acceptable reliability levels: Inference, .701; Recognition of Assumptions, .771; Deduction, .784; Interpretation, .736; and Evaluation of Arguments, .807.

B. Interview Protocol

Researcher-made interview protocols were utilized to gather data about the experiences in instructional planning approach and teaching demonstrations of the research participants from the two groups. These were used at the end of the intervention in May 2016.

C. Diary

Each participant was asked to keep a diary to record their experiences during the two phases of the research. 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 record.

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The Microteaching Multiple-Representation Lesson Study (MRLS). The Microteaching MRLS framework was modeled from the steps described by Cerbin and Kopp (2006). First, topics in Physics that were labeled "difficult" and that required various representations were identified by the researcher and the subject teacher. The nine identified topics in the different areas of Physics were then assigned to both the experimental and comparison group. Second, members of each MRLS group designed the research lesson based on the goals that they have formulated. They identified teaching strategies that were applied, the instructional materials that they used, and evaluation techniques and procedures that measured student learning. Third, they decided how to investigate the learning process; that is, they devised a strategy to examine students' manner of learning the lesson. Fourth, the lesson plan was implemented. One of the group members executed the plan while the other members observed how the students learned the topic. The subject teacher and the researcher also observed and assessed the implementation of each plan. Attention was placed on the demonstrator's delivery of the lesson, student interactions, instructional materials, flow of the lesson, student activities, student discipline, and on other aspects that affected attainment of the goals that were initially set. Fifth, Lesson Study members and the facilitators (subject teacher and researcher) convened to discuss all observations and to assess the execution of the lesson plan. The comments and observations were incorporated in the revised version of the plan. Sixth, the revised lesson plan was implemented by the same pre-service teacher while the other members observed and recorded their observations. Another post-lesson discussion followed and the instructional plan was modified for the second time. Finally, the group documented the Lesson Study process to allow other MRLS sub-groups to scrutinize their work and learn from it.

It must be noted that certain modifications of the Lesson Study framework were employed in this research. One is that technology-driven multiple representations were integrated into the study lessons where a second version of the lesson was required rather than optional. The second version of the lesson was implemented by the same pre-service teacher who implemented the first version rather than another pre-service teacher. Other than that, the non-participant "students", that is, the pre-service teachers who played as "students" during the microteaching, took part in the post-lesson assessment which followed immediately after the demonstration teaching of the first version of the lesson. The traditional Lesson Study process lacked the student-perspective for it exclusively involved the lesson study members with or without the facilitator or supervisor. The Multiple-Representation Lesson Study afforded the MRLS participants to view the lesson in the eye of the "students" which was hardly observed in the conventional Lesson Study process.

Figure 1 summarizes the Microteaching MRLS procedure.

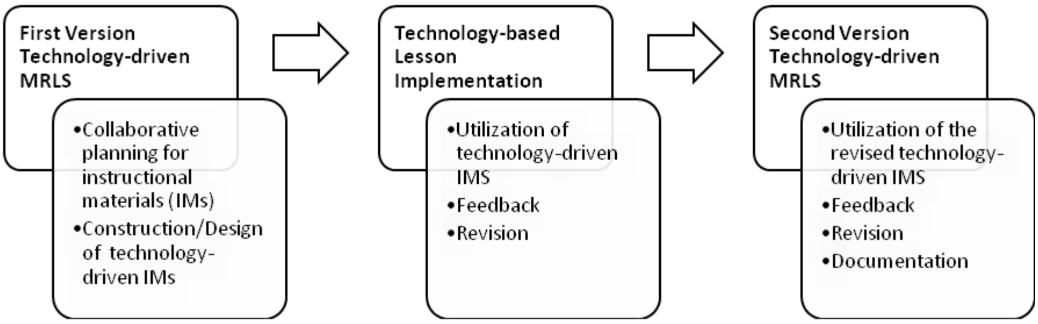

Figure 1. Microteaching MRLS.

The Traditional Instructional Planning Approach (TIPA). The TIPA is the prevailing instructional approach applied by the university in preparing the pre-service teachers for their future career. This has been practiced since the university has offered undergraduate education programs. The TIPA reflects the predominant instructional practice in the Department of Education of the Philippines.

In this research, the pre-service teachers in the TIPA group individually developed the nine lesson plans. The subject teacher and the researcher collected and assessed each lesson plan. The corrected plans were returned for modifications. The TIPA participants then proceeded to construct the instructional materials by themselves after receiving the corrected plans. They were given the prerogative to choose the type of material used, either technology-driven or conventional materials.

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Both the TIPA and the Microteaching MRLS participants were allowed to use the resources of the university such as the internet, books, and other printed and/or electronic resources. Likewise, both groups followed the same schedule in the development of lesson plans per topic and the preparation of instructional materials, hence, an approximately equal amount of time was devoted for the instructional intervention by the two groups. The entire data collection procedure lasted for five weeks.

Table 2 provides the summary of the experiment. Explicit steps are shown for both groups.

Table 2. Summary of the experiment.

MRLS Group	TIPA Group
• Critical Thinking Pre-test	• Critical Thinking Pre-test
• Orientation	• Orientation
• Intervention (Multiple-representation Lesson Study) • Collaborative instructional planning • Collaborative material preparation • Microteaching (Tech-based 1st, and 2nd Versions) • Class-based post-lesson discussions	• Intervention (Traditional Instructional Planning Approach) • Individual instructional planning • Individual material preparation • Feedback
• Critical Thinking Post-test	• Critical Thinking Post-test

Data Analysis

This research employed the Mann-Whitney *U* Test to compare the pre-test and post-test scores of the MRLS group and the TIPA group in the Critical Thinking Inventory. These were set at α=.05 level of significance.

Correspondingly, the qualitative data were analyzed using conceptual content analysis. The participants' responses in the interview and the entries in their diary were coded based on the benefit or detriment, the challenges they encountered, and the coping mechanisms that they employed in the respective intervention they were exposed to. Meanwhile, the responses in the open-ended portion which required the participants to explain their choice in the objective part were evaluated using the Holistic Critical Thinking Scoring Rubric (HCTSR) by Facione and Facione (2013).

Research Results

Initial comparability in critical thinking. Table 3 exhibits the pre-test results of the Critical Thinking Inventory. Results revealed a slightly better performance of the MRLS group (*Md* = 118, *Mn* = 124, *SD* = 31.2) than the TIPA group (*Md* = 115, *Mn* = 118, *SD* = 24.8). It must be noted that the highest possible score for the entire test was 300 points. Each of the five sub-tests or components was worth a maximum of 60 points.

Table 3. Pre-test results for the critical thinking inventory.

Test/Group	*N*	*Md* (Max.=300)	*Mn* (Max.=300)	SD	$(SD)^2$	η	$η^2$
Pre-test							
MRLS	9	118 (39.3%)	124 (41.3%)	31.2	973		
TIPA	9	115 (38.3%)	118 (39.3%)	24.8	615	.110	.012
Total	18	117 (39.0%)	121 (40.3%)	27.5	756		

Note: Max. Score=300; Md=median; Mn=mean; SD=standard deviation; $(SD)^2$=variance; and η and $η^2$=measures of association

Though the pre-test median scores between the comparison (*Md* = 115) and experimental (*Md* = 118) groups slightly differed, the Mann-Whitney *U* test revealed that the scores were not significantly different (U = 36.0, p = .691) as exhibited in Table 4. This connotes that the two groups were comparable prior to the conduct of the research.

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Table 4. Mann-Whitney *U* test of the critical thinking inventory pre-test.

Test/Group	*N*	Mean Rank	Mann-Whitney *U*	*Z*	*p*	*r (ES)*
Pre-test						
MRLS	9	10.0	36.0	-.398	.691	.094
TIPA	9	9.00				

Table 5 presents the group mean scores of the participants and the Mann-Whitney *U* test analysis per critical thinking component. Pre-test results revealed no significant differences in the scores between the TIPA and MRLS group in all the subtests or components, namely, Inference ($U = 34.5$, $p = .954$), Recognition of Assumption ($U = 36.0$, $p = .691$), Deduction ($U = 35.0$, $p = .626$), Interpretation ($U = 26.0$, $p = .199$), and Evaluation of Arguments ($U = 38.0$, $p = .824$). These indicate that the MRLS and the TIPA group were comparable in terms of making inferences, recognizing assumptions, making deductions from given data, interpreting ideas, and evaluating arguments prior to their participation in the study.

Table 5. Mann-Whitney *U* test per component of the critical thinking inventory pre-test.

CT Component	*MRLS*		*TIPA*		*M-W U*	*Z*	*p*	*r (ES)*
	Mn (Max.=60)	Mean Rank	*Mn* (Max.=60)	Mean Rank				
Inference	31.3 (52.2%)	10.2	28.9 (48.2%)	8.83	34.5	-.533	.594	.126
Recognition of Assumptions	22.9 (38.2%)	9.00	24.7 (41.2%)	10.0	36.0	-.398	.691	.094
Deduction	24.3 (40.5%)	8.89	24.9 (41.5%)	10.1	35.0	-.487	.626	.115
Interpretation	27.7 (46.2%)	11.1	22.1 (36.8%)	7.89	26.0	-1.29	.199	.303
Evaluation of Arguments	17.8 (29.7%)	9.22	17.6 (29.3%)	9.78	38.0	-.222	.824	.052

Effects of the Microteaching MRLS on critical thinking. The post-test results, as shown in Table 6, were relatively better than the Pre-test results for both groups. The MRLS group ($Md = 246$, $Mn = 242$, $SD = 12.8$) outperformed the TIPA group ($Md = 159$, $Mn = 152$, $SD = 15.4$) in the overall critical thinking inventory. Scores at this evaluation period were less dispersed than in the Pre-test for both groups as seen on the lower computed standard deviations. Data revealed that variability in the group scores associated to instructional approach was 92%, a value indicating a high association or effect.

Table 6. Post-test results for the critical thinking inventory.

Test/Group	*N*	*Md* (Max.=300)	*Mn* (Max.=300)	*SD*	$(SD)^2$	η	η^2
Post-test							
MRLS	9	246 (82.0%)	242 (80.7%)	12.8	160		
TIPA	9	159 (53.0%)	152 (50.7%)	15.4	236	.959	.920
Total	18	190 (63.3%)	197 (65.7%)	48.3	2337		

Note: Max. Score=300; Md=median; Mn=mean; SD=standard deviation; $(SD)^2$=variance; and η and η^2=measures of association

Although both groups exhibited a considerable increase in group mean scores, the Mann-Whitney *U* test shown in Table 7 indicated that the MRLS group scored significantly higher than the TIPA group (U=.0001, p<.001) and recorded a large effect size ($r = .844$).

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Table 7. Mann-Whitney *U* test of the critical thinking inventory post-test.

Test/Group	*N*	Mean Rank	Mann-Whitney *U*	Z	*p*	*r (ES)*
Post-test						
MRLS	9	14.0	.000	-3.58	.0001**	.844
TIPA	9	5.00				

*Note: **p<.01*

The results of the post-test per critical thinking component are shown in Table 8. It can be gleaned from the table that the scores of the MRLS group were significantly higher than the TIPA group ($U \leq 1.00$, $p < .001$) across all critical thinking components in the post-test. Moreover, large effect sizes ranging from *r*=.826 *to r*=.845 were obtained. These results signified a positive effect of the microteaching MRLS in fostering critical thinking skills among pre-service Physics teachers.

Table 8. Mann-Whitney *U* test per critical thinking component for the post-test.

Critical Thinking Component	Group	Post-test			
		Mn (Max.=60)	Mean Rank	*M-W U*	*p*
Inference	MRLS	52.1 (86.8%)	14.0	.000	.0001**
	TIPA	33.9 (56.5%)	5.00		
Recognition of Assumptions	MRLS	45.3 (75.5%)	14.0	.000	.0001**
	TIPA	26.4 (44.0%)	5.00		
Deduction	MRLS	47.4 (79.0%)	14.0	.000	.0001**
	TIPA	29.0 (48.3%)	5.00		
Interpretation	MRLS	49.4 (82.3%)	13.9	1.000	.0001**
	TIPA	32.8 (54.7%)	5.11		
Evaluation of Arguments	MRLS	47.4 (79.0%)	14.0	.000	.0001**
	TIPA	29.6 (49.3%)	5.00		

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

Discussion

The Critical Thinking Inventory used in this research was in the Physics context - a domain-specific instrument. The more favorable effects of the MRLS than the TIPA in the participants' critical thinking can be ascribed to the nature of the intervention. First, the collaborative lesson planning and instructional materials-preparation provided the experimental group an opportunity to discuss different facets of specific Physics content. Knowles' (1973, 1984) theory of adult learning has stipulated that creating a cooperative learning climate and establishing collaborative planning mechanisms can maximize learning. Conversely, Cerbin and Kopp (2006) have explained that lesson study members can illuminate queries and uncertainties, can probe procedures, and can reflect about any stage of the instructional process. This result is further justified by Laal and Laal's (2012) contention that a fundamental feature of a collaborative learning is an open discourse that allows learners to articulate and defend their ideas leading them to create their own unique conceptual frameworks. Essentially, these endeavors are indications of conceptual and procedural learning in a content-based critical thinking.

Participant E8 of the MRLS group expressed how collaborative work made an impact to her learning in the following statement:

> *"…it's very helpful that I have partners (that will) [who] help me, to give additional advices [pieces of advice], [to give] additional ideas for [my] lesson and [on] how to deliver the lesson." (E8; Interview, May 25, 2016) [giving pieces of advice or recommendations]*

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Although the TIPA group prepared nine sets of lesson plans and IMs while the MRLS group prepared only three sets per sub-group, the individual preparation may have limited the TIPA participants to learn more on their own or even when supported by the researcher's and subject teacher's feedback on their outputs. No learning, or a very limited one, may have been derived from their peers due to the individualistic nature of the Traditional Instructional Planning Approach (Mitcheltree, 2006). These results support the findings of Cajkler, Wood, Norton, Pedder, and Xu, (2015), Hixon (2009), Kolenda (2007), and Quilario (2014). They all have expressed positive effects of the Lesson Study like eradicating isolationism, ensuring a reflective learning, and providing an opportunity for teamwork. Likewise, these results conform with the findings of Burroughs and Luebeck (2010) who have reported that engaging in lesson study can provide the pre-service teachers with opportunities to be critical thinkers and to think like real teachers.

Second, the microteaching MRLS have prompted the experimental group to utilize multiple representations in their lesson plans which incited them to operate at a higher level thinking (Larkin & McDermott, 1978; Mayer, n.d.). Moreover, the MRLS participants integrated multimedia systems in their lessons. Scholars have reported that the employment of multiple representations through multimedia systems can function as rich learning resources (Ozmantar, Akkoc, Bingolbali, Demir, & Ergene, 2010; Cairncross & Mannion, 2001). These findings support the contentions of Laal & Laal (2012) and Klemm (1994) that a collaborative learning enterprise utilizing multiple representations in the form of multimedia can promote the development of critical thinking skills. The Multiple-representation Lesson Study has set a teaching-learning environment that adheres to this provision.

Third, the microteaching MRLS may have instilled a deeper sense of critical thinking in the experimental group. By implementing the lesson plans to their peers, an "internal pressure" has pushed them to do their best through careful planning and execution (Cavin, 2007; Cerbin & Kopp, 2006). They were challenged to provide activities that require higher thinking. The class interaction compelled them to function at higher order thinking considering that "students'" knowledge of content and pedagogy were comparable to them. More so that the researcher was present during their microteaching. In an interview, Participant E5 disclosed his apprehension when he did his demonstration teaching.

"E5: Yes, Sir. Based on the what we experienced as a teacher, we are [were] curious about [our] students ***[felt conscious of the presence of] especially if they are just [our] classmates***. ***They already know the concepts, so [we] are [were] also*** . . . bagan nakukuan mo ba Sir in your demo. Nacu-curious [conscious] ka gihap imo ginyiyinakan. (. . .**[we] tend to be affected in [our] demo, Sir. [We] also tend to be conscious of what [we] say**.)
I: Curious or conscious?
All: ***Conscious***. [chuckled]
E5: Naco-conscious kami gihap hit amon classmate...tas presence gihap nimo Sir. . . (**We tend to be conscious [intimidated]of our classmates. . . and your presence as well, Sir**.)
I: Okay. So, you get intimidated. . .
E5: Yes, Sir.
I:. . .because you feel that they are more learned than you? So, that was a challenge for you?". . .(everybody nods) - (Interview, August 19, 2016) **[feeling anxious about being observed]**

Finally, during the conduct of microteaching MRLS, the participants had a full one hour of teaching. Moreover, the researcher and/or their subject teacher consistently gave feedback on their outputs. Post-lesson discussions were, likewise, ensured which ran from 30 minutes to one hour in the presence of the researcher and all group members. Aside from pedagogical and technological aspects of microteaching, scrutiny in the content was emphasized. These were so because microteaching MRLS possesses essential features of a collaborative learning engagement such as sense of responsibility, social skills, direct interaction, and collective effort (Cajkler, Wood, Norton, Pedder, & Xu, 2015; Cerbin & Kopp, 2006; Hixon, 2009; Kolenda, 2007; Laal & Laal, 2012). These elements were lacking in the TIPA.

Conclusions and Implications

Results suggest that the microteaching MRLS can promote the development of the overall critical thinking and all of its sub-skills. Additionally, results suggest that feedback from experts, interaction with fellow pre-service teachers and students, length of preparation and of teaching, and availability of instructional technologies influ-

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ence the enhancement of critical thinking of prospective teachers. Results further imply that persistent praxis is necessary for a sustained development or acclimatization of a critical thinking culture. Likewise, results indicate that asking for justifications on participants' responses in the multiple-choice items of the Critical Thinking Inventory can provide a holistic assessment of pre-service teachers' critical thinking.

Certain implications to the teaching-learning process stem from these findings. The pre-service teachers can be challenged to think critically in a host of learning endeavors by utilizing collaborative and multi-representation-based activities. Science teaching can uphold the integration of multiple representations to explicate pre-service teachers' conceptions of scientific ideas and critical thinking skills. Verbal, pictorial, graphical, and mathematical presentations may be utilized to instill inference-making, recognizing assumptions, deducting information or ideas, interpreting data, and evaluating arguments among pre-service teachers.

Preparatory courses prior to practice teaching can prompt pre-service teachers to explore, develop, and utilize an array of both technology-based and conventional instructional materials. They can be trained to evaluate educational technologies based on certain parameters such as relevance to the topic and appropriateness to the students or audience.

Pre-service teacher education can promote collaborative learning designs to support the collegial spirit and suppress professional isolation among pre-service teachers. A learning environment emphasizing a healthy exchange of ideas may be designed to exercise critical thinking skills.

To amplify the desirable effects of the MRLS, a provision of physical, professional, and technical support is imperative. Supporting pre-service teachers with sufficient and functional teaching resources may establish an atmosphere that spontaneously cultivates critical thinking; the primary concern of which must be the provision of a teaching space conducive to learning. Likewise, giving adequate time for preparation, implementation of lesson plans, and post-lesson discussions can possibly assist pre-service teachers towards a systematic teaching. Opportunities like collaborative microteaching may scaffold their teaching competence and critical thinking that will soon be in use during their practice teaching and beyond.

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