INTERNATIONAL JOURNAL

OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

VOLUME 2 ISSUE 1 • MARCH 2022

ISSN 2799-1601 (Print) • 2799-161X (Online)

For publication concerns, contact the publisher at ijstem@iiari.org.

ISSN 2799-1601 (Print)
2799-161X (Online)

Published by:
Institute of Industry and Academic Research Incorporated
South Spring Village, Bukal Sur
Candelaria, Quezon, Philippines
Postal Code 4323
Contact Numbers: (042) 785-0694 • (+63) 916 387 3537
Visit the website https://iiari.org

INTERNATIONAL JOURNAL OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS
ISSN 2799-1601 (PRINT) 2799-161X (ONLINE)

Volume 2 Issue 1 | March 2022

ISSN 2799-1601 (Print)

2799-161X (Online)

This journal is published quarterly every March, June, September and December.

For more information, visit the website **https://iiari.org/journals/ijstem.**

Aims and Scope

International Journal of Science, Technology, Engineering and Mathematics (IJSTEM) is an open-access refereed journal focused recent developments relative to biomedical science, software applications development, modelling and systems design, and mathematics education research. It is a selective multi-track journal, covering all aspects of biomedical engineering, nanotechnology, solving and expressing mathematical problems with digital tools, mathematical modelling, networking and information security as well as their involvement in the telecom market, contemporary computer technologies and applications, computer vision, advanced computer research and topics in mechatronics.

The journal employs rigorous double-blind review to ensure quality publications. Authors receive formative feedback through feedforward communication approach. It is the prime objective of the reviewers to help authors improve the quality of the papers. As the journal promotes internationalization and collaboration, the multi-dimensional perspectives of the author and reviewers add high value to the research article. Moreover, the journal has solid support system for copyediting and formatting. The journal ensures that the research articles are within the standards of international publication.

The journal covers, but not limited to, the following:

- Chemical and Physical Science
- Biomedical Imaging
- Computer architecture, modeling, and optimization
- Sustainable and renewable energy
- FinTech
- Artificial Neural Networks, Fuzzy Systems and Hybrid Systems
- Computational Intelligence and Evolutionary Computation
- Data Communication, Computer Network and Security & Forensic
- Decision Support and Recommender Systems
- Data Mining, Knowledge Discovery, and Knowledge Management
- Image Processing and Pattern Recognition
- Information Retrieval, Natural Language Processing, and Ontology
- Software Engineering and Software Development
- Web and Mobile Computing
- Game Development and Multimedia
- Data security and Cybersecurity
- Big Data and Data Analytics
- Robotics and Artificial Intelligence
- Green Computing
- Other topics related to ICT and its Applications
- Pure and Applied Mathematics

Editorial Board

EDITORIAL POLICIES

Statement of Open Access

The IIARI upholds and supports open access research publication that allows global sharing of scholarly information without restrictions. Through this platform, free access to shared information promotes knowledge and education. As such, this journal publishes open-access research articles that anyone can reproduce, redistribute and transform, commercial or non-commercially, with proper attribution. The articles' first publication in the journal should always be acknowledged.

Copyright

Repository Policy

The authors are allowed to deposit their articles in institutional repositories, publish in institutional websites and upload in social networking sites with proper attribution and link to the article's DOI. This journal uses OJS/PKP submission that allows archive of pre-print. The post-print in PDF version is also deposited in Internet Archive for long-term preservation of the articles.

Authors' Warranties

Upon signing the copyright transfer form, authors ensure that:

- The article is an author's original work.
- It is not considered for publication nor any part previously published elsewhere.
- The author confirms, to the best of his knowledge, the authenticity and integrity of the data gathered.
- There is no fabrication, plagiarism, material misrepresentation, academic dishonesty, discriminatory and bigoted language contained in the article.
- The author obtains prior permission for the use of any previously published text or material owned by another person.

Peer Review

The journal recruits external experts in the field to assist the editor in the evaluation and selection of the papers. They are selected based on their qualification and specialization. All submitted papers duly accepted by the editor for suitability to journal scope or structural requirements are sent to the reviewers. The journal editorial staff reserve the right to choose the appropriate reviewer based on their knowledge of the topic. The journal adheres to the double blind peer-review process. Neither the author nor the reviewers know each other's identity. Invitations are sent to potential reviewers. Thereafter, the paper is sent only to those who agreed to accept the review invite. The editor makes the decision after the receipt of at least two reviews.

For other editorial policies and publication details, you can visit the following:
Editorial Policies: https://iiari.org/journals/ijstem/policies/

Author Guidelines: https://iiari.org/journals/ijstem/guidelines/

Table of Contents

	Page
Exploring Students' Procedural Fluency and Written Adaptive Reasoning Skills In Solving Open-Ended Problems *Stephanie Gayle B. Andal & Rose R. Andrade*	**1**
Problem-Based Learning Approach in Developing Mathematical Skills *Jerlyn B. Arbo & Delon A. Ching*	**26**
Street Food's Microbiological Load and Vendors' Food Hygiene and Safety Practices Compliance in the Schools of Cebu City *Ritchelle W. Origenes, Rowena Espinosa-Gelisanga & Sheila B. Alturas*	**48**
Building Model for Crime Pattern Analysis Through Machine Learning Using Predictive Analytics *Jonard R. Asor, Francis F. Balahadia, Gene Marck B. Catedrilla & Mia V. Villarica*	**61**

International Journal of Science, Technology, Engineering and Mathematics
Volume 2 Issue 1 March 2022
DOI: https://doi.org/10.53378/352927

Exploring Students' Procedural Fluency and Written Adaptive Reasoning Skills In Solving Open-Ended Problems

[1]Stephanie Gayle B. Andal & [2]Rose R. Andrade

Abstract

Developing students' mathematical skills requires both procedure and reasoning. However, the declination of possessing these skills is still evident today. Hence, this study aimed to describe the students' procedural fluency in terms of accuracy, flexibility, and efficiency and written adaptive reasoning in terms of explanation and justification in solving open-ended problems. The study employed descriptive-correlational design through purposive sampling of thirty students from a National High School in Laguna, Philippines. The quantitative data revealed that in procedural fluency, students can quickly submit a complete solution leading to correct answer. However, they fail to provide two or more solutions in solving open-ended problems. The results also showed that students can clearly explain the problem but struggle to justify their solution. Moreover, procedural fluency is positively correlated to their adaptive reasoning. Consequently, students with an average level of mathematical achievement scored significantly higher than those at a low mathematical level in terms of flexibility. Pedagogical implications suggest that problem-solving activities for students should not solely focus on getting the correct procedures and answers. Further, it is recommended that teachers should expose students in open-ended problems and allow them to try and justify their own unique solutions irrespective of their mathematical achievement.

Keywords: *mathematical achievement, open-ended problems, procedural fluency, problem-solving, written adaptive reasoning*

Received: January 8, 2022 **Reviewed:** January 29, 2022 **Accepted:** February 21, 2022

Suggested Citation: Andal, S.B. & Andrale, R.R. (2022). Exploring Students' Procedural Fluency and Written Adaptive Reasoning Skills in Solving Open-Ended Problems. *International Journal of Science, Technology, Engineering and Mathematics*, Volume 2 Issue 1, pp. 1 - 25. DOI: https://doi.org/10.53378/352872

About the authors:

[1]Laguna State Polytechnic University. San Pablo City Campus

[2]Corresponding author. Laguna State Polytechnic University. San Pablo City Campus

1. Introduction

Education is often considered a real success behind any future success. It paves the way for the people to have a promising future and to receive ample opportunities along the way (Al-Shuaibi, 2014). Therefore, Philippine education implemented its educational reform called the K to 12 program to achieve its unending pursuit of a better educational system and ensure that every Filipino student receives a high-quality basic education. One of the major fields of the current curriculum for basic education is Mathematics (Department of Education, 2016). It is given priority for being a queen of all sciences.

Even after the implementation of K to 12 program, the Philippines' first participation in Programme for International Students Assessment (PISA) in 2018 resulted to Filipino students achieving lower than the average points expected from the Organisation for Economic Co-operation and Development (OECD). It was shown that among 79 countries, the Philippines ranks 70s in mathematics and science. In addition, the National Achievement Test (NAT) results in 2017-2018 also showed that mathematics has the lowest mean percentage score, and problem-solving is still way below the acceptable mean percentage score. Therefore, the need to improve the problem-solving skills in Mathematics is not just important but an urgent matter that every student and educator must address.

Problem-solving is said to be the heart and soul of mathematics (Stupel & Ben-Chaim, 2017). The National Council of Teachers of Mathematics (NCTM) recommends that problem-solving be the focus of mathematics teaching since its significance in everyday living cannot be denied. It was also emphasized that problem-solving is the application of knowledge, which must be taught in various ways and strategies. Bernard and Chotimah (2018) acknowledged that one of the avenues that would extend the students' problem-solving skills is allowing them to answer an open-ended problem with various answers and solutions. Open-ended problems are questions with multiple solutions and answers (Milos, 2014). These are rarely utilized in mathematics classrooms since most teachers rely on textbooks for instruction, which use only closed-ended questions with examples and exercises that all have the same solution and fixed answer.

According to Noureen et al. (2015), one way to assess students' problem-solving abilities is to investigate their level of mathematical proficiency. Mathematical proficiency is composed of five interconnected strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Accordingly, Bernard and Chotimah (2018) also emphasized that using an open-ended approach may instill students' mathematical reasoning

ability and promises an opportunity for students to use the various strategies, procedures, and ways that they believe will fit in a given question. It implies that exposure to open-ended questions would enhance students' procedural fluency and adaptive reasoning, which are parts of the five interconnected strands in mathematical proficiency. In addition, Rizki et al. (2017) also highlighted both procedural fluency and adaptive reasoning as requirements in developing students' mathematical ability. Procedural fluency is said to be the foundation among all the strands of mathematical proficiency (NCTM, 2014). Inayah et al. (2020) relates procedural fluency to students' comprehension of mathematical ideas and problems which Foster (2017) refers to as fundamental in students' mathematical development. On the other hand, adaptive reasoning involves students' ability to think logically about relationships between mathematical concepts (Dewi et al., 2020). As explained by Muin et al. (2018), it is a vital skill in learning mathematics that demonstrates learning ability.

In today's academic landscape, students find it challenging to use an accurate and flexible method in solving a problem. They also lack the ability to reason out and even expound their solutions. It was particularly confirmed by the study of Aprianti (2014) that no students had provided a fluent mathematical procedure. Similarly, Asmida (2016) revealed that the adaptive reasoning of the students was in the middle average only. Numerous researchers have also demonstrated a significant association between students' procedural fluency and adaptive reasoning (Bautista, 2012; Dewi et al., 2020).

This study aims to determine the relationship between the level of procedural fluency and adaptive reasoning skills of the students. Parallel to the studies of Dewi et al. (2020) and Bautista (2012) which used geometric proofs and thermodynamic problems in physics, this study explores application of the skills on Grade 10 mathematics. Supported by the study of Awofala (2017) that students' mathematical achievement is significantly related to all strands of mathematical proficiency, this study also fills the literature gap by exposing students to open-ended questions in mathematics, which provide opportunities to learn diverse solutions and strategies regardless of their mathematical achievement. Specifically, it aims to determine the students' level of procedural fluency in solving open-ended problems in terms of accuracy, flexibility and efficiency and the level of written adaptive reasoning skills in solving open-ended problems as to explanation and justification. It will also provide answers to the following hypotheses:

Ho1: Students' procedural fluency significantly relate to their written adaptive reasoning skills in solving open-ended problems.

Ho2: Students' procedural fluency significantly differ to their written adaptive reasoning skills when grouped according to mathematical achievement.

2. Literature review

2.1. Procedural Fluency

Among the five strands of mathematical proficiency, procedural fluency is said to be the foundation of all strands (NCTM, 2014). Procedural fluency, sometimes called "smooth procedural" and "mathematical fluency" involves knowledge on when and how to apply a method, strategy, or procedures and being able to accurately, efficiently, and flexibly. Foster (2017) states that achieving procedural fluency is fundamental in students' mathematical development. Moreover, repetitive exercise is a common technique to develop this ability. Laswadi et al. (2016) mentions that learning experiences greatly help students to construct procedures.

In order to develop procedural fluency, students need experience in integrating concepts, processes and building on familiar methods as they create their own informal strategies and procedures (NCTM, 2014). Students need opportunities to justify both informal strategies and commonly used techniques mathematically, support and justify their choices of appropriate processes, and strengthen their understanding and skill through distributed practice. Thus, augmenting students' procedural fluency in mathematics is gravely important.

In the study of Bautista (2012), students' procedural fluency is influenced by their mathematical ability, whereas their written-mathematical explanation varies depending on their English ability. In addition, Dewi et al. (2020) analyzed the adaptive reasoning abilities and procedural fluency of students in a study which showed that students can think logically in choosing the right concepts and situations. Inayah et al. (2020) also found that students can solve problems with more than one method but some students are incapable to do streamline steps and make accurate calculations. This is in parallel to the findings of Aprianti (2014) and Asmida (2016) that none of the students had the smooth mathematical procedure and procedural fluency which impede their mathematical development. All these studies used accuracy, flexibility, and efficiency as parameters in measuring the level of procedural fluency of the students.

*Accuracy***.** It is the ability of the students to obtain the correct answer without committing any mistakes. However, several researchers agreed that accuracy is the most difficult indicator of procedural fluency for students to achieve (Inayah et al., 2020; Aprianti, 2014; Asmida 2016). The

results of their studies showed that accuracy was the lowest achievement compared to the other indicators. Most of the students did not meet the expected accuracy in problem-solving. They made continuous mistakes because they lack interest in re-checking their solutions and answers.

*Flexibility***.** According to Inayah et al. (2020), flexibility is the students' ability to recognize strategies necessary to complete a mathematical task and to apply learned strategies to alternative mathematical tasks - particularly in solving problems. As applied in Inayah et al. (2020) study, students' flexibility is taken as students' capability to determine strategies in problem-solving and carry out problem-solving procedures using known methods. The study shown that this indicator was the highest achievement indicator compared to other indicators. Most of the students can provide more than one way, strategy, or solution to solve specific problems.

*Efficiency***.** As defined by Asmida (2016), efficiency is the ability of the students to provide a strategy in the quickest way to solve problems. Inayah et al. (2020) found in a study that some students were unable to immediately provide correct procedures or solutions in a shortest possible time. In addition, there were some students who yielded the correct answer but employed an incorrect strategy. This suggested that this indicator was on the average achievement of the students.

2.2. Written Adaptive Reasoning

Developing students' mathematical skills requires both procedures and also reasoning (Rizki et al., 2017). According to Muin et al. (2018), reasoning is a major component in mathematics and should be emphasized as a foundation of mathematics. Adaptive reasoning is also one of the five strands of mathematical proficiency. Dewi et al. (2020) defined adaptive reasoning as students' ability to think logically about relationships between mathematical concepts; a process to justify work (Wibowo, 2016) and a fact, procedure, concept and mathematical solution to be adapted to the situation (Syukriani et al., 2017). According to Muin et al. (2018), it is one of the mathematical skills that must be possessed by students to demonstrate their learning ability. Its importance has been recognized by several researchers.

Muin et al. (2018) studied and used intuitive-inductive (guess and make general conclusion) and intuitive-deductive (guess and make logical conclusion) as indicators of adaptive reasoning. The study showed that these two indicators have only slight differences and almost balanced. It can be said that the creative problem-solving learning model is effective learning to develop students' mathematical adaptive reasoning skills. Moreover, Syukriani et al. (2017) also

investigated the adaptive reasoning and strategic competence of a male and female student as they solved mathematical problems and found that male and female subjects used different strategies to understand, formulate, and represent a problem situation. The study also used explanation and justification as their standards in measuring the level of adaptive reasoning of the students.

*Explanation***.** Andrews et al. (2019) asserts that the act of explaining can help students develop new understandings of mathematical ideas, construct rules for solving problems, become aware of misunderstandings or a lack of understanding, and develop their mathematical communication. The students' explanations can also offer opportunities for a teacher to understand more fully what the students are thinking.

*Justification***.** Analyzing students' justification skills allows teachers to study the development of mathematical understanding and create a learning design that helps students on how to justify their answers (Eko et al., 2018). The ability of a person to justify is closely related to his reasoning ability because justification means giving reasonably clear reasoning. Furthermore, justification is the process of validating a statement by giving reasons, proven definitions, or theorems. Thomas (2018) adds that justification is the act of providing a foundation, proofs, or arguments to convince another person that a claim is true.

2.3. Mathematical Achievement

Mathematics plays a vital role in most careers. However, DepEd, PISA, and NAT proven that it remains the concern in the Philippines. Carey et al. (2017) affirm that high level of mathematical skills have long been recognized as essential not only for academic success but also for efficient functioning in everyday life. However, Arigbabu (2013) proved that many students performed poorly in both internal and external examinations in mathematics which explains their lack of mathematical proficiency. Among the mathematical skills, procedural fluency and adaptive reasoning also need to be addressed in assessing students' performance. Awofala (2017) found a significant positive correlation between the student mathematical achievement and all components of mathematical proficiency which includes procedural fluency and adaptive reasoning. Students reach a high level of these components when they are on the above average level.

2.4. Open-Ended Problems

In order to develop students' mathematical ability, mathematics learning should provide students with the opportunity to freely try their own possible solutions (Kwon et al., 2016). Dewi

et al. (2020) argued that a problem could only boost students' thinking if it cannot be solved via a well-known routine approach. In this perspective, many researchers (Kwon et al., 2016; Levav-Waynberg & Leikin, 2012; Wijaya, 2017; Wessels, 2014) suggested using open-ended problems to stimulate students' divergent thinking and mathematical creativity.

According to Wijaya (2017), open-ended problems provide students with the chance and stimulus to investigate alternative solutions, methods, or tactics. Hadiastuti et al. (2019) added that there are three types of open-ended problems: problems with multiple answers, problems with many ways of solving a problem, and problems that can be developed into new problems. However, Albab and Wangguway (2020) mentioned only two types of open-ended problems: one answer with many ways of solutions, and the other is several solutions with many answers. These kinds of problems are valuable since they allow students to learn new methodologies, enhance their mathematical knowledge, and develop their mathematical creativity (Yuniatri et al., 2017). Furthermore, they stated that open-ended problems are tools that contain references to various types of knowledge, different levels of complexity in mathematical thinking, and multiple levels of creative thinking in its various dimensions (fluency, flexibility, complexity, and creativity).

Wijaya (2017) recommended the use of open-ended problems in honing students' mathematical creativity. It was further affirmed that students' mathematical creativity can be gauged by the students' ability to employ various solutions or strategies in problem-solving. Albab and Wangguway (2020) used open-ended problems and found out that students have quite good creative and innovative thinking skills; they can use several ways to solve problems, they are able to find unique ideas to solve problems, and they are able to expand, select, analyze and evaluate the basic idea of problem-solving. Furthermore, Belecina and Ocampo (2018) found that students' critical thinking improved significantly after using problems, and positive attitudes and feelings were apparent among students after its use.

The idea of using open-ended problems strongly agrees with the fact that it breaks the stereotype that every problem has only one answer and one solution. Though there are lots of positive results in using open-ended problems in the classroom, its application is not predominant in the classroom. Nold (2017) mentioned that teachers lack the necessary knowledge, skills, and tools to promote a higher level of critical thinking and problem-solving which hinder them to evaluate different solutions, methods, strategies, and answers provided by students. Thus, exposure to open-ended problems and training in employing several heuristics in problem-solving are deemed necessary.

3. Methodology

The study utilized descriptive-correlational with a comparative research design. The level of procedural fluency (in terms of accuracy, flexibility, and efficiency) and written adaptive reasoning (in terms of explanation and justification) of the grade 10 students in solving open-ended problems, their relationship and differences when they are grouped according to their level of mathematical achievement were described and analyzed.

Thirty respondents were chosen using purposive sampling. Due to pandemic, it is critical to address students' internet connectivity. Ten students for each level of mathematical achievement were considered as samples. These students were all from Grade 10 students of Masaya Integrated National High School, Bay, Laguna, Philippines. They were categorized into three levels of mathematical achievement, namely: high, average and low.

Table 1

Profile of the Students According to their Mathematical Level

Grades	Mathematical Achievement		Verbal Interpretation
	f	%	
91-100	10	33.3	High
81-90	10	33.3	Average
Below-80	10	33.3	Low
Total	30	100.0	

As shown in table 1, the mathematics grades of the students were equally distributed into three levels of mathematical achievement, namely: high, average, and low. Each level consists of 10 students, or 33.33% of the respondents, and a total of thirty Grade 10 students with 18 females and 12 males.

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

Open-ended Problems. The study employed five researcher-made open-ended problems. Each problem includes guide questions in answering to determine the level of students' procedural fluency skills in terms of accuracy, flexibility, and efficiency; and written adaptive reasoning skills as to explanation and justification. These problems consist of two algebraic word problems, two probability problems, and one figure to arrange open-endedly.

Procedural Fluency and Adaptive Reasoning Scoring Rubrics. Two scoring rubrics were used to describe the students' procedural fluency and adaptive reasoning. The study used a researcher-constructed scoring rubric to analyze the students' procedural fluency in terms of

accuracy, flexibility, and efficiency in solving open-ended problems. A scoring rubric was also created to analyze the adaptive reasoning skill of the students in terms of their explanation and justification.

Validation. Prior to the conduct of the study, the seven open-ended problems and the scoring rubrics were evaluated by the experts consisting of six teachers from different High Schools in Laguna, Philippines. The experts consist of five Mathematics teachers and one English teacher who focused on the grammar of the instruments. Moreover, the instrument underwent pilot testing to determine its reliability. Based on the test reliability result, it was found out that the problem-solving test obtained an acceptable level of reliability.

Final Revision. All the five open-ended problems got the acceptable mean score to include in the study. The suggested sentence constructions and grammars were strictly followed for the two rubrics prior to the implementation.

Several panels of experts evaluated the study to ensure the quality of the content. Prior to the conduct of the study, suggestions and comments were carefully examined.

An approval letter and request permission from the principal of the school was sought. After receiving consent to perform the study, the master list of students with their math grades was obtained in order to attain the target number of students in each level of mathematical achievement. Due to the pandemic, the study was conducted with the supervision of Grade 10 head teacher and mathematics teacher through the use of an internet platform, specifically Facebook messenger. The study's objectives were communicated to the selected respondents. The test problem material, which comprised of five-open ended problems, was distributed to the grade 10 head teacher via their platform. The test paper contains detailed instruction for solving the problem as well as the researcher's contact information for queries and clarifications. The head teacher allotted two weeks for students to complete the test problems. After two weeks, the researcher collected data directly from the students in conformity to their teachers' instruction.

In analyzing the level of procedural fluency and written adaptive reasoning, mean, standard deviation, frequency and percentage were used. To determine whether there is a significant relationship between procedural fluency and adaptive reasoning of the students in solving open-ended problems, Pearson-product – moment correlation was employed. Furthermore, one-way ANOVA and Scheffe Post Hoc Test Analysis were applied to identify if significant difference exists between the level of procedural fluency and adaptive reasoning of the students when they are grouped according to their mathematical achievement.

4. Findings and Discussion

Table 2

Students' Overall Procedural Fluency

	Mean	SD	Verbal Interpretation
Procedural Fluency			
Accuracy	16.70	6.43	Moderate
Flexibility	10.03	4.00	Moderate
Efficiency	15.30	6.18	Moderate
Over-all Mean	**14.01**	**5.53**	**Moderate**

Table 2 reveals that over-all students' procedural fluency is at moderate level with a mean score of 14.01 and standard deviation of 5.53. This indicates that there are more students who can quickly submit a complete solution that leads to the correct answer. This finding asserts Inayah et al. (2020) that the level of mathematical procedural fluency of the students has an average performance which is in the moderate category. However, it is apparent that flexibility has the lowest mean score which implies that students struggle in providing two or more solutions.

Table 3

Students' Scores in Procedural Fluency in Solving Open-Ended Problems as to Accuracy

Score	Accuracy		Verbal Interpretation
	f	%	
17-25	16	53.3	High
9-16	10	33.3	Moderate
0-8	4	13.3	Low
Total	30	100.0	

It can be gleaned from table 3 that in accuracy, most of the students in solving open-ended problems got 17-25 points, with a total of 16 students or 53.33% of the respondents. It can also be noted that out of these 16 students, 4 students (Student 9, 15, 16, 23) got perfect scores, and three of them belong to the average level of mathematics achievement. As a result, majority students have a high level of accuracy. This implies that students can provide correct answers with complete solutions in open-ended problems.

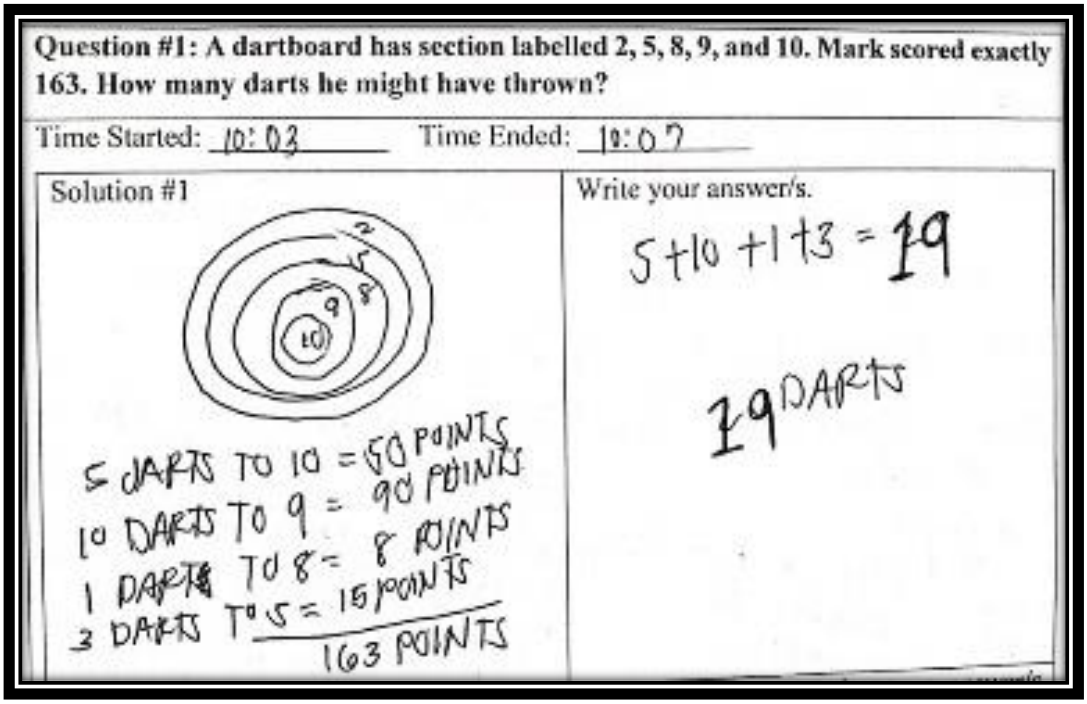
This supports the study of Glass and Kang (2020) that students can provide accurate answer in an activity since they tend to look for the accurate answer on the internet or other sources at home. However, the result contradicts the study of Inayah et al. (2020) which shows that accuracy is the most challenging component in procedural fluency. It can be inferred that students commit

mistakes since they do not have a chance to re-check their answers as reflected in the guided question section in the test material.

Student 15 is an example of a student with a high level of accuracy. His solution to Problem 1 is depicted in figure 2.

Figure 2

Sample Solution of Student 15 in Problem 1



]

It is shown that Student 15, who is in the average level of mathematical achievement, was able to solve the problem by providing a complete solution and correct answer. Since the problem asked for the possible number of darts, he multiplied each point of the dartboard to a possible number of darts and added these points to come up with 163 points. It can also be noticed that aside from the solution, he illustrates a dartboard with corresponding points from the problem as he solved it. This figure confirms the study of Al-Balasi and Barham (2010) that students can employ a variety of mathematical representations to enhance their problem-solving mathematical abilities. Pentang et al. (2021) emphasized that discovering multiple representations leads to effective and efficient problem-solving.

Table 4

Students' Scores in Procedural Fluency in Solving Open-Ended Problems as to Flexibility

Score	Flexibility		Verbal Interpretation
	f	%	
17-25	1	3.3	High
9-16	20	66.7	Moderate
0-8	9	30.0	Low
Total	**30**	**100.0**	

It can be depicted from table 4 that in flexibility, majority of the students in solving open-ended problems got 9-16 points, with a total of 20 students or 66.67% of the respondents interpreted as having a moderate level of flexibility. This summarizes that the students can apply only one strategy leading to the correct procedure and answer. They had difficulty producing more than one solution, limiting them in using one strategy. Akin with Pentang et al. (2021), this can be attributed to the scarcity of students' knowledge on different heuristics and satisfaction once they got the correct answer which led them in providing a single algorithm in problem-solving.

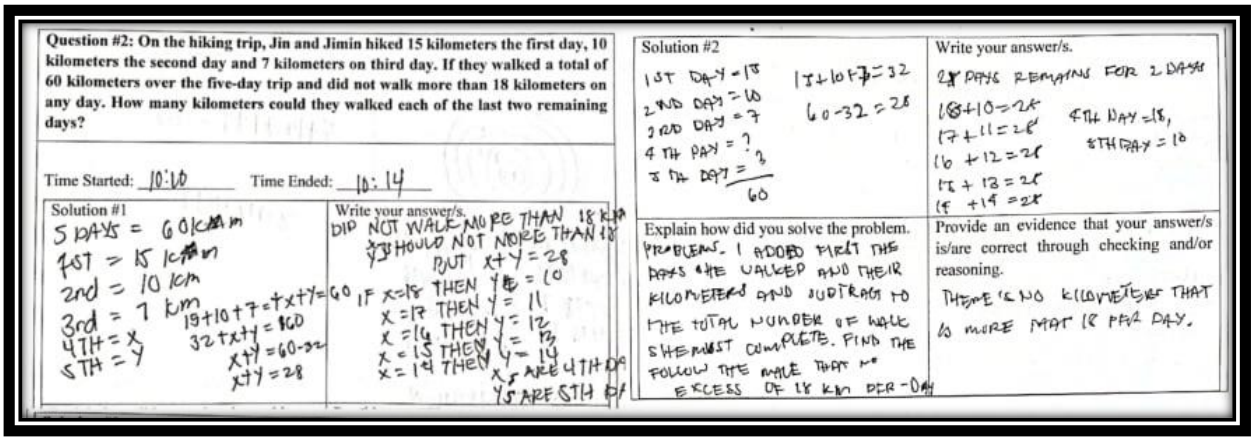
This finding affirms Brookes (2015) who found that students have difficulties providing two or more solutions since they lack motivation and interest to do it once they already arrived at the correct answer on their first solution. He added that flexibility can be fully maximized with the teachers' aid by exposing them to several strategies. In addition, Schukajlow and Krug (2014) concluded that developing students' ability to provide multiple solutions significantly improves mathematical knowledge. This infers that in order for students to develop a high level of flexibility focused on providing multiple solutions in a problem, educators should put emphasis on providing open-ended problems that allow students to apply multiple solutions throughout the instruction.

It can be further noted that one of the thirty respondents got 17-25 points interpreted as a high level of flexibility. This denotes that this student could apply more than one strategy leading to the correct procedure and answer who belong to the average level of mathematical achievement. Therefore, it can be deduced that having a high level of mathematical achievement does not always guarantee a high level of flexibility.

The solutions provided by Student 23 can be seen in figure 3.

Figure 3

Sample Solution of Student 23 in Problem 2



Student 23 belongs to the average level of mathematical achievement who provided more than one solution to this problem. She employed guess and check strategy by applying several computations while staying below the 18-kilometer limit specified by the given problem. Besides, she executed linear equation using x and y as variables. She created an equation such as 15+10+7+x+y=60 which led to x+y=28 that aided her to yield the correct values.

Table 5

Students' Scores in Procedural Fluency in Solving Open-Ended Problems as to Efficiency

Score	Efficiency		Verbal Interpretation
	f	%	
17-25	13	43.3	High
9-16	12	40.0	Moderate
0-8	5	16.7	Low
Total	30	100.0	

It can be gleaned from table 5 that in efficiency, most of the students in solving open-ended problems got 17-25 points, with a total of 13 students or 43.33% of the respondents. As a result, there are more students who have a high level of efficiency. This implies that students can accomplish the task with no errors in the shortest possible time (≤ 5 minutes).

As mentioned by Best (2020), students can immediately answer it because they possess the metacognitive ability to constantly identify the best appropriate techniques for the given challenge. This also demonstrates their flexibility in providing a single answer to a specific problem. In

conclusion, having a precise solution in mind for a certain problem enables students to solve problems quicker.

Table 6

Students' Overall Written Adaptive Reasoning

	Mean	SD	Verbal Interpretation
Written Adaptive Reasoning			
Explanation	12.77	6.34	Moderate
Justification	11.63	7.51	Moderate
Over-all Mean	**12.20**	**6.93**	**Moderate**

Table 6 displays that over-all students' written adaptive reasoning is at moderate level with a mean of 12.20 and a standard deviation of 6.93. It means that there are more students capable of explaining and justifying their answer in solving open-ended problems. Similarly, Asmida (2016) found out that the adaptive reasoning of the students was in the middle average only.

Table 7

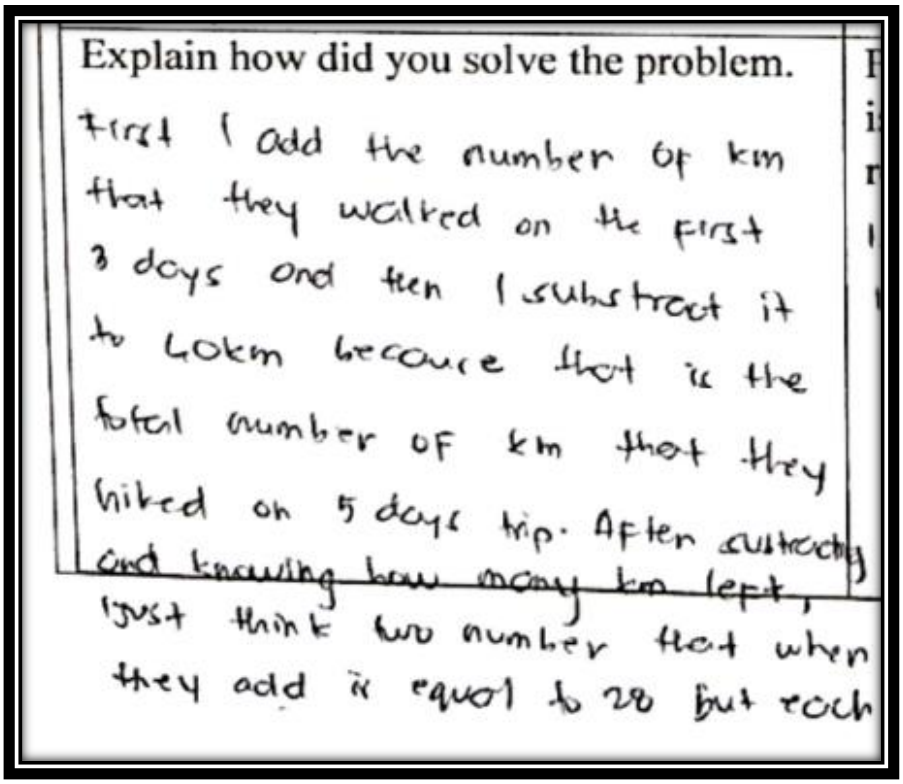
Students' Scores in Written Adaptive Reasoning in Solving Open-Ended Problems as to Explanation

Score	Explanation		Verbal Interpretation
	f	%	
17-25	9	30.0	High
9-16	14	46.7	Moderate
0-8	7	23.3	Low
Total	**30**	**100.0**	

Table 7 demonstrates that in explanation, most of the students in solving open-ended problems got 9-16 points, with a total of 14 students or 46.67% of the respondents. As a result, there are more students who possess a moderate level of explanation. This implies that students are capable of explaining how they arrived at their solution to each problem. However, it can be observed that they continued to make errors in terms of offering a thorough explanation in which they can incorporate other concepts essential to adequately explain their solution to a particular problem. To elaborate on this assertion, figure 4 shows the explanation of Student 26.

Figure 4

Sample Explanation of Student 26 in Problem 2



As shown in figure 4, the explanation provided by Student 26 was simply in sentence form kind of solution. She started her explanation by the solution she had provided and not by how she came up with that solution. Hence, it indicates that she has provided a clear explanation but not a detailed one.

This finding confirms the study of Bautista (2012) in which the mathematical explanation of the students is still not achieved since cognition in mathematics has a great impact on it. The students lacked cognition about the concepts and ideas in mathematics. Additionally, Andrews (2019) noted that students do not have the ability to provide an explanation in mathematics since they incapable to expand their comprehension of mathematical ideas, unable to construct rules for solving problems, and develop their mathematical communication. This suggests that explanation is critical in the process of mathematics learning. Thus, the teacher's continuous provision of tasks is deemed necessary to fully develop the students' explanation for their responses.

Table 8

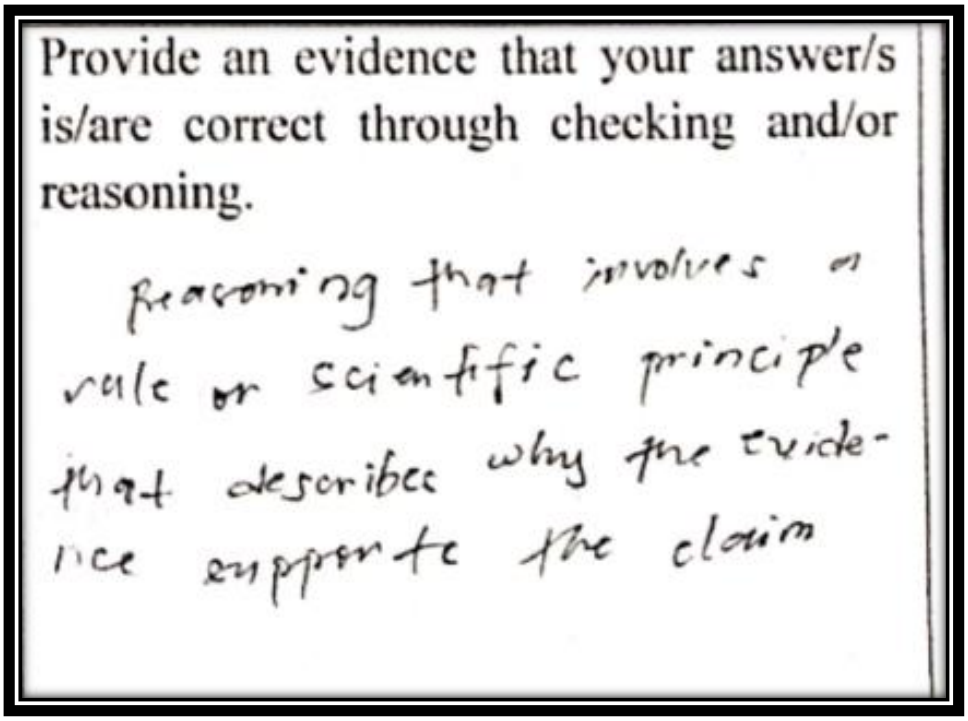
Students' Scores in Written Adaptive Reasoning in Open-Ended Problems as to Justification

Score	Justification		Verbal Interpretation
	f	%	
17-25	10	33.3	High
9-16	8	26.7	Moderate
0-8	12	40.0	Low
Total	**30**	**100.0**	

Based on the table, most of the students in solving open-ended problems got 0-8 points, with 12 students or 40% of the respondents. Consequently, there are more respondents who have a low level of justification. This reveals that students lack the ability to provide clear evidence that supports their answer, whether it is reasoning or checking.

Figure 5

Sample Justification of Student 4 in Problem 3



Evidently, figure 5 shows that Student 4 provides a statement for justification that is totally irrelevant in supporting her answer. Likewise, she demonstrated a piece of unclear evidence that

justifies her response to the given problem. Thus, Student 4 is regarded to have a low level of adaptive reasoning in terms of justification.

This is in consonant to the findings of Eko et al. (2018) in which they conducted a study to measure the level of justification ability of the students. From level 3 to 1, they found out that 66% of the students are in level 1, which means students provided unnecessary statements that are irrelevant to the given problem and displayed wrong mathematical concepts to justify their answers. A high level of justification is achieved when students comprehend the proper application of several mathematical concepts in defending their answers.

Table 9

Relationship between the Students' Procedural Fluency and Written Adaptive Reasoning in Solving Open-Ended Problems

Procedural Fluency	**Written Adaptive Reasoning**	
	Explanation	**Justification**
Accuracy	.712**	.687**
Flexibility	.497**	.494**
Efficiency	.722**	.702**

*** Correlation is significant at the 0.01 level (2-tailed)*

As shown in table 9, it was found that a high positive significant relationship exists between procedural fluency (in terms of accuracy, flexibility, and efficiency) and adaptive reasoning (in terms of explanation and justification) of the students. This finding indicates that the existence of high or low level in procedural fluency is linked to the occurrence of high or low level in adaptive reasoning. Furthermore, improving the students' adaptive reasoning can be highly associated with enhancing students' procedural fluency. Teachers should give paramount attention in intensifying the students' procedural fluency for it is highly correlated to their adaptive reasoning.

The result affirms the study of Mellony and Stott (2012) that procedural fluency and adaptive reasoning complement each other, and when it happens, a balance of knowledge and the connection between mathematical understanding and computational proficiency is required. This explains that students can provide strategies in solving the problems for they possess enough conceptual understanding. Higher level of mathematical proficiency is only obtained if the students totally acquire the lower level of mathematical proficiency.

Table 10

Difference on the Students' Procedural Fluency and Written Adaptive Reasoning

		Sum of Squares	df	Mean Square	f	Sig.
Procedural fluency accuracy	Between Groups	178.400	2	89.200	2.361	0.113
	Within Groups	1019.900	27	37.774		
	Total	1198.300	29			
flexibility	Between Groups	115.467	2	57.733	4.486	0.021
	Within Groups	347.500	27	12.870		
	Total	462.967	29			
efficiency	Between Groups	135.200	2	67.600	1.880	0.172
	Within Groups	971.100	27	35.967		
	Total	1106.300	29			
Adaptive reasoning explanation	Between Groups	140.867	2	70.433	1.853	0.176
	Within Groups	1026.500	27	38.019		
	Total	1167.367	29			
justification	Between Groups	198.867	2	99.433	1.867	0.174
	Within Groups	1438.100	27	53.263		
	Total	1636.967	29			

Table 10 reveals no significant difference in procedural fluency in terms of accuracy and efficiency between levels of mathematical achievement. Likewise, there is no significant difference in adaptive reasoning as to explanation and justification between levels of mathematical achievement. This can be inferred that regardless of students' mathematical achievement, it does not affect their performance to provide accurate answers with complete solutions in a shortest possible time. Moreover, their ability to provide an explanation and justification was not influenced by their mathematical achievement.

This is relevant to the study of Brezavšˇcek et al. (2020) that the students' gender and achievement do not affect their performance in mathematics. They found out that attitudes toward mathematics and how they value the importance of the subject greatly impact students' mathematical performance.

The result also shows a significant difference in procedural fluency in terms of flexibility between levels of mathematical achievement with p-value of 0.021. This displays that students' ability to provide two or more strategies in solving open-ended problems varies according to their mathematical achievement level.

Table 11

Post Hoc Test Analysis on Flexibility of the Students in Solving Open-Ended Problems

Dependent Variable			Mean Difference	Std. Error	Sig.	95 % Confidence Interval Lower Bound	Upper Bound
Flexibility	High	Average	-2.60	1.60	0.286	-6.76	1.56
		Low	2.20	1.60	0.403	-1.96	6.36
	Average	High	2.60	1.60	0.286	-1.56	6.76
		Low	4.80	1.60	0.021	0.64	8.96
	Low	High	-2.20	1.60	0.403	-6.36	1.96
		Average	-4.80*	1.60	0.021	-8.96	-0.64

**. The mean difference is significant at the 0.05 level*

In table 10, flexibility is the only component of procedural fluency which showed a significant positive difference when the students were grouped according to their level of mathematical achievement. Table 11 presents the Scheffe Post Hoc Test Analysis on the students' flexibility in solving open-ended problems.

The table displays that in procedural fluency in terms of flexibility, the scores of students' high level of mathematical achievement has no significant difference to average and low level of mathematically achievement students. This implies that students who belong to the high level of mathematical achievement have also experienced difficulty exhibiting at least two strategies in problem-solving. The majority of the students on a high level of mathematical achievement got the same score in the flexibility compared to the low and average level of students in mathematical achievement. It can be concluded that having a high level of mathematical achievement does not guarantee a huge difference in the score in the flexibility as compared to low and average students. This is in contrast to Kattou et al. (2012) that a positive correlation exists between mathematical creativity and ability. The result contradicts that mathematical ability impacts students' creativity in terms of fluency, flexibility and originality.

It is also shown that the average and low scores have a significant difference with a p-value of 0.021. It reveals that those students in the average level of mathematical achievement scored significantly higher than those at a low mathematical level. It can be noted that only one student achieved a high level of flexibility who belongs to an average level of mathematical achievement. As shown in table 3, three out of four students who got perfect scores in accuracy belong to an average level of mathematical achievement. It can be inferred that the same student exhibits both high level of flexibility and a perfect score in accuracy. With further association of the results to the personal profile of the respondent, this particular student is an officer of a mathematics club in

their school and an active participant of MTAP sessions every year before the pandemic. This concludes that attending mathematics session can assist students in developing multiple answers to a single problem resulting to much higher score on the flexibility scale. This supports Andrade and Fortes' (2019) results that students' exposure to a variety of training sessions and competitions increases their mathematical creativity which includes flexibility. Furthermore, the claim affirms the findings of Schukajlow and Krug (2014) which found positive results in terms of students' achievement, interest, and motivation, as well as their ability to provide multiple solution. Students who maintain a high-grade point average are more likely to provide multiple solutions. Likewise, Achmetli and Schukajlow (2019) claimed that the students' ability to construct multiple solutions while solving real-world problems is influenced by their achievement and interest before and during the procedures.

5. Conclusion

The main purpose of this study is to describe the level of students' procedural fluency and written adaptive reasoning skills. It was found out that students can provide accurate answers with complete solution in a quickest amount of time. However, they struggle in providing more than one solution in solving open-ended problems. The study also revealed that a highly positive significant relationship exists between students' procedural fluency as to accuracy, flexibility, efficiency, and written adaptive reasoning as to explanation, and justification. Consequently, there is a substantial difference in the students' procedural fluency in terms of flexibility according to mathematical achievement.

Students should be taught general mathematical problem-solving skills, but the precise strategies should be left for them to discover. Similarly, in classroom drills, teachers should allow students to choose any solution that they feel best suits the problem and their abilities, rather than enforcing one. It was also shown that they committed errors in their explanations and justifications. Therefore, activities for students should not solely focus on getting the correct procedures and answers. Adding tasks on explanation and justification must be implemented concurrently, as procedural fluency and written adaptive reasoning skills are inextricably linked. Further, it is recommended that teachers should expose students in open-ended problems and allow them to try and justify their own unique solutions irrespective of their mathematical achievement.

Given that only flexibility differs significantly among all components, future researchers may conduct a similar study with a larger sample size in multiple learning modalities. The sample

size of this study is limited due to students' internet access under the modular distance learning. A mixed-method research design is also recommended to better comprehend students' solutions and reasoning.

References

Achmetli, K., & Schukajlow, S. (2019). Multiple Solutions, The Experience of Competence, and Interest. *Affect and Mathematics Education. ICME-13 Monographs. Springer, Cham.* https://doi.org/10.1007/978-3-030-13761-8_3

Albab, A., & Wangguway, Y. (2020). Profile of Students' Creative and Innovative Thinking in Solving Open-ended Mathematics Problems about the Coffee Plantation. *Journal of Physics: Conference Series 1538*. https://doi.org/10.1088/1742-6596/1538/1/012071

Al-Balasi, R., & Barham, A. (2010). The effect of using multiple mathematical representations on the attainment of mathematical concepts among basic eighth grade students and their ability to solve verbal problems. *Dirasat: Educational Sciences(37)1,* 1-13.

Al-Shuaibi, Abdulghani. (2014). The Importance of Education.

Andrews, N., Ingram, J., & Pitt, A. (2019). *When students offer explanation without the teacher explicitly asking them to*. Retrieved from Educ Stud Math: http://doi.org/10.1007/s10649-018-9873-9.

Aprianti, C. (2014). Mathematical études: embedding opportunities for developing procedural fluency within rich mathematical contexts. *International Journal of Mathematical Education in Science and Technology, 44(5),* 765–774. https://doi.org/10.1080/0020739X.2013.770089

Arigbabu, A. (2013). Effects of framing and team individualised instructional strategies on senior secondary school students' attitudes toward mathematics. *Acta Didactica Napocensia, 6*(1), 1-22.

Asmida, A., Sugiatno, S., & Hartoyo, A. (2018). Developing The Mathematics Conceptual Understanding And Procedural Fluency Through Didactical Anticipatory Approach Equipped With Teaching Aids. *Journal of Education, Teaching and Learning*, 367. http://dx.doi.org/10.26737/jetl.v3i2.796

Awofala, A. (2017). Assessing Senior Secondary School Students' Mathematical Proficiency as Related to Gender and Performance in Mathematics in Nigeria. *International Jounal of*

Research in Education and Science (IJRES), 3(2), 488-502. https://doi.org/10.21890/ijres.327908

Bautista, R. G. (2012). The Students Procedural Fluency and Well-Written Explanation on Constructed Response Tasks in Physics. *Journal of Technology and Science Education, vol. 3*, 49-56. https://doi.org/10.3926/jotse.68

Bas, V. C. (1977). The Pragmatics of Explanation. *American Philosophical Quarterly Vol. 14, No. 2*, 143-150.

Belecina, Rene R. & Jose M. Ocampo, Jr. (2018). "Effecting Change on Students' Critical Thinking in Problem Solving" in *EDUCARE: International Journal for Educational Studies*, Volume 10(2), February, pp.109-118. Bandung, Indonesia and BS Begawan, Brunei Darussalam: Minda Masagi Press owned by ASPENSI and BRIMAN Institute, ISSN 1979-7877. https://doi.org/10.2121/edu-ijes.v10i2.949

Bernard, M., & Chotimah, C. (2018). Improve student mathematical reasoning with open-ended approach using VBA for powerpoint. *AIP Conference Proceeding*, 1-2. https://doi.org/10.1063/1.5054417

Brezavšˇcek, A., Jerebic, J., Rus, G., & Žnidarši ˇc, A. (2020). Factors Influencing Mathematics Achievement of University Students of Social Sciences. *emathematics*, 50-62. https://doi.org/10.3390/math8122134

Carey, E.; Hill, F.; Devine, A.; Sz″ ucs, D. (2017). The Modified Abbreviated Math Anxiety Scale: A Valid and Reliable Instrument for Use with Children. *Front. Psychol*. 8.

Dewey, J. (1938) *Experience and Education*. New York: Collier Books.

Dewi, K., Waluya, S. B., Rachmad, & Firmasari, S. (2020). Adaptive reasoning and procedural fluency in three-dimensional. *Journal of Physics: Conference Series 1511*.

Eko, Y., Prabawanto, S., & Jupri, A. (2018). The role of writing justification in mathematics concept: the case of trigonometry. *Journal of Physics: Conference Series 1097*. https://doi.org/10.1088/1742-6596/1097/1/012146

Fortes, E.C., & Andrade, R.R. (2019). Mathematical Creativity in Solving Non-Routine Problems. The Normal Lights, 13(1), 108 – 135

Foster, C. (2017). Developing Mathematical Fluency: Comparing Exercises. *Educ Stud Math (2018) 97:121–141*. https://doi.org/10.1007/s10649-017-9788-x

Gerber, B., Cavallo, A., & Marek, E. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education Volume 23, 2001 - Issue 5,* 535-549. https://doi.org/10.1080/095006901750162892

Glass, A., & Kang, M. (2020). Fewer students are benefiting from doing their homework: an eleven-year study. *Educattional Psychology, DOI: 10.1080/01443410.2020.1802645*.

Hadiastuti, D., Soedjoko, E., & Mulyono. (2019). Analysis of Mathematical Representation Ability Based on Students' Thinking Style in Solving Open-Ended Problems. *Unnes Journaal of Mathematics Education 8 (3) 2019: 195-201*. https://doi.org/10.15294/ujme.v8i3.34189

Inayah, S., Septian, A., & Fazrianto, R. (2020). Student Procedural Fluency in Numerical Method Subjects. *Desimal: Jurnal Matematika Vol 3 No 1 (2020),* 53-64. https://doi.org/10.24042/djm.v3i1.5316

K-12 Mathematics Education Curriculum Guide Mathematics (2016). Department of Education.

Kattuo, M., Kontoyianni, K., Pitta-Pantazi, D., & Christou, C. (2012). Connecting mathematical creativity to mathematical ability. *ZDM Mathematics Education.* doi:10.1007/s11858-012-0467-1

Kilpatrick, J., Swafford, J., & Findell, a. B. (2001). *Adding It Up: Helping Children Learn Mathematics.* Washington, DC: National Academy Press.

Klavir, R., & Hershkovitz, S. (2008). Teaching and Evaluating 'Open-Ended' Problems.

Kwon, O., Park, J., & Park, J. (2016). Cultivating divergent thinking in mathematics through an open-ended approach. *Asia Pacific Education Review, 7(1), 51–61*. https://doi.org/10.1007/BF03036784

Laswadi, Kusumah, Y., Darwis, S., & Afgani, J. (2016). Developing Conceptual Understanding and Procedural Fluency for Junior High School Students Through Model-Facilitated Learning. *European Journal of Science and Mathematics Education Vol. 4, No. 1, 2016, 67-74*.

Mellony, G., & Stott, G. (2012). *Conceptualising Procedural Fluency as a Spectum of Proficiency.* South Africa: Rhodes University.

Milos, C. (2014). Open-Ended Tasks and Questions in Mathematics.

Muin, A., Hanifahand, S., & Diwidian, F. (2018). The effect of creative problem solving on students' mathematical. *Journal of Physics: Conference Series 948*, 1.

Mushtaq, F. (2013). Mathematics achievements among high school students: Gender difference in math achievements. *Karlstads Universitet*, 112-123.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all.* Reston VA: Author.

Nold, H. (2017). Using Critical Thinking Teaching Methods to Increase Student Success: An Action Research Project. *International Journal of Teaching and Learning in Higher Education*, 17-32. doi:https://files.eric.ed.gov/fulltext/EJ1136016.pdf

Noureen, G., Awan, R.-U.-N., & Irfan, I. (2015). Assessment of Students' Problem-Solving Proficiency in Mathematics at Grade VI. *Pakistan Journal of Education*, 2.

Pentang, J. T., Ibañez, E. D., Subia, G. S., Domingo, J. G., Gamit, A. M., & Pascual, L. E. (2021). Problem-solving performance and skills of prospective elementary teachers in Northern Philippines. *Journal of Hunan University Natural Sciences, 48*(1), 122-132.

Programme for International Student Assessment (PISA). (2018) Retrieved on 4 December 2019 from http://www.pisa.oecd.org/

Rizki, H., Frentika, D., & Wijaya, A. (2017). Exploring students' adaptive reasoning skills and van Hiele levels of geometric thinking: A case study in geometry. *Journal of Physics: Conf. Series 983*. https://doi.org/10.1088/1742-6596/983/1/012148

Rodriguez, C., & Bonner, E. (2018). The Impact of Teacher Questioning and Open-ended Problems on Mathematical Communication. *The Journal of Teacher Action Research*.

Samuelsson, J. (2010). The Impact of Teaching Approaches on Students' Mathematical Proficiency in Sweden. *International Electronic Journal of Mathematics Education Vol.5, No.2*. https://doi.org/10.29333/iejme/250

Schukajlow, S., & Krug, A. (2014). Do Multiple Solutions Matter? Prompting Multiple Solutions, Interest, Competence, and Autonomy. *Journal for Research in Mathematics Education Vol.45 No.4*, 497-533. https://doi.org/10.5951/jresematheduc.45.4.0497

Stupel, M., & Ben-Chaim, D. (2013). One problem, multiple solution: How multiple proofs can connect several areas of mathematics. *Far East Journal of Mathematical Education*, *11*(2), 129.

Syukriani, A., Juniati, D., & Siswono, T. (2017). Investigating adaptive reasoning and strategic competence: Difference male and female. *AIP Conference Proceedings 1867, 020033 (2017)*. https://doi.org/10.1063/1.4994436

Thomas, S. (2018). *Practical reasoning in natural language (3rd ed).* Englewood Cliffs: NJ:Prentice-Hall.

Yuniatri, Y., Kusumah, Y., Suryadi, D., & Kartasasma, B. (2017). The Effectiveness of Open-Ended Problems Based Analytic-Synthetic Learning on the Mathematical Creative Thinking Ability of Pre-Service Elementary School Teachers. *International Electronic Journal of Mathematics Education*, 655-666. https://doi.org/10.29333/iejme/640

Wijaya, A. (2018). How do Open-Ended Problems Promote Mathematical Creativity? A Reflection of Bare Mathematics Problem and Contextual Problem. *IOP Conf. Series: Journal of Physics: Conf. Series 983 (2018)*. https://doi.org/10.1088/1742-6596/983/1/012114

International Journal of Science, Technology, Engineering and Mathematics
Volume 2 Issue 1 March 2022
DOI: https://doi.org/10.53378/352873

Problem-Based Learning Approach in Developing Mathematical Skills

[1]Jerlyn B. Arbo & [2]Delon A. Ching

Abstract

Many students perceive mathematics as an abstract because it involves development of problem-solving skills. This study employed problem-based learning (PBL) approach to make simple strategies in the teaching and learning process. This study used descriptive-correlational research method. For the school year 2020-2021, 40 Grade 9 students from Calamba City Science High School took the validated adapted-modified three-item examination and answered a researcher-made survey questionnaire. The results showed no significant relationship between respondents' perceptions of problem-based learning in terms of authentic problem, collaboration, developing expertise, and authentic assessment, and their problem-solving performance in terms of conceptualizing the problem, devising a strategy, implementing the strategy, and reflecting on the solution. The study affirms that the teacher's expertise in implementing the PBL approach is critical. Further results imply that the learning abilities and techniques of the students have significant impact to the teaching-learning process.

Keywords: *students' perception, authentic problems, collaboration, developing expertise, authenthic assessment, problem-solving skills*

Received: August 31, 2021 **Revised:** February 15, 2022 **Accepted:** February 23, 2022

Suggested Citation: Arbo, J.B. & Ching, D.A. (2022). Problem-Based Learning Approach in Developing Mathematical Skills. *International Journal of Science, Technology, Engineering and Mathematics*, Volume 2 Issue 1, pp. 26 - 47. DOI: https://doi.org/10.53378/352873

About the authors:

[1]Undergraduate Student at Laguuna State Polytechnic University, San Pablo City Campus.

[2]Instructor I, Laguna State Polytechnic University- San Pablo City Campus

** This paper is a finalist in the IIARI Research Competition (IRC) – 2021 Category 2 – Undergraduate*

1. Introduction

Mathematics is widely seen as an abstract idea to be studied (Fritz, 2019). Most of the times, many people believe that "it is okay" not to be like math because "not everyone can be a math genius" (Rattan, 2012). These concepts of the subject lead to the bad interest and fear of the students in learning mathematics. With the preconceived notion, students emerge disengaged, uninterested and demotivated to face and study numerical subjects.

Studies show that the students' perception of mathematics as a difficult subject posed extreme consequences resulting to failure and dropping out from school (Fhloinn et al., 2014). Many students develop a mental anguish on mathematics which hamper their performance. The extreme consequences of the wrong perception seriously challenge the students in most of the subjects with numerical contents. While most of the students associate mathematics as irrelevant to their personal and professional life, many scientific and technological sectors rely heavily on mathematics. According to Li and Scoenfeld (2019), learning mathematics opens more opportunities for students when finding jobs and chasing after their careers. Without math, the world would misplace the key component to its composition (Schuster, 2016).

Mathematicians have always considered problem solving as the center of the discipline because without problem solving there is no mathematics (Klerlein & Hervey, 2017). Problem-solving has been at the center of educational theory (Pólya, 1945) which illustrates mathematics as not similar to sports. For the students to understand mathematics, they must try to do it. It means to be able to solve mathematical problems, they must try to solve it (O'Brien et al., 2011).

In learning mathematics, the use of real-world problem solving can assist people to be familiar with managing and handling daily occurrences. In the same way, the use of authentic problems in the teaching and learning can build students' real world problems solving skills. This is the exact concept of the problem-based learning (PBL). The PBL is an instructional style that provides students with the tools to solve problems using real-world scenarios. It begins with an unstructured challenge for students to solve. Afterwards, students identify information they already know from the data they need to learn in order to find a solution after investigating the situation. Students as learners, educators as guides, and the problem as the setting are the three main components of this method (Carrió et al., 2011).

The importance of problem solving in mathematics education was induced this study, which sought to investigate the correlation between students' problem-solving skills and their use

of the PBL approach. The four principles of problem solving by Polya (1945), which includes understand and explore the problem, find a strategy, use the strategy to solve the problem and look back and reflect on the solution as well as the four elements of PBL Approach in classroom including authentic problems, collaboration, developing expertise, and authentic assessment were considered. The study specifically looked into the relationship between the four elements of PBL and the learners' problem-solving skills.

2. Literature Review

2.1 Problem-Based Learning Approach

PBL is an effective heuristic teaching method that enlightens the development of student autonomy through collaboration between students and lecturers, as well as among students. It is a student-centered instructional model that places learning in a real-world problem-solving environment, and it has been used as an experimental teaching tool in medical schools and some technology courses for decades (Yin et al., 2021). The four elements of PBL include authentic problems, collaboration, developing expertise and authentic assessment (Mills & Tuesday, 2017).

Authentic Problems. According to Mills and Tuesday (2017), within the real world, students experience problems that are complex, not well characterized, and need a clear solution and approach. They ought to be able to identify and apply distinctive methodologies to solve these problems. Be that as it may, problem solving abilities do not essentially create actually; they have to be an unequivocally instructed in a way that can be exchanged across multiple settings and contexts.

Collaboration. The autonomous evolution of students can only be accomplished by heuristic instruction. Heuristic teaching entails active intellectual interaction with the aim of improving students' fundamental skills. PBL is an effective heuristic teaching method that enlightens the development of student autonomy through collaboration between students and lecturers, as well as among students. With a focus on cooperation, PBL provides a period of identifying the problem statement, independent analysis, group discussion, and presentation of a problem-solving plan, as well as reflection (Yin et al., 2021).

Developing Expertise. Expertise is a process of continuous reinvestment of relevant discipline-based expertise and skills, according to Sammamish Collaboration (2015), to build increasingly higher levels of knowledge and problem solving skills. Learning expertise includes

awareness and skills in content, practice in education and learning, and access to the social and cultural capital that exists within a culture.

Authentic assessment. Authentic assessment seeks to emulate the tasks and performance expectations usually found in the world of work and has been found to have a positive effect on student learning, autonomy, motivation, self-regulation and metacognition; highly employability-related skills. The lack of conceptualization of the term authentic evaluation that is sufficient to inform evaluation design at the individual course level may be one challenge (Koçyiğit, 2011).

2.2 Problem- Solving Skills

As stated by Vettleson (2010), "i*n the discipline of mathematics, the use of problem solving skills has been extremely important and highly influential. Problem solving is the foundation of all mathematical and scientific discoveries.*" There is a very large impact in the fields of mathematics utilizing problem solving skills. According to Dahar (2011), "*the ability to solve a problem is basically the main purpose of the educational process*." It is really important to solve math problems so that the general objective of teaching mathematics, even as the center of mathematics, is more important than the method and, as a result, the emphasis of school mathematics and aims to help improve mathematical thought. The four principles of problem solving includes understand and explore the problem, find a strategy, use the strategy to solve the problem and look back and reflect on the solution.

Understanding the Problem. According to Vula and Kurshunmlia (2015), the problem-solving difficulties of students can be solved by different methods and practices. The comprehension of the problem, particularly the terms that are used in some problems, is a particular part of solving word problems. Not knowing such words poses the difficulties of solving word problems, allowing sufficient mathematical operations to be misapplied. In addition, if learners understand the definition of vocabulary, they can easily learn mathematical concepts and improve the requisite math skills.

Find a Strategy. According to Polya (1945), one of the most important factors in solving a problem is determining the right strategy. Estimation, systematic list, finding similarities, drawing diagrams, writing equations or inequalities are among the most problematic problem-solving methods, allowing easy use of solutions to similar problems with retrospection and judging by tables (Ersoy & Güner, 2014). In this regard, the focus is placed on coping with cognitive, emotional and behavioral problem-solving skills in order to assess the most suitable approach and collect knowledge about the problems (Tüysüz, 2013).

Applying the Strategy. At this level, teachers help learners acquire 4C skills through networking and design thinking (critical thinking, innovation, communication, and collaboration). This, at the same time, helps learners to collaboratively accomplish goals (Zsuzsanna et al., 2020). According to Lein et al. (2020), intervention results for schema-based transfer instruction were greater than those for schema-based instruction. The use of schema wherever possible, demonstrating that mathematical word-problem-solving approaches are often appropriate for students with learning disabilities and/or mathematical difficulties.

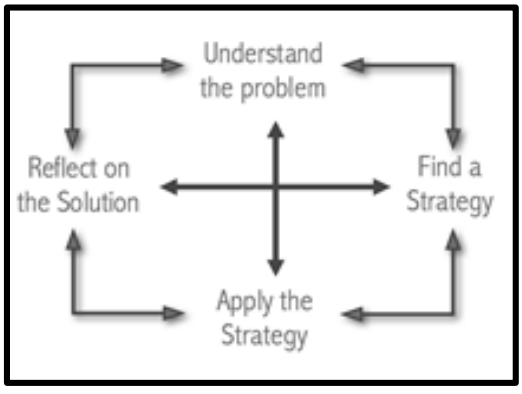
Reflecting on the Solution. Hung and Seokhee (2018) assert that any idea or solution gained by students through independent internalization will remain in the long term as an active part of their knowledge and mathematical arguing. Evaluation, consideration, and feedback help all problem solving methods. The solution does not work for everyone, may cause new issues, or may be so efficient. None of that is possible without taking the time to analyze and, if necessary, change the success of the solution generated in the problem solving model (Smart, 2020).

2.3 Theoretical Framework

According to Klerlein and Hervey (2017), a successful instructor models positive problem-solving behaviors for their students. Their questions are intended to assist children in solving problems using a range of techniques and resources. Without a strategy in mind, students sometimes want to begin. The instructor gives students some structure to start the problem without telling them exactly what to do, through necessary questions. The following four problem-solving principles by Pólya (1945) help teachers help their students.

Figure 1

Pólya's principles of problem-solving



In accordance with this model, there are considerations for using PBL. Rather than teaching relevant material and subsequently having students apply the knowledge to solve problems, the

problem is presented first. PBL assignments can be short, or they can take a whole semester and be more active. Students generally must: examine and define the problem; explore what they already know about underlying issues related to it; determine what they need to learn and where they can acquire the information and tools necessary to solve the problem; evaluate possible ways to solve the problem; solve the problem and report on their findings (Nilson, 2010).

PBL is fundamentally based on constructivist assumptions about learning. Constructivism is defined by five tenets concerning knowledge, meaning making, and learning (Jonassen, 1991). Constructivism in education has its roots in epistemology, which is a theory of knowledge in philosophy that is concerned with the logical categories of knowledge and their justification (Steffe & Gale, 2012). According to Zhang (2012), two major types of constructivism have been valued in educational fields over the years of evolution of constructivism. They are cognitive constructivism, which is based on Jean Piaget's learning theory (1972), and social constructivism, which is based on Vygotsky's theory that is part of scaffolding learning theory (1978).

3. Methodology

This study utilized descriptive-correlational research design. This study adapted a descriptive and correlational research design to examined the relationship of the implementation of a problem-based learning approach and the students' performance towards their problem solving skills. Descriptive research design is a scientific method that entails examining and describing a subject's behavior without affecting it in any manner. The major purpose of a descriptive correlational study is to characterize links between variables rather than attempting to establish a causal link (Katzukov, 2020).

The respondents were composed of 40 Grade 9 students from Calamba City Science High School in the Philippines. The random sampling was used to give each student an equal probability of being chosen. According to Thomas (2020), each member of the population has an exact equal chance of being chosen using this sampling method.

The research instruments involved the researcher-created exam that assessed the pupils' problem-solving skills as well as a series of survey questionnaire checklists designed to evaluate the pupils' perceptions of the problem-based learning strategy. The examination, a three-item test utilized the principle of *problem solving* and that was guided with designated Most Essential Learning Competency (MELC). This tool examined the impact of the implementation of the problem-based learning approach as well as the application of the different steps while answering

an authentic problem. On the other hand, the survey questionnaire contained the 4 key elements of problem-based learning approach. It is a 5-point Likert scale developed to measure and to explore the problem solving skills of the students through the implementation of the teaching approach.

The instruments passed the metric for determining internal consistency before it was actually used. The Cronbach's alpha is a metric for determining the internal consistency or dependability of a set of scale or test items. The reliability refers to how constant it is in measuring a notion measured through Cronbach's alpha (Goforth, 2015). It accepts numbers from 0 to 1, with 1 denoting total inner precision. In addition, Cronbach alpha levels of less than 0.7 indicate adequate inner accuracy (Taber, 2017). The instrument's test of internal consistency is presented in Table 1.

Table 1

Cronbach's alpha

Subscale	No. of Items	Cronbach's Alpha
Problem-based Learning Approach		
Authentic Problem	5	.953
Collaboration	9	.792
Developing Expertise	5	.838
Authentic Assessment	5	.910

The table reveals that the Cronbach's Alpha result for all sub-variables is greater than .70, indicating that the given items in each of the independent variable's components are all internally consistent from acceptable to very good level with .80 or greater.

Descriptive statistics was used to describe the problem-based learning of Grade 9 students with authentic problems, collaborate, developing expertise, academic discourse and authentic assessment on the variables and descriptors set in the study. Frequency and percentages were used in response to the presentation of descriptive data on the examination on problem-solving skills assessment. Spearman's Rho correlation was used to test the significant relationship between the problem-based learning approach and the students' problem-solving skills.

4. Findings and Discussion

Table 2 shows the students' perception towards the authentic problems element of the PBL. It has an overall mean of 4.41 with an SD of 0.65 and an interpretation of 'Agree.' This indicates

an evident majority of students were exposed to problems that led into more than one viable solution or strategy for a solution that enhanced the students' ability to learn. Results also show that the highest mean of 4.55 among the indicators (*helps me be familiarized on provided word problems*), equates to an assumption that exposure to authentic problems in PBL helps the student be more familiarized with provided problems and they are more likely to answer word problems if they already encountered the given topic. On the other hand, the lowest mean of 4.33 (*aids me to relate condition in the problem to real life contexts*) means an evident indication that if the students are aware of the given problem they become more engage in answering and finding the solution.

Table 2

Students' Perception towards Authentic Problems Element of PBL

Indicators	Mean	SD	Interpretation
Being exposed to Problem Based Approach…			
1. helps me be familiarized on provided word problems.	4.55	0.55	Strongly Agree
2. makes me competent to solve the word problems given.	4.40	0.67	Agree
3. aids me to relate condition in the problem to real life contexts.	4.33	0.73	Agree
4. provides me detailed evidences of authentic situations from the problems.	4.38	0.70	Agree
5. helps me associate learnt concept to real practice.	4.40	0.59	Agree
OVERALL	**4.41**	**0.65**	**Agree**

Legend: *4.50-5.00 Strongly Agree/Highly Evident, 3.50-4.49 Agree/Evident, 2.50-3.49 Moderately Agree/Moderately Evident, 1.50-2.49 Disagree/Less Evident, 1.00-1.49 Strongly Disagree/Not Evident*

The results are parallel to the exact explanation of Gurat (2018) that problems situated in real-life context become more authentic, which students tend to be more appreciative to understand the lesson. Similarly, the results affirm the findings of Lehtinen et al. (2017) on the importance of repeated practice leading to the mastery of the skills.

Table 3 shows the students' perception towards the collaboration element of the PBL. The overall mean of 4.33 implies that when students are exposed to PBL, teachers can help the students improve their communication and relationship-building abilities. In this case, the constant collaboration with the teacher produces effective results in solving a problem. The results further show that when the students are exposed to PBL, it makes them aware of adapting ideas and strategies in solving problems (4.55) and they are able to get the idea they want to know (4.50).

Table 3

Students' Perception towards Collaboration Element of PBL

Indicators	Mean	SD	Interpretation
Being exposed to Problem Based Approach…			
1. makes me be aware of adapting ideas and strategies in solving problems from my instructor.	4.55	0.64	Strongly Agree
2. I am now able to solve word problems through the interaction with my teacher.	4.38	0.59	Agree
3. I am able to get the idea I want to know through discussing it with my teacher.	4.50	0.60	Strongly Agree
4. My learning ability is developed through work collaboration with my teacher.	4.40	0.71	Agree
5. I can present information, findings and arguments clearly, concisely and logically in the class.	4.13	0.72	Agree
6. I am more confident in engaging in the course discussion.	4.18	0.71	Agree
7. I can develop ideas and uses style appropriate to the purpose and learning tasks.	4.45	0.68	Agree
8. I can clearly address alternatives, opinions and perspectives with confidence and logic.	4.25	0.59	Agree
9. I can speak clearly and participates actively in class discussion.	4.18	0.71	Agree
OVERALL	**4.33**	**0.66**	**Agree**

Legend: *4.50-5.00 Strongly Agree/Highly Evident, 3.50-4.49 Agree/Evident, 2.50-3.49 Moderately Agree/Moderately Evident, 1.50-2.49 Disagree/Less Evident, 1.00-1.49 Strongly Disagree/Not Evident*

Through the PBL approach, teacher provides guidance to the students on the necessary steps students need to consider in accomplishing the solutions. This result coincides with the findings of Kojo et al. (2018) and Hähkiöniemi and Francisco (2019). Similarly, the collaboration between the teacher and the students in answering Mathematical problems create positive working connections as explained by Ching (2020) and Arthur et al. (2017).

Table 4 shows the students' perception towards the developing expertise element of the PBL. The overall mean of 4.57 (SD=0.56) with an interpretation of 'Strongly Agree' means that exposure to PBL helps students develop their expertise in solving problems through the development of the necessary skills. Among the indicators, the PBL helps students enhance their ability to learn has the highest mean of 4.73 (SD=0.45) while the PBL ensures mastery of the most essential learning competency got the lowest mean of 4.38 (SD=0.70). The results are congruent

to the explanation of Hendriana et al. (2018) that problem-based or scenario-based approaches help students develop the skills to become experts in Mathematics.

Table 4

Students' Perception towards Developing Expertise Element of PBL

Indicators	Mean	SD	Interpretation
Being exposed to Problem Based Approach…			
1. helps me enhance my ability to learn.	4.73	0.45	Strongly Agree
2. enhances my critical thinking skills.	4.68	0.53	Strongly Agree
3. improves my strategy in learning.	4.58	0.55	Strongly Agree
4. helps me to enhance my computational skills.	4.48	0.55	Agree
5. ensures mastery of the most essential learning competency.	4.38	0.70	Agree
OVERALL	**4.57**	**0.56**	**Strongly Agree**

Legend: *4.50-5.00 Strongly Agree/Highly Evident, 3.50-4.49 Agree/Evident, 2.50-3.49 Moderately Agree/Moderately Evident, 1.50-2.49 Disagree/Less Evident, 1.00-1.49 Strongly Disagree/Not Evident*

Table 5 shows the students' perception towards the authentic assessment element of the PBL. The overall mean of 4.48 (SD=0.68) explains the ability of the students to complete tasks in addition to the quality of their work. This is the exact assertion of Koh (2017) that authentic assessment in Mathematics problem solving encourages students to demonstrate their deep comprehension, higher-order thinking, and sophisticated problem solving which would enable learners to understand fully the lessons. The results further show that authentic assessments are linked to reference for future endeavors (M=4.53; SD=0.60). As the PBL requires that the problems in the assessment given to the students are always expressed in real-life applications, the results suggest that students are highly appreciative of the worded problems given to them.

Table 5

Students' Perception towards Authentic Assessment Element of PBL

Indicators	Mean	SD	Interpretation
Being exposed to Problem Based Approach…			
1. provides learning assessments that establishes my creativity, conciseness and logical ability.	4.45	0.71	Agree
2. allows me to experience answering assessment with high-quality of questions that engage us to solve correctly.	4.40	0.84	Agree
3. helps me think and use different strategies in solving math problems.	4.50	0.60	Strongly Agree
4. provides assessment that are linked to reference for future endeavors.	4.53	0.60	Strongly Agree
5. provides a variety of assessments for me to enhance my problem solving skills.	4.50	0.64	Strongly Agree
OVERALL	**4.48**	**0.68**	**Agree**

Legend: *4.50-5.00 Strongly Agree/Highly Evident, 3.50-4.49 Agree/Evident, 2.50-3.49 Moderately Agree/Moderately Evident, 1.50-2.49 Disagree/Less Evident, 1.00-1.49 Strongly Disagree/Not Evident*

Table 6
Students' Performance under "Understanding the Problem" Principle

Scores	Frequency	Percent	Interpretation
17-21	27	67.5	Advanced
12-16	10	25.0	Proficient
6-11	2	5.0	Developing
0-5	1	2.5	Beginning

Mean= 17.65, SD= 4.16, VI= Advanced
Legend: *17-21 Advanced, 12-16 Proficient, 6-11 Developing, 0-5 Beginning*

Table 6 shows the students' performance in the researcher-made tests reflecting their understanding of the problem. The majority of the students at 67.5% performed in the advanced level while the 25% are in the proficient level. However, there are still three students in the lower levels; 5% under developing and 2.5% under the beginning level.

Since most of the students performed at an advanced level wherein the steps in problem-solving were followed, this implies that students read the problem carefully, analyzed what is the given and what is needed in the given problem. By reading the problem efficiently, it is evident among students who reached the advanced level that they were able to identify effectively what is being asked which guides them to think of potential ways how to solve the problem. This coincides with the explanation of Gurat (2018) that students were able to identify the details needed in the solution as a process of understanding the problem.

Under the advanced level of skill in the principle of understanding the problem, the example in figure 2 clearly demonstrates that the MELC was met. The student clearly enumerates the given in the problem and stated what was being questioned.

Figure 2

Sample Student Response with Highest Score in Understanding the Problem

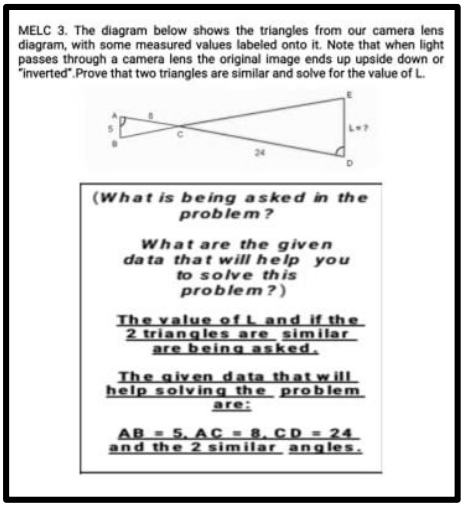


Figure 3 illustrates that student's response demonstrates a poor understanding of the topic and its broader context. This indicates a lack of capacity to demonstrate the key ideas required for a smooth and comprehensive flow of answers and strategies into the following stages of problem-solving.

Figure 3

Sample Student Response with Lowest Score in Understanding the Problem

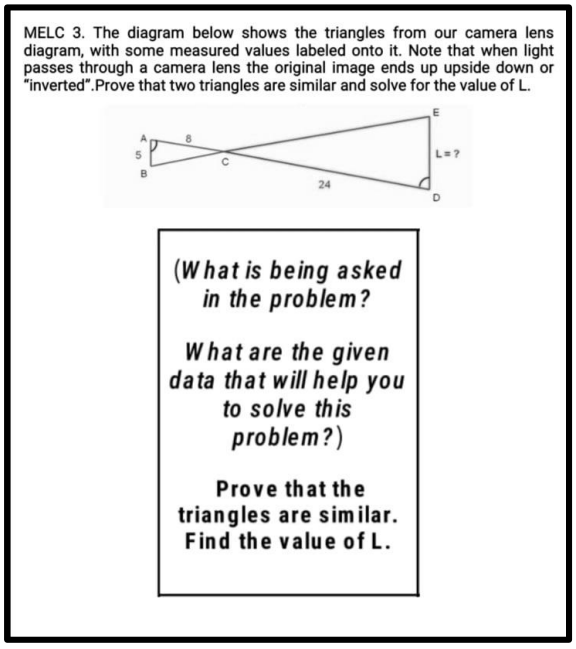


Table 7

Students' Performance under "Finding a Strategy" Principle

Scores	Frequency	Percent	Interpretation
17-21	10	25.0	Advanced
12-16	9	22.5	Proficient
6-11	20	50.0	Developing
0-5	1	2.5	Beginning

Mean= 13.08, SD= 4.70, VI= Proficient
Legend: *17-21 Advanced, 12-16 Proficient, 6-11 Developing, 0-5 Beginning*

As observed in table 7, most of the students are in the developing level (50%) when it comes to finding a strategy to be employed in answering a problem in Mathematics. It means that the students are on progress to device an appropriate plan as to operation to be used and the appropriate way in order to solve the problem. Even though they were able to identify what is being asked and the details needed in the solution for the understanding stage, students find it difficult to plan effectively the necessary steps in solving the problem. However, there are 25% in

the advanced level and 22.5% in the proficient level. There is still one student (2.5%) in the beginning level. The results are similar to the findings of Utomo and Syarifah (2021) that students in Mathematics find it difficult to strategize in answering worded problems.

Figure 4

Sample response in Finding Strategy with the highest score

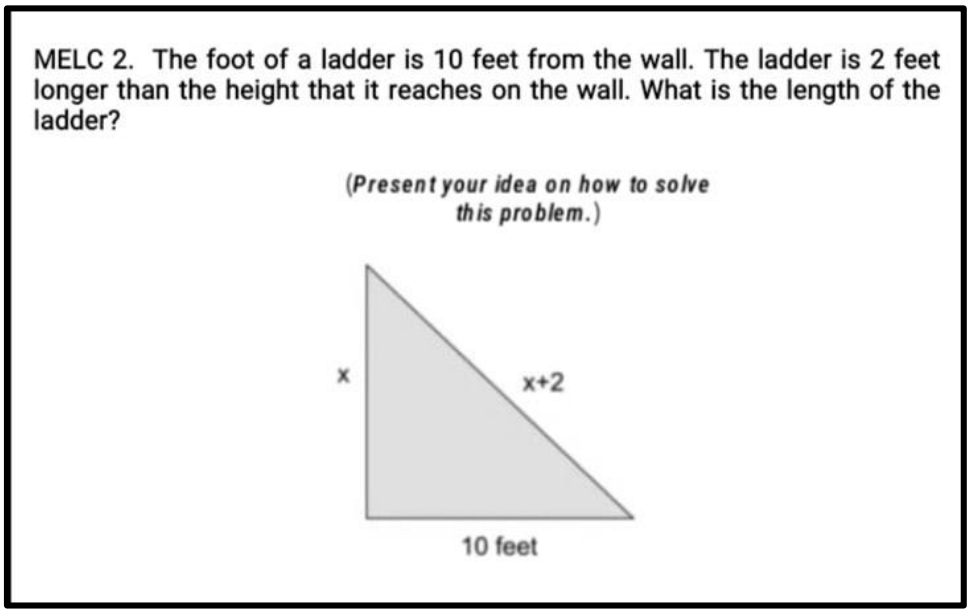
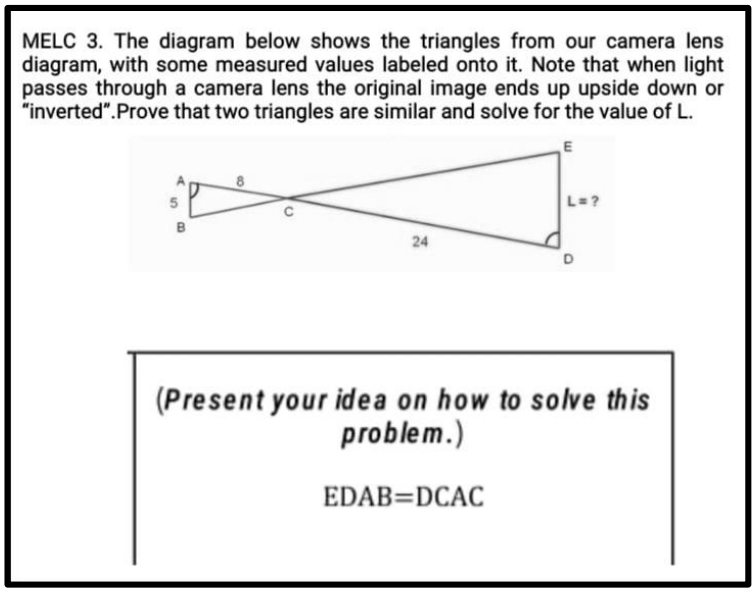


Figure 4 shows an example showing student's strategy with the highest score. Based on student's solution, there is an insufficient description of what should be done after seeing a visual representation of the method. In addition, this implies the need of a broaden and exact explanation of how and what strategy should be utilized for the given problem. This implies that the student can identify a viable strategy especially when keywords are provided and plan is straight forward.

Figure 5

Sample response in Finding Strategy with lowest score



As shown in figure 5, the answer of student is in the beginning level that the student chooses a method without respect to the circumstances in the problem and instead rely on basic phrases or keywords in the problem. It shows a small amount of representation that the two triangles are similar, but it is still insufficient.

Table 8

Students' Performance under "Application of the Strategy" Principle

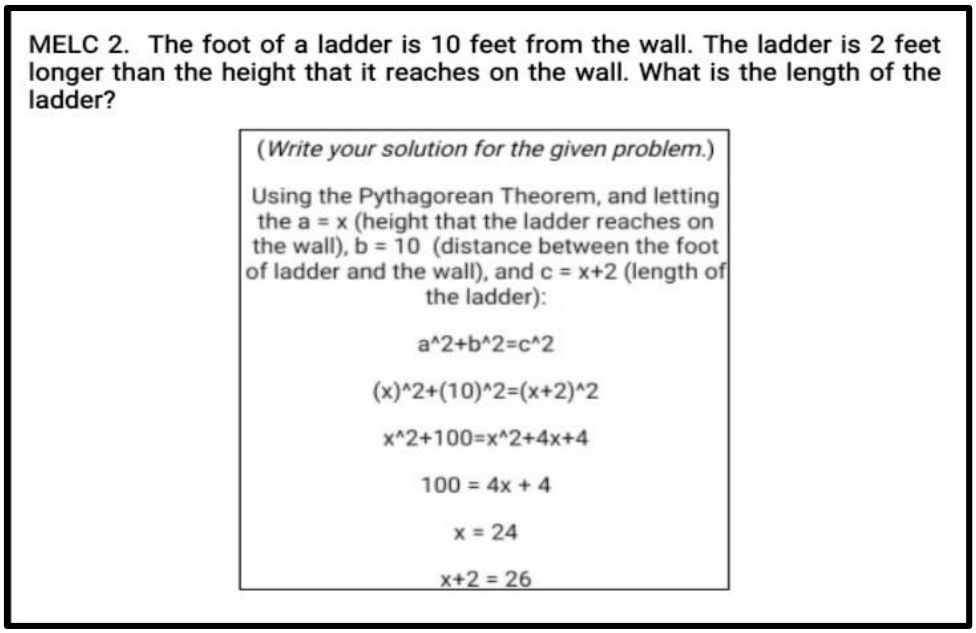
Scores	Frequency	Percent	Interpretation
17-21	28	70.0	Advanced
12-16	9	22.5	Proficient
6-11	3	7.5	Developing
0-5	-	-	Beginning

Mean= 17.55, SD= 3.62, VI= Advanced
Legend: *17-21 Advanced, 12-16 Proficient, 6-11 Developing, 0-5 Beginning*

It is depicted in table 8 that most of the students (70%) are in the advanced level in applying the strategy. This shows the students ability for proper execution with complete and clearer flow of the solution. Students were able to apply what they have learned with their teacher in executing an appropriate solution. In this case, students followed the demonstrated solution of the teacher and applied those in the problems that they encountered. This is similar to the explanation of Ng and Dindyal (2016) that students in the advanced level create a pattern to execute the same flow with the same problem-set to be given by the teacher.

Figure 6

Sample response in Applying the Strategy with the highest score



For the highest score shown in figure 6, the result indicates that the learner understands the need for multiple paths to complete the strategy. The ability to reason or think is completely developed. The student was able to carry out plans including multiple processes or steps (including inverse processes) and reliably identify at least one correct or feasible (often creative) solution (s).

Figure 7

Sample response in Applying the Strategy with the lowest score

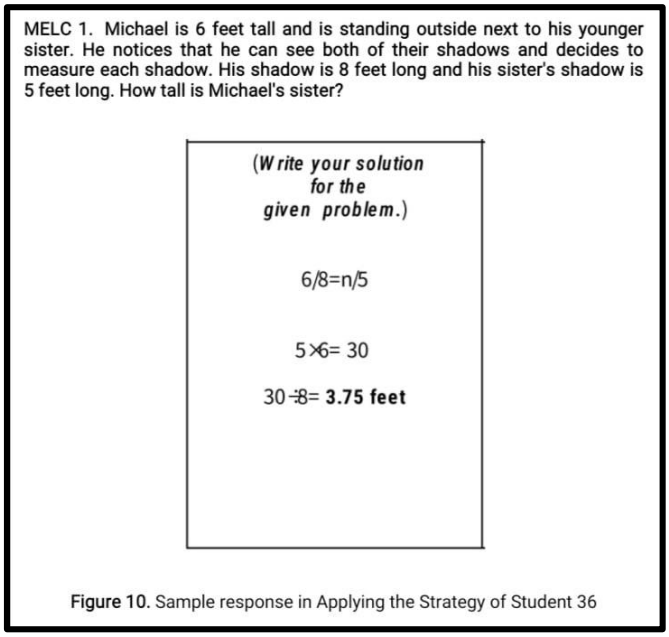


Figure 7 shows a sample with lowest score where the offered solution is incomplete. The learner does not display well-developed thought or reasoning in carrying out the plan at this level of presenting ideas. The learning competency that must be demonstrated by the student is partially met.

Table 9

Students' Performance under "Reflect on the Solution" Principle

Scores	Frequency	Percent	Interpretation
17-21	12	30.0	Advanced
12-16	5	12.5	Proficient
6-11	20	50.0	Developing
0-5	3	7.5	Beginning

Mean= 12.35, SD= 5.48, VI= Proficient
Legend: *17-21 Advanced, 12-16 Proficient, 6-11 Developing, 0-5 Beginning*

Table 9 shows that most of the respondents are in the developing level (50%) when it comes to the principle of reflecting on the solution while there are only 30% of the students in the

advanced and 12.5% in the proficient levels. The results proved that students can solve problems and have a right answer but failed to show and reflect on their solutions. In this scenario, students lack the ability to analyze and reflect on whether they arrived at the correct answer or not. As suggested by Nurkaeti (2018), there is a need to check or verify whether the process is correct by means of substituting the derived answer to the Mathematical equation if it will equate to the process.

Figure 8

Sample response in Reflection on the Solution with the highest score

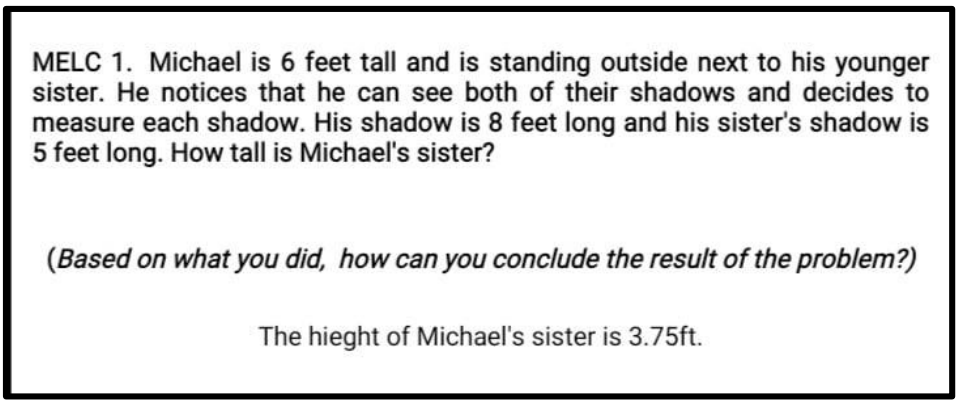


Figure 8 shows an example on reflection. It is noted that the student's response is in the developing stage. This level of skill indicates that the student identified partially correct solutions with some reasoning and a limited ability to check their answer and, if so, is unable to make adjustments in their planning or execution stages.

Figure 9

Sample response in Reflection on the Solution with the lowest score

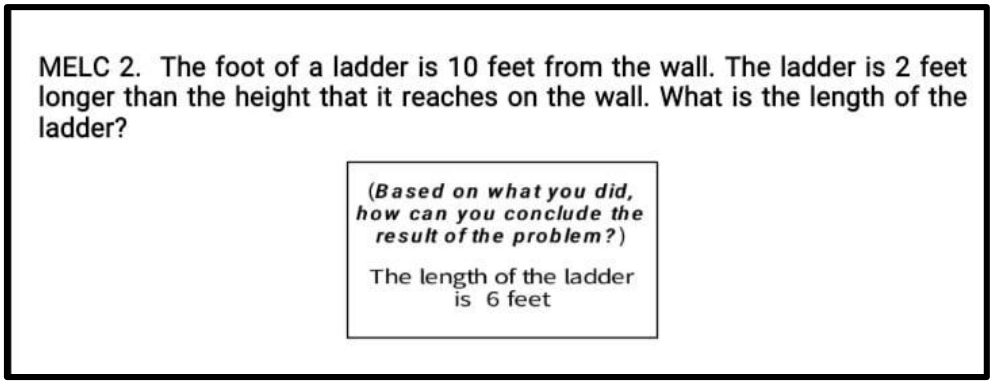


Figure 9 shows a wrong response with respect to reflection. The fact that the student gave a wrong response is the first factor that contributes to the low score. This means that,

despite the fact that there are four stages, the student does not examine or synthesize the outcomes, implying that solutions are rarely checked. With little reasoning, the student also recognizes unworkable solutions.

Table 10
Relationship between PBL Approach and Problem Solving Skills

Problem-Based Learning	Problem Solving Skills			
	Understanding the Problem	Find a Strategy	Applying the Strategy	Reflecting on the Solution
Authentic problems	0.091	0.158	-0.003	0.135
Collaboration	0.113	0.277	0.050	0.211
Developing Expertise	0.092	0.234	0.064	0.237
Authentic Assessment	-0.020	0.066	-0.102	-0.026

Table 10 shows the test of relationship between the PBL approach and problem solving skills of the students. Overall, the result shows no significant relationship between the use of the PBL approach and the students' performance in problem solving. This is the exact opposite of Kadir et al. (2016) that PBL approach has been widely used in various disciplines which improved students' soft skills.

In addition, there is a weak positive correlation for some sub-variable of the PBL and problem-solving principles. There is limited evidence that when students are exposed to authentic problems, it will help students to process well the problem in order to find meaning from it. This is also in contrast to the discussion given by Bevan and Capraro (2021), that when the problems in Mathematics are expressed with real-life implications, the more that they can understand the context and importance of the concepts.

There is also a weak positive relationship between the collaboration of the teacher and students to ensure success in solving Mathematical problems. It only means that there is no enough evidence to tell that the efforts of the teacher in assisting the students in explaining the solutions help them understand the process of solving it. There might be other factors that help students to successfully arrive at the correct answer considering that they are at home during modular learning modality. This explains the findings of Kalogeropoulos et al. (2021) that students also collaborate with parents, classmates, and others whom they seek help while learning at home.

Similarly, there is a weak positive relationship between the mechanism of developing expertise in PBL and the skills in problem solving. There is no enough evidence that when the students become experts in mathematics through PBL it indicates that they can successfully understand the problem, device and apply a plan and reflect on the final answers. As Mazana et al. (2019) explained that other factors help them develop their ability to execute solving the problems such as positive attitude and eagerness to learn.

Finally, being exposed to authentic assessments in PBL has a weak relationship in developing the skills in problem-solving. The connections of the assessment contents to real-life contexts may not only be the indication to help students understand the problems given by the teachers. Since students were oriented already by the examples provided by the teacher, students treat it as a solution pattern to directly solve the problem while ignoring its connection to a real-life situation (Ulu, 2017).

5. Conclusion

This study sought to determine the relationship between PBL approach and the problem-solving skills of Grade 9 students. The findings showed no correlation between respondents' perceptions of PBL and their problem-solving performance. Although the majority of the results in terms of learners' perceptions of the implementation of the PBL approach are agreed upon, it was depicted that there is no enough evidence to tell that PBL helps in developing the Mathematical skills of the students in solving problems. This indicates that being exposed to a PBL strategy has minimal influence on the problem-solving skills developed by learners. Furthermore, there is limited evidence that when students are exposed to authentic challenges, they interact, build knowledge, and authentically evaluate themselves, all of which would aid them in problem-solving when it comes to the four principles given.

This study hypothesizes that the teacher's mastery of the technique's implementation is crucial. It does, however, imply that the students' learning abilities and techniques have a substantial impact on the teaching-learning process. Accordingly, full collaboration and a positive attitude from both students and the teachers in the teaching and learning process are highly suggested in order to get a beneficial result from the application of this method. Future studies can use an experimental research design.

References

Ali, S. S. (2019). Problem based learning: A student-centered approach. *English language teaching*, *12*(5), 73-78.

Arthur, C., Badertscher, E., Goldenberg, P., Moeller, B., McLeod, M., Nikula, J., & Reed, K. (2017). Strategies to Improve All Students' Mathematics Learning and Achievement. *Education Development Center, Inc.*

Bevan, D., & Capraro, M. M. (2021). Posing creative problems: A study of elementary students' mathematics understanding. *International Electronic Journal of Mathematics Education*, *16*(3), em0654.

Borwick, J., (2013). A3 thinking: understand problems before trying to solve them.

Carrió, M., Larramona, P., Baños, J. E., & Pérez, J. (2011). The effectiveness of the hybrid problem-based learning approach in the teaching of biology: a comparison with lecture-based learning. *Journal of Biological Education*, *45*(4), 229-235.

Ching, D. A. (2020). Two Cubed Approach in a Collaborative Classroom and the Enhanced Algebra and Social Skills of College Students. *Universal Journal of Educational Research*, *8*(10), 4920-4930.

Dahar, R. W. (2011). Teori-teori belajar dan pembelajaran. *Jakarta: Erlangga*, *136*, 141.

Dostál, J. (2015). Theory of problem solving. *Procedia-Social and Behavioral Sciences*, *174*, 2798-2805.

Ersoy, E., & Guner, P. (2014). Mathematics teaching and mathematical thinking. *Journal of Research in Education and Teaching*, *3*(2), 102-112.

Fritz, A., Haase, V. G., & Rasanen, P. (2019). International handbook of mathematical learning difficulties. *Cham, Switzerland: Springer*.

Goforth, C. (2015). Using and interpreting Cronbach's alpha. *University of Virginia Library*, *15*.

Gurat, M. G. (2018). Mathematical Problem-Solving Strategies among Student Teachers. *Journal on Efficiency and Responsibility in Education and Science*, *11*(3), 53-64.

Hähkiöniemi, M., & Francisco, J. (2019). Teacher guidance in mathematical problem-solving lessons: Insights from two professional development programs. In *Problem solving in mathematics instruction and teacher professional development* (pp. 279-296). Springer, Cham.

Hendriana, H., Johanto, T., & Sumarmo, U. (2018). The Role of Problem-Based Learning to Improve Students' Mathematical Problem-Solving Ability and Self Confidence. *Journal on Mathematics Education*, *9*(2), 291-300.

Ibañez, E. D., Subia, G. S., Medrano-Allas, S., Mendoza, J. I., & Mina, J. C. (2021). Modern Mathematics Applications: Solutions to Challenges Encountered in Teaching Spiral Progression in Mathematics 7. *Open Access Library Journal*, *8*, e7623.

Kalogeropoulos, P., Roche, A., Russo, J., Vats, S., & Russo, T. (2021). Learning Mathematics from Home during COVID-19: Insights from Two Inquiry-Focussed Primary Schools. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(5).

Klerlein, K., & Hervey, S. (2019). Mathematics as a complex problem-solving activity.

Koçyiğit, S. (2011). *Otantik Görev Odaklı Yapılandırmacı Yaklaşımın öğretmen Ydaylarının Başarılarına, Derse Karşı Tutumlarına ve Problem çözme Becerilerine Etkisi* (Doctoral dissertation, Marmara Universitesi (Turkey)).

Kojo, A., Laine, A., & Näveri, L. (2018). How did you solve it?–Teachers' approaches to guiding mathematics problem solving. *LUMAT: International Journal on Math, Science and Technology Education*, *6*(1), 22-40.

Lehtinen, E., Hannula-Sormunen, M., McMullen, J., & Gruber, H. (2017). Cultivating mathematical skills: From drill-and-practice to deliberate practice. *ZDM*, *49*(4), 625-636.

Lein, A. E., Jitendra, A. K., & Harwell, M. R. (2020). Effectiveness of mathematical word problem solving interventions for students with learning disabilities and/or mathematics difficulties: A meta-analysis. *Journal of Educational Psychology*, *112*(7), 1388.

Li, Y., & Schoenfeld, A. H. (2019). Problematizing teaching and learning mathematics as "given" in STEM education. *International Journal of STEM Education*, *6*(1), 1-13.

Mazana, Y. M., Suero Montero, C., & Olifage, C. R. (2019). Investigating students' attitude towards learning mathematics.

Mills, K., & Kim, H. (2017). Teaching problem solving: Let students get 'stuck'and 'unstuck.'Brookings.

Ng, L. K., & Dindyal, J. (2016). Examples in the teaching of mathematics: teachers' perceptions. In *Developing 21st Century Competencies In The Mathematics Classroom: Yearbook 2016, Association Of Mathematics Educators* (pp. 189-211).

Ní Fhloinn, E., Fitzmaurice, O., Mac an Bhaird, C., & O'Sullivan, C. (2014). Student perception of the impact of mathematics support in higher education. *International Journal of Mathematical Education in Science and Technology*, *45*(7), 953-967.

Nilson, L. B. (2010). *Teaching at its best: A research-based resource for college instructors* (2nd ed.). San Francisco, CA: Jossey-Bass.

Nurkaeti, N. (2018). Polya's strategy: an analysis of mathematical problem solving difficulty in 5th grade elementary school. *Edu Humanities| Journal of Basic Education Cibiru Campus*, *10*(2), 140.

Özreçberoğlu, N., & Çağanağa, Ç. K. (2018). Making it count: Strategies for improving problem-solving skills in mathematics for students and teachers' classroom management. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1253-1261.

Pagander, L., & Read, J. (2014). Is Problem-Based Learning (PBL) An Effective Teaching Method?: A Study Based on Existing Research.

Pham, H., & Cho, S. (2018). Nurturing Mathematical Creativity in Schools. *Turkish Journal of Giftedness & Education*, *8*(1).

Rattan, A., Good, C., & Dweck, C. S. (2012). "It's ok—Not everyone can be good at math": Instructors with an entity theory comfort (and demotivate) students. *Journal of experimental social psychology*, *48*(3), 731-737.

Sammamish Collaborative (2015), 7 Key Elements of Problem-Based Learning (PBL) Classrooms https://bsd405.org/wp-content/uploads/sites/33/2015/08/Key-Elements-SHS-Final-July2015.pdf

Schuster, B. (2016), Importance of Mathematics, LaPorte High School, Indiana in US

Smart, J., (2020). How to improve your problem solving skills and build effective problem solving strategies https://www.sessionlab.com/blog/problem-solving-skills-and-strategies/

Stangor, C., & Walinga, J. (2019). 3.5 psychologists use descriptive, correlational, and experimental research designs to understand behaviour. *Introduction to Psychology*.

Steffe, L. P., & Gale, J. (2012). Assisting construction: The role of the teacher in assisting the learner's construction of preexisting cultural knowledge. In *Constructivism in education* (pp. 451-464). Routledge.

Su, H. F. H., Ricci, F. A., & Mnatsakanian, M. (2016). Mathematical teaching strategies: Pathways to critical thinking and metacognition. *International Journal of Research in Education and Science*, *2*(1), 190-200.

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability*, *12*(23), 10113.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, *48*(6), 1273-1296.

Tüysüz, C. (2013). Üstün Yetenekli Öğrencilerin Problem Çözme Becerisine Yönelik Üstbiliş Düzeylerinin Belirlenmesi/Determination of Gifted Students' Metacognition Level about Problem Solving Skills. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *10*(21), 157-166.

Ulu, M. (2017). The Effect of Reading Comprehension and Problem Solving Strategies on Classifying Elementary 4th Grade Students with High and Low Problem Solving Success. *Journal of Education and Training Studies*, *5*(6), 44-63.

Utomo, D. P., & Syarifah, D. L. (2021). Examining mathematical representation to solve problems in trends in mathematics and science study: Voices from Indonesian secondary school students. *International Journal of Education in Mathematics, Science and Technology (IJEMST)*, *5*(3).

Vettleson Jr, L. (2010). Problem Solving Based Instruction in the High School Mathematics Classroom,—Bemidji. *Minnesota, USA*.

Vula, E., & Kurshumlia, R. (2015). Mathematics word problem solving through collaborative action research. *Journal of Teacher Action Research*, *1*(2), 34-46.

Yin, Q., Guo, C., Dong, C., & Wang, T. (2021). May problem-based learning get higher evaluation from student?. *International Journal of Crowd Science*.

International Journal of Science, Technology, Engineering and Mathematics
Volume 2 Issue 1 March 2022
DOI: https://doi.org/10.53378/352874

Street Food's Microbiological Load and Vendors' Food Hygiene and Safety Practices Compliance in the Schools of Cebu City

[1]Ritchelle W. Origenes, [2]Rowena Espinosa-Gelisanga & [3]Sheila B. Alturas

Abstract

This study utilized descriptive statistics to assess the microbiological load and the vendor's compliance with eight international codes of food safety and hygiene principles among 51 randomly chosen street food vendors in the north and south district schools of Cebu City. Samples of *kwekwek* and two kinds of dipping sauce were collected and sent to the Department of Science and Technology (DOST) laboratory. The compliance levels were rated based on a yes/no scale calculated from the compliance scores of every food hygiene and safety principle. The E. coli count reported from the laboratory tests showed that every food sample from all locations suggested fecal contamination. Results of the compliance scores showed that food vendors from the selected study areas have very good compliance with the use of protective clothing, provision of water at vending point, cleanliness of fingernails, and use of appropriate kitchenware for dishing out food to consumers but very poor compliance with the use of head covering, obtaining a business permit and sanitary/health card. Although the study revealed a marginally good overall compliance score, the result could imply no possible association between the vendors' food safety and hygiene practices and the presence of E. coli in the food samples tested.

Keywords: *Street Foods, Food Consumption, Food Security, Food Safety and Hygiene, Microbiological Assessment, E. coli*

Received: January 13, 2022 **Revised:** February 4, 2022 **Accepted:** March 3, 2022

Suggested Citation: Origenes, R.W., Espinosa-Gelisanga, R. & Alturas, S.B. (2022). Street Food's Microbiological Load and Vendors' Food Hygiene and Safety Practices Compliance in the Schools of Cebu City. *International Journal of Science, Technology, Engineering and Mathematics*, Volume 2 Issue 1, pp. 48 - 60. DOI: https://doi.org/10.53378/352874

About the authors:

[1]Corresponding author. Master Teacher, Mabolo National High School, Cebu City, Philippines

[2]Faculty, Griffin Foundation School District, Arizona, USA

[3]Faculty, Holy Name University, Tagbilaran City, Philippines

1. Introduction

Street vended foods are not only liked by the public for their tasty flavors, but also because of their cheap price, availability, and accessibility. These are beverages or drinks and ready-to-eat food prepared and sold in the streets and other public places (Ekanem, 1998; FAO, 1997). Like its Southeast Asian neighbors, Philippine's street foods are meant to ease hunger. Because the Filipinos have a knack for combining flavors and making the most of any ingredients at their table, they have developed sumptuous quick bites that have a variety of flavors (Fernando, 2021). Just like the consumers of street foods from other countries, Filipinos are increasingly fascinated by traditional or ethnic foods (Winarno & Allain, 1991). These street foods are also liked by the school children because they are not just delicious but also cheap and easy to find. School children are found to be the important consumers of street food and most of them eat street food every day (Poster, 1983; Chauliac et al., 1994; Webb & Hyatt, 1998). The hygienic and nutritional quality of this street food gave satisfaction to most of the school children but the opinion of their parents differ (Neffati, 2004).

In spite of the importance of nutrition value, taste, and affordability of the street food, they are mostly criticized because vendors do not normally follow personal, food and environmental safety and hygiene (Selepe et al., 2017; Joglekar, 2013). Without proper and safe personal and food hygiene, these foods could be contaminated by microorganisms like species of Salmonella, Bacillus, E. coli, among others, which can cause serious food infections. Some microorganisms produce toxins in foods eventually leading to food-borne illnesses mainly due to the unhygienic practices while preparing and serving food (Chakravarthy, 2003). Street vended foods can cause foodborne diseases such as diarrhea and food poisoning (Sofos, 2013). The leading cause of death in children is a diarrheal disease and it is causing more than 1,400 childhood deaths per day worldwide and about 526,000 childhood deaths per year (WHO, 2015). Though there is a dearth of data focusing on the health risks of street food in school areas, still school children are at risk of these foodborne diseases.

An incident related to health risks and hazards of street foods happened in CARAGA Region, Philippines where almost 2000 school children were affected by food poisoning due to eating street food. These children experienced stomach cramps, diarrhea, vomiting, and headaches (Llacuna, 2015). Another related incident happened in Calasiao, Pangasinan where thirty-three grade school children were hospitalized for food poisoning after eating "*isaw*" burgers sold by a

vendor outside the school (Cardinoza, 2017). However, there are no reported incidents of food poisoning due to street food and no available information on the health risks of street food to school children in Cebu City. But the DepEd Region VII reminded the schools to advise the parents to make sure that their children buy only from the school canteen. The DepEd Region VII also reminded the schools to regulate vendors operating in the vicinity (Cabahug, 2017).

Regulating street vendors operating in the streets and in the school is a must to avoid such incidents. In order to prevent possible food contamination, proper food handling and storage for better sanitary and hygienic control must be observed (Barcelon et. al, 2015). Although there is an existing act to strengthen the food safety regulatory system in the country (Republic Act No. 10611), it is obvious that the government does not have full management of the local food and food products. The missing pieces of the management are close monitoring and evaluation of the foods sold locally and a strict food safety regulatory system. The incidents of food poisoning and lack of management of the government of the street foods are issues concerning the health safety of the school children and the public. For instance, Rustia et al. (2021) cited the identified gap in the concept of food safety in the street food industry and ambulant vendors in the country was generally influenced by the practice of a vendor compromising food safety for business profits. The food safety practices such as display of sanitary permits, health certificate IDs, washing of raw fruits with potable water, washing hands thoroughly with soap and water, and use of chlorine solutions for utensils were not properly demonstrated by the street food vendors (Rustia et al., 2017). With this food handling issues, Van Olem and Olmogues (2021) recommend local government constant monitoring on these street food vendors to strengthen food safety practices as these vendors serve different types of consumers.

Given the vast impact of the street foods on the health of school children, this study assessed the microbiological load of the street food in the North and South District Schools of Cebu City. It also assessed the food safety and hygiene practices of the street food vendors. Since there is no available information on the correlation between the microbiological load and existing local and international code of practices in handling food, this study evaluated the possible association of the microbiological load of the street food and the vendors' food handling practices.

2. Methodology

2.1. Research Design

This study employed a cross-sectional analytical study and descriptive-correlational research design. For the cross-section analytical study, the food samples were bought from the street food stalls in the north and south districts of Cebu City and analyzed in the laboratory for bacteriological contamination by *Escherichia coli*. For the descriptive-correlational research, the street food vendors' food hygiene and safety practices compliance was investigated through the characteristics of a given population.

2.2. Respondents and Sampling Technique

The study utilized a stratified random sampling method in selecting its respondents. Stratified sampling is where the population is divided into strata (or subgroups) and a random sample is taken from each subgroup (Taherdoost, 2016). The researchers randomly selected 2 street food stalls in the north district of Cebu City near the schools and the other 2 street food stalls in the south district also near the schools. The study also randomly selected 26 street food vendors in the north district and 25 street food vendors in the south to answer the survey questionnaire on food hygiene and safety practices compliance.

2.3. Microbiological Analysis

Samples of Filipino street food like *kwek-kwek*, which is a deep-fried hard-boiled quail egg covered with orange batter and two types of dipping sauce were collected directly from different street food stalls located outside the top four most populated public elementary schools in the northern and southern zones of Cebu City. These food samples were collected aseptically in pre-sterile polybags and sterile bottles, kept in an ice-box, and labeled accordingly. Samples were then transferred to the Department of Science and Technology (DOST) laboratory and were stored at 4°C until being analyzed following Bacteriological Analytical Manual 8th ed. Online 1998 Rev., Chapter 4: *Escherichia coli* and the *Coliform Bacteria.* The microbiological analysis performed in the DOST Laboratory was Total Coliform Count. A colony-forming unit per gram (cfu/g) was used as the measuring unit of the presence of E. coli in this study. A level of <3 cfu/g has been given as the satisfactory criteria for this organism. Levels exceeding 100 cfu/g are unacceptable and indicate a level of contamination (Food Standards Australia New Zealand, 2001).

2.4. Food Hygiene and Safety Practices Compliance Assessment

For the food hygiene and safety practices compliance assessment, 51 randomly selected street food vendors from the northern and southern zones of the Cebu City division were asked to answer the survey questionnaire. This survey questionnaire assessed the vendors' compliance on selected food hygiene and safety principles from the recommended international code of practice, general principles of food hygiene developed by the World Health Organization which include, (1) the use of protective clothing such as apron or vest (2) provision of water and food vending site (3) cleanliness of fingernails (4) dishing out of food with appropriate kitchenware (5) protection of food from flies and dust (6) head covering (7) sanitary permit and (8) business permit. The assessment of the vendors' compliance to the selected food hygiene and safety principles was based on a yes/no scale (Monney et al., 2014) which assigns a compliance level to a particular principle based on a computed compliance score (C-score) as shown in Table 1. The Overall C-scores (OC- scores) were then computed separately for each location based on the C-scores for the food hygiene and safety principles.

Table 1

Compliance scores and corresponding compliance levels

Compliance Score	Compliance Level	Description
0.0 – 0.20	Very Poor	0% - 20% of food vendors comply with a particular food hygiene and safety principle
0.20 – 0.40	Poor	20% - 40% of food vendors comply with a particular food hygiene and safety principle
0.40 – 0.60	Average	40% - 60% of food vendors comply with a particular food hygiene and safety principle
0.60 – 0.80	Good	60 % - 80% of food vendors comply with a particular food hygiene and safety principle
0.80 – 1.00	Very good	80% - 100% of food vendors comply with a particular food hygiene and safety principle

Source: Adapted from Rajan & Aruna, (2017)

2.5. Statistical Technique

The data gathered were analyzed using descriptive statistics such as frequencies and percentages.

2.6. Ethical Considerations

In the conduct of the research, the ethical considerations including the risk-benefit assessment, content, comprehension, and documentation of risk-benefit assessment, authorization to access private information, confidentiality procedures, and conflict of interest were considered.

Risk-Benefit Assessment. The possible problem involved in the conduct of this research was the research respondents' lack of cooperation. The benefits of this research were for the improvement of the food hygiene and sanitation practices among street food vendors. The objectives of the study were properly communicated to the respondents.

Authorization to Access to Private Information. The study obtained the authorization to access to private information once the informed consent letter was signed and permission was granted by the respondents. The study assured that data were gathered with authority and permission.

Confidentiality Procedure. The study assured confidentiality of data and information gathered. The respondents were oriented that the study is for research and academic purposes only. No personal or business information of the respondents were disclosed during and after the data gathering.

Conflict of Interests. The conflict of interest is declared before the administration of the questionnaire. The respondents were informed that they can withdraw from answering the survey at any time should they feel uncomfortable answering any question or they have any conflicts answering any questions.

3. Results and Discussion

3.1.Microbiological Analysis

Table 2

E.Coli Count Of Different Food Samples

Food Samples	Location A	Location B	Location C	Location D
Dipping Sauce: Vinegar	<1 x 10 cfu/g	<1 x 10 cfu/g	<1 x 10 cfu/g	<1 x 10 cfu/g
Dipping Sauce: Sweet	<1 x 10 cfu/g	<1 x 10 cfu/g	<1 x 10 cfu/g	<1 x 10 cfu/g
Kwek-kwek	<1 x 10 cfu/g	<1 x 10 cfu/g	<1 x 10 cfu/g	2 x 10 cfu/g

Table 2 shows the E. coli count in the samples from the street food vendors. The laboratory tests showed every food sample from all locations with *E. coli* count. This is similar to the study of Rajan and Aruna, (2017) on street foods in India with minimal but still showed in the results. This is an implication of fecal contamination in the food samples. This is also congruent to the studies conducted in Brazil and Kenya that the presence of E. coli indicates fecal contamination (Kothe et al., 2016; Kariuki et al., 2017).

Ideally, E. coli should not be detected, and as such a level of <3 cfu/g has been given as the satisfactory criteria for this organism. Levels exceeding 100 cfu/g are unacceptable and indicate a level of contamination which may have introduced pathogens or that pathogens, if present in the food prior to processing, may have survived (Food Standards Australia New Zealand, 2001). The presence of *E. coli* in the sample street food is not desirable because it signifies poor hygienic practices which have led to not adequate heat treatment and contamination. Ideally, *E. coli* should not be detected in ready-to-eat foods. Even though some *E. coli* are safe and harmless, *Enterohaemorrhagic E. coli* (EHEC) can produce one or more toxins and a specific serovar O157:H7 has been related to the haemolytic uraemic syndrome, thrombotic thrombocytopaenic purpura, and haemorrhagic coliti. Enterotoxigenic *E. coli* (ETEC) is also associated or related to traveler's diarrhea (Madueke, et al., 2014).

Food Hygiene and Safety Practices Compliance Assessment

Table 3

Vendors' Compliance Scores in 8 Food Hygiene and Safety Practices

Food Hygiene and Safety Practices	Responses (%)		Compliance Score
	Yes	No	
the use of protective clothing such as apron or vest	82	19.6	0.82
provision of water and food vending site	92.2	7.8	0.92
cleanliness of finger nails	96.1	3.9	0.96
dishing out of food with appropriate kitchenware	100	0	1
protection of food from flies and dust	92.2	7.8	0.92
head covering	31.4	68.6	0.31
Business permit	5.9	94.1	0.06
Sanitary card	5.9	94.1	0.06

Table 3 showed that food vendors from the selected study areas have a very good compliance with the use of protective clothing (C-score= 0.82), provision of water at vending point (C-score = 0.92), cleanliness of fingernails (C-score = 0.96), and use of appropriate kitchenware for dishing out food to consumers (C-score = 1). This is very important because FAO/WHO on "Basic texts on Food Hygiene" (2009) necessitates that food vendors should have access to clean water for washing utensils and hands regularly as the fingernails and hands could serve as harbourages for pathogens and lead to possible results in contamination of food upon contact (Edima et al., 2014; Nurudeen, 2014). The vendor's hygiene is very crucial because the microbial that can cause foodborne disease transmission can be found in the skin, nose, and mouth (Pascual et al., 2019). The FAO/WHO also recommended that food handlers to ensure food protection from contamination including dust and flies, and wear appropriate protective attire and head covering, results showed very poor compliance with this hygiene and safety practice (C-score = 0.31), very poor compliance score in obtaining a business permit (C-score = 0.06) and sanitary / health card (C-score = 0.06) with only 3 out of 51 respondents admitting to having their food stalls registered. This is in contrast with the findings in Iloilo City, Philippines where food vendors always practiced availing sanitary permits or registration (Calopez et al., 2017). This implies that the street food vendors in Cebu City do not comply with City's ordinance on getting mandatory health cards and sanitary permits.

The overall score (OC- scores) calculated as 0.61 represents a marginally good overall average compliance to all the internationally required food hygiene and safety principles used in the study. This good overall compliance is also the same as the overall result of degree of practice among street food vendors in Iloilo City in terms of their food hygiene and safety practices (Calopez et al., 2017). This is also the same as the findings of the research conducted in Vietnam (Minh, 2017). However, it was found that *E. coli was* present in the tested food samples. This could mean that there is no possible association between the vendors' food hygiene and safety practices and the presence of *E. coli* in the food samples tested. This further indicated that the results did not convene with the guidance on the hygiene indicator organisms in ready-to-eat food, in which *E. coli* is a commonly used fecal indicator organism (Buttiaux & Mossel, 1961; Food Safety Authority of Ireland, 2007). This also further implies that there are poor sanitary conditions and poor food hygiene practices of the street food vendors that potentially led to the presence of *E.coli* in the tested samples. Kariuki et al. (2017) cited Yeboah- Manu et al. (2010) that the

presence of E. coli in food types is an indication of fecal contamination probably at one stage of preparation or from the materials used by the street food vendors.

Generally, the respondents in this study were predominantly men which is consistent with the reports of Muinde and Kuria (2005) in Kenya, Chander et al. (2013) in India, Rosnani et al. (2014) in Malaysia, Minh (2017) in Vietnam and Calopez et al. (2017) in Iloilo City, Philippines. However, this contrasts with the studies of Apanga et al. (2014) and Monney et al. (2014) in Ghana, Tessema et al. (2014) in Ethiopia, Chukuezi (2010) in Nigeria and Van Olem and Olmogues (2021) in Dipolog City, Philippines which showed that street food vending business in developing countries is a trade predominated by women. These different results further reveal that gender of food vendors is dependent on the geographical region being studied. However, Mekasha et al. (2016) found out that females were shown to be better at following food safety practices than males, and sex was found to be substantially associated with hygiene practices.

In terms of the highest level of education attained by food vendors, the results pointed out that the majority of them reached the high school level and have been in the street food industry for more than five years which means that they are already familiar with food handling. This finding is consistent with that of Minh (2017), Calopez et al. (2017) and Van Olem and Olmogues (2021). Rebouças et al. (2017) believe that level of food vendors' formal schooling is one of the factors that contribute to food safety. Thus, secondary education as well as college and university training may imply that street food vendors are giving better quality and safe food.

4. Conclusion

The overall good compliance score of the vendors' food hygiene and safety practices did not give a comforting feeling of security towards the health of the school children due to the presence of *E. coli* in the food samples. In addition, the non-compliance of the vendors in obtaining a health card and business permit poses great risks to all children in the nearby schools as these food stalls have not been checked by the city health office. These vendors could have diseases that are contagious and hazardous to the school children's health. A compliant food vendor is more likely to practice good hygiene, thus, it is advisable that the street food vendors should obtain sanitary and business permits. Good hygiene practices prevent food-borne illness, which could be

done through education of the food handlers on food safety practices and close and strict supervision of street foods prepared and served in the school areas.

Food safety is an utmost priority anywhere in the world and for this to be achieved, appropriate legislation and strict implementation should be done. Over the years, Cebu City has developed quite a number of enforcements as reported by their city health officer but findings from this study revealed that these legal instruments and institutional frameworks on food safety and hygiene have not achieved their goals. There should be a strengthened implementation of the Republic Act No. 10611, the Food Safety Act of 2013, in the local government to address this current dilemma in the city.

References

Apanga, S., Addah, J. and Danso R.S. (2014). Food Safety Knowledge and Practice of Street Food Vendors in Rural Northern Ghana. *Food and Public Health* 4(3): 99-103.

Barcelon, E. G., et. al. (2015). Consumer Perception and Microbiological Analysis on Safety of Street Food Dipping Sause. *Asian Journal of Agriculture and Food Sciences,* 3(1).

Buttiaux, R., & Mossel, D. A. A. (1961). The significance of various organisms of faecal origin in foods and drinking water. *Journal of Applied Bacteriology*, *24*(3), 353-364.

Cabahug, Melissa. (2017). DepEd to school kids: Don't buy street food. Cebu Daily New – Inquirer. *Retrieved from https://cebudailynews.inquirer.net/63909/deped-to-school-kids-dont-buy-street-food#ixzz5RhVKluVP*

Calopez, C. G., Herbalega, C. M. L., Canonicato, C. J., Españo, M. F., & Francisco, A. J. M. (2017, January). Food safety awareness and practices of street food vendors in Iloilo City. In *2017 CEBU International Conference on Studies in Arts, Social Sciences and Humanities (SASSH-17) January* (pp. 26-27).

Cardinoza, Gabriel. (2017). 33 pupils in Pangasinan school ill after eating 'isaw' burgers. Inquirer. *Retrieved from https://newsinfo.inquirer.net/908080/33-pangasinan-grade-school-pupils-fell-ill-after-eating-isaw-burgers#ixzz5RhPn63pW*

Chakravarthy I. (2003). Street foods: Safety, Risk and Nutrition Potential, Nutrition Goals for Asia-Vision 2020. *Nutrition Foundation of India 2003; 660-662.*

Chauliac, M., T. Monnier, and M. A. Bendech. (1994). Bamako school age children and their diet from street vendors (in French). *Santé 4:413- 423.*

Chukuezi, C.O. (2010). Food safety and hyienic practices of street food vendors in Owerri, Nigeria. *Studies in Sociology of Science*. 1(1): 50–57.

Fernando, Cielo. (2021). 13 Irresistible Street Food in the Philippines That Will Give You Major Foodgasm. ZenRooms. Retrieved from https://www.zenrooms.com/blog/post/street-food-philippines/

Food Safety Authority of Ireland (2007) Interim guidance document on the use of: 1) Food safety criteria specified in Commission Regulation (EC) No 2073/2005 on Microbiological Criteria for Foodstuffs and 2) Guidelines for the Interpretation of Results of Microbiological Analysis of Some Ready-to-Eat Foods Sampled at Point-of-Sale (FSAI GN No. 3)

Food Standards Australia New Zealand. (2001). Guidelines for the microbiological examination of ready-to-eat foods.

FSAI. (2014). Guidelines for the Interpretation of Results of Microbiological Testing of Ready-to-Eat Foods Placed on the Market (Revision1).

Joglekar, Abhaya. (2013). A study on personal hygiene of street food vendors of Raipur City. *Asian Journal of Home Science. 8. 586-589*.

Kariuki, E. N., Waithera, N. Z., & Wanzala, P. (2017). Bacteriological contamination of street foods among street food vendors in githurai and gikomba markets-Nairobi county, Kenya. *Int J Innov Res Adv Stud*, *4*, 337-346.

Kothe, C. I., Schild, C. H., Tondo, E. C., & da Silva Malheiros, P. (2016). Microbiological contamination and evaluation of sanitary conditions of hot dog street vendors in Southern Brazil. *Food Control*, *62*, 346-350.

Llacuna, Jose. (2015). Number of Caraga poisoning victims rises to almost 2,000. ABS-CBN. *Retrieved from https://news.abs-cbn.com/nation/regions/07/12/15/number-caraga-poisoning-victims-rise-almost-2000.*

Madueke, S. N., Awe, S., & Jonah, A. I. (2014). Microbiological Analysis of Street Foods Along Lokoja-Abuja Express Way, Lojoka. *American Journal of Research Communication, 2*(1), 196–211.

Mekasha, T., Neela, S., & Kumela, D. (2016). Food safety knowledge, practice and attitude of food handlers in traditional hotels of Jimma Town, Southern Ethiopia. Ann. *Food Sci. Technol*. 17, 507–517.

Minh, N. P. (2017). Food safety knowledge and hygiene practice of street vendors in mekong river delta region. *Int. J. Appl. Eng. Res*, *12*, 15292-15297.

Monney, I., Agyei, D. and Owusu. W. (2013). Hygienic practices among food vendors in educational institutions in Ghana: the case of Konongo. *Foods*. 2: 282-294.

Neffati, L, et al. (2004). Street food among children: A Study in North Tunisia. *Sante. Jan-Mar; 14(1): 43-8*

Nurudeen, A. A., Lawal, A. O. and Ajayi, S. A. (2014). A survey of hygiene and sanitary practices of street food vendors in the Central State of Northern Nigeria. *Journal of Public Health and Epidemiology*. 6(5). 174-181.

Pascual, P. L., Olobia, L. P., Pascual, G. L., & Abenis, N. D. (2019). Knowledge, Attitudes and Practices (KAPs) on Food Safety Among Food Handlers in School Canteens in Eastern Visayas, Philippines. *Journal of Science, Engineering and Technology*, 7, 58-67.

Posner, J. (1983). Street foods in Senegal. *Chevy Chase, MD: Equity Policy Center*.

Rajan, V., & Aruna, N. (2017). Microbial Analysis of Street Foods of Different Locations at Chennai City, India. *Innovat International Journal of Medical & Pharmaceutical Sciences*, *2*(1), 23–25.

Rebouças, L. T., Santiago, L. B., Martins, L. S., Rios Menezes, A. C., Araújo, M. D., & Almeida, R. C. (2017). Food safety knowledge and practices of food handlers, head chefs and managers in hotels' restaurants of Salvador, Brazil. *Food Control*, 73, 372-381. https://doi.org/10.1016/j.foodcont.2016.08.026

Rustia, A., AZANZA, M., & GASCON, F. (2017). Food safety knowledge assessment model for pre-trained food handlers. *Philippine Journal of Science*, *146*(4), 371-385.

Rustia, A. S., Tan, M. A. P., Guiriba, D. N. S., Magtibay, F. P. S., Bondoc, I. R. J., & Mariano, C. B. D. (2021). Defining Risk in Food Safety in the Philippines. *Current Research in Nutrition and Food Science Journal*, *9*(1), 233-257.

Sofos J. (2013). Advances in microbial food safety. *Cambridge: Woodhead Publishing, 2013.*

Selepe, Mosa and Mjoka (2017). Food hygiene practices and attitudes of the street food vendors at KwaDlangezwa, Northern KwaZulu Natal. *African Journal of Hospitality, Tourism and Leisure, Volume 6 (3).*

Taherdoost, H. (2016). Sampling methods in research methodology; how to choose a sampling technique for research. *How to Choose a Sampling Technique for Research (April 10, 2016).*

Van Olem, E., & Olmogues, A. J. (2021). Food Safety Practices among Street Food Vendors in Dipolog City.

Webb, R. E., and S. A. Hyatt. 1988. Haitian street foods and their nutritional contribution to dietary intake. *Ecology of Food and Nutrition 21:199-209.*

Winarno, F. G., & Allain, A. (1991). Street foods in developing countries: lessons from Asia. *Alimentation, Nutrition et Agriculture (FAO); Alimentacion, Nutricion y Agricultura (FAO).*

World Health Organization (WHO). *Diarrhoeal disease. Geneva: WHO, 2015*. [Cited 2017 Jan 11].

Yeboah-Manu, D., Kpeli, G., Akyeh, M., & Bimi, L. (2010). Bacteriological quality of ready-to-eat foods sold on and around university of Ghana campus. *Research Journal of Microbiology*, *5*(2), 130-136.

International Journal of Science, Technology, Engineering and Mathematics
Volume 2 Issue 1 March 2022
DOI: https://doi.org/10.53378/352875

Building Model for Crime Pattern Analysis Through Machine Learning Using Predictive Analytics

[1]Jonard R. Asor, [2]Francis F. Balahadia, [1]Gene Marck B. Catedrilla & [3]Mia V. Villarica

Abstract

Crime has a big impact in both the human lives and the society's growth, which needs to be addressed and controlled. Machine learning algorithms as the fanciest technology to assist decision makers in policy making has proven its reliability in showing unseen patterns in crime. This research aims to examine the capability of trees and ensemble trees in classifying crime through model development. Experiments were done to enhance the capability of the ensembles in both classification and regression. Feature extraction like synthetic minority oversampling technique was applied in order to address the problem in the imbalanced data. Different metrics relevant to classification and regression were considered in evaluating the performance of each model used. With the use of different metrics, Gradient boosted tree was found to have better classification capability in crime dataset after outperforming decision tree and random forest in both classification and regression problem. Furthermore, random forest was also found to have a promising capability in classification by regression. Therefore, it is highly recommended that this ensemble algorithm be further examined and considered in developing model in other datasets.

Keywords: *Crime incidents, crime report, crime patterns, Laguna, Decision Tree algorithm, KDD*

Received: January 13, 2022 **Revised:** February 4, 2022 **Accepted:** March 6, 2022

Suggested Citation: Asor, J.R., Balahadia, F.F., Catedrilla, G.B. & Villarica, M.V. (2022). Building Model for Crime Pattern Analysis Through Machine Learning Using Predictive Analytics. International Journal of Science, Technology, Engineering and Mathematics, Volume 2 Issue 1, pp. 61- 73. DOI: https://doi.org/10.53378/352875

About the authors:

[1]Instructor I, Laguna State Polytechnic University, Los Baños, Laguna, Philippines

[2]Assistant Professor II, Laguna State Polytechnic University, Siniloan, Laguna, Philippines

[3]Assistant Professor I, Laguna State Polytechnic University, Sta. Cruz, Laguna, Philippines

1. Introduction

Crime is a severe problem of any country that needs to be addressed and controlled by the community and the world itself, for it affects not only the people, but the community's growth as well (Almaw & Kadam, 2018). To address the social dilemma, technology integration is one of the most effective and efficient tools in supporting social peace and order. For instance, the introduction of machine learning algorithm in crime analysis and prediction brings a whole new perspective in one's security agency. This intelligent approach in crime eradication outstands the human approach in analysis by mimicking the human concept (Shah et al, 2021). The usage of machine learning algorithms can be helpful to the crime analysts to their fight against crimes and in saving humanity (ToppiReddy et al., 2018).

Predictive analytics is a branch of data analysis used for the advantage of policy maker in empowering their decision-making. This approach becomes prominent and auspicious in crime analysis through the use of machine learning algorithm (Ippolito & Lozano, 2020). Machine learning algorithms such as k-NN, naïve bayes and decision tree were used in classifying crime in a small amount of data (Wibowo & Oesman, 2019). In an experiment by Iqbal et al. (2013), it was found that decision tree was a better performing machine learning compare to naïve bayes after gaining a much higher accuracy, precision and recall. It was proven to give a high accuracy, which can still be improved by integrating ensemble methods or application of different feature selection (Aldossari, et al., 2020). Similarly, the decision tree was found as reliable predicting algorithm when integrated in computer systems (Ahishakiye et al., 2017). Furthermore, other classification techniques were used to improve the performance of decision tree like regression (Sapin et al., 2021).

Regression machine learning algorithms have been used to predict crime (Ajagbe et al., 2020). Linear regression is found to be more effective in terms of handling the randomness of test samples than decision trees. Further, the precision of machine learning in predicting crime to slow down crime occurrences is well worth through knowledge discovery (McClendon & Meghanathan, 2015). Random forest as regressor show a promising result compared to other regression algorithms with equal hyperparameters in crime prediction including linear regression (Kadar et al., 2016). Moreover, the performance of each machine learning algorithms depends on the amount of data. It was already proven that the size of the dataset to be used in model development using machine learning really matters (Althnian et al., 2021).

On the case of limited features for prediction, gradient boosting found to be more effective based on the accuracy rather than other machine learning that uses regression (Lamari et al., 2020). In the issue of imbalanced data, machine learning algorithms such as support vector machine (SVM), neural networks and ensemble algorithms like random forest and gradient boosting were found to perform well in terms of prediction (Nguyen et al., 2017). A crime analysis was conducted using boosted decision tree and k-NN and proven that gradient boosted decision tree is more effective than the other algorithms (Kim et al., 2018).

This research work aims to develop a model for crime prediction through ensemble and trees machine learning algorithm in crime dataset. An experiment to enhance the performance of trees and ensembles is done to assure its viability once integrated as model for intelligent system.

2. Methodology

2.1. Data Collection

Table 1 presents the dataset that contains the attributes and description of the crime records of the Philippine National Police (PNP) in Laguna.

Table 1

Crime records of PNP – Laguna

Attribute	Description	Data Type
Date	The date when the crime was committed.	Date
Time	Exact time when the crime was committed.	Time
Address	Location where the crime happened.	String
Violation	Type of crime that is being committed.	String
V_Sex	Sex of the victim.	String
V_Age	Age of the victim.	Numerical
V_Nationality	Nationality of the victim.	String
S_Use	Weapon or device used by the suspect to commit the crime.	String
S_Sex	Sex of the suspect.	String
S_Age	Age of the suspect.	Numerical
S_Nationality	Nationality of the suspect.	String
Action_Taken	Appropriate legal action that the PNP was conducted.	String
Status	The status of the case whether it was filed or not.	String
Remarks	The status of the filing of the case in the court level.	String

Crime records of the PNP in Laguna, Philippines are used as dataset in this study. It contains different attributes that may or may not contribute to the performance of the model once

developed. These attributes were the so called ‘features’ which play the most vital and crucial part in model development (Barnadas, 2016).

2.2. Data Pre-processing

The dataset undergone different processing to assure the reliability and its efficacy when used for model development. Since the dataset contains some duplicated value in the ‘violation,’ which is used as the label or class to be predicted, a modification was done with the help of a criminologist. Civil code inputted in the dataset was converted into the actual crime that is committed, rather than keeping the instances with ‘RA’ or crime code, it was classified by the criminologist and converted into the actual crime like theft, physical injury, among others. Upon finishing this process, each line with missing ‘violation’ value was removed while those lines with ‘violation’ value, but missing other values were kept and still considered in the model development procedure. Further, all the remaining data in the dataset were converted into lowercase to assure that there is no bias or noise in terms of instance meaning. Conversion of the dataset into numerical form was also done for classification by regression procedure. Lastly, some attributes are dropped to enhance the performance and run-time in classification of every classifier that were used.

Table 2

Preprocessed Crime records of PNP – Laguna

Attribute	Description	Data Type
Date	The date when the crime was committed.	Date
Time	Exact time when the crime was committed.	Time
Address	Location where the crime happened.	String
Violation	Type of crime that is being committed.	String
V_Sex	Sex of the victim.	String
V_Age	Age of the victim.	Numerical
S_Sex	Sex of the suspect.	String
S_Age	Age of the suspect.	Numerical
Action_Taken	Appropriate legal action that the PNP was conducted.	String

2.3. Model Development

Figure 1

Model Development Process

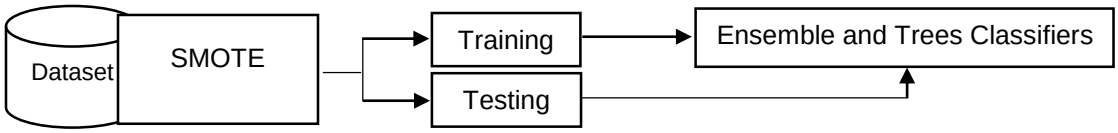


Figure 1 represents the procedure followed in this study to develop a model using ensemble and trees classifiers. In this study, the dataset was found to have an imbalanced data. Imbalanced data has a high impact in deteriorating the performance of even the most prestige machine learning. It drastically decreases the reliability of a particular model (Somasundaram & Reddy, 2016). To address this problem, synthetic minority oversampling technique (SMOTE) was applied. SMOTE was found to be effective in creating new and reliable data which can be used for balancing the dataset by oversampling the minority in a dataset (Peng et al., 2019; Sapin et al., 2021). Moreover, the dataset provided was separated into two (2) parts, the training dataset and the testing dataset. This step was done for validating the performance of the trained model, wherein the 20% of the dataset is used as testing dataset while the remaining 80% is the training dataset (Birba, 2020).

Three different algorithms concerning trees were used to develop the model. Decision tree (DT), random forest (RF) and gradient boosted trees (GBT) were found to be a promising algorithm in developing models for crime dataset. As discussed by many researchers, a tree learned by splitting the source into subsets based on the independent variables or the attributes inside the dataset. The result of these splits is one of the most understandable machine learning approaches for human interpretation (Singh & Pal, 2020). On the other hand, ensemble tree is the concept of bagging and boosting a tree. Bagging creates an ensemble of trees to create new training set from the actual training set, this new training sets were called bags (Banfield et al., 2007; Nagpal, 2017; Singh & Pal, 2020).

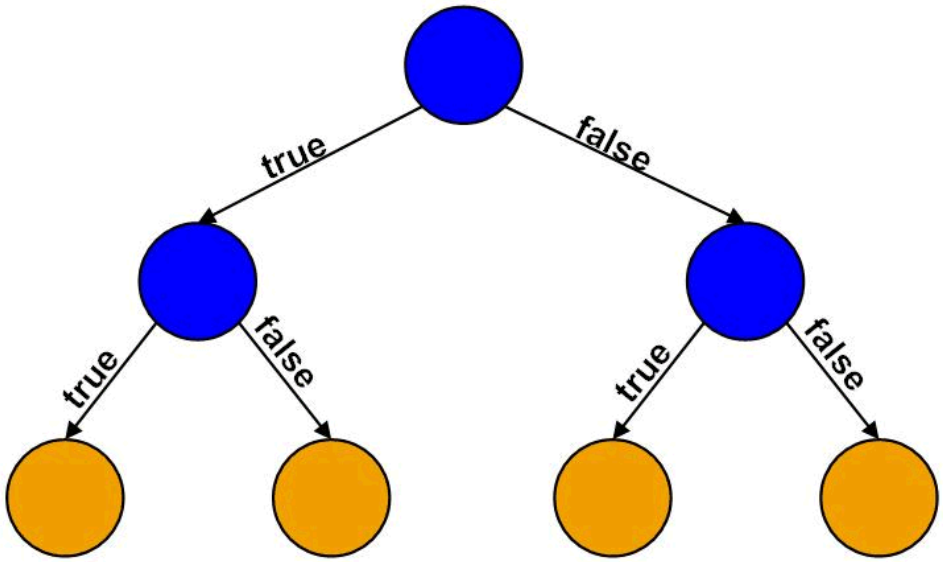
In the decision tree, the terminal nodes are considered as the class/label attribute which is known as dependent variable or the one to predict represented by Y in mathematical expression. Whereas, the non-terminal nodes, including internal and root nodes are the independent variables or the attributes to be split to have a pattern and new knowledge, commonly represented by x in mathematical representation. In mathematical formulation, decision tree has the following form:

$$3. \quad (x, Y) = (x_1, x_2, x_3, \ldots\ldots\ldots x_n, Y) \tag{1}$$

The external node or dependent variable Y is the target value to be classified or predict. Whilst, the independent variable or vector x will be the input variable, $x_{1,}x_{2,}x_{3,}$ which will be used to do the task. This approach will develop a tree that can be interpreted by *if-else* approach to understand the pattern that is being considered by the decision tree. Figure 2 portrays the architecture of a decision tree:

Figure 2

Decision tree architecture

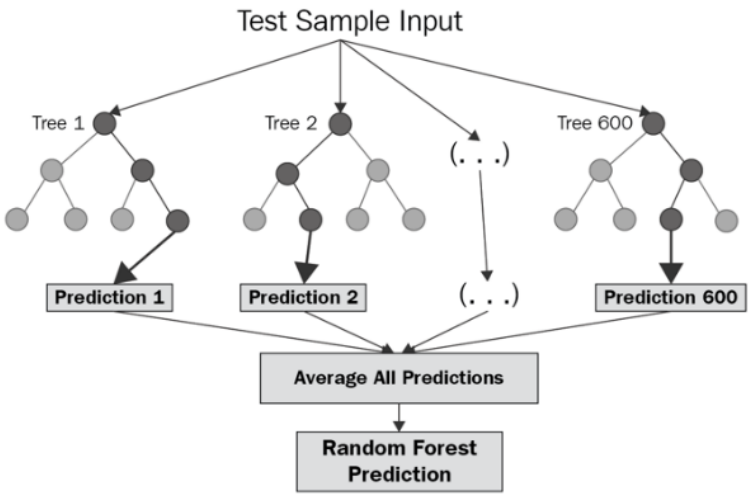


Source: https://tinyurl.com/fnp33822

Random forest is basically a collection of trees that works together in finding the most relevant independent variable in classifying the dependent variable through mode. This machine learning algorithm consists of numerous structured-trees $\{h(x, \Theta_k), k = 1 \ldots\}$ where the $\{\Theta_k\}$ are the independent random but identical vectors distributed to cast votes in finding the most common class for each *x.* Figure 3 is the representation of how random forest finalized its prediction based on the result of the votes of every tree inside it.

Figure 3

Random Forest architecture

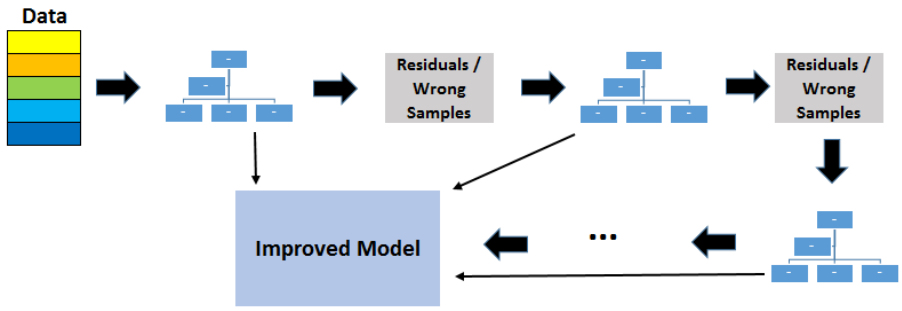


Source: https://tinyurl.com/2fu4ws5a

Gradient boosting is the process of buffering weak to enhance their performance. In this work, gradient boosted tree was used to further enhance the performance of decision trees. Figure 4 represents the top-view of the gradient boosted tree:

Figure 4

Gradient boosted tree ensemble architecture



Source: https://tinyurl.com/ukcd5p48

In the finalizing and assuring the reliability and avoid biases in the result, the experiment was conducted. Similarities of hyperparameter were observed considering their applicability in each machine learning algorithm used. Aside from k-fold validation, shown in table 2 is the hyperparameters used in this study.

Table 2

Hyperparameters used in the first experiment

Hyperparameter	Decision Tree	Random Forest	Gradient Boosted Tree
Pruning	True	True	n/a
Pre-pruning	True	True	n/a
Reproducible	n/a	n/a	True
Minimal Gain	0	0	n/a
Number of trees	n/a	50/100/200	50/100/200
Learning rate	n/a	n/a	0.01

Pruning and pre-pruning is applied in both DT and RF to assure that no overfitting happens in the model development, thus, it is not appropriate or not a parameter in GBT. Nevertheless, reproducible is an alternative to pruning that is only done in GBT. Minimal gain is a parameter for calculating node splitting, a higher value of its result to a not split at all. Number of trees are only applicable to ensemble algorithms which is used to determine how many trees to generate in the ensemble. In this paper, three values for the number of trees (50, 100 & 200) were used to see the veracity of ensembles in terms of repetition. The learning rate is the capability of the model to interrelate each vector in the dataset for classification, hence, it is better to be in a lower value to assure the reliability of the model's performance and to address the overfitting issue.

Moreover, classification by regression was also done. Since all the machine learning algorithms stated were designed to solve problems through the nominal label, a conversion to classification into regression was done to have another substantial result in performance enhancement of tree and ensembles. This process is a nested operator that creates a subprocess which generates classification model through regression learning.

2.4. Validate Model

As stated in model development phase, the dataset was divided into two for validation–the training and testing dataset. With this, necessary validation metrics are produced in order to have a reliable validation of the performance of each machine learning algorithm. Moreover, together with k-fold validation other necessary metrics were calculated in both classification and regression

techniques. For classification, metrics such as accuracy, kappa, recall, precision, specificity, false positive rate (FPR), false negative rate (FNR), Matthew's coefficient correlation (MCC) and f-score were used to evaluate the algorithms' performance while root mean square error (RMSE), mean square error (MSE) and R-square were used for evaluating regression technique. Both the metrics for classifications and regression were used to understand how accurate the classifiers or algorithms are, by examining the numbers of correct and incorrect classified data.

5. Results and Discussion

Using the hyperparameters in table 2, results of the experiments are shown in this section. As shown in table 3, GBT got the highest accuracy with a total score of 80.43%, thus it also outperformed the DT and RF in different viability metrics. Further, the RF outperformed the GBT in regression problem in terms of R^2 evaluation with 0.034 difference, however, it is noticeable that GBT has a better classification capability after getting a better RMSE and MSE score compare to the other two algorithms.

Table 3

Classifier performance with default metrics

	Classification									**Regressor**		
Classifier	Accuracy	Kappa	Recall	Precision	Specificity	FPR	FNR	MCC	Fscore	RMSE	R^2	MSE
DT	48.07	0.423	0.48	0.5	0.90	0.1	0.52	0.37	0.43	1548.00	0.442	2154.994
GBT	80.43	0.783	0.8	0.8	0.97	0.03	0.2	0.77	0.79	1353.00	0.47	2014.696
RF	54.73	0.497	0.55	0.63	0.92	0.08	0.45	0.48	0.5	1509.00	0.504	2127.675

After the first experiment, it is shown that ensemble trees are better at classifying crime than the decision tree itself. Hence, another experiment was done to further evaluate the performance of the two highest performing ensembles where their common hyperparameters were constantly modified. Reflected in table 4 are the performance of the GBT and RF in both classification and regression with a hundred trees as main parameter. Still, GBT has outperformed RF in classification with 82.72.% vs 54.5% differences in accuracy. Nevertheless, both GBT and RF have a total R^2 score of 0.53 for regression, hence, GBT outperformed RF after having a

better RMSE and MSE score. These show that GBT has a better performance than RF in both classification and regression problem when there are more trees.

Table 4

Ensemble's performance with 100 trees

	Classification									Regressor		
Classifier	Accuracy	Kappa	Recall	Precision	Specificity	FPR	FNR	MCC	Fscore	RMSE	R^2	MSE
GBT	82.72	0.803	0.82	0.81	0.98	0.02	0.18	0.79	0.81	1479.00	0.53	2106.419
RF	54.5	0.494	0.55	0.63	0.92	0.08	0.46	0.47	0.49	1488.00	0.53	2112.818

Table 5 shows the result of the last experiment done in this study. For this experiment, the number of trees was raised to 200. It is noticeable that GBT still outperforming the RF in classification problem after acquiring a total accuracy of 83.03% and a Fscore of 82%. Also in regression, GBT still shows a promising classification capability after outperforming RF in all the regression metrics used in this experiment.

Table 5

Ensemble's performance with 200 trees

	Classification									Regressor		
Classifier	Accuracy	Kappa	Recall	Precision	Specificity	FPR	FNR	MCC	Fscore	RMSE	R^2	MSE
GBT	83.03	0.811	0.83	0.82	0.98	0.02	0.17	0.8	0.82	1266.00	0.54	1948.846
RF	54.73	0.497	0.55	0.63	0.92	0.08	0.45	0.48	0.5	1482.00	0.50	2108.554

4. Conclusion

In this research paper, decision trees and ensemble trees were used to develop a model in crime reports in the province of Laguna, Philippines. Synthetic minority oversampling technique (SMOTE) is used to address the issue of imbalanced data. It was found that ensembles like random forest and gradient boosted tree were better in classifying law violation or crime than decision tree. Furthermore, after the experiments, it was found that gradient boosted tree was more effective in both classification and regression than the random forest especially when the number of trees were more than a hundred. Nonetheless, the random forest shows a promising capability in regression after outperforming the gradient boosted tree in the first experiment where it gains a higher R^2 score.

For future studies, the result of this research paper can be a model for intelligent system in predicting crime for a strategic planning basis for the PNP in Laguna. Random forest shows an unexpected result during classification by a regression process which implicates for a better classification capability, therefore, a study about random forest enhancement must be considered. In this study, a validation for current crime occurrence was not done yet, hence, it is recommended that the model developed must be test in current crime record to have clearer findings in terms of variance accurateness. Moreover, similar study must be done in a larger data set.

References

Ahishakiye, E., Omulo, E. O., Taremwa, D., & Niyonzima, I. (2017). Crime Prediction Using Decision Tree (J48) Classification Algorithm. *International Journal of Computer and Information Technology*, 188-195.

Ajagbe, S. A., Idowu, I. R., Oladosu, J. B., & Adesina, A. O. (2020). Accuracy of Machine Learning Models for Mortality Rate Prediction in a Crime Dataset. *International Journal of Information Processing and Communication, 10*(1&2), 150-160.

Aldossari, B. S., Alqahtani, F., Alshahrani, N. S., Alhammam, M. M., Alzamanan, R. M., Aslam, N., & Irfanullah. (2020). A Comparative Study of Decision Tree and Naive Bayes Machine Learning Model for Crime Category Prediction in Chicago. *2020 The 6th International Conference on Computing and Data Engineering* (pp. 34-38). Senya: ACM. doi:10.1145/3379247.3379279

Almaw, A., & Kadam, K. (2018). Survey Paper on Crime Prediction using Ensemble Approach. *International Journal of Pure and Applied Mathematics, 118*(8), 133-139. Retrieved from https://www.acadpubl.eu/jsi/2018-118-7-9/articles/8/18.pdf

Althnian, A., AlSaeed, D., Al-Baity, H., Samha, A., Dris, A. B., Alzakari, N., . . . Kurdi, H. (2021). Impact of Dataset Size on Classification Performance: An Empirical Evaluation in the Medical Domain. *Applied Science, 11*(2), 1-18. doi:10.3390/app11020796

Banfield, R. E., Hall, L. O., Bowyer, K. W., & Kegelmeyer, W. P. (2007). A Comparison of Decision Tree Ensemble Creation Techniques. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 173-180. doi:10.1109/tpami.2007.250609.

Barnadas, M. V. (2016, September 1). Machine Learning Applied to Crime Prediction. Barcelona.

Birba, D. E. (2020). A Comparative study of data splitting algorithms for machine learning model selection. *Degree Project in Computer Science and Engineering*.

Ippolito, A., & Lozano, A. C. (2020). Tax Crime Prediction with Machine Learning: A Case Study in the Municipality of Sao Paulo. *22nd International Conference on Enterprise Information Systems. 1*, pp. 452-459. Czech Republic: Science and Technology Publications. doi:10.5220/0009564704520459

Iqbal, R., Panahy, P. H., Murad, M. A., Mustapha, A., & Khanahmadliravi, N. (2013). An Experimental Study of Classification Algorithms for Crime Prediction. *Indian Journal of Science and Technology, 6*(3), 4219-4225.

Kadar, C., Iria, J., & Cvijikj, I. P. (2016). Exploring Foursquare-derived features for crime prediction in New York City. *KDD - Urban Computing WS '16.* San Francisco: ACM. doi:10.1145/1235

Kim, S., Joshi, P., Kalsi, P. S., & Taheri, P. (2018). Crime Analysis Through Machine Learning. *9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON).* Vancouver: IEEE. doi:10.1109/IEMCON.2018.8614828

Lamari, Y., Freskura, B., Abdessamad, A., Eichberg, S., & Bonviller, S. d. (2020). Predicting Spatial Crime Occurrences through an Efficient Ensemble-Learning Model. *International Journal of Geo-Information, 9*(645), 1-20. doi:10.3390/ijgi9110645

McClendon, L., & Meghanathan, N. (2015). Using Machine Learning Algorithms to Analyze Crime Data. *Machine Learning and Applications: An International Journal, 2*(1), 1-12. doi:10.5121/mlaij.2015.2101

Nagpal, A. (2017, October 18). *Decision Tree Ensembles- Bagging and Boosting*. Retrieved from towardsdatascience: https://towardsdatascience.com/decision-tree-ensembles-bagging-and-boosting

Nguyen, T. T., Hatua, A., & Sung, A. H. (2017). Building a Learning Machine Classifier with Inadequate Data for Crime Prediction. *Journal of Advances in Information Technology, 8*(2), 141-147. doi:10.12720/jait.8.2.141-147

Peng, M., Zhang, Q., Xing, X., Gui, T., Huang, X., Jiang, Y.-G., . . . Chen, Z. (2019). Trainable Undersampling for Class-Imbalance Learning. *The Thirty-Third AAAI Conference on Artificial Intelligence* (pp. 4707-4714). Hawaii: AAAI.

Sapin, S. B., Lerios, J. L., Padallan, J. O., Buama, C. A., & Asor, J. R. (2021). Fire incidents visualization and pattern recognition using machine learning algorithms. *Indonesian*

Journal of Electrical Engineering and Computer Science, 22(3), 1427-1435. doi:10.11591/ijeecs.v22.i3

Shah, N., Bhagat, N., & Shah, M. (2021). Crime forecasting: a machine learning and computer vision approach to crime prediction and prevention. *Visual Computing for Industry, Biomedicine, and Art, 4*(9), 1-14. doi:10.1186/s42492-021-00075-z

Singh, R., & Pal, S. (2020). Machine Learning Algorithms and Ensemble Technique to Improve Prediction of Students Performance. *International Journal of Advanced Trends in Computer Science and Engineering, 9*(3), 3970-3976. doi:10.30534//ijatcse/2020/221932020

Somasundaram, A., & Reddy, U. S. (2016). Data Imbalance: Effects and Solutions for Classification of Large and Highly Imbalanced Data . *1st International Conference on Research in Engineering, Computers and Technology* (pp. 28-34). Peru: IEEE.

ToppiReddy, H. K., Saini, B., & Mahajan, G. (2018). Crime Prediction & Monitoring Framework Based on Spatial Analysis. *Internation Conference in Computational Intelligence and Data Science* (pp. 696-705). Ohio: Elsevier. doi:10.1016/j.procs.2018.05.075

Wibowo, A. H., & Oesman, T. I. (2019). The comparative analysis on the accuracy of k-NN, Naive Bayes, and Decision Tree Algorithms in predicting crimes and criminal actions in Sleman Regency. *iCAST-ES 2019. 1450*, pp. 1-6. Bali: Journal of Physics: Conference Series. doi:10.1088/1742-6596/1450/1/012076