

A Mixed Methods Study of the Influence of Phenomenon-based Learning Videos on Students' Mathematics Self-efficacy, Problem-solving and Reasoning Skills, and Mathematics Achievement

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Abstract This study investigated the influence of phenomenon-based learning videos (PhBLVs) on students' mathematics self-efficacy, problem-solving skills, reasoning skills, and mathematics achievement using mixed methods experimental embedded design. The participants of this study were the two intact classes both mathematics education students enrolled in Calculus class at USTP-CDO Philippines. The study used an adapted instrument on mathematics self-efficacy scale and four researcher-made instruments on problem solving, reasoning, mathematics achievement, and in-depth interview subjected to validity and reliability tests. The quantitative aspect utilized quasi-experimental pretest-posttest control group design with one control group exposed to conventional short-video lectures from YouTube and one experimental group exposed to PhBLVs during asynchronous online classes. An in-depth interview followed with 11 participants from the experimental group chosen as informants. The quantitative data were analyzed using mean, standard deviation, and ANCOVA, while the qualitative data were analyzed using thematic analysis technique. Quantitative data analysis revealed that students exposed to PhBLVs had significantly higher mathematics self-efficacy, problem-solving and reasoning skills as compared to students exposed to non-phenomenon-based videos. However, the result showed that students' mathematics achievement under control and experimental groups are comparable. This was supported by the results of qualitative data analysis which revealed that students exposed to PhBLVs had remarkable experiences with five key themes emerged: difficulty with problem construction, enhancement of reasoning and problem-solving skills, solving real-world problems relevant to social issues, relating math to real-life contexts, and confusing yet enjoyable activities. This implies that PhBLVs can increase students' mathematics achievement and can significantly influence the mathematics self-efficacy, problem-solving and reasoning skills of students. Hence, the researcher recommends to tertiary mathematics educators to use PhBLVs for Calculus and its related mathematics courses as students are engaged in an inquiry or discovery form of learning cultivating their higher-order thinking skills.

Keywords: *explanatory sequential design, mixed method experimental embedded design, instructional material, educational video, mathematics education, teaching strategy*

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1. Introduction

1.1. Background

Recent theories in teaching and learning as well as the fast-changing landscape of work have continually increased its demands on advanced skill sets. Hence, adjustments in organizational and technological structures in the schools and workplace have been made. To cope

with this, problem-solving and reasoning skills as two of the demand skills for future jobs [1] become two of the top priorities of curriculum development [2,3]. It has been emphasized that the schools and educators should put priority to developing students' mathematical knowledge and skills in order to compete globally and meet the new workplace demands [4].

However, today's mathematics education falls far short of high-level thinking abilities which include problem-solving and reasoning skills [5]. Being able to reason out and solve complex problems are just one of the many

contributions of mathematics, however, some students especially those in non-STEM fields have not recognized these and the big impact of mathematics in preparing themselves for college and future careers, and so teachers should do something to address this issue [6]. This dilemma has been evident in the Philippines being ranked second from the bottom in the report of the Programme for International Student Assessment (PISA) 2018, i.e., the mathematics literacy mean score of Filipino students was significantly below the mean score of the Organisation for Economic Co-operation and Development (OECD) [7,8].

Aside from the demand of cognitive skills, affective skills such as self-efficacy are also considered essential factors in the coping up with the current changes in the educational and work environment landscapes. Students need to have high self-efficacy to achieve success in mathematical learning process and improve achievement [9]. Self-efficacy is a belief of a person about his own capabilities, being able to reach the desired goals [10]. It has an important role in academic and learning motivation especially when students manage their learning tasks [11] and eventually in their professional undertaking [12].

As online education becomes the best resort of schools especially in universities or colleges, a careful planning in the development of the curriculum must have to be done to achieve success in the teaching and learning process. There should be varied activities and options for students to participate and interact online, and to attend virtual classes synchronously and/or asynchronously to increase online students' academic success [13].

A study on the use of instructor-generated video content in asynchronous online learning has shown that students had a closer connection to the instructor than in a face-to-face class, received greater individual attention, and improved in their responses to assignments [14]. Another study reported that the instructor-generated video content positively influenced the overall students' satisfaction and engagement in asynchronous online courses [15]. Studies had shown also that students' motivation and attitude in learning were evidently improved using short video lectures or worked-example videos, but its effect to mathematics learning such as the problem-solving and reasoning skills remain unclear and therefore need for further study [16,17].

Moreover, some of the videos used for asynchronous online class are downloaded like video clips from YouTube or Khan Academy which do not situate the content to the context of the learners. Hence, as presented, many studies have investigated the use of educational videos particularly its effect to students' achievement, motivation and attitude in class. However, few studies, if there exist, have investigated if and how educational or learning videos can effectively influence students' problem-solving and reasoning skills and consequently their mathematics achievement and self-efficacy, most especially, in asynchronous remote instruction setting.

One of the educational pedagogies recently discovered was the phenomenon-based learning which was officially

launched at Finland educational system in 2016. Phenomenon-based learning (PhBL) is a form of learning or pedagogy anchored on the theory of constructivism where students learn about real-world topic in a multidisciplinary way rather than in a subject-based approach [18]. Hence, PhBL is a learning approach that starts by observing an explorable phenomenon which has practical impact to students helping them develop competencies essential to their lives.

Several studies conducted in a face-to-face setup have shown that phenomenon-based learning significantly improves students' metacognitive awareness and academic outcomes [19,20]. In the Philippines, only few studies to date have been conducted on the use of phenomenon-based learning and these studies showed that students' mathematics achievement, appreciation, and mathematical creativity have been significantly improved using the phenomenon-based learning approach [21,22].

Considering these situations, phenomenon-based learning videos (PhBLVs) were recently designed and developed for asynchronous online learning modality [23]. PhBLVs were primarily designed for Calculus class with the hopes to improve students' problem-solving and reasoning skills. The learning of students is believed to be more meaningful when their interests are given the priority and real-life phenomena are integrated in the delivery of the lessons [24,25].

This study aimed to determine the influence of PhBLVs on students' problem-solving and reasoning skills as well as their mathematics achievement and self-efficacy as compared to the conventional YouTube videos used by teachers in Calculus class.

1.2. Theoretical Framework

This study is anchored on constructivism learning theory of Jerome Bruner which asserts that learning is an active process in which learners construct knowledge based on their experiences or past knowledge, and that every student has unique experiences creating unique viewpoint in life. It is believed that as students learn, they construct meaning and knowledge for themselves individually or socially [26]. This supports the advocacy of the phenomenon-based learning approach which is to let students discover and generate knowledge based on their prior experience or past knowledge about something or their personal interest that they want to address [27]. These prior experiences or past knowledge of the students that are observable and explorable are the phenomena which can be the springboard in the learning mathematics and developing their problem-solving and reasoning skills [28].

Aside from Bruner, the other major proponents of constructivism learning theory were Piaget and Vygotsky. It is believed that learning is an active mental work where problem-solving, higher-order thinking skills, and deep understanding are emphasized, i.e., students' logical and conceptual growth are on its top priority. Thus, teachers are expected to create learning environments that give direct exposure of students to the material being studied [29].

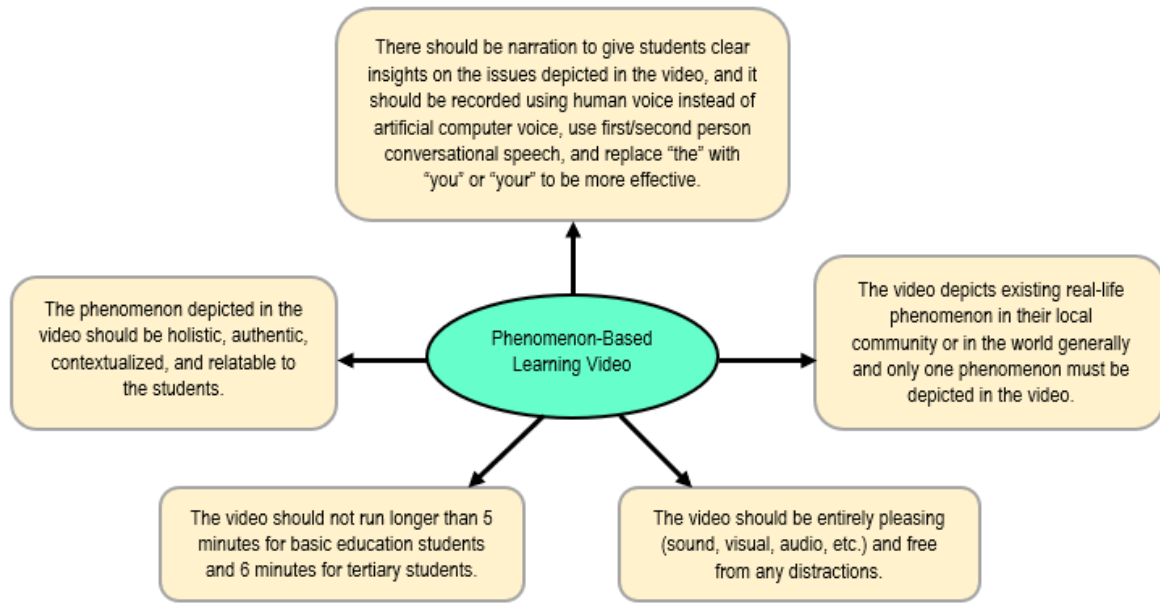


Figure 1. Basic Principles of Phenomenon-Based Learning Video

This is in support to the theme of phenomenon-based learning approach where students are guided by the teachers to actively construct new knowledge based on their prior experiences. Like when students are exposed to a scenario of a phenomenon in a short video clip, and tasks to solve problems and give reasons to justify their proposed solutions, they will be encouraged to not only understand new knowledge but also examine, investigate and criticize this new knowledge during the learning process leading them to develop their problem-solving and reasoning skills and consequently improve their mathematical self-efficacy. Constructivists also believe that the multimedia technology plays an important role in making students explore, discover, and construct new knowledge actively [30] and in this study, the use of phenomenon-based learning videos or PhBLVs. The design of PhBLVs were anchored on the dimensions of phenomenon-based learning and some important principles in designing a learning or educational video [23], as shown in Figure 1.

With the constraints brought by Covid-19 pandemic and the curriculum ultimate goal which is to develop student's skills needed in the new workplace, there is a need for school administrators and educators to plan appropriate framework for the emerging educational realities [31]. As reported, students who joined the asynchronous online learning in addition to their conventional face-to-face class lecture have better student engagement and academic outcomes than those students who were only exposed to conventional face-to-face class lecture [32].

1.3. Objectives

This study seeks to answer the following questions:

- 1.3.1 What are the pre-test and post-test profile of the students in terms of problem-solving skills, reasoning skills, mathematics achievement and self-efficacy?
- 1.3.2 How do the levels of mathematics self-efficacy, problem-solving skills, reasoning skills, and

mathematics achievement compare as influenced by conventional method and phenomenon-based learning videos during asynchronous online classes?

- 1.3.3 What are the experiences of the participants who were exposed to phenomenon-based learning videos?

1.4. Related Studies

1.4.1. Phenomenon-Based Learning

Phenomenon-based learning (PhBL) is described as a learner-centered pedagogical approach with multidisciplinary learning modules and integrative teaching; hence, it is considered as not just an approach but a new way of thinking [33,34]. Multidisciplinary learning modules (MLs) are introduced as study periods of integrative instruction based on cooperation between subjects [18]. Thus, MLs are designed to engage students in a holistic exploration of true phenomena that are viewed as real-world themes and so cannot be contained in a single subject. PhBL has originated and officially launched at Finland in 2016, which aims to open the bigger picture to the world and understanding it. The starting point is by exposing students to real-world phenomena and letting them discover and construct knowledge from it based on their past experiences with the hopes of bringing joyful and creative learning making the students' competence more developed and strengthened [35].

The term "phenomena" is frequently used to describe things as they seem in our environment or experiences such as current affairs or local issues that may be observed and investigated. Thus, a phenomenon can be a source and springboard for exploration [36]. Learning through and about real-world topics has a practical impact for students and can help them develop competencies essential to their lives [18,37]. Students observe a phenomenon, which is a real-world-related tasks, and gather valuable experience related to the phenomenon under investigation [38]. Students can gain information by observing a phenomenon

and then utilize that knowledge to generate and test phenomenon-related explanations [39] in order to respond causal inquiries [40].

Several studies have shown that the use of PhBL has positive influence to students' success and academic outcomes. PhBL helped students understand physics through problems presented with phenomena and problem-solving based on phenomena [20]. Studies also showed that the use of PhBL can help promote students reasoning skills and problem-solving skills, improve student learning outcomes, and even school's success [41,42].

Despite the favorable results of PhBL, switching from describing a phenomenon to establishing a manageable multidisciplinary research unit around it is difficult for teachers and students [43]. Yet, the use of PhBL approach continues to help develop students' metacognitive awareness [19], effectively improve students' mathematical creativity especially when embedded with proof writing [21], and increase students' scientific justification through developing claims based on observed phenomena and data collected through investigation [44]. Hence, students' learning becomes more meaningful when their interests are highlighted and real-world phenomena are integrated in the class [24,25]. In addition, phenomenon-based conversational microlesson packets (PBCMPs) were recently developed, learning materials embedded with phenomenon-based learning activities, and arrived with the following results: phenomenon-based learning materials positively influenced the students' mathematics achievement and appreciation, and mathematics achievement of students exposed to phenomenon-based learning material is significantly higher than those students exposed to non-phenomenon based [22].

1.4.2. Mathematics Self-Efficacy

Self-efficacy, as described by Albert Bandura, is a person's belief in his or her capacity to do a task successfully [45]. Self-efficacy beliefs determine how people feel, think, behave and motivate themselves. Thus, self-efficacy is crucial in education because students who trust in their skills do not avoid tough activities; instead, they see them as challenges that must be addressed. Self-efficacy plays a vital role in improving students' academic and learning motivation, achieving success in mathematical learning process, and becoming successful of anyone's professional undertaking [46-51]. Recent studies further elaborated that students with a higher self-efficacy level can set higher and more challenging goals and often work harder to achieve them, as well as become willing to solve more cognitively demanding problems and get higher problem-solving performance, in particular [52,53].

It is noted also that self-efficacy pertains to specific tasks, i.e., a person may have high self-efficacy for some tasks and low self-efficacy for others [53]. Moreover, self-efficacy is more specific and readily developed than self-confidence, and it is a strong predictor of how effectively a person will perform a given task. Therefore, the importance of self-efficacy in improving learning and engaging students more effectively in mathematical problems cannot be overstated [54]. Self-efficacy beliefs influence individuals' thought patterns and emotional reactions, i.e., self-efficacy beliefs are powerful factors and predictors of individuals' level of achievement.

In search of strategies to improve students' success and academic outcomes, previous researches have shown that students who are exposed to inquiry or problem-based learning gain higher level of self-efficacy and become more autonomous and academically motivated and successful than those students who are not exposed to problem-based learning [55,56]. Students with higher self-efficacy or level of self-confidence will definitely have higher mathematical communication skills, i.e., students are able to express or communicate well their solutions or ideas in mathematical problems when they have higher belief or confidence of themselves in dealing with difficult academic tasks [57].

1.4.3. Problem-Solving Skills

In recent studies, problem-solving skills are highly considered essential to students' success in the university [58], as well as, to employees' success in their workplace [59]. With this, it is imperative that schools should always put emphasis on developing the problem-solving skills of students so that they will become ready and equipped professionals of their career in the future and become more responsible citizens in their community. A study on mathematical problem-solving found that exposing students to problems based on real-life scenarios is relatively better than the conventional worded problems [60]. With this, there should be a focus of learning in real-life contexts through practical tasks to ensure that knowledge is logical and relevant. As emphasized, problem solving training increases problem solving skills. Hence, with constant exposure of students to problem solving and consistency in following the appropriate flow or process of the solution, the increase of problem-solving skills is undeniably evident [61].

When students are given praise and feedback, their skills in solving non-routine problems will certainly be developed. It was reported that when students are exposed to discovery learning with learning materials based on realistic mathematics education approach, their mathematical problem-solving ability as well as self-efficacy will increase [62,63]. This is because the learning materials used by the students are designed based on the nature or interests of students in which they are able to apply their prior experiences or knowledge in solving mathematical problems, thus, making the learning process more meaningful. This is in line with Ausubel's Learning Theory stating that learning is the process of connecting new information or material to existing notions in one's cognitive framework. Moreover, some studies have shown that when students are trained to solve problems scientifically and systematically having been directed to develop their ability to create new knowledge and apply various problem-solving strategies, their problem-solving ability will improve [64,65,66].

1.4.4. Reasoning Skills

Mathematical reasoning is a process where mathematical concepts are communicated, explained, verified, and revised in a disciplinary and learning community. It is one of the four essential skills, along with problem-solving skills, required to be in any curriculum to ensure that student learning and student independence are given emphasis [67]. Mathematical reasoning is developed in

classrooms where students are encouraged to test their own ideas. Teachers and students should be receptive to other students' inquiries, reactions, and elaborations in the classroom. Students must be able to explain and justify their reasoning, as well as recognize and analyze flaws in others' reasoning.

To reason effectively is one of the important aspects of critical thinking, which is an important skill to become a successful professional and overcome every situation in an increasingly complex world [68]. Thus, education should put emphasis on improving students' logical reasoning skills. In addition, it was showed that interactive dialogue should be an integral part in a learning environment in order to construct understanding and develop mathematical thinking [69]. Teachers should engage students in making reflections on their works and make changes in the classroom and mathematical practices to make students learn the ways of thinking and acting, thus enabling them understand their role as learners. With this, students are able to reconstruct some of their reasoning and their peers' explanations.

The teacher's strong engagement is essential in promoting students' mathematical reasoning [70]. A central difficult action may elicit a generalization or justification when seeking to improve students' mathematical reasoning, but it usually necessitates numerous follow-ups acts by the teacher. By generalizing and justifying, students can improve their mathematical reasoning skills and can be better equipped to do mathematical proof activity later on. In addition, practical approach to mathematics is also advised for teachers to use in their math classes as it can promote better students' reasoning and communications skills than the traditional teaching approach [71,72].

1.4.5. Mathematics Achievement

Mathematics achievement refers to a student's proficiency in the discipline of mathematics and it is measured by a mathematics achievement test score [73]. Thus, every mathematics educator primarily aims to improve the mathematics achievement of the students after delivering the intended lessons in a given period of time in any mathematics class. In the result of PISA 2018, the entire education sector of the Philippines was devastated as the country landed on the second spot from the bottom among all the participating countries in the world, which makes the mathematical proficiency or literacy of the Filipino students a serious problem [7,8].

As reported, students' academic achievement is a measure of their knowledge, comprehension, or skills in a certain subject or a range of subjects, and can be defined as a successful achievement in a specific subject area [74]. Several studies were conducted by researchers and scholars on the underlying factors of students' mathematics achievement which can be generally categorized as student-related factors, teacher-related factors, and school-related factors [75,76,77,78,79]. As reported, the achievement of students in mathematics is primarily influenced by their study orientation and their attitude or confidence towards dealing mathematical tasks. This means that students with higher study orientation will have higher achievement in mathematics, and when

students actively engaged themselves in the class with strong self-confidence and positive attitude towards mathematics, their performance or achievement in mathematics will definitely be improved. They have to be persevering and responsible in immersing themselves to different mathematical tasks such as solving problems and communicating their solution to problems with justification. When problem-solving skills and reasoning or critical thinking skills of students are strengthened, their conceptual understanding, procedural fluency, strategic competence, and reasoning abilities will also be strengthened and consequently, increase their achievement in mathematics. Moreover, it was argued that teachers have crucial roles in improving students' achievement in mathematics. Teachers should be the best motivators in increasing students' interest in learning mathematics; teachers should encourage always the students in the best possible way to engage themselves in activities that require the use of mathematical thinking.

2. Materials and Methods

This study employed explanatory sequential research design, specifically a mixed methods experimental embedded design. It is an approach in which the researchers embed the collection, analysis, and integration of quantitative and qualitative data within an experimental quantitative research design [80]. For quantitative aspect, the researchers used quasi-experimental pretest-posttest control group design where the experimental group was given a pre-test, then a treatment (the PhBLVs), followed by a post-test. On the other hand, the control group received a pre-test, did not get treatment, and was then given a post-test. For qualitative aspect, in-depth interview was utilized. The researchers collected qualitative data through interview after the experiment to understand how the participants experience the treatment and to help explain variations in outcome responses.

The participants of this study were the two intact classes enrolled in Calculus 2 class for the second semester academic year 2021-2022 at the University of Science and Technology of Southern Philippines. They are all second-year mathematics education students and the assignment of groups as control and experimental were conducted randomly with 27 students in the control group and 28 students in the experimental group. After the experimental part was the in-depth interview where eleven (11) participants from the experimental group were considered using the data saturation principle. These 11 participants from the experimental group were chosen by the researcher to get their experiences of the phenomenon-based learning videos during their asynchronous online classes.

In the implementation of PhBLVs, during the first meeting of the first week, the researchers informed the participants from the experimental group that four PhBLVs were posted in the school learning management system (LMS), and another four PhBLVs would be posted in the LMS during the first meeting of the fifth week. Furthermore, they were informed to only choose one PhBLV based on their interest which they would be using for four weeks, i.e., one chosen PhBLV would be used for

the first four weeks and another chosen PhBLV would be used for the next four weeks. In total, eight PhBLVs were presented to the students portraying eight different phenomena such as HIV, Covid-19, traffic congestion, flooding, unemployment rate, 2022 Philippine election, investment scam, and sea-level rise. Since Calculus 2 is a 4-unit course or equivalent to 4 hours per week, students were informed that the first 2 hours would be a synchronous online class where a short online class was conducted for the weekly lesson and the remaining 2 hours would be an asynchronous online class where students watched their chosen PhBLV and constructed a problem based on the video and looked for a solution with justification applying what they learned from the weekly lesson.

Meanwhile, participants from the control group were also informed that during the asynchronous online class they would watch a short-video lecture from YouTube to further hone their knowledge on the lesson of the week, and their task was to create their own problem (any problem) and then find a solution for it with justification applying what they learned from the weekly lesson. These YouTube short-video lectures were chosen by the researchers on the following basis: discussed topic that is similar to the weekly lesson, style of discussion that is different to how the online synchronous class was done, and its number of views in YouTube. Lastly, as requested by the students, recordings during the synchronous online class were sent in both control and experimental groups for them to review the discussion.

Mathematics Self-Efficacy Belief Scale, an adapted instrument for mathematics self-efficacy, was utilized in this study [81]. Meanwhile, researchers-made instruments for problem-solving skills, reasoning skills, mathematics achievement, and interview-guide questionnaire were used in the study, which all underwent validity and reliability tests. The interview-guide questionnaire, a semi-structured questionnaire, was validated by six experts in qualitative research with 0.95 content validity index (CVI) value. Another six experts in the field of mathematics validated the instruments for problem-solving skills, reasoning skills, and mathematics achievement with CVI value of 0.93 for each of these instruments. Accordingly, these CVI values are in the range for acceptable instruments [82]. Also, the reliability tests for the instruments of problem-solving skills, reasoning skills, and mathematics achievement resulted to acceptable Cronbach's Alphas of 0.71, 0.73, and 0.89, respectively [83,84]. Moreover, adapted problem-solving skills rubric [85] and rubric for scoring mathematical reasoning test [86] were used to measure the problem-solving and reasoning skills of the participants.

Mean, standard deviation (SD), and analysis of covariance (ANCOVA) for unequal sample sizes were used to analyze the data with the pre-test scores of the participants in mathematics self-efficacy, problem solving, reasoning, and mathematics achievement as covariates. Furthermore, the researchers tested and satisfied the assumptions for ANCOVA. On the other hand, the qualitative data gathered were analyzed using thematic analysis guided by the six steps for qualitative data

analysis [87]. Thematic analysis is one of the most commonly used qualitative research techniques to analyze data collected from interviews, which involves familiarizing the data, generating codes, constructing themes, reviewing potential themes, defining and naming themes, and producing the report [88]. The researchers categorized, reduced, analyzed, and interpreted the collected qualitative data to further describe the concept and the problem situation. Specifically, reading, transcribing, and taking initial notes were used to familiarize the data. Lastly, the final themes generated by the researchers were checked by another qualitative research expert to validate the results.

Furthermore, the quantitative and qualitative data were studied and interpreted based on their similarities and contrasts, as well as the extent to which the quantitative results could be explained by the qualitative findings. The common name for this method is converging and diverging data [89]. Convergence of results is simply described as the interpretations of quantitative and qualitative results, and hence, diverging data is evidence that contradicts the quantitative findings and the quantitative outcomes [90]. Data integration is the heart of the whole mixed methods study [91] and it can occur at the interpretation and reporting level through narrative, data transformation, or joint display [92]. Specifically, the data integration of this study took place when quantitative and qualitative results are merged, and the approach used for integration was identified by the researchers whether it is connecting, converging or diverging.

3. Results and Discussion

3.1. Pre-test and Post-test Profiles

Table 1 shows that there was an increase of the mean scores for both groups, but the experimental group yielded a higher mean score as compared to that of the control group. In terms of standard deviation, the control group had shown more dispersed scores than that of the experimental group as manifested in the results from the table. Furthermore, it can be observed that after the treatment, the mean gain of the experimental group is 0.57, while the control group is 0.20. This shows that students under the experimental group improved better in their mathematics self-efficacy than the students under the control group because of higher mean gain and lower standard deviation.

A good learning result in mathematics is a better increased self-efficacy. Based on studies, good standing and strengthened self-efficacy has a major role in increasing students' academic performance [47,48,49,56]. The higher students' self-efficacy, the higher the ability that they can do and perform mathematical activities. Students are more determined to face and address challenges, and more motivated to do tasks successfully. These supported the claims that self-efficacy is a predictor of achievement in mathematics and that students with high self-efficacy trust their skills not to avoid tough activities [50,51].

Table 1. Level of Students' Mathematics Self-Efficacy

Groups	Pre-test			Post-test		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
Control Group	3.55	0.37	High	3.75	0.44	High
Experimental Group	3.52	0.27	High	4.09	0.37	Very High

Perfect Mean: 5.00

Legend:

Interval	Descriptive Levels	Interpretations
4.00 – 5.00	Very High	With high confidence and assurance to deal and find a solution to difficult mathematical problems or tasks
3.00 – 3.99	High	With confidence and assurance to deal and find a solution with difficult mathematical problems or tasks
2.00 – 2.99	Low	With poor confidence and assurance to deal and find a solution with difficult mathematical problems or tasks
1.00 – 1.99	Very Low	With very poor confidence and assurance to deal and find a solution with difficult mathematical problems or tasks

Although students have high mathematics self-efficacy already before the experiment for both groups, their 8-week exposure to the weekly task, which is constructing their own problem and finding a solution with justification, made a little increase of their post-test mean scores categorized as high level. Nonetheless, it is worth to note that the increase of the post-test mean score in the experimental group is 0.34 higher than that of the control group. This concludes that the mathematics self-efficacy of students exposed to phenomenon-based learning videos (PhBLVs) was better improved than those students who were just exposed to short-video lectures downloaded from YouTube.

With the phenomenon-based learning videos in the experimental group, students conducted careful scientific investigation of the phenomenon depicted in the video, i.e., they used real-life situation to discover new knowledge based on their previous experience or knowledge. Specifically, students exposed to PhBLVs constructed their own problem about the phenomenon by relating it to their weekly lesson in Calculus, and then generated and communicated a solution with logical justification. This activity lasted for eight weeks which may have helped students to improve their mathematics self-efficacy. This result supports the claims that students who are usually exposed to inquiry or problem-based learning integrating scientific investigation gain higher level of self-efficacy than those students exposed to traditional teaching [46,55,57].

Table 2 shows the descriptive results of the level of students' problem-solving skills. The mean score during pre-test in the experimental group is a little bit higher than the control group, however, with just a difference of 2.61, the pre-test means' scores for both groups were almost the same. This implies that the level of students' problem-solving skills before the conduct of the experiment were comparable. It can be observed further that the scores in the control group during pre-test is more dispersed than the experimental group.

From Table 2, it is noticeable that the experimental group had a higher mean score than the control group, indicating that students who engaged in PhBLVs had a better performance in solving mathematical problems. Students under experimental group who used PhBLVs integrated an existing phenomenon in the society in constructing their own problem, thereby, requiring them to explore first the phenomenon and conduct scientific inquiry and investigation in order to create a problem based on the phenomenon and is related to their weekly topic in Calculus 2 subject.

This result supports the claim that students exposed to problems based on real-life scenarios are relatively better than those exposed in conventional worded problem [60]. The constant exposure of students to problem solving training increases their problem-solving skills [61]. Furthermore, the discovery type of learning with learning materials based on realistic mathematics education approach develops the students' mathematical problem-solving ability and self-efficacy [62,63].

Table 3 presents the summary of analyses of the descriptive statistics of the students' reasoning skills. During pre-test, the control group yields a slightly higher mean compared to that of the experimental group. Students both from control and experimental groups have a *beginning* level of their reasoning skills before the experiment. Furthermore, the standard deviation of the control group during pre-test is a little bit higher than that of the experimental group, which implies that the pre-test scores of students from the control group is more dispersed than the experimental group. Yet, it can be observed that aside from the mean scores for both groups which are almost the same, their standard deviations are also comparable. This explains why both groups had nearly identical levels of variation in test scores before the experiment. This concludes that before the experiment, the level of reasoning skills of the students under control and experimental groups are comparable.

Table 2. Level of Students' Problem-Solving Skills

Groups	Pre-test			Post-test		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
Control Group	26.82	10.07	Low	28.26	10.29	Low
Experimental Group	29.43	6.45	Low	43.50	20.07	Average

Perfect Score: 112

Legend:

Interval	Descriptive Levels	Interpretations
74.66 – 112	High	Was able to correctly identify almost all mathematical connections and conceptual understanding of the problem, devised and carried out the plan, and communicate a detailed and correct solution with logical reasoning.
37.33 – 74.65	Average	Was able to correctly identify the important mathematical connections and conceptual understanding of the problem, devised and carried out the plan, and communicate correct solution with logical reasoning but with some defects.
0 – 37.32	Low	Was able to identify key facts of the problem, devised a plan but unable to correctly carry out and communicate logically leading to a multiple erroneous solution.

Table 3. Level of Students' Reasoning Skills

Groups	Pre-test			Post-test		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
Control Group	6.33	7.65	Beginning	34.56	19.89	Beginning
Experimental Group	5.12	7.34	Beginning	43.65	17.11	Emerging

Perfect Score: 120

Legend:

Interval	Descriptive Levels	Interpretations
80 – 120	Proficient	Reasoning in solving problem is almost complete and excellent. Mathematical connections and solutions are identified and presented logically with concluding statement in line with the task.
40 – 79.99	Emerging	Reasoning in solving problem is adequate. However, defects or errors emerge clearly in either the mathematical connections, solutions, or concluding statement.
0 – 39.99	Beginning	Reasoning in solving problem is extremely limited with many defects. Solutions are incorrect with very few mathematical connections and vague concluding statement presented.

During the post-test, Table 3 reveals that the students' reasoning skills under control and experimental groups both increased after the experiment. This outcome can be attributed to the fact that students from each group were exposed for eight weeks to learning activities that require them not just to write a solution for the problem they created but also to give justification of their solution. But it is worth to note that students from experimental group yields a higher mean score than the control group with a mean score difference of 9.09. This can be an indicator that PhBLVs better help students in improving their reasoning skills.

In general, before the experiment began, both the control and experimental groups obtained scores that were classified as *beginning* level of reasoning skills. As evidenced by their pre-test results, students were unable to establish reasoning skills prior to the experiment. After the experiment, students from experimental group obtained a mean score that was classified as *emerging* level of reasoning skills, while that of students from control group remained in a *developing* level of reasoning skills. Despite the fact that the mean scores of both groups increased on the post-test, it is noticeable that the students in the experimental group outperformed the control group, demonstrating that exposure to PhBLVs increased students' reasoning skills.

During the scheduled asynchronous online class, students under the control group were instructed to watch the short-video lecture posted in the LMS. This video was downloaded from YouTube. Then, they were tasked to create their own problem (any problem) and find a solution of this problem with justification applying what they learned from the lesson of the week. It should be noted that students under control and experimental groups were both given a lesson guide every week and also the class recording of the synchronous online class of the week (as they had requested) for them to review how the lesson went through.

During the post-test, the findings showed that both groups' post-test mean scores had increased, indicating that both groups increased in their mathematics achievement as shown in Table 4. From *average* level during pre-test, both control and experimental groups obtained post-test mean scores categorized as *high* level. In terms of standard deviations in their post-test, it can be observed also that the dispersion of their scores from the means are almost the same with a difference of only 1.18. These results imply that the achievement scores of the students under control and experimental groups after the treatment are still comparable.

Based on Table 5, the computed p-values for mathematics self-efficacy, problem-solving and reasoning skills are all less than the 0.05 level of significance. This implies that there is enough evidence to reject the null hypothesis. That is, there is a statistically significant difference in self-efficacy towards mathematics, problem-solving and reasoning skills between students in the control and experimental groups during the post-test. Hence, the post-test mean scores in mathematics self-efficacy, problem-solving and reasoning skills in the experimental group who were exposed to PhBLVs were significantly higher than the control group. Therefore, PhBLV has significant influence in improving students' problem-solving skills, reasoning skills, and self-efficacy towards Mathematics and it is more effective than the YouTube short-video lectures commonly used by teachers during asynchronous online class.

However, with p-value of 0.542 which is greater than the 0.05 level of significance, there is enough evidence not to reject the null hypothesis stating that there is no significant difference of mathematics achievement between students in the control and experimental groups during the post-test. This implies that there is sufficient evidence to conclude that the mathematics achievement of students exposed to phenomenon-based learning videos is comparable to the mathematics achievement of students exposed to short-video lectures from YouTube.

Table 4. Level of Students' Mathematics Achievement

Groups	Pre-test			Post-test		
	Mean	SD	Descriptive Level	Mean	SD	Descriptive Level
Control Group	13.19	3.39	Average	20.37	4.58	High
Experimental Group	12.61	3.18	Average	20.57	3.40	High

Perfect Score: 25

Legend:

Interval	Descriptive Levels	Interpretations
16.66 – 25.00	High	Exhibit proficiency in mastering the concepts of the lessons with good ability in solving mathematical problems.
8.33 – 16.65	Average	Exhibit average conceptual knowledge of the lessons with developing ability in solving mathematical problems.
0 – 8.32	Low	Exhibit poor mastery of the concepts of the lessons with poor ability in solving mathematical problems.

Table 5. One-Way ANCOVA Summary Results

Variables	Source	df	Adjusted Sum of Squares	Adjusted Mean Squares	F	p-value
Mathematics Self-Efficacy	Treatment Between Groups	1	2.001	2.001	27.523	0.0001*
	Error	52	3.780	0.073		
	Corrected Total	54	10.350			
Problem-Solving Skills	Treatment Between Groups	1	1038.183	1038.183	20.505	0.0001*
	Error	52	2632.820	50.631		
	Corrected Total	54	9164.436			
Reasoning Skills	Treatment Between Groups	1	1787.396	1787.396	12.851	0.001*
	Error	52	7232.197	139.081		
	Corrected Total	54	15434.836			
Mathematics Achievement	Treatment Between Groups	1	5.099	5.099	0.574	0.452**
	Error	52	461.941	8.883		
	Corrected Total	54	522.436			

*Significant at $\alpha=0.05$

**Not Significant at $\alpha=0.05$.

3.2. Significant Influence of Phenomenon-Based Learning Video

Note that students under control and experimental groups both received a synchronous online class every week that focused on training them how to solve mathematical problems and how to logically communicate and justify a solution for a mathematical problem. Students for both groups were exposed to a learning environment that force them to think critically and to generate a logical and organized solution. Hence, these students were able to advance their conceptual knowledge of the lessons and improve their mathematics achievement, from an *average* level in the pre-test to a *high* level in the post-test, as shown in Table 4. The significant increase of their achievement score from pre-test to post-test was not solely due to their exposure to PhBLVs for the experimental group and short-video lectures from

YouTube for the control group, but also how they were taught and trained during their synchronous online class.

These results revealing that students both in control and experimental groups had improved in their mathematics achievement after the experiment support the claims that the use of learning videos in mathematics lessons have significant and positive influence in the achievement scores of the students [93,94]. Accordingly, using video lessons in teaching is effective and that teachers should employ watching video lessons in teaching learners in mathematics because it improves their class performance [95]. Moreover, these findings support the assertion that the confidence of students exposed to the inquiry form of learning are significantly influenced and therefore perform significantly better than those students who are just exposed to traditional way of learning [55]. Also, this result supports the notion that self-efficacy in mathematics is a crucial part of mathematical education [54].

$f(x) = 0.8x^3 + 0.79x^{\frac{1}{2}} + 51.26$
 $f'(x) = 3(0.8)x^2 + \frac{1}{2}(0.79)x^{-\frac{1}{2}} + 0$
 $f'(x) = 2.4x^2 + 0.395x^{-\frac{1}{2}}$
 $f''(x) = 2(2.4)x + (-\frac{1}{2})(0.395)x^{-\frac{3}{2}}$
 $f''(x) = 4.8x + (-0.1975)x^{-\frac{3}{2}}$
 $f''(x) = 4.8x - 0.1975x^{-\frac{3}{2}}$
 $f''(0.75) = 4.8(0.75) - 0.1975(0.75)^{-\frac{3}{2}}$
 $f''(0.75) = 3.2959$

Q1: I need constant rule, constant multiple rule, power rule and sum/difference rule.
 Q2: Getting the first derivative, I applied the identified rules on differentiation to the given function.
 $f(x) = 0.8x^3 + 0.79x^{\frac{1}{2}} + 51.26$
 This results to,
 $f'(x) = 2.4x^2 + 0.395x^{-\frac{1}{2}}$
 To get the second derivative, I also applied the identified rules on differentiation to the first derivative above that results to,
 $f''(x) = 4.8x - 0.1975x^{-\frac{3}{2}}$.
 Substituting x to 0.75 , I get,
 $f''(0.75) = 3.2959$.
 Q3: Therefore, $f''(0.75) = 3.2959$ given the function $f(x) = 0.8x^3 + 0.79x^{\frac{1}{2}} + 51.26$. Furthermore, be careful in applying the different rules on differentiation and (applying) simplifying algebraically, especially with decimal forms.

Figure 2. Response of Student A under Control Group on Problem-Solving Test Item Number 2 during Post-test

2. $f(x) = 0.8x^3 + 0.79x^{1/2} + 51.26$. Find the 2nd Derivative of $f(x)$ when $x = 75\%$.

First, I used the power rule, and the constant rule as well to solve the problem.

So,

$$f'(x) = 3(0.8)x^2 + \frac{1}{2}(0.79)x^{-1/2}$$

$$= 2.4x^2 + 0.395x^{-1/2}$$

$$f'(x) = 2.4x^2 + \frac{0.395}{x^{1/2}}$$

Then, get the second derivative. If $f'(x) = 2.4x^2 + 0.395x^{-1/2}$,

So,

$$f''(x) = 2(2.4)x + \left[-\frac{1}{2}(0.395)x^{-3/2} \right]$$

$$f''(x) = 4.8x - 0.1975x^{-3/2}$$

$$f''(x) = 4.8x - \frac{0.1975}{x^{3/2}}$$

Next, if $f''(x) = 4.8x - \frac{0.1975}{x^{3/2}}$, such that $x = 75\%$ or 0.75 . Do direct substitution.

Hence,

$$f''(0.75) = 4.8(0.75) - \frac{0.1975}{(0.75)^{3/2}} = \underline{\underline{3.295 \text{ or } 3.30}}$$

*∴ the second derivative of the function $f(x) = 0.8x^3 + 0.79x^{1/2} + 51.26$ is given by $f''(x) = 4.8x - \frac{0.1975}{x^{3/2}} = 3.30$, where $x = 75\%$ or 0.75 .

Furthermore, I realized how important the rules of differentiation are. It should just be followed correctly and be careful about the signs of your equation to get the right answer.

Figure 3. Response of Student B under Experimental Group on Problem-Solving Test Item Number 2 during Post-test

Figure 2 and Figure 3 show the content analysis of students' responses during post-test on question number 2 both under control and experimental groups. During the post-test, the response of student B for problem number 2 under the experimental group is way better than the response of student A in the control group. The way the solution of student A from control group was communicated is not logical, i.e., it did not follow formal argument and there is no logical progression of the strategy and reasoning used. Though student A and student B both identified key facts and mathematical connections of the problem, devised a plan, and arrived with the correct answer, student B was able to carry out better the plan in a formal argument and communicated the complete solution logically and in a formal way. The progression of the results of derivatives of student B from the given $f(x)$ until $f''(x)$ was presented and explained better than that of student A.

In this study, students in the experimental group were exposed to PhBLVs that promote scientific investigation and inquiry on real-life issues. Hence, when students' interests are recognized and real-world phenomena are blended into the classroom, learning becomes more successful and meaningful [24,25]. Likewise, the result of this study has a similar effect on students who had a better understanding in physics using problems presented with phenomena and problem-solving tasks that are based on phenomena [20].

In the use of PhBLVs, students were exposed to a learning process where they incorporate or use a certain phenomenon and conduct an exploration or scientific investigation on this phenomenon to create a new mathematical problem. Then, students will activate and use their prior experience or knowledge to generate a solution for the problem they created with logical justification. This learning process took place for eight weeks, i.e., students constantly exposed themselves every week for eight weeks to problem-solving activity which is

a higher-level mental learning activity that demands more complicated thinking process. Hence, the result of this study supports the claim that students who are consistently involving themselves to problem solving training [61] with the use of real-world phenomenon [41] will have an improved and better problem-solving skill.

Figure 4 shows the week 5 output of a student under the control group in relation to the topic Rate of Change, while Figure 5 shows the week 5 output of a student under the experimental group in relation to the same topic but with integration to HIV phenomenon portrayed in the phenomenon-based learning video chosen by the student. As reflected in Figure 4, the problem created by the student under the control group is just a straightforward and usual simple problem presented in a class. Since students were just instructed, after watching the short-video lecture, to create any problem as long as related to the topic for the week, no further scientific investigation or exploration was initiated.

The findings of this study on students' reasoning skills support the claim that the phenomenon-based learning approach can help students to be more mindful of their actions and strategies in dealing challenging problems especially phenomenon-based problems [19]. Students who keep on trying new things, constantly do tasks that require justification, and urge one's self to be creative could really improve their reasoning skills [96]. Moreover, it is worth to note that the student in the experimental group was able to create a problem related to the phenomenon depicted in the PhBLV, as shown in Figure 6. It is evident that the student used inquiry or discovery learning and conducted an exploration of the phenomenon in order to create a problem that is based on the phenomenon and related to their topic in Calculus, which resulted to a more developed creativity and confronting ways to difficult issues or complex problems like climate change or economic sustainability [38].

Week 5 "Rate of Change"

Problem: Find the rate of change of a function $f(x) = 5x^2 + 12x + 4$ with interval of $(x_1, x_2) = (3, 5)$

<p><u>Solution</u></p> <p>Solve first for $f(x_1)$ and $f(x_2)$</p> $f(x_1) = 5(3^2) + 12(3) + 4$ $= 5(9) + 36 + 4$ $= 85$ $f(x_2) = 5(5^2) + 12(5) + 4$ $= 5(25) + 60 + 4$ $= 189$ <p>Solve for the rate of change</p> $\frac{\Delta y}{\Delta x} = \frac{f(x_2) - f(x_1)}{x_2 - x_1}$ $= \frac{189 - 85}{5 - 3}$ $= \frac{104}{2}$ $\frac{\Delta y}{\Delta x} = 52$	<p><u>Justification</u></p> <p>Question 1: What mathematical rules or definitions you use to solve the problem?</p> <p>→ Definition 5.1 Rate of change</p> <p>Question 2: How do you solve or find the solution to the problem?</p> <p>→ Using Definition 5.1, the average rate of change of the function $f(x)$ is given by $\frac{f(x_2) - f(x_1)}{x_2 - x_1}$</p> <p>Since $x_1 = 3$ and $x_2 = 5$, solve first $f(3)$ and $f(5)$</p> <p>From the given function $f(x) = 5x^2 + 12x + 4$</p> <p>This gives us $f(3) = 85$ and $f(5) = 189$. Then, substituting these results we get</p> $\frac{f(5) - f(3)}{5 - 3} = \frac{189 - 85}{5 - 3} = 52$ <p>Question 3: What is your conclusion and reflection to the problem?</p> <p>→ Therefore, the average rate of change of the given function $f(x) = 5x^2 + 12x + 4$ with the interval of $(3, 5)$ is 52.</p> <p>Moreover, you need to understand the definition and follow the process in order to get the accurate answer.</p>
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Figure 4. Student's Week 5 Output under Control Group in relation to Rate of Change

HIV Phenomenon

Let $N(t)$ be the total number of newly diagnosed HIV cases in the Philippines at time t . The table gives the approximate values of this function by providing end of month estimates from January to December in year 2020. Find the estimate of the rate of change of N with respect to time when $t=6$ (month of June). Justify your solution.

t	$N(t)$
January	1,039
February	1,224
March	1,489
April	2,254
May	185
June	490
July	522
August	133
September	1,215
October	735
November	618
December	1,073

Solution:

We will solve $N(t)$, so we have

$$N'(t) = \lim_{t \rightarrow 6} \frac{N(t) - N(6)}{t - 6}$$

From the table, when $t=5$ (month of May)

$$\frac{N(5) - N(6)}{5 - 6} = \frac{185 - 490}{5 - 6}$$

$$= \frac{185 - 490}{-1}$$

$$= 305$$

when $t=7$ (month of July)

$$\frac{N(7) - N(6)}{7 - 6} = \frac{522 - 490}{7 - 6}$$

$$= \frac{522 - 490}{1}$$

$$= 32$$

Hence, the estimate of the rate of change of N when $t=6$ is $\frac{305 + 32}{2} \approx 169$ people per month.

Reason or Justification

Question 1: what mathematical rules or definitions you use to solve the problem?

✓ definitions 5.1 and 5.2
✓ Remark 5.4

Question 2: How do you solve or find the solution to the problem?

✓ From the actual data in the table, estimate the rate of change of N at time $t=6$ using Remark 5.4. To put it another way, using Definition 5.1, determine the average rates of change of N with respect to t over the intervals $[5, 6]$ and $[6, 7]$. This gives $\frac{N(5) - N(6)}{5 - 6} = 305$ and $\frac{N(7) - N(6)}{7 - 6} = 32$.

Next, get the average of these two rates of change to get the estimate of the rate of change of N with respect to t when $t=6$. Hence, we have $\frac{305 + 32}{2} \approx 169$, people per month.

Question 3: what is your conclusion and reflection to the problem?

✓ Therefore, the total number of newly diagnosed HIV cases in the Philippines is expected to increase by 169 people per month by the end of June 2020.

Figure 5. Student's Week 5 Output under Experimental Group in relation to Rate of Change and the HIV phenomenon

In this study, students under the experimental group were able to practice thinking beyond the box in constructing a problem to have a connection not just to the weekly topic but also to their chosen phenomenon [21]. Thinking beyond the box means thinking beyond what they usually know and thinking creatively about new ideas instead of employing typical or expected ideas. As a consequence, it improved the way students approach mathematical problems and the way they look into the details of their solution especially when making a logical justification. It is worth to note that students under the experimental group used PhBLVs during their asynchronous online class which significantly influenced their way of justifying a solution. PhBLVs ignite students' curiosity to explore the currently existing phenomenon depicted in the video chosen by them based on their interest. With the task reflected in PhBLVs, students conducted a thorough investigation on the phenomenon depicted in the video in order to pose or create their own problem based on the phenomenon. Through this discovery or inquiry form of learning in PhBLVs, students were trained to think logically and critically to create a problem with correct relations or descriptions of variables and the relevant data they used in the problem. Also, the presentation of how Calculus relates to a phenomenon through a sample problem in PhBLVs helped students organize their ideas to produce a mathematically and grammatically acceptable problem. Hence, exposing students to PhBLVs improved better their reasoning skills than those students exposed to non-phenomenon-based videos.

As what Table 2 revealed that the scores in problem-solving test of students under control and experimental groups from pre-test to post-test had increased after their 8-week exposure to problem solving and justifying solutions, this implies that students with improved problem-solving skills will consequently have an improved performance in mathematics also [78], and hence, teachers' attention should focus on developing

students' problem-solving skills in order to improve the overall performance of students in mathematics, e.g., mathematical reasoning skills. As suggested, it is more important for students to be cognitively than affectively engaged in their mathematics learning [75]. Students who are trained and exposed to problem-based and problem posing activities will have a more developed and improved mathematics performance in general [77,79].

The heart of mathematics is problem solving, and so, every student should develop the skills in solving problems to get high mathematical achievement [8]. Moreover, deep processing or higher-order critical thinking skills should be taught to students and be given the utmost priority in order to improve their achievement in mathematics [7,76]. Effective reasoning or critical thinking in students should be highlighted to have a successful mathematics learning. Therefore, constant training of students to problem solving especially with training on how to logically reason out a certain solution plays a major role in increasing students' achievement in mathematics.

3.3. Lived Experiences in Phenomenon-Based Learning Video

The experiences of the participants with regard to PhBLVs are varied, ranging from benefits experienced, difficulty, realization, confusion to enjoyment. To further explain these experiences, themes are discussed, which were extracted from the participants' answers. Five themes emerged, as reflected in Figure 6, from the interview data of the participants: (1) difficulty with PhBLVs often centers on problem construction, (2) benefits of PhBLVs often include honing skills of reasoning and understanding, (3) PhBLVs highlight real-world solving for societal problems, (4) relating math to real-life contexts is a vital feature of PhBLVs, and (5) activities of PhBLVs may be processed in varied ways ranging from confusion to enjoyment.

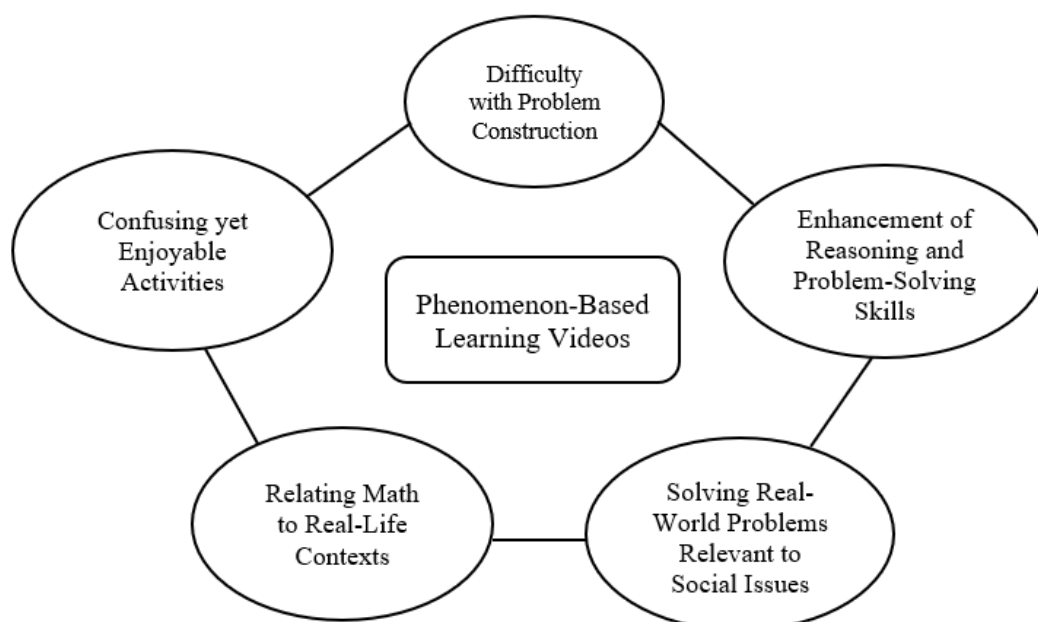


Figure 6. Thematic Analysis Result on Lived Experiences of Students Exposed to Phenomenon-Based Learning Videos

Difficulty with Problem Construction. When asked, a number of participants have said that the problem construction activity is one exercise that mainly caused discomfort for them since this step is challenging as well as new and unexpected. As a participant puts it: “...medyo mahirap yong... weekly activity [somewhat difficult] (P2).” The challenge of formulating one’s own mathematical problem in relation to PhBLVs targeted critical, reasoning, and problem-solving skills that the participants may not have greatly exercised for other matters. According to a participant, the approach made me feel pressured and it is challenging since

“...kami mismo ang mag-buhat sa problem and at the same time ang mas naka-challenging is among e-link ang amo mabuhay na problem based sa amu phenomenon na napili then based sa topic. That is why, mas maka-pressure sya during sa pag construct siguro sa kanang problem, mas uncomfortable kay lage mao to ako gi-ingun na dili puyos ato na situation na ako mismo magbuhat sa problem...” [we had to make the problem as well as link this problem to our chosen phenomenon... it gives pressure and discomfort; we do not usually come up with our own problem.] (P1)

By requiring the students to produce their own problem, PhBLVs have targeted creative thinking and making connections, especially since the problem has to be anchored on a real-life phenomenon. Thus, unsurprisingly, difficulty is experienced. One of the goals of phenomenon-based learning approach is to equip students with the skills necessary to solve problems in the actual world [33]. With phenomenon-based learning, students are asked to discover the knowledge and abilities needed to address real-world issues rather than passively learning abstract concepts [21]. Students are required to explore the phenomenon based on their interest and generate new knowledge or solution of the problem or issue in the phenomenon through inquiry or discovery learning [18]. Hence, students would usually find this activity challenging or difficult on their first attempt or exposure. This finding supports the claim that switching from describing a phenomenon to establishing a manageable multidisciplinary research unit around it is difficult for teachers and students [43]. However, when students can relate difficult or complex phenomena to reality, students can comprehend them better and could come up meaningful learning outcome.

Enhancement of Reasoning and Problem-Solving Skills. The challenges and new insights posed by PhBLVs have targeted one’s problem-solving and reasoning skills, skills useful for one’s future. In the interviews with the students, one has said, “Nakoy ma-learn bitaw, Sir, na ma-apply dayon sa the near future sa akoang skills kay naa nay advancement...” [I have learned, Sir, and I can apply this in the future—my skills—there is advancement] (P3). There may be times that learners often fall into the bad habit of simply finding out what needs to be done without really understanding the reasons behind the process of solving. PhBLVs uncover the reasons behind the solving processes, and so reasoning on the part of the learner is enhanced. In the context of high school, a participant has this to say:

“...mga high school kay dili sila ganahan sa math, kay feeling nila dili nila magamit. Pero kung matun-an na

nila makita nila na importanti diay kaayo ang math and basin someday kung ano na sila professional na sila na mahimo silang makatabang sila sa pag solve sa mga problem tungod sa ilang natun an anang asynchronous online class kanang phenomenon-based learning videos. Based sa imong mga kuan bitaw, Sir, sa mga lesson like analytical skills ug diba kadtong reasoning and justification na na part kay importanti kaayo to na part na ikaw ang mo solve sa problem...” [High school students may not like math because they think it is not that useful. Someday, they may see its importance, like when they’re professionals—they can help by solving [real-life] problems because of what they have learned from asynchronous online class, the phenomenon-based learning videos... lessons like analytical skills... reasoning and justification... these things are very important to solve a problem.] (P4)

The skills of reasoning and problem solving are highly relevant not only because these are two of the demand skills for future jobs [1,67,68], but also, they have vital roles to help resolve issues and problems in the society [97]. With this, teachers should see to it that the learning environment and direction of their mathematics classes are focused in shaping students’ mathematical problem-solving and reasoning skills [66,70].

Solving Real-World Problems Relevant to Social Issues. Many participants have also mentioned that through the use of PhBLVs, they realized that phenomenon-based learning in mathematics can prepare them for problem solving of real-world problems encountered by the nation and even the global community. One even emphasized that in the 21st century, the learner has to be aware of changes in the world—a reality, which phenomenon-based learning brings to the forefront. He said, “...ga-change sya labi na kay naay technology... kaning phenomenon-based learning kanang relevant kaayo sya...” [there are changes, especially with technology... thus, phenomenon-based learning is very relevant] (P5).

Moreover, the students are given the option to choose a PhBLV with phenomenon upon which problem construction is based. Thus, this learning modality requires students to have contextual knowledge based on the real world, current issues and problems that are still afflicting society at large. With this aspect of phenomenon-based learning, a certain participant expressed his appreciation with these words: “kani... na type of learning... feeling nako mas naka-learn ko better... maningkamot ug sabot ani nga topic...” [this type of learning, I feel that I learn better... you make more effort to understand the topic] (P6). In agreement with this, other participants have said that:

“...phenomenon-based learning is very important because I think one of the purpose of education is dapat dili lang ta ma, dili lang ang discussion is ma relate sya sa classroom mismo, but at the same time isa sa purpose sa education is to relate it sa outside nga environment which is to solve problems sa atong mga society...” [This phenomenon-based learning is very important because I think one of the purposes of education is not just relating the discussion to classroom set-up rather education must relate to the environment which is solving problems in our society...] (P1)

There is a need to revisit and improve the teaching and learning process by integrating real-life phenomena where students are encouraged to learn scientific insights through their senses and personal experience [98]. Teachers should promote students' interest and motivation as well as their emotional and social competencies. With this, the learning of the students will become more meaningful and productive [24,25].

Relating Math to Real-Life Contexts. Relating mathematics to real-life contexts is a vital feature of PhBLVs. It seems that this is one of the main reasons why students have found this mathematical experience memorable in their learning. In the context of people saying mathematics is unimportant, the participants pointed out that

“Sa una sir kay gapangutana gyud ko unsay pulos sa mathematics if ma apply ba gyud sya sa real life, tungod atong phenomenon-based learning kay murag nagakita nako ang math in different forms na ma connect man diay nako sya ato social problems nato nowadays sir.” [Before Sir, I really asked myself about the use of mathematics in real-life. Because of phenomenon-based learning, I see mathematics in different forms that I could connect it to the social problems nowadays.] (P4)

“...kanang kasagaran sa mga tawo karon ga reklamo nganu mag study paman ug math na dili man sya magamit in the future, dili man sya magamit in reality. So maong through aning video na phenomenon-based learning murag didto jud sya na importanti gyud mag learn ug math kay kuan gyud kay math is everywhere man gyud... so ma-apply... gyud sa ingun na phenomenon-based or social issues...” [often people complain why should math be studied when it cannot be used in the future—it is not used in reality... through phenomenon-based learning, through this, we learn it is important—that math is everywhere... so we can apply math in phenomena or social issues] (P8)

Phenomenon-based learning approach is a tool that can debunk the idea of mathematics' uselessness as a myth. Not only is mathematical solving applicable to natural phenomena, but social issues may also be analyzed mathematically. As emphasized, exposing students to problems based on real-life scenarios is relatively better than the conventional worded problems [60]. Hence, learning in real-life contexts through practical tasks should be the focus to ensure that knowledge is logical and relevant.

Confusing yet Enjoyable Activities. Activities or tasks of PhBLVs may be processed in varied ways ranging from confusion to enjoyment. Encountering new and surprising approaches to relating mathematics and reality, it is to be expected that learners may be initially confused. A participant narrated his experience as follows:

“...Naglibog ko at first so, kuan nag ask kos ako mga classmate kay para naa pud ko idea unsaon and then and murag apil pud sila naglibog, Sir, so akong gibuhat nag search ko sa Google...” [I was confused at first so I asked my classmates so that I can have an idea how, and then they too were actually confused, Sir, so I resorted to Google search...] (P6)

This statement shows that the confusion stage is not experienced in an isolated case, but rather it is fairly

common. As with all learning though, this stage can be overcome, and so learners can even begin to enjoy the learning process. The participant testified,

“...sa calculus gamit ani na strategy...na enjoy pod ko sir ba kay at least naa pud ko na realize pud na pwede diay gyud sya ma connect gyud ng mga real world na problem sa calculus.” [...In Calculus using this strategy, I enjoyed because I learned that we can connect real world problem to Calculus.] (P3)

After getting through a stage of confusion, learners often then realize the benefits and rewards reaped by learning despite difficulty. This reality was experienced by the participants of PhBLVs in this study. Reading the codes assigned to the varying answers, one can have an appreciation of the participants' different experiences: “time pressure,” “enjoyment,” “startled,” “confused,” “asking myself: is this for me?”, “greater appreciation,” “surprised,” “challenged and stressed,” “excited,” “intense study” and “challenged, independent.” The varied experiences point to the fact that learners will necessarily have differing responses to the various stages of the learning process in the phenomenon-based learning modality [18]. Employing multidisciplinary learning materials and integrative teaching make phenomenon-based learning approach unique from other learning approaches [34]. It aims to open the bigger picture to the world and understanding it. With the use of phenomena, it is hoped to bring joyful and creative learning to students by exposing them to real-world phenomena that interest them with the goal of developing and strengthening their skills essential to their lives [35].

3.4. Mixed Methods or Data Integration Results

The foundation of presenting mixed method findings and results is integration. In Table 6, the innovative integration of both quantitative and qualitative findings of this study which utilized mixed methods experimental embedded design is presented. Bringing together qualitative and quantitative data and triangulating the findings frequently leads to fresh perspectives and accurate evaluation findings. In this case, the approaches of integration used in the study are classified as connecting, converging, or diverging. Accordingly, connecting takes place when one form of data links with another through a sample frame. Converging occurs when results from one data support or explain the results of the other data. Lastly, diverging occurs when there is conflicting evidence between the results of the two different data.

As reflected in Table 6, the results of data integration between quantitative and qualitative findings are mostly converging findings. On students' problem-solving skills, it was found out that students under experimental group showed greater improvement during their post-test than students under control group. Furthermore, quantitative finding shows that students under experimental group showed greater improvement during their post-test on mathematical reasoning test than students under control group. That is, PhBLVs have significant influence on students' problem-solving and reasoning skills. Similarly, participants have claimed that their experience with

PhBLVs helped them enhance their abilities in solving problems and in making justification of their solution. These converging findings are illustrated as follows:

“...Ang sa problem-solving skills sir kanang...enticing kaayo kanang makuha na bitaw nimo ang...sakto na solution murag...ma motivate ka ba pag ayo. Then, sa reasoning skills sir, mas clear gyud nako na na improve gyud sya... [In problem-solving skills, it was enticing because the moment you got the solution, you were already motivated. Then, in reasoning skills, I can clearly see that it was really improved...]” (P5)

Indeed, the use of PhBLVs helped enhance the skills of students in solving mathematical problems and the way they logically reason out their solution. When phenomena are incorporated in the class, the learning process becomes more creative giving students a fresh, interesting, and challenging experience [33]. These converging findings support the claim that the experience of students in phenomenon-based learning helped them solve problems and understand better their lessons in Physics class [20]. The use of phenomena helps navigate the class to do exploration and scientific discovery learning [18,36], and thereby, helps develop and strengthen the skills essential to students' lives [37].

Moreover, Table 6 shows that there is no significant difference on the post-test mean scores in achievement test of those students exposed to PhBLVs and those students exposed to non-phenomenon-based videos. After the experiment, the achievement scores of students both in control and experimental group are comparable. These students under experimental group did not significantly outperform those students under control group though they have a little bit higher post-test mean score because they experienced difficulty performing the task in PhBLV that they had chosen. As uttered by participants in qualitative findings, the weekly activities relating the problems to be constructed to the real-life phenomenon in the video were really difficult for them. Hence, a convergent finding is established.

In phenomenon-based learning approach, students are shifted to learn by doing scientific investigation in the form of inquiry or discovery learning using their prior knowledge or experience. Switching from a traditional way of learning to phenomenon-based learning would somehow become a challenge or difficult experience for teachers and students [43]. Hence, this difficulty experienced by the students who were exposed to PhBLVs is a natural occurrence in phenomenon-based learning as it was their first-time experience to be subjected to this learning approach. Accordingly, when students are constantly exposed to a nerve-wracking activity, they will become used to it and certainly will develop [61].

Furthermore, quantitative findings revealed that the post-test mean score in mathematics self-efficacy of the students from the experimental group is significantly higher than the post-test mean score of the students from the control group. Likely, a theme Confusing yet Enjoyable Activities from qualitative results emerged implying that students with PhBLVs intervention enjoyed and appreciated their learning experience which contributed and helped them a lot. Despite of the difficult and nerve-wracking activities they experienced, they were able to learn to appreciate and see the relevance of PhBLVs in honing their creativity and

persevering attitude. Hence, this is another convergent finding. As narrated by the following participant that:

“...kuan lang sya sir new sa akua pero murag excited aning phenomenon-based learning approach kadtong videos na introduce sa ako unya kaning although new sya sa ako sir, para sa akong perception sir murag makatabang gyud sya sa ako na ma value bitaw nako ang essence sa mathematics through real-life situation... [Although it was new to me, I felt excited with regards to phenomenon-based learning approach through the videos introduced to me. Even if it was new, my perception was it will really help on my end that I could value the essence of mathematics through real-life situation...]” (P9)

Inevitably, difficult learning experience with better results turns out to be more appreciated and valued by the students. When students see the relevance of the activity in their learning endeavor and most especially in our society, they become more motivated and persistent academically in the best possible way. As argued, students with higher self-efficacy level can manage to handle higher and more challenging tasks, work harder to achieve good results, and willingly solve more cognitively demanding problems [52,53]. Students can manage to communicate or express their ideas even for certain difficult mathematical problems when the level of their self-efficacy is high [57].

Meanwhile, Table 6 shows that the post-test mean scores in problem solving and reasoning tests of the students from the experimental group are significantly higher than the post-test mean scores of the students from the control group. That is, students exposed to PhBLVs significantly outperformed the students exposed to non-phenomenon-based videos in terms of their problem-solving and reasoning skills. Similarly, the themes Solving Real-World Problems Relevant to Social Issues and Relating Math to Real-Life Contexts had emerged from the qualitative findings. These are connecting findings because when the students' skills in solving mathematical problems and in justifying their solutions are developed and strengthened, they become more ready and equipped in relating mathematics to reality and solve real-life problems that exists in our society. The following participant mentioned that:

“...phenomenon-based learning is very important because I think one of the purpose of education is dapat dili lang ta ma, dili lang ang discussion is ma relate sya sa classroom mismo, but at the same time isa sa purpose sa education is to relate it sa outside nga environment which is to solve problems sa atong mga society...phenomenon-based learning is very important kay as a 21st centuryof course naa napod tay mga bag-o na challenges like this pandemic...at the same time for future na makatabang to generate more researches and innovation” [This phenomenon-based learning is very important because I think one of the purposes of education is not just relating the discussion to classroom set-up rather education must relate to the environment which is solving problems in our society...As a 21st century learner, of course, phenomenon-based learning is very important, especially the challenges in this pandemic, and to help generate more research and innovation.] (P1)

Table 6. Data Integration Results of Both Quantitative and Qualitative Findings

Quantitative Findings	Qualitative Findings	Approach of Integration
From Table 2 & Table 5 , the post-test mean score (M = 43.50) in problem solving test of the students from the experimental group is significantly higher (p-value = 0.0001) than the post-test mean score (M = 28.26) of the students from the control group.	Figure 6 on students' experiences on PhBLVs has a theme Enhancement of Reasoning and Problem-Solving Skills.	Converging
From Table 3 & Table 5 , the post-test mean score (M = 43.65) in mathematical reasoning test of the students from the experimental group is significantly higher (p-value = 0.001) than the post-test mean score (M = 34.56) of the students from the control group.	Figure 6 on students' experiences on PhBLVs has a theme Enhancement of Reasoning and Problem-Solving Skills.	Converging
From Table 5 , there is no significant difference (p-value = 0.452) on the post-test mean scores in mathematics achievement test between the students in control and experimental groups.	Figure 6 on students' experiences on PhBLVs has a theme Difficulty with Problem Construction.	Converging
From Table 1 & Table 5 , the post-test mean score (M = 4.09) in mathematics self-efficacy of the students from the experimental group is significantly higher (p-value = 0.0001) than the post-test mean score (M = 3.75) of the students from the control group.	Figure 6 on students' experiences on PhBLVs has a theme Confusing yet Enjoyable Activities.	Converging
From Table 2 , Table 3 , & Table 5 , the post-test mean scores in problem solving and reasoning tests of the students from the experimental group are significantly higher than the post-test mean scores of the students from the control group.	Figure 6 on students' experiences on PhBLVs has a theme Solving Real-World Problems Relevant to Social Issues.	Connecting
From Table 2 , Table 3 , & Table 5 , the post-test mean scores in problem solving and reasoning tests of the students from the experimental group are significantly higher than the post-test mean scores of the students from the control group.	Figure 6 on students' experiences on PhBLVs has a theme Relating Math to Real-Life Contexts.	Connecting
From Table 2 , Table 3 , & Table 5 , the post-test mean scores in problem solving and reasoning tests of the students from the experimental group are significantly higher than the post-test mean scores of the students from the control group.	Figure 6 on students' experiences on PhBLVs has a theme Difficulty with Problem Construction.	Diverging

Students in phenomenon-based learning environment are considered as active builders of knowledge generating new ideas through problem solving, built from small parts into a whole that is appropriate for the current circumstance [34,99]. Thus, students develop a profound comprehension of the topic because they are active contributors rather than passive recipients of it. Accordingly, when students actively construct knowledge using real-life phenomena that interest them, their learning journey becomes more interesting and meaningful [24,25]. In addition, it was pointed out that to reason effectively is an important skill to succeed professionally and overcome difficult circumstances in this increasingly complex world [68]. Teaching mathematics in a practical way is suggested to better improve students' reasoning and communication skills rather than teaching it using the traditional approach [71,72]. Thus, teachers are encouraged to create learning materials embedded with phenomenon-based learning approach to promote better improvement of students' learning outcome [22].

Still from [Table 6](#), qualitative findings revealed that a theme Difficulty with Problem Construction had emerged from the interview of participants which is in contrary to the quantitative findings stating that students from the experimental group had significantly higher problem-solving and reasoning skills than those students from the control group. Therefore, the report of qualitative findings contradicted the quantitative findings' underlying assumption. The fact that it was their first exposure to PhBLVs and the full online learning modality may have contributed to this result. The following response of the participant illustrated these diverging findings:

“...what makes uncomfortable is yung pag relate ng lesson to the problem. Kay I think wala ko kasabot ug lisod kaayo sya e relate... [What makes it uncomfortable is relating the lesson to the problem. I

think I did not comprehend and found it difficult to relate...]” (P7)

The nature of phenomenon-based learning is holistic and multidisciplinary with phenomena as its central feature and students as active builders of knowledge [18,34]. It is similar to problem-based learning which requires students to generate a solution to a clearly defined authentic problem using flexible application of knowledge, and hence, should require also a considerable amount of time to process and solve such complex problem [100]. The students should have access to enough materials and assistance as they complete their assignments to take on self-led activities [38].

4. Conclusion and Recommendation

Taking into account the empirical inquiry and comprehensive analysis of the data collected, the researchers concluded that the use of PhBLVs is an effective tool in developing the students' mathematics achievement, self-efficacy, problem-solving and reasoning skills. More specifically, integrating phenomena in learning videos can better improve the mathematics self-efficacy, problem-solving and reasoning skills of the students than the conventional YouTube video-lectures. PhBLVs are as good as the short-video lectures from YouTube in improving the mathematics achievement of students during asynchronous online classes. The findings of this study have implications to existing theory and practice in terms of utilizing phenomenon-based learning approach and learning videos in the classroom, especially for asynchronous remote instruction or asynchronous online classes. It is hoped that by integrating phenomena in educational videos as learning materials, students' self-efficacy towards mathematics and their problem-solving

and reasoning skills will be influenced and have a significant positive increase.

With this, the researchers hereby recommend that tertiary educators handling Calculus and other mathematics related courses may try to use PhBLVs to better strengthen the students' mathematics self-efficacy, problem-solving and reasoning skills, and consequently improve their achievement scores. To confirm the considerable impacts of the PhBLVs on students' mathematical self-efficacy, problem-solving and reasoning skills as opposed to conventional short-video lectures, a larger sample size and entirely face-to-face learning delivery may be taken into consideration. Further researches may also be considered regarding the influence of PhBLVs to other higher-order thinking skills like students' mathematics creativity, critical thinking, metacognition, including mathematical communication skills and other relevant factors of students' performance such as students' engagement, anxiety, or students' attitude towards mathematics. PhBLV is not limited to mathematical courses, therefore researchers may pursue further research in fields other than STEM-related fields, like English.

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