

Problem-Based Learning Strategies and Critical Thinking Skills Among Pre-Service Teachers

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Abstract

Mathematical underachievement among students was not only a source of concern in the Philippines, but has now spread throughout the world. Low critical thinking skill among Filipino students is one of the causes contributing to the country's poor performance in mathematics. Students' lack of critical thinking abilities may be due to teachers' knowledge and expertise. To explore the critical thinking skills of pre-service teachers through the use of problem-based learning strategies is the main objective of the study. Quasi-experimental with a counterbalanced design was employed, presenting two problem-based learning strategies namely authentic strategy and non-linear strategy to two groups of teacher candidates. The results showed that students' critical thinking skills in evaluating arguments and drawing conclusions are lacking. There is also a substantial difference in critical thinking skills between students in groups 1 and 2, except for the capacity to recognize assumptions. The pre-service teachers' critical thinking skills do not differ significantly by sequence. The study results indicated that the pre-service teachers' critical thinking skills were still low, particularly in terms of evaluating arguments and drawing conclusions due to inadequate background knowledge and lack of in-depth understanding of the mathematics concepts. The results imply that schools focus more on building strategies to improve and develop students' critical thinking skills in mathematics education. Moreover, the study suggests that further research develop successful techniques for planning effective initiatives to increase critical thinking teaching and learning in higher education and training programs that could help improve the students' critical thinking skills.

Keywords: *Problem-Based Learning Strategy, Authentic Strategy, Non-linear Strategy, Critical thinking skills*

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1. Introduction

In today's present circumstances, people are confronted with a plethora of issues in daily lives that require good decisions. The vast majority of decisions are made instinctively, which does not necessitate much deliberation and frequently results in the erroneous option being made (Alban, n.d.). Consequently, it is necessary to foster decision-making skills to children through development of critical thinking to make sound decisions (Patterson, 2020). By employing critical thinking skills, individuals would avoid making mistakes and, in general, result in better decisions (Fisher, 2011). Thus, the World Economic Forum listed critical thinking as one of the 21st-century skills that learners must acquire, which could eventually enhance students' academic performance (Rayhanul, 2015).

In the academic setting, higher-level performance is associated with critical thinking (Wulandari et al., 2021). Critical thinking is the ability to think logically and realistically, which aids in the ability to successfully grasp and solve problems in an appropriate manner. According to Chikiwa and Schäfer (2018), critical thinking can assist learners in discovering new and more effective approaches to tackle problem situations. Because mathematics has a structured form and is extremely easy to understand in terms of its function, students can develop their rational, logical, and critical thinking abilities through mathematics learning (Aizikovitsh & Amit, 2011).

Muhlisin et al. (2016) argue that many students lack critical thinking skills, and this is linked to the traditional teaching style used in the classroom. As it is not a simple task to shift the mindset and behavior of present teachers in order for them to learn to think critically (As'ari et al., 2017), educating future teachers is far more strategic than teaching current teachers (Prahmana et al., 2012). This implies that it is a better choice to train future teachers to become critical thinkers (As'ari et al., 2017). Rusmansyah et al. (2019) affirmed that one key factor contributing to the enhancement of pre-service teachers' critical thinking skills is problem-based learning (PBL). It is a powerful pedagogical strategy that provides opportunities for students to learn how to think critically. In information-rich environments, PBL challenges students to solve real-world problems where they should establish a solution that leads to the most effective experience, such as methods, processes, and epistemology (Yazar, 2015).

The K-12 Basic Education Mathematics Curriculum aims to improve students' critical thinking and problem-solving skills (DepEd, 2012). Despite the curriculum's emphasis, students' mathematics performances are still low. In the 2017-2018 National Achievement Test (NAT), mathematics had the lowest mean percentage score of 35.34, and it also had the lowest mean

percentage score in critical thinking with 32.42. According to Lugtu (2018), the absence of critical thinking skills among Filipino students has been a problem for generations. Furthermore, Marquez (2017) stated that the primary contributing element to this problem is the stress placed on rote memorization, wherein recitations and tests simply serve to strengthen the memorization capacity of the students in the first place. It has become worse because of the increased use of smartphones and technology. In addition, technology hinders the student's ability to address the problems because majority of the solutions are available on the internet (Rodzalan & Saat, 2015).

When it comes to problem-solving, one of the reasons why Filipino students struggle is because they frequently solve the same problems as their teachers do (Salangsang & Subia, 2020). It is possible that some students have a strong understanding of math principles, but when they are asked to apply those concepts in the real world and write them down, they find it more challenging (Angateeah, 2017). Even mathematics pre-service teachers have had difficulty understanding the stages of a problem because they have failed to classify the problems appropriately (Dimasindel, 2017). According to Saputra et al. (2019), by presenting problems to students, the learning process allows them to improve their critical thinking skills by trying to solve them. Exposure to authentic non-routine, and ill-structured problems serve as avenues to hone the critical thinking skills of the students (Apriliana et al., 2019; Bingolbali, 2011; Romanoff, 2019). Therefore, critical thinking skills could be developed using several types of problems.

The research conducted by Arviana et al. (2018) and Yuliati et al. (2018) are deemed parallel to this investigation. While the primary purpose of the current study is to explore the effects of PBL in the critical thinking skills of teacher-candidates, the two previous studies were conducted in another country, and the majority of the respondents were in middle school. The same research paradigm would be explored and applied at one state university in the Philippines. Thus, the current study aims to investigate the effects of PBL on pre-service teachers' critical thinking skills. Further, its specific goal is to assess the critical thinking skills of a group of students exposed to the first sequence (Non-Linear – Authentic) and the second sequence (Authentic-Non-Linear) in terms of their ability to recognize assumptions, evaluate arguments, and draw conclusions. It also seeks answers to the following hypothesis:

Ho1: There is no significant difference in the critical thinking skills based on their group and sequence as to non-linear-authentic and authentic-non-linear.

2. Literature Review

2.1. Problem-Based Learning

Padmavathy (2013) asserts PBL as the most effective way to teach mathematics. By adopting the PBL method, teachers can create engaging mathematics lessons. The business world requires many creative thinkers, critical decision-makers, and problem solvers who make creative decisions. A problem-based learning instructional strategy positively affects content knowledge, creating increased learning opportunities to learn content and stimulating the students' enthusiasm, interest, participation, and motivation. This positively motivates the learners to have a positive attitude towards math which encourages them to understand math better and leads to better retention of math facts. It provided the audience with a predictable and desired outcome. Similarly, Loyens et al. (2015) provide shreds of proof of PBL's effectiveness. He held three groups of students as they were exposed to three different methods. The PBL group's performance was more likely to demonstrate on-task performance, outperforming those students exposed to the lecture-based and self-study groups. It was further supported by Tupas (2012) that whether students solved the problem as a group or individually, they improved significantly. It leads them to be creative enough in finding the best solution, which is the essence of mathematics instruction.

Ibrahim et al. (2018) describe PBL as a useful learning strategy. Based on students' answers, the effectiveness of the PBL was found to increase through experience. Though programs based on PBL play a significant role in acquiring information and soft skills, it is crucial to choose the intended program to capture and evaluate the effects of PBL. PBL is active in soft skills enhancement; therefore, tutors' training to master essential basics in processes, skills, and attitudes may be required to deal with this method effectively. Rokhmawati et al. (2016) inferred that PBL models can be applied to strengthen students' problem-solving skills. The problem presented in the learning process illustrates the real-world problems that people face on a daily basis. Implementation of the PBL model may also increase students' self-efficacy (Maulidia et al., 2020), cognitive abilities (Khoiriyah & Husamah, 2018) and problem-solving skills.

According to Asad et al. (2015), teaching through PBL enhanced students' ability to solve problems and think critically, with 60% of first-year students and 71% of second-year students agreeing that these sessions improved their ability to learn knowledge and use it to solve multiple-choice questions (MCQs). They discovered that their ability to learn how to read

nonverbal cues, demonstrate a higher level of intrinsic motivation, and develop creative precepts for clinical reasoning had improved. The students who took part in projects or collaboratively worked together found their projects to be quite successful. In another study by Andini and Hobri (2017), the PBL was orientated in a Lesson Study for Learning Community (LSLC), hence increasing student participation in meaningful learning. Students' tasks include reviewing and presenting problems, strategizing, putting the plan into action, and examining and evaluating the results, with a high average value activity for each subsequent stage. Similarly, the study conducted by Arviana et al. (2018) showed PBL's impact on students' ability to think critically. Students were asked to provide a "yes or no" response throughout the learning process, as well as a "why and how" response. The pupils were urged to be able to take or validate a position on a subject. Likewise, Yuliati et al. (2018) stressed that the application of authentic problem-based learning to physics learning enhances students' critical thinking capabilities. Therefore, problems dealing with real-world issues are preferred to be used to hone students' critical thinking skills.

Non-Linear. Students learn in a variety of ways and receive a wide range of perspectives, thoughts, ideas, and solutions as a result. In this way, it is an issue that may be approached in a variety of ways. Apino and Retnawati (2017) discovered that using more than one answer is an efficient strategy for students to practice their arithmetic thinking skills because it requires them to think in a creative manner. Furthermore, as students develop their ability to think creatively, they will be able to discover new ways for dealing with complex challenges. According to Guberman and Leikin (2012), solving tasks that permit multiple solutions enhance teachers' problem-solving skills. The discovery of various solutions is part of pedagogical awareness of material, a significant indicator of students' academic achievements in mathematics (Baumert et al., 2010).

Arikan (2016) highlighted that prospective teachers state that they sustain their recollection of the formulas, rules, and knowledge they once forgot in conjunction with problem-solving. They felt that using multiple approaches to problem-solving would improve their academic knowledge and become experts in their fields. When teachers look for new educational solutions in the classroom and when they share ideas outside of the classroom, students' views about mathematics lessons will be more favorable. Further, Bingolbali (2011) asserted that students' creativity and critical thinking skills are enhanced as a result of attempting to solve problems in a variety of methods. Developing multiple solutions positively affects students' enjoyment and adverse effects on their boredom (Schukajlow & Rakoczy, 2016).

Authentic. In education, the word "authentic" is widely used, mainly without much meaning. Some scholars have attempted to establish the authenticity elements and aspects to understand authentic contexts (Wang et al., 2012). Based on Roach (2018), the term authentic learning refers to learning immersed in an environment that aligns learning goals with activities, content, and context in the real world. Authentic learning is when students use their own knowledge, experience, and resources to learn about new ideas and techniques.

Through real-life connections, learners can improve their knowledge and achievement in mathematics (Karakoc & Alacaci, 2015). Various research stated that the more motivated students are, the more likely they are to perform well in mathematics (Muijs & Reynolds, 2011). Further, Apriliana et al. (2019) stated that using authentic problems prompt students to solve the task by finding possible solutions and appropriate strategies. With consistent use of real-world problems, it will ignite students' mind and knowledge in doing problem-solving tasks.

2.2. Critical Thinking Skills

Critical thinking is a cognitive activity related to the use of the mind (Padmanabha, 2018) in order to interpret, assess, evaluate, and explain wrong information (Saputra et al., 2019). The ability to think critically indicates the use of mental processes such as attention, categorization, selection, and judgment (Kumar & James, 2015); concepts such as cognitive and meta-cognitive skills, practices and abilities, dispositions and character, logic, and reflection (Ennis, 2011) and skills such as analyzing, synthesizing, evaluating, and summarizing (Dwyer et al., 2014). As a learning method, critical thinking emphasizes the agreement or disagreement with facts, judge reality, and modify misinformation to generate new ideas (Florea & Hurjui, 2015). However, apart from a lack of capacity, many individuals who can develop more efficient analytical thinking can be prevented from doing so for different reasons. Personal and emotional or affective factors, in particular, may create barriers (Cottrell, 2011).

Critical thinking is a higher-order thinking skill that can be considered reflective thinking (Apriliana et al., 2019). According to Nuriadin et al. (2015), someone who uses reflective thinking will have the ability to identify problems, choose alternative solutions, analyze problems and evaluate solutions, and conclude and decide the best solution to the problem given. As Jensen (2011) has mentioned, critical thinking requires an efficient and effective mental process to follow appropriate and accurate knowledge. Wijaya (2011) discussed the task of examining thoughts or ideas in a more specific way, separating them clearly, selecting and

recognizing them as well as pursuing further research and enhancing them in a more effective way.

Mustaji (2012) believes that critical thinking is rooted in making decisions about what to believe or do, which is synonymous to decision-making, strategic planning, and problem-solving (Husnaeni, 2016). It is a method of increasing knowledge and intellect by contrasting several current and potential issues in order to arrive at a conclusion and a solution. Instead of outright acceptance of various concepts, critical thinking entails deep reasoning and analysis (Fahim & Pezeshki, 2012). This means that people's opinions and suggestions about a phenomenon cannot be believed entirely until they go through a structured and rational process of discovering the facts. Learning to think critically is essential for applying critical thinking in school settings because people who think critically are able to recognize and correct common logic errors as well as understand and connect logical connections between concepts. Critical thinkers can also construct and test arguments, recognize and correct common logical errors as well as solve problems systematically (Chukwuyenum, 2013). Efforts to improve critical thinking in mathematics education have become the focus of global mathematics curriculum development. Critical thinking promotes originality and autonomous thinking by encouraging students to apply critical thinking skills in their regular activities and assignments (Firdaus et al., 2015).

Recognize Assumptions. Ekstrom (2021) defines assumption as an unexamined belief because the conclusion or inferences begin with assumptions that have not been critically analyzed and tested, and assumptions are what we presume without evidence. Assumptions are considered accurate based on a lack of evidence. It is easy to assume all information presented is true, even though not all was provided. Recognizing assumptions allows the identification of the factual evidence presented and how relevant it is. Identifying assumptions helps discover pertinent information, highlights issues and gives a better overview of issues (Davis, 2019). Several proposed assumptions follow each statement. The learner must determine whether these assumptions can be taken for granted, whether they are justifiable, and whether they are unjustifiable (Kumar & James, 2015). The stronger the assumptions, the stronger the thinking (Meegan, 2012).

According to Egan (2016), when people learn that something is based on assumptions, they tend to take it for granted that it is accurate. These are considered part of their belief system. They feel that their values and assumptions are correct, and they utilize these beliefs to form

their perception of the world. It is from these assumptions that beliefs and conclusions are formed, which may be logical or irrational depending on whether there is evidence to support the assumptions. The goal is for the difference to be recognized and appreciated. Inferences are built on the foundation of assumptions. In order to make sense of what is going on around as rapidly as possible, people generate inferences. Assumptions and the inferences that result from them permeate every aspect of our life.

Evaluate Arguments. The core component of critical thinking is argument. Arguments are defined as assertions meant to convince someone to do something or believe something. Understanding arguments is crucial in developing critical thinking skills—analyzing an assertion and doing so accurately. Arguments can create agreement or disagreement with the information given (Kuhn, 2010) but the validity of arguments requires critical thinking skills (Chen, 2014). Arguments can be wrong, and this part of the RED model teaches how to recognize the tendency to discover and consider proof that confirms prior beliefs (Davis, 2019). It is desirable to differentiate strong and weak arguments when making decisions about important issues. An argument is weak if it is not explicitly connected with the problem (Kumar & James, 2015). Students must back up their claims with logical arguments that are supported by real examples or facts that are in opposition to their claims (Indrawatiningsih, 2018). It must be relevant and directly related to the problem for a claim to be strong.

Draw Conclusions. According to Bahat heg (2019), inference is described as the ability or mental ability to use what was known to draw a vague or missing conclusion from experience and facts. It is also known as executive cognitive ability, which helps learners demonstrate the degrees of accuracy or inaccuracy of a particular outcome using their experiences and all available knowledge, or clarify a missing component of its aspects based on its relativity to the information. It deals with the conclusion that logically follows from the available evidence. Individuals who hold this skill do not make inadequate generalizations beyond the evidence. People with good discernment are typically viewed as having good judgment because they make good decisions (Davis, 2019). Relatively, an inference is a conclusion that can be drawn from some observed or assumed facts by an individual. Several possible inferences follow each statement of fact. Conclusions are drawn from the stated facts (Kumar & James, 2015).

3. Methodology

3.1. Research Design

Quasi-experimental with counterbalanced design was used to investigate the critical thinking skills of pre-service teachers in terms of recognizing assumptions, evaluating arguments, and drawing conclusions through problem-based learning strategies. Similarly, this method was used since the aim was to determine whether there was a significant difference in critical thinking skills according to their group and sequence as to non-linear – authentic strategy and authentic- non-linear strategy. A different sequence of interventions is administered to each group than to the others followed by an observation of the outcome (Singh, 2021).

3.2. Respondents of the Study

Thirty pre-service teachers from one state university in the Philippines took part in this study during the academic year 2020-2021, which was conducted towards the end of the school year. Purposive sampling with matching was used to select the respondents for this study because only students who took geometry were considered for inclusion. When it comes to geometry subjects, non-linear and authentic questions are more prevalent, and these challenges serve as the foundation for developing, modifying, and validating research instruments.

3.3. Instrumentation and Data Collection

The details of the purpose and development of the instruments are the following:

Assessment of Critical Thinking Skills as exposed to Non-Linear and Authentic Strategies. This consists of six questions, 3-item test for each strategy consisting of typical word problems with additional questions designed to foster critical thinking. This is based on Usta (2020) and was evaluated by four mathematics teachers to ensure content validity.

Scoring Rubric for Critical Thinking Skills. As part of the evaluation of critical thinking skills, students were exposed to non-linear and authentic strategy. This was used to evaluate the students' responses to the assessment of critical thinking skills. There are four mathematics teachers and one English teacher who validated this rubric, which ensured that the rubrics were linked with the essential learning competency.

Data Collection. The researcher divided the class into two groups. Each group was exposed to non-linear strategy and authentic strategy. The first group was exposed to the non-linear – authentic strategy. The questions given to the first group could be solved in multiple ways. The respondents were given 15 minutes to accomplish each question. On the other hand, second group was exposed to the Authentic – Non-linear strategy. This implies that while the first group was answering the first set, the second group was provided three questions utilizing Authentic Strategy. The students had to seek answers to the questions using real-world or relevant problems that are meaningful to respondents. On the second session, the first group and second were exposed to Authentic Strategy and Non-linear strategies, respectively. This was the time that both groups had interchanged answering the question sets that were provided to them during the first session. Afterwards, the researcher guided the students by providing some questions to assess the students' critical thinking skills. Lastly, the last 5 minutes in each session were used to finalize and compile answers before the submission. After students completed the test, several students in each group underwent an interview. The researcher used the interview to clarify the students' answers particularly to complete the students' responses to Problem-Based Learning Strategies, which could not be found in the assessment. The assessment answered through the implementation of strategies was interpreted using the researcher-made critical thinking scoring rubric.

Data Analysis. In analyzing the critical thinking skills of the students, frequency and percentage were used. To determine whether there is no significant difference on the critical thinking skills of the students, paired t-test was used. Furthermore, independent t-test were applied to identify if significant difference exists on the critical thinking skills of the students according to their sequence.

3.4 Ethical Consideration

The study maintained the privacy of the results and the personal details of the respondents. The researcher and the thesis advisor were responsible for the outcomes of the data in the sample test. The names of the respondents were kept highly confidential all throughout the completion and publication of the study.

4. Findings and Discussions

Table 1
Level of Critical Thinking Skills of the Students Exposed in the First Sequence

Score Range	Non-Linear		Authentic		Average		Interpretation
	f	%	f	%	f	%	
Recognize Assumption							
3.50 - 4.00	1	6.7	1	6.7	1	6.7	Advanced
2.50 - 3.49	3	20	9	60	7	46.7	Proficient
1.50 - 2.49	7	46.7	2	13.3	5	33.3	Developing
1.00 - 1.49	4	26.7	3	20	2	13.3	Beginning
Evaluate Arguments							
3.50 - 4.00	2	13.3	1	6.7	-	-	Advanced
2.50 - 3.49	4	26.7	2	13.3	4	26.7	Proficient
1.50 - 2.49	8	53.3	8	53.3	10	66.7	Developing
1.00 - 1.49	1	6.7	4	26.7	1	6.7	Beginning
Draw Conclusions							
3.50 - 4.00	1	6.7	-	-	-	-	Advanced
2.50 - 3.49	2	13.3	-	-	2	13.3	Proficient
1.50 - 2.49	6	40	5	33.3	8	53.3	Developing
1.00 - 1.49	6	40	10	66.7	5	33.3	Beginning

Table 1 shows the level of critical thinking of the students exposed in the first sequence through recognizing assumption, evaluating arguments and drawing conclusions as indicators.

In terms of recognizing assumption, there are more students at the proficient level (46.7%). This shows that students were able to identify at least one correct mathematical concept or fact used to solve the question. It is possible that time constraint was the driving force for the creation of one mathematical concept wherein students did not have enough time to double-check and consider an alternative concept to the one presented in the question. Furthermore, some students lacked the necessary understanding to use suitable terminology, which resulted to inability to correctly identify some of the ideas discussed. As a result, only common concepts were determined by pre-service teachers. According to Caviola (2017), the presence of a time constraint can have an adverse effect on performance in any arithmetic or problem-solving circumstance. As a result of time constraints, students may either become more involved in the work or may choose an improper notion to solve the task. On the other hand, it also displays that using authentic strategy, the majority of the students are at the proficient level with 60%. This implies that the students were able to identify two or three mathematical concept/s or fact/s used to solve the problem. Some students have experienced problems similar to those presented in this strategy, making them more adept at identifying them. Mathematics proficiency, or the ability to think about mathematical problems, is contingent upon familiarity with mathematical concepts.

Student engagement in a range of problem-solving scenarios is influenced by the amount and breadth of relevant knowledge a student can recall, as well as the breadth and depth of ideas a student knows (Lindquist et al., 2019).

It is evident that most of the students perform better in authentic strategy in terms of recognizing assumptions. According to Carvalho et al. (2015), implementing a solution based on real-life situations is a powerful strategy for improving problem-solving ability in the sciences classroom. As a result, this strategy enables students to develop their critical thinking skills, particularly in assessing and identifying the concepts related to solving complicated real-world problems. Furthermore, it is also apparent that one student belongs in the advanced level in both strategies. This only means that she was able to identify clearly, accurately, and appropriately more than three key concepts or facts that were used to solve the problem. It was also noted that Student 1 is one of the outstanding students in their class, especially in mathematics subjects. According to Lepasana (2018), students who excel in mathematics typically possess good critical thinking abilities to identify mathematical concepts and solve complex mathematical problems. Likewise, she was also a former student from another university program, in which she has already taken higher mathematics subjects. According to Rogers (2013), mathematical exposure has a more significant influence on mathematics achievement and develop mathematical critical thinking skills.

In terms of evaluating arguments, the majority of students in the non-linear and authentic strategies were classified as developing, with 53.3% each. This shows students were able to justify one of the results of the procedures and seldom explain their answers. As explained by Ergen (2020), this could be because they did not identify all of the fundamental concepts that were required for solving the questions in order to provide a complete explanation of the solutions to the questions. Nevertheless, some students belong to the advanced level. Generally, most of the students exposed to the first sequence in terms of evaluating arguments are on the developing level with 66.7%, which means that the students have a fair performance in conducting a systematic and comprehensive examination of given evidence and arguments and in justifying and explaining how they arrived at their answers.

In non-linear strategy, there are two students at the advanced level: Student 5 and Student 11. This implies that they were able to justify more than three results or procedures and explain their answer thoroughly. While they have reached the proficient level in recognizing assumptions, they still demonstrate exceptional performance when it comes to explaining the

process by which they arrived at their answers. After they are exposed to authentic strategy, they fall into the proficient category. Meanwhile, in authentic strategy, only one student reached the advanced level, which is Student 1. This means that Student 1 was able to justify more than three results or procedures and thoroughly explain their answer. It is also observed that Student 1 is the only student who belongs to the advanced level in terms of recognizing assumptions in both strategies. According to Apostol (2017), students who are more accurate in their use of mathematical concepts and ideas are better able to carry out a procedure entirely and explain the answer adequately. For this reason, Student 1 exhibits an excellent performance in explaining the procedure of the solution she was provided. Nonetheless, she was at the proficient level when she was exposed to non-linear strategy as a result of having an incorrect answer to one of the problems given.

In terms of drawing conclusions, most of the students under the non-linear strategy are at the beginning and developing levels, with 40.0% each. This shows that most of the students were not able to draw coherent or clear conclusions. It is also noted that the students were able to obtain a relevant but abbreviated or simplified conclusion that is not fully supported. This could be attributed to the fact that some students are doubtful of their answers, which led to having difficulty in presenting and explaining the evidence that would support their conclusion. It means students do not have the best proof to show that their answer is correct.

Conversely, in the authentic strategy, most of the students are at the beginning level, with a percentage of 66.7. This is surprising given the fact that the respondents of this study are mathematics pre-service teachers. It implies that most of the students were not able to draw a coherent and clear conclusion despite the fact that their expertise is mathematics. According to Muhlisin et al. (2016), making deductions is one of the difficulties that needs to be resolved among students. According to the interview, some students say that they could not figure out whether or not their answer was correct when they were faced with complicated and real-world problems. Seemingly, the students somehow performed better when exposed to the non-linear strategy in terms of drawing conclusions. This is consistent with Mabilangan et al. (2011) who found that exposing students to non-routine tasks can help them strengthen their mathematical reasoning skills and comprehend that mathematics is a creative pursuit.

Overall, most of the students exposed to the first sequence in terms of drawing conclusions are at the developing level with a percentage of 53.3, which indicates that the students manifested a fair performance in collecting the information and utilizing it to arrive at

logical conclusions and convincing answers. This can be due to the level of their recognizing assumptions, as shown in table 1. According to Egan (2016), assumptions serve as the foundation for inferences. It can be noted that the identified concepts influence the conclusions drawn by the students. Even though the majority of students are proficient in recognizing assumptions, they exhibit a low level of ability in drawing conclusions. The lack of evidence in their arguments and insufficient explanations of their conclusions are discernible in their solutions. This result was supported by Siriwat et al. (2017) that students with low skills developed a conclusion from a single discovery, and most of the conclusions drawn were oversimplified and therefore incomprehensible.

Table 2
Level of Critical Thinking Skills of the Students Exposed in the Second Sequence

Score Range	Non-Linear		Authentic		Average		Interpretation
	f	%	f	%	f	%	
Recognize Assumption							
3.50 - 4.00	1	6.7	-	-	-	-	Advanced
2.50 - 3.49	8	53.3	1	6.7	3	20	Proficient
1.50 - 2.49	5	33.3	7	46.7	11	73.3	Developing
1.00 - 1.49	1	6.7	7	46.7	1	6.7	Beginning
Evaluate Arguments							
3.50 - 4.00	1	6.7	-	-	-	-	Advanced
2.50 - 3.49	3	20	3	20	3	20	Proficient
1.50 - 2.49	7	46.7	9	60	10	66.7	Developing
1.00 - 1.49	4	26.7	3	20	2	13.3	Beginning
Draw Conclusions							
3.50 - 4.00	-	-	-	-	-	-	Advanced
2.50 - 3.49	-	-	-	-	-	-	Proficient
1.50 - 2.49	5	33.3	8	53.3	7	46.7	Developing
1.00 - 1.49	10	66.7	7	46.7	8	53.3	Beginning

Table 2 shows the level of critical thinking of the students exposed in the second sequence through recognizing assumption, evaluating arguments and drawing conclusions as indicators.

In terms of recognizing assumption, most of the students under the authentic strategy are at the proficient level with a percentage of 53.3, which means that the students identify two to three mathematical concepts or facts used to solve the problem. Based on the interview conducted, most of the students had difficulty with the problems presented in the authentic strategy. Nevertheless, they still outperformed the authentic strategy in identifying the mathematical concepts used to solve the problem. They easily connect the ideas in real-life

situations due to their prior experiences. According to Welty (2010), experience is the most important factor for students since it generates needs, interests, and motivations to solve problems.

In the non-linear strategy, there are more students who are at the beginning and developing levels, with a percentage of 46.7 each. This entails that the students were not able to identify an appropriate concept that was used to solve the problem. It was also noted that students were able to identify at least one correct mathematical concept or fact that was used to solve the problem. Based on the interview conducted, some students struggled to grasp the problem, and they were confused about concepts they should use to solve the problem. They also do not encounter that kind of problem, so they have difficulty recognizing the concepts they use.

It is apparent that the students perform better when they are exposed to authentic strategy. Cai and Lester (2010) assert that using authentic problems build an inextricable link between problem solving and concept acquisition. In addition, comprehension through concepts and procedures should be practiced to develop the problem-solving skills among students.

Overall, most of the students exposed to the second sequence in terms of recognizing assumptions are at the developing level with a percentage of 73.3, which demonstrates the students have fair performance in identifying the factual evidence presented on a given problem and examining how relevant it is to the problem.

In terms of evaluating arguments, there are more students classified as developing under the authentic and non-linear strategies, with percentages of 46.7 and 60.0, respectively. This shows that the students could justify one of the results or procedures but seldom explain their answers. According to Booth (2011), the concept identified influences their ability to explain and justify their answers and solutions. As seen in table 2, most of the students are at the developing level in terms of recognizing assumptions, and this is why students only justify one of the results or procedures. However, only one student qualifies for the advanced level of the authentic strategy. Student 27 justified key results, procedures and explained the answer thoroughly. Students who can look at and evaluate arguments or claims show that they have critical thinking skills (As'ari, 2017).

In the non-linear strategy, out of 15 students, nine are on the developing level, which means that they were able to justify at least one result or procedure and seldom explain their answers. Apostol (2017) found that students who use math concepts and ideas correctly are more likely to finish a process and explain the answer.

Overall, the majority of the students exposed to the second sequence in terms of evaluating arguments are at the developing level with a percentage of 66.7, which means that the students exhibit fair performance in conducting a systematic and comprehensive examination of given evidence and arguments and in justifying and explaining how they arrived at their answers. Indrawatiningsih (2018) stated that the most crucial main indication of critical thinking ability is students' capacity to formulate arguments for or against material provided to them. Evaluating arguments against known facts is an essential technique for evaluating students' critical thinking abilities, particularly their understanding of arguments. Students must be able to sift through information effectively and not get fixated on arguments/claims made by others.

In terms of drawing conclusion, all of the students under the authentic strategy and non-linear are at the beginning and developing levels with a percentage of 66.7, 33.3, 46.7, and 53.7, respectively. This means students were not able to draw a coherent or clear conclusion. It is also noted that most of the students were able to obtain a relevant but abbreviated or simplified conclusion that is not fully supported. These findings are consistent with the Association of American Colleges and Universities (AACU) (2017), which found that students' ability to form conclusions was a weak point in their study. Similarly, Utami et al. (2019) showed that it was still difficult for students to connect facts, solutions, ideas, and concepts because students lack confidence in interpreting and justifying the solutions because they cannot form valid and supported conclusions. This is contrary to Indriani and Julie (2017), who found that the students' capacity to draw conclusions reached a very high category because they were used to employing deductive thinking, which implies that students used their experiences to develop reasoning, which then became provisions for solving problems.

Generally, all students exposed to the second sequence in terms of drawing conclusions are at the beginning and developing levels with a percentage of 66.7, which means that the students demonstrate a fair performance in collecting the information and utilizing it to arrive at logical conclusions and persuasive responses. According to Visande (2014), the ability to conclude does not stop with assessing the text with knowledge and experience. It also entails judgment based on direct evidence from the text. In the case of the students, they did not conduct a thorough investigation of the given statement. According to the assertions in the test, they have most likely created assumptions rather than reasoned from the information. The students' ability to understand without having to think about it is likely to be common.

Table 3
Difference on the Critical Thinking Skills by Group

Indicators	Nonlinear		Authentic		t	df	Sig. (2-tailed)
	M	SD	M	SD			
Group 1							
Recognize Assumption	2.13	0.78	2.49	0.86	-2.416	14	0.03
Evaluate Arguments	2.33	0.78	1.91	0.71	2.679	14	0.018
Draw Conclusion	1.93	0.86	1.42	0.48	3.286	14	0.005
Group 2							
Recognizing Assumption	2.6	0.63	1.56	0.45	-6.313	14	0
Evaluate Arguments	2.04	0.81	1.89	0.48	-0.847	14	0.411
Draw Conclusion	1.29	0.35	1.49	0.43	1.79	14	0.095

Table 3 shows the difference in the critical thinking skills of the two groups of students.

In terms of group 1, results show that the mean in authentic strategy in terms of recognize assumptions (2.49) is higher than the mean in non-linear strategy (2.13). This implies that the students perform better when exposed to authentic strategy. Carvalho et al. (2015) stated that real-life problem-solving strategies allow students to improve their critical thinking abilities, especially in evaluating and recognizing ideas relevant to addressing complex real-world situations. Accordingly, these data were subjected to statistical analysis, revealing a significant difference ($t=-2.416$; $p=0.030$) between the non-linear and authentic strategies. In evaluating arguments, the mean in non-linear strategy (2.33) is higher than the mean in authentic strategy (1.91). This indicates that when students are exposed to the non-linear strategy, they perform better. Students who continuously work on problem-solving (non-routine problems) are more creative and critical in explaining the procedures of the solution and their answers (Maulana et al., 2018). Consequently, these data were subjected to statistical analysis, revealing a significant difference ($t=2.679$; $p=0.018$) between the non-linear and authentic strategies. In terms of drawing conclusions, the mean in the non-linear strategy (1.93) is higher than the mean in the authentic strategy (1.42). This reveals that students perform better when exposed to non-linear strategy. According to Pratiwi et al. (2021), students should be used to working on non-routine problems in order to develop their mathematical reasoning abilities and ability to solve problems effectively. As a result, these data were subjected to statistical analysis, which revealed a significant difference ($t=3.286$; $p=0.005$) between the non-linear and authentic strategies.

It can be concluded that the respondents perform better when they are exposed to problems where multiple strategies and solutions could be employed. There is a higher chance that their critical thinking skills will be developed. This is consistent with Firdaus et al. (2015)

that showed that exposing students to non-routine problems could lead to developing their critical thinking skills.

In terms of group 2 students, it is shown that there is a significant difference in the critical thinking skills of the students in terms of recognizing assumptions. It implies that the level of critical thinking skills of group 2 from authentic to non-linear strategy has a significant difference with a p-value of 0.000. It means that most students perform better when exposed to the authentic strategy of identifying the factual evidence presented and examining how relevant it is. It is also noted that the students feel it is easier to identify the mathematical concepts in the authentic strategy considering it has something to do with real life. Cai and Lester (2010) emphasized that in an authentic problem-solving environment, students may communicate their answers to their group or class in a manner that seems natural to them and learn mathematics via social interactions, meaning negotiation, and achieving a common understanding. As a result, students are given chances to clarify their thoughts and get new views on the topic or idea they are studying. However, there is no significant difference in the critical thinking skills of the students as to evaluating arguments and drawing conclusions. This means that regardless of the strategies being utilized in the study, they do not significantly affect students' performance in the critical thinking skills as to evaluate arguments and draw conclusions. Regardless of their exposure to the two strategies, the students' lowest critical thinking skill is found in evaluating arguments and drawing conclusions. Students' lack of critical thinking can be evident in their arguments where their explanations are insufficient, there are fewer logical assumptions, and there is less evaluation based on evidence (Muhlisin et al., 2016).

Table 4
Difference on the Critical Thinking Skills of the Students by Sequence

	N-A		A-N		t	df	Sig. (2-tailed)
	M	SD	M	SD			
Recognizing Assumption	2.31	0.77	2.08	0.44	1.013	28	0.320
Evaluate Arguments	2.12	0.68	1.97	0.56	0.685	28	0.499
Draw Conclusion	1.68	0.63	1.39	0.33	1.581	28	0.125

Table 4 displays the difference in the critical thinking skills of the students according to their sequence. The result shows that the mean in the first sequence (N-A) in terms of recognizing the assumption (2.31) is higher than the mean in the second sequence (A-N) (2.08). This indicates that the students in the first sequence perform better. However, these data were

subjected to further statistical analysis, which revealed no significant difference ($t=1.013$; $p=0.320$) existed as to sequence.

In evaluating arguments, the mean in the first sequence (2.12) is higher than the mean in the second sequence (1.97). This demonstrates that students who belong in the first sequence performed better. Nevertheless, these data were statistically analyzed, and the results showed no significant difference ($t=0.685$; $p=0.499$) according to sequence.

In terms of drawing conclusions, the mean in the first sequence (1.68) is higher than in the second sequence (1.39). This reveals that the students in the first sequence perform better. Nonetheless, these data were statistically examined, and the findings indicated no significant difference in terms of sequence ($t=1.581$; $p=0.125$).

Overall, students' critical thinking skills have no significant difference regardless of which strategy they use first. This means that the order of strategy does not matter to the students' critical thinking skills. For that reason, it can be concluded that the sequence could not affect the level of the students' critical thinking skills and problem-solving. This is parallel to Bankole (2012), where they failed to make a definitive statement on teaching strategies that may help students develop critical thinking skills.

5. Conclusion

The main purpose of this study is to investigate pre-service teachers' critical thinking skills through problem-based learning strategies. This study reflects that evaluating arguments and drawing conclusions are low-skilled as to critical thinking skills, despite the fact that the respondents are mathematics pre-service teachers. It was found that there was a significant difference in Group 1 in the critical thinking skills in recognizing assumptions, evaluating arguments, and drawing conclusions. However, in Group 2, significant difference exists only as to recognizing assumptions. This study also revealed that there is no significant difference in the critical thinking skills of the students according to their sequence. This implies that students' critical thinking skills have no significant difference regardless of what strategy they use first.

Critical thinking skill among pre-service teachers is still lacking, particularly in terms of evaluating arguments and drawing conclusions due to a lack of prior information and a thorough comprehension of mathematics ideas. With this, the researcher recommends that future researchers build viable approaches for developing effective initiatives to promote critical

thinking teaching and learning in mathematics education. They may also expose students, especially pre-service teachers, to different types of training in order to enhance their critical thinking skills.

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