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Problem-Based Learning Materials in Upskilling Mathematics Critical Thinking Skills

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Abstract

This study aimed to determine the effectiveness of Problem-Based Learning (PBL) material to the critical thinking skills of Grade 10 students in Mathematics. The study used experimental research design by measuring the improvement on the performance of the students after the implementation of the researcher-made PBL material. It also used survey strategy to assess the acceptance of the students on the quality of the developed PBL material and correlated the results with the critical thinking skills before and after the use of the material using paper and pen test. Results revealed that learning experiences relate to inferring, communicating, and problem-solving. There is also significant relationship between learning outcomes and communicating and problem solving. Both effectiveness and efficiency and user-friendliness significantly relate to communicating learning experience while congruence relates significantly to all critical thinking skills. Thus, learners' use of the PBL material increases their critical thinking skills as evidenced by the t–test results showing significantly different critical thinking skills before and after the use of PBL material. With the improved level of students' critical thinking skills, the PBL material may be used as a supplementary in the delivery of the lessons in any subject area.

Keywords: *Problem-Based Learning,, Critical Thinking Skills, Mathematics, Learning Materials*

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1. Introduction

Improving learners' critical thinking skills is the primary focus of educators, especially in teaching mathematics. Learning mathematics is closely related to the practices and methods of learning and thinking since the characteristics of mathematics are mathematics and human activity, that is, mathematics is a method of thinking, a method of organizing logical evidence, which is carefully used by defined terms, clear, and accurate (Mendoza, 2018).

The common problem among students today is understanding a mathematical concept only in its theoretical context with critical thinking skills underdeveloped. For example, in the most recent profile of non-numerates in San Bartolome Integrated High School (SBIHS), at least 38.52% of Grade 7 students for the school year 2019 – 2020 are considered non-numerates. From this context, non-numerates were assessed as those who got a score below 9 out of a 40-item teacher–made and expert–validated standardized test for numeracy. This statistic is further supported by the results of the First Quarterly Mean Percentage Score (MPS) with the Mathematics MPS being second to the lowest in 8 of the subjects, with almost all numbers leading to a decline in the Mathematics Performance of the Learners (SBIHS School Monitoring, Evaluation and Adjustments, 2020).

Problem-based learning (PBL) can naturally shape student thinking activities and help them solve their learning problems (Rosy & Pahlevi, 2015). PBL is also more effective than conventional classroom instruction and has a positive impact on student critical thinking skills (Asyhar, 2015). As PBL can help to build new knowledge (Padmavathy & Mareesh, 2013), critical thinking skills in mathematics must be continually developed, particularly through PBL.

In this study, the PBL material applied three approaches: individual investigations, collaborative investigations or presenting assignments. As such, this study aimed to determine the effectiveness of PBL material in improving critical thinking skills of Grade 10 students in Mathematics. Specifically, it aimed to evaluate the PBL material based on learning experiences, learning outcomes, effectiveness and efficiency, user-friendliness, and congruence. During the implementation, it assessed the level of critical thinking skills of the students before and after the use of the material in terms of observing, analyzing, inferring, communicating, and problem-solving. For the statistical inference, the study revealed that there is significant difference in the pretest and posttest level of critical thinking skills of the student-respondents.

2. Literature review

2.1 Problem-Based Learning (PBL)

Problem-based learning approaches improve students' abilities to adapt or transfer their thoughts to new situations and tasks. They achieve this through cultivating greater awareness of the subject: they consider the assignments and settings of various learning situations, as well as themselves as students in these contexts. Pintrich (2012) observes that students must "think about" these systems rather than merely practicing them. As Zohar and Barzilai (2015) point out, knowledge development is required as one learns.

Hitchock (2014) used the term "problem-based learning" to describe the process of pondering reasoning. With PBL, students become more aware of own learning experiences and the exercises include into personal and professional development. They are more prepared to comprehend themselves throughout the learning process and can develop ability to contemplate, interact with, and evaluate learning on a daily basis. PBL can help students tackle their learning challenges by naturally shaping their thinking activities (Baharun & Ummah, 2018). It is also more successful than regular classroom instruction and improves students' critical thinking abilities (Asyhar, 2015). Critical thinking skills in mathematics must be regularly strengthened, notably through PBL, because PBL can assist build new knowledge (Padmavathy & Mareesh, 2013).

2.2 PBL Materials

Learning resources are good technique to bridge the gap between the learners' requirements and the knowledge and skills they need to learn. Understanding the soft-skills pupils must possess is critical to implementing PBL. When it comes to problem-based learning, the capacity to communicate, think critically, compromise, and collaborate are all necessary skills. The teacher must be aware and need to devote time to teaching and assessing these abilities. Students must also be able to evaluate themselves and their peers, as well as express what they have learned and justify their solutions. Furthermore, the instructor must anticipate when pupils may become stuck and what materials they will want (Kuhfeld et al., 2020).

Individual lessons, units, and even entire curricula can be taught using PBL. It is frequently used in a team setting to develop skills such as consensus decision making,

communication and discussion, team maintenance, conflict resolution, and team leadership. While the core method of problem solving in placed environments has been employed throughout the history of education, the term PBL was not coined until the 1970s as an alternative to medical education (Jones, 2013).

2.3 Critical Thinking Skills

Thinking is a cognitive process for gaining knowledge. The ability to think is a skill that can be learned. The three crucial parts of thinking skills are critical thinking, creative thinking, and problem solving (Launch Pad, 2001).

Barry (2012) outlined ten skills that are required to succeed in the twenty-first century, which include critical thinking skills, communication, leadership, collaboration, adaptability, competitiveness and accountability, innovation, global citizenship, entrepreneurial skills and spirit, and the ability to access, analyze, and synthesize content. Students will be prepared for global economic struggle through education in the twenty-first century. According to the Partnership for 21st Century Skills, 21st-century learning must teach four skills: communication, cooperation, critical thinking, and creativity. In addition, Frydenberg and Andone (2011) suggested that everyone needs critical thinking abilities, digital literacy skills, information literacy, media literacy, and mastery of information and communication technologies in order to face up to learning in the twenty-first century.

Derilo (2019) found in a study that students' academic achievement in Mathematics is related to their degree of Basic Critical Thinking Skills (BSPS), but not to their level of Integrated Critical Thinking Skills (ICTS). This implies that when a student's BSPS are improved, he may be able to do better in Mathematics. Similarly, students with a low level of critical thinking skills might expect poor academic success.

2.4 PBL and Critical Thinking Skills

Numerous research suggest that problem-based learning can be applied to a learning content if educators see the need. Critical thinking is the ability to think logically, coherently, and rationally while correctly identifying the connections between and among ideas and concepts. Observing, analyzing, inferring, communicating, and problem-solving are all skills that underpin critical thinking. Being able to think critically necessitates having the ability to

creatively uncover connections between things. Allowing pupils to think outside the box fosters their curiosity and allows them to benefit from a wider range of learning opportunities. When comparing, students should be able to tell whether things, thoughts, or ideas are connected or not solely by looking at how different or similar they are. Certain problems have a pattern that makes them easier to solve than others. Critical thinking abilities that have been developed make it easier to recognize this pattern, giving the student less time to solve it. Critical thinking abilities were an effective technique of improving students' grasp of mathematics ideas since they assisted in perceiving, analyzing, evaluating, and presenting facts in a logical and sequential manner (Chukwuyenum, 2013).

Activity materials based on PBL may include individual investigations, collaborative investigations, and the presentation of assignments (Arends, 2007). Individual investigative exercises allow students to discuss non-routine mathematics topics that may improve critical thinking skills (NCTM, 2000) while group exercises may provide opportunities to exchange ideas, connect and inform others about mathematics problem-solving strategies. Encouraging students to communicate and interact with others is very important in building critical thinking skills (Jacobs, 2012). By presenting assignments, students can practice and get used to speaking in public with confidence to communicate ideas (Arends, 2007).

When the role of teachers is facilitators rather than teachers (Arends, 2007), students are therefore expected to be independent, self-control and to evaluate their thinking (Facione, 2011). Students are taught to have the ability to identify and analyze the information in a given problem, especially the situation that are complex and ambiguous, and students are able to analyze the information to assess the justification. Therefore, the activities in the materials can encourage students to identify and interpret information, information analysis, and evaluation of the evidence and arguments. Thus, an intervention may be made for them, through a learning approach.

This learning approach may be in the form of a strategy or an activity material. Mendoza (2018) describes effective learning material as to learning experience, learning outcomes, effectiveness and efficiency, and user-friendliness. The congruence of the learning material to PBL approach was lifted from Hadley (2012). The collection of students' knowledge and personal experience, the significant and essential learning that students have achieved and can reliably demonstrate, and the usefulness, value, efficacy, and a well-defined structure and

organization of the content are essential to determine the effectiveness of the learning material. These qualities will be of consideration on the level of critical thinking skills of the learners. Consequently, components of critical thinking skills in mathematics can be measured by observation, analysis, inference, communication and problem solving of the evidence and arguments (Facione, 2011).

Aliliran (2016) concludes that PBL can actually contribute meaningfully to the positive development of creative and critical thinking skills in mathematics and science in a face-to-face classroom set up. But the gap has been identified whether PBL can still be of significant contribution to the said skills development if it will be focused solely on mathematics and critical thinking skills only and is applied not as a strategy but used as a learning material.

3. Methodology

3.1. Research Design

This study used experimental one group pretest-posttest research design. It is an experimental research design characterized as simply the attempt to establish relationships and check the development of specific skills (Creswell, 2012) through a systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet criteria of internal consistency and effectiveness. A PBL material was used to test if there is an improved critical thinking skills of the Grade 10 students in Mathematics.

3.2. Participants of the Study

Participants of this research were 10th Grade students of an integrated high school in the Philippines. Considering that there is only one section conducting online class, which consist of 38 learners, they were purposively chosen as sample group. Purposive sampling, also known as judgmental, selective, or subjective sampling, is a non-probability technique based on characteristics. In this study, participants must be Grade 10 students who are under the online delivery of remote instructions (Crossman, 2020).

3.3. Research Instrument

The study used two main instruments: a survey questionnaire and a teacher-made test for Critical Thinking Skills. The survey questionnaire was primarily used to measure the perception

of the respondents as to the PBL material. It is divided into five sub-indicators, namely learning experience, learning outcomes, effectiveness and efficiency, user-friendliness, and congruence. Each sub indicator has five statements each rated using a Likert Scale ranging from 1 to 4, with 4 being the highest.

A teacher-made test for Critical Thinking Skills has five parts, one for each skill: observing, analyzing, inferring, communicating, and problem–solving. Fifteen (15) points were allotted for each skill with a total of 75 points. The test was content validated by experts. A table of specifications was also provided to highlight the distribution of test items per skill.

3.4. Research Procedure

The study covered three phases: the pre-assessment, the implementation and the post assessment stages.

For the pre-assessment, the research instruments were validated through presentation to a panel of experts. After securing the necessary permission from relevant offices, learners were given the teacher-made, expert-validated critical thinking skills test in the form of a pretest. This was done to measure the initial level of skills of the learners.

The implementation stage was the center of the study. In this phase, the researcher used the PBL material on a regular basis for six (6) weeks for quarter 3 of school year 2021 - 2022. The problem-based enriched learning material was applied in three approaches: individual investigations, collaborative investigations or presenting assignments. The approach was determined based on the nature of the lessons. It used one or combination of two or more of the approaches. As usual, the material starts with the learning targets covered by the Most Essential Learning Competencies and the Specific Learning Objectives. It was followed by an activity, which served as the springboard of the lesson discussion and highlighted the different approaches – though the approaches were also applied to other parts of the lesson. After the activity, it allowed students to explore on the lesson and then finally they were assessed through process questions aligned with the PBL approach.

In the post assessment, the respondents took the critical thinking skills test as well as answered the evaluation questionnaire for the PBL materials to identify its strengths and different areas for improvement. From the gathered results, data analysis was performed.

3.5. Statistical Treatment of Data

To decide on the actual results of the study and its findings, descriptive and inferential statistics were used. In order to describe the perception of the respondents as to the use of PBL Materials, mean and standard deviation was used. Frequency and percentage were applied to describe the level of skills of the respondents before and after the use of PBL materials. For the inferential statistics, Pearson-moment product correlation was used to reveal whether the perception of the learners relate significantly to their level of critical thinking skills. To find whether there is a significant difference in the participants' level of critical thinking skills before and after the use of PBL materials, paired samples t-test was applied. All inferential statistics were done at five percent (5%) level of significance.

4. Findings and Discussion

Table 1

Students' Evaluation of the PBL Material Quality

Indicators	Mean	SD	Remarks
Learning Experience	3.80	0.20	With high quality
Learning Outcomes	3.23	0.55	With quality
Effectiveness and Efficiency	3.27	0.46	With quality
User-friendliness	3.52	0.39	With high quality
Congruence	3.72	0.31	With high quality

Legend: 1.00 to 1.49 (With poor quality); 1.50 to 2.49 (With low quality); 2.50 to 3.49 (With quality); 3.50 to 4.00 (With high quality)

Table 1 presents the summary of the effectiveness of the PBL material. The result indicates that generally, there is a very positive perception on the quality of the material. On the five indicators used, three indicators, learning experience, user – friendliness and congruence all had a mean of above 3.50, thus considered with high quality while the remaining two indicators, learning outcomes and effectiveness and efficiency have a mean value of between 2.50 to 3.49 which interprets as with quality.

For learning experience, the students found it very much effective because the material has meaningful learning opportunities which were thought to be of great significance to the learning that happened inside and outside of the classroom. It is supported by the study of Aleong (2012) that in order to have high quality learning experiences the teachers can control,

direct and influence the students through planning and implementing the curriculum which will make students journey of learning worthwhile.

Learning outcomes also have a verbal interpretation of 'with quality.' This result is similar to the study of Aziz et al. (2012) that majority of the students find learning outcomes valuable because they use them in their studies in many ways. Since the ultimate goal of education is the learning outcomes, this has been the primary consideration in crafting and designing the PBL material. Competencies were anchored on the curriculum guide, which enumerates the desired competencies for each subject for a particular grade level.

In terms of effectiveness and efficiency, it also has a mean that translates to with quality. Since an initial assessment of what has been done and what needs to be done has been made, students perceived the PBL material as a means to address their needs and its topics are made very timely. Kaiser (2020) mentioned in his study that in order to make effective and efficient learning possible, then the focus must be on the students, models of learning and techniques to be used in teaching which can then improve and compliment the traditional approach like lecture or expository instruction.

In a digitally inclined world, students find technology as a means of interaction, socially and academically. Socially through gaining friends and academically as a strategy for teaching as used by some or most teachers. In the study conducted by Simui et al. (2017), they enumerated the key elements that an instructional designer needs to consider including presentation and layout of content, inclusion of real-life situations, and use of interactive language. These elements were considered in designing the learning material used in this study, thus students find it user-friendly. This result is supported by the study of Jayaram and Dorababu (2015), which emphasized that the focuses of learning materials are the flexibility of the process, friendly and informal climate in numerous learning situations, the use of experience, and the enthusiasm and commitment of students as well as the teachers.

The study claims that the material is of high quality. According to Maranan (2020), the quality of a material is also related to the effects it provides to the learners. When teachers are able to craft learning materials that are tailored to the needs, capacities and needs improvement of learners, they are expected to perform better. At the onset of the pandemic, teachers have shifted from being end-users of learning materials to being developers. Thus, capacity building for teachers in developing learning modules must be strengthened.

Table 2

Pretest and Posttest Scores on Critical Thinking Skills

Grade	Pre-Test		Post-Test		Remarks
	F	%	F	%	
Observing					
90 and above	11	28.95	38	100.00	Outstanding
85 to 89	25	65.79		0.00	Very Satisfactory
80 to 84	2	5.26		0.00	Satisfactory
75 to 79		0.00		0.00	Fairly
74 and below		0.00		0.00	Needs improvement
Analyzing					
90 and above		0.00	37	97.37	Outstanding
85 to 89	2	5.26	1	2.63	Very Satisfactory
80 to 84	8	21.05		0.00	Satisfactory
75 to 79	26	68.42		0.00	Fairly
74 and below	2	5.26		0.00	Needs improvement
Inferring					
90 and above		0.00	35	92.11	Outstanding
85 to 89		0.00	3	7.89	Very Satisfactory
80 to 84	4	10.53		0.00	Satisfactory
75 to 79	19	50.00		0.00	Fairly
74 and below	15	39.47		0.00	Needs improvement
Communicating					
90 and above		0.00	13	34.21	Outstanding
85 to 89		0.00	23	60.53	Very Satisfactory
80 to 84	5	13.16	2	5.26	Satisfactory
75 to 79	21	55.26		0.00	Fairly
74 and below	12	31.58		0.00	Needs improvement
Problem- Solving					
90 and above		0.00	10	26.32	Outstanding
85 to 89		0.00	25	65.79	Very Satisfactory
80 to 84	6	15.79	3	7.89	Satisfactory
75 to 79	22	57.89		0.00	Fairly
74 and below	10	26.32		0.00	Needs improvement

In terms of observing, the test scores revealed that before the learners' exposure to the PBL, the majority of their scores fall under very satisfactory, with eleven (11) students being able to have an outstanding score and only two (2) got a score of satisfactory. After the use of the learning material, all of the learners were able to get outstanding scores. The question for observing revolved around identifying the main problem and deciding on the most significant

values that can be derived from the problem. These results imply that after the use of the PBL Material, the students find it easier to come up with a central problem from a given situation and are able to make deductions on the values presented.

In terms of analyzing, initial scores are greatly concentrated on the range of fairly that covers test scores from 75 to 79. This implies that they are only able to present the formula, substitute the proper values and solve for the final answer. However, after the use of the PBL Material, the concentration of the scores have drastically shifted to the 90 and above or the outstanding level. The outstanding level of analyzing shows that aside from giving the appropriate values, they can also think of other ways of presenting the analysis, such as the use of a venn diagram. They were also able to explain what these values mean and what their diagram is all about. The PBL Material, specifically the questions, examples and discussions, enabled the learners to use their analyzing skills.

The table also shows that the scores for inferring skills fall between needs improvement and fairly with score range of 75 to 79 and 74 and below before the teacher used the PBL Material. For those who did not meet the expectations, they only wrote numbers or digits found in the situation. For those who scored fairly, they simply showed their final answers. After exposure to the materials, there scores can be described as outstanding. They can present the values and how they can be used for the solution, and they were able to briefly and concisely provide discussion on what they need to do to arrive at a precise and accurate answer. They were able to explain further the context of their calculations after being exposed to the learning material. Their scores were then concentrated on the outstanding bracket, ranging from scores of 90 and above.

As to communicating, the scores are generally close to that of inferring likely found between needs improvement and fairly for the pre-test but for the post-test, the students were more of very satisfactory and outstanding, with 60.53% and 34.21%, respectively. This leads to the conclusion that after the use of the PBL Materials, the learners find themselves more open to communicating to their fellow students and to their teacher. This is supported by the personal message from a student respondent who said that they had more time talking when the PBL Material was used in their online class. It served as a springboard for learners to be communicative about their thoughts and ideas specially when solving problems.

For the problem-solving skills, the same can be said as for communicating. The general scores are found in the two lower brackets before the students' exposure to the learning material, needs improvement and fairly and were raised to very satisfactory after the use of the material. Specific skill observed was use of percentage, decimals and fraction in presenting relevant relationship on how the problem may be solved but still cannot elaborate on how the numbers can be applied in relation to the problem given. There were also 26.32% of the population that were able to perform outstandingly. It is therefore concluded that after the use of the PBL Material, the students are more versed in applying the solutions in a real-life context.

Table 3

Relationship between the Qualities of PBL Material and Level of Critical Thinking Skills

Qualities of PBL Material	**Critical Thinking Skills**				
	Observing	Analyzing	Inferring	Communicating	Problem Solving
Learning Experiences	0.130	-0.070	0.397*	-0.363*	0.357*
Learning Outcomes	0.014	0.200	-0.298	0.539**	-0.379*
Effectiveness and Efficiency	0.059	0.224	-0.314	0.352*	-0.149
User – friendliness	-0.096	0.213	-0.294	0.373*	-0.182
Congruence	0.439**	-0.352*	0.545**	-0.378*	0.419**

*Legend: *. Correlation is significant at the 0.05 level (2 – tailed).*
***. Correlation is significant at the 0.01 level (2 – tailed).*

For the test of relationships performed between the quality of the PBL materials and CTS, it revealed learning experience significantly relates to inferring, communicating and problem solving, but has no significant relationship to observing and analyzing. This elucidates that learning experience of the students, as provided for in the learning material, are greatly varied and utilize situations and problems that are highly relatable to the skills of the learners. This further implies that inferring and problem solving are positively affected by learning experiences. Learning experiences focused on the vocabulary and comprehension and independent and collaborative learning which are related to communication, adapting to needs, interests and abilities that are the focused of inferring and individual competencies of learners in terms of problem solving.

Positive significant relationship between learning experiences and inferring and communicating have been found. This means that the high perception of the learners in the material is reflected in their inferring and problem solving skills. This further implies that the learning experiences provided by the PBL Material are found by the students to be significantly contributory to their level of inferring and communicating skills and that the students who took the critical thinking skills test are also the ones with developed inferring and communicating skills. This is supported by the high perception of the respondents and their scores. This is further supported by some parts of the PBL Material where it provided varied learning experiences as reflected in the activities provided in the material. The significant negative correlation between the learning experiences and communicating imply that the students who positively perceived the learning experiences in the material were the ones who got the low scores for the said skill. This leads to the conclusion that communicating skills of the learners are not heavily affected by the way they perceive the learning experiences in the learning materials.

Learning outcomes also significantly relate to the specific skills communicating and problem solving. Positive significant relationship for communicating and negative significant relationship for problem solving. The students who are aware of the learning outcomes as specified in the materials scored satisfactorily to the communication skills test. This may be true because by allowing the students to present their assignments to class, they were able to find the level of communication relevant in achieving their learning goals. Likewise, the open channel of communication between the teacher and the learner, and amongst learners made them share a common goal for learning. For the problem-solving skills, the learners who perceived highly of the learning outcomes had low scores for the skill. This entails that since learning outcomes are very much specific in the material, yet very broad in the context of problem solving, they are having a hard time connecting the learning outcomes to real-life situations.

Communicating significantly related to the effectiveness and efficiency and user-friendliness as primary desired qualities of the learning material. Effectiveness and efficiency discusses about the qualities of the learning material in terms of addressing the needs of the learners. These learners have scored highly were able to perceive the material as effective and efficient in addressing their needs. Effective in the sense that it provided a variety of examples and efficient as it can readily answer questions emerging from the learners as the discussion progresses. With the use of less texts and more of graphical presentations and images, students were able to understand better the lessons. The step-by-step procedures on performing the more

complex solutions also helped the learners. This may be the reason why the user – friendliness of the material significantly related to the communication skills of the learners. As claimed by Suarez (2018), students are more inclined into seeing graphical representations rather than reading texts.

All Critical Thinking Skills showed significant relationship to the level of congruence. Since PBL material has been proven to develop critical thinking skills as a teaching strategy, and now when applied in a learning material, the results support and further strengthen these claims. This leads to the conclusion that the more congruent the material becomes, the more it will be able to develop the level of Critical Thinking of the student respondents.

Table 4

Test of Difference in the Critical Thinking Skills Before and After the Use of PBL Material

Critical Thinking Skills	Test	Mean	SD	Paired Differences					t	Df	Sig. (2-tailed)
				Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Observing	Pretest	89.18	3.46	-7.42	4.77	0.77	-8.99	-5.85	-9.594	37	0.000
	Posttest	96.61	2.26								
Analyzing	Pretest	78.82	3.04	-17.24	3.34	0.54	-18.33	-16.14	-31.809	37	0.000
	Posttest	96.05	1.52								
Inferring	Pretest	76.21	3.13	-18.58	3.68	0.60	-19.79	-17.37	-31.116	37	0.000
	Posttest	94.79	2.42								
Communicating	Pretest	77.05	3.18	-12.11	3.57	0.58	-13.28	-10.93	-20.902	37	0.000
	Posttest	89.16	2.57								
Problem Solving	Pretest	76.71	2.99	-12.24	4.30	0.70	-13.65	-10.82	-17.559	37	0.000
	Posttest	88.95	2.84								

Legend: Sig. < 0.05 significant

Table 4 shows that all of the Critical Thinking Skills, observing, analyzing, inferring, communicating and problem-solving, are significantly different, in favor of the posttest as reflected by the values of the mean.

For observing, there has been a significant difference based from the values of the mean and standard deviation of the pre and posttest. It suggests that initially there were students who struggled in finding the main problem and identifying the pertinent values. Therefore, observing has been improved because the PBL Material used guide questions that allowed them to choose which values such as the given, the operation to be used and the processes they need to undertake are useful and which are otherwise.

In terms of analyzing, students were able to gain a systematic view of how problems may be solved. They used a variety of methods including graphical representations, direct substitution and solving to show that all these solutions ultimately lead to a single final answer. Students also had the chance to collaborate with each other so that they can check other students' ideas.

As to inferring or the ability of the learners to generate explanations, they are already capable of generating clear and understandable explanations presented in a logical manner after being exposed to the PBL Material. One reason for this is that the lessons are anchored on the most essential learning competencies and that the lessons were tailored to the needs of the learners. This is consistent with the findings of Hart and Martin (2018) that when it comes to inferring skills, it is better that students be presented with a general problem, have them solve it and explain, then allow them to explore the context of their explanations.

With regards to communication, the students really had anxiety toward the subject and was coupled with their intimidation with the teacher. This has resulted to low pretest scores and was admitted by one of the respondents. But as the students were exposed to the use of the PBL Material and were subjected to activities wherein they would present their works, they gained more confidence and talked even better with their teachers and fellow students. They were also able to use their own words to get messages across based on how they were able to understand the problem and its context. Not only that, but they also showed that after computing, they are capable of explaining what these numbers mean.

The results also show that problem-solving skills have also been improved. It was observed by the researcher that the students have the skill of applying the meaning of the computed values in order to solve the problem at hand. For example, when the students were asked in one of the classes whether it would be better to have more goods or less goods in a sari – sari store, one of the students answered that having more goods would mean a greater probability that the goods the customers are looking for are in the store increases the chances of serving the customer. However, if there are less goods, it would have less probability that the store has what the customer needs.

5. Conclusion

This study aimed to determine the effectiveness of PBL material to the critical thinking skills of Grade 10 students in Mathematics. The study used experimental research design focused

on students' perception on the quality of the material and its effectiveness in improving the critical thinking skills of the students. The findings showed that PBL Material content are aligned with the learning outcomes, effectiveness and efficiency. For learning experience, students agreed to its user-friendliness and congruence. The pre-exposure tests scores were generally concentrated on the scales interpreting to needs improvement, fairly and satisfactory ranging from below 74 and 80 to 84. After the use of the PBL material, the scores raised to 85 to 89 and 90 and above ranges, very satisfactory and outstanding. This is true for all the Critical Thinking Skills that were tested. Significant relationships were found between learning experiences and inferring, communicating and problem-solving. Learning outcomes related significantly to the communicating and problem-solving scores while effectiveness and efficiency and user-friendliness both have significant relationship to communicating. All Critical Thinking Skills have significant relationship to Congruence. The scores before and after exposure to the PBL material were significantly different in terms of observing, analyzing, inferring, communicating and problem-solving. All scores for the different skills are in favor of the posttest.

This study concludes that if the material can further enhance the desired qualities, learning experiences, learning outcomes, effectiveness and efficiency, user-friendliness and congruence, it is likely that the learners will have a higher level of Critical Thinking Skills. The PBL material, or the exposure to it, has developed the level of Critical Thinking Skills of the students. With these, this study suggests that the material can be used to develop the inferring and communicating skills of the learners by providing meaningful learning experiences as reflected by the significant relationship. The same can be said for learning outcomes, effectiveness and efficiency and user-friendliness which all related to communicating, with learning outcomes also relating to problem-solving. The congruence of the material to PBL also related to all the critical thinking skills. Thus, it is recommended that to strengthen these parts of the material to further develop the skills. All critical thinking skills were developed by the PBL material, leading to the conclusion that it may be used as a supplementary material which teachers can use in the delivery of the lessons. This may be further tested in different learning modalities implemented in the school.

References

Aleong, R. (2012). Engaging Students in Meaningful Learning: Understanding Student Perspectives of Engineering Design Education. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://ojs.library.queensu.ca/index.php/PCEEA/article/view/4610

Aliliran, C. (2016). *Improving Critical Thinking Skills in Mathematics and Science through Problem-Based Leaning.*

Arends, I.R. (2007). *Learning to Teach*, 7th edition. New York: McGraw Hill Companies

Asyhar, A. H. (2015). Aplikasi Metode Nilai Eigen Dalam Analytical Hierarchy Process Untuk Memilih Tempat Kerja. *Jurnal MANTIK Pendidikan Matematika*, 1(1).

Aziz, A. A., Yusof, K. M., & Yatim, J. M. (2012). Evaluation on the Effectiveness of Learning Outcomes from Students' Perspectives. *Procedia - Social and Behavioral Sciences*, 56, 22–30. https://doi.org/10.1016/j.sbspro.2012.09.628

Baharun, H. & Ummah, R. (2018). Strengthening Student's Character in Akhlaq Subject Through Problem-based Learning Model. *Jurnal Tadris Keguruan Dan Ilmu Pendidikan*, 3(1).

Barry M. (2012) *What skills will you need to succeed in the future?* [Internet].Tempe, AZ: University of Phoenix; Available from: Phoenix Forward

Chukwuyenum, A. N. (2013). Impact of critical thinking on performance in mathematics among senior Secondary School students in Lagos State. *IOSR Journal of Research & Method in Education (IOSRJRME)*, 3(5), 18–25. https://doi.org/10.9790/7388-0351825

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Crossman, A. (2020, February 2). *What is qualitative research?* ThoughtCo. Retrieved May 10, 2022, from https://www.thoughtco.com/qualitative-research-methods-3026555

Derilo, R. C. (2019). Basic and integrated thinking skills acquisition and achievement of Seventh-grade learners. *European Journal of Education Studies*. Retrieved February 2022, from https://oapub.org/edu/index.php/ejes/article/view/2405/5043

Facione, P.A. (2011). *Critical Thinking: What It Is and Why It Counts*. Millbrae, CA: The California Academic Press

Frydenberg, M.E., Andone D. (2011). Learning for 21st Century Skills. *IEEE's Int Conf Inf Soc*. 2011;314–8.

Hart, E. W., & Martin, W. G. (2018). *Discrete mathematics is essential mathematics in a 21st century school curriculum.*

Hitchock, D. (2014). Russel and Critical Thinking. *Journal of the Betrand Russel Studies*.

Jacobs, K., & Finch, D. (2012). Online education: Best practices to promote learning. *PsycEXTRA Dataset*. https://doi.org/10.1037/e572172013-114

Jayaram, K. and Dorababu, K.K. (2015), "Self learning materials in distance education system", *International Journal of Current Research*, Vol. 7 No. 10, pp. 21929-21934.

Jones, K. (2013), Diagrams in the teaching and learning of geometry: Some results and ideas for future research, *Proceedings of the British Society for Research into Learning Mathematics*, 33(2), 37–42.

Kaiser, G. (2020). *Mathematical modelling and applications in education*.

Kuhfeld, M., Soland, J., Tarasawa, B., Johnson, A., Ruzek, E., & Liu, J. (2020). Projecting the potential impacts of COVID-19 school closures on academic achievement. *Educational Researcher*, 49(8), 549-565.

Launch Pad. (2001) *Thinking Skill*. Westminster Institute of Education. Oxford Brookes University.

Maranan, A. (2020). *The modular Instruction, Content-Process in Classroom Teaching*.

Mendoza, C. (2018). *Designed Self - Directed Learning Guide: Input to an Improved Science Process Skills of Grade 11 Students*

NCTM (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

Padmavathy, & Mareesh. (2013). Effectiveness of Problem-based Learning In Mathematics. *Journal of Education*, 2(1).

Pintrich, Paul R. (2012). The Role of metacognitive knowledge in learning, teaching, and assessing. *Theory into Practice*, 41(4). 219-225.

Simui, F., Thompson, L., Mundende, K., Mwewa, G., Kakana, F., Chishiba, A., & Namangala, B. (2017). *Distance Learners' Perspective on User-friendly Instructional Materials at the University of Zambia*

Suarez, L. (2018). *Impact of Interactive Reading Strategies on the Reading Comprehension Skills of Grade 9 Students at Col. Lauro D. Dizon Memorial National High School*

Zohar, A., & Barzilai, S. (2015). Metacognition and teaching higher order thinking (HOT) in science education: Students' thinking, teachers' knowledge, and instructional practices. In R. Wegerif, L. Li, & J. Kaufman (Eds.), *Routledge international handbook of research on teaching thinking* (pp. 229–242). Oxon: Routledge.