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Improving Problem Solving Performance Through Varied Teaching Approaches: A Meta-Analysis

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IMPROVING PROBLEM SOLVING PERFORMANCE THROUGH VARIED TEACHING APPROACHES: A META - ANALYSIS

A Thesis
Presented to the Faculty of
College of Graduate Studies and Teacher Education Research
Philippine Normal University
Manila

In Partial Fulfillment of the Requirements
for the Degree Master of Arts in Education
with Specialization in Mathematics Education

ANGELITA VIERNES CORBILLON

April 2019

APPROVAL SHEET

This thesis entitled **"IMPROVING PROBLEM SOLVING PERFORMANCE THROUGH VARIED TEACHING APPROACHES: A META – ANALYSIS"** prepared and submitted by **ANGELITA V. CORBILLON** in partial fulfillment of the requirements for the degree Master of Arts in Education with specialization in Mathematics Education is hereby recommended for approval and acceptance.

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DEDICATION

First, this work of labor and love is humbly and
whole-heartedly dedicated to
our ***Almighty God*** *who is the source*
of my knowledge
and wisdom. His powerful guidance
and supreme presence, gift of
intelligence, knowledge and understanding
He bestowed me has helped me made
this study a reality.
Second, to all ***Mathematics educators*** *to hasten*
their teaching approaches in improving
the problem
solving performance of our students and of course to the
Mathematics students *as the main*
beneficiary of this study.
I hope and pray that the result
of this study
would be of great help to them.
Finally, this is lovingly dedicated to
my ***husband Fred*** *and*
daughter Felize "Lizzie".

-Angel Viernes Corbillon-

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Above all, to the **most high and Almighty Lord** for the utmost inestimable love and guidance until the final phase of this study.

A.V.C

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ABSTRACT

Title	:	**IMPROVING PROBLEM SOLVING PERFORMANCE THROUGH VARIED TEACHING APPROACHES: A META – ANALYSIS**
Researcher	:	**ANGELITA V. CORBILLON**
Key Concepts	:	**problem solving performance, teaching approaches meta – analysis**
Degree	:	**Master of Arts in Education**
Specialization	:	**Mathematics Education**
Adviser	:	**ERMINDA C. FORTES, Ph.D.**

Researchers and educators in the field of Mathematics sought changes on how to improve the problem solving performance of students. The main purpose of this study was to describe the different researches or studies on improving the students' problem solving performance in Mathematics through varied teaching approaches using Glass Meta – analysis technique. This study used the purposive sampling design. The reviewed studies were 43 experimental studies both unpublished and published online dissertations, theses and journal articles from 2002– 2017. These studies were qualified based on the inclusion criteria set by the researcher. The effect size was computed using the Glass' formula. Results revealed that among the research designs Solomon Four Group design had a huge mean effect size of 2.51.

In terms of the level of participants, secondary pupils had a very large mean effect size of 1.48. The number of participants ranging from 181 to 240 had a very large mean effect size of 1.45. Simple random sampling technique had a very large mean effect size of 1.51. The four different teaching approaches have their own impact to the problem solving performance of the pupils. While the use of cooperative learning approach with a mean effect size of 1.46 (Δ=1.46), would yield the greatest impact, technology – oriented approach (Δ=1.09), practical work approach (Δ=1.03) and problem solving heuristics approach (Δ=1.10), could also help the students to improve their problem solving performance. It implies that the Therefore, these approaches may be used as alternatives in teaching mathematics.

CHAPTER 1

PROBLEM AND LITERATURE REVIEW

Background of the study

Mathematics has been acknowledged as a difficult subject to many people worldwide. However, Mathematics plays a vital role in people's daily life - people cannot get away from it because mathematics is everywhere. It is a major part of the school curriculum in most countries and offers a variety of valuable tools that help students to solve problems that they encounter in everyday life. Through mathematics, each and every one knows how to budget, count, solve daily problems and give different solutions.

However, some students' attitude towards it is negative as shown in many research findings that students expressed disinterest and disinclination in it which might be caused by experiencing difficulties in mathematical tasks or problems due to lack of understanding of the basic concepts and the prerequisite Mathematics skills. Teachers are the best mentors and transformers of lives. Therefore it is necessary to have teachers who are efficient, competent and understanding on the needs of the pupils. Keogh (2014) stated that great teachers teach children how to think not what to think.

Effective Mathematics instruction must be evident in all educational levels. In the primary level, basic Mathematical concepts and foundation are developed first. In the secondary level, these concepts are enhanced, while in tertiary level, the Mathematical concepts developed are needed in student's future career or profession (Gomez, 2014).

It is not easy to understand and solve problems if there are misconceptions and gaps in the learning process. That is why teachers have to be resourceful in terms of the most suitable or appropriate teaching methodologies or approaches to make the learning of mathematics enjoyable and effective. An important thing to consider in mathematics instruction is how the learners will understand the concepts. To prepare learners as life-long learners and able to compete in the real word, understanding of the concepts must be taught to them. It may be easy for the students to have a better problem solving performance if teachers let them understand the different mathematical concepts in a more meaningful way.

The performance of the students in terms of problem solving as one of the major issues or concerns in the field of mathematics education needs to be addressed. Problem solving has been a major concern in the field of Mathematics education. It is one of the twin goals of Mathematics in the basic education, (DepEd, K to 12 Curriculum Guide Mathematics, 2013) and it has a big role in the mathematics education of K – 12 pupils (NCTM, 2017). Teachers should be aware of this to be able to include it in the planning of activities and instructional materials, and in improving the mathematics curriculum.

Verschaffel, Greer, and De Corte (2007) referred to problem solving as mathematical tasks that challenge the mathematical understanding and intellectual capacity of the students. Story problems serve as a tool for developing and enhancing the student's problem solving skills. Meanwhile, Odegaard (2015) mentioned that problem solving is one of the most important skills in mathematics. It is a way or a process of looking into the details of a problem to arrive at a complete

and accurate solution. When solving a problem, one applies the previous knowledge of the skills to a new situation to meet a generalization or conclusion and develop an answer. To be able to become a successful individual in math classes and other disciplines and future careers, students must develop the habit of problem solving.

Moreover, problem solving is a means for developing students' logical thinking because it makes the pupils think mathematically and enhances student's ability to transfer skills to unfamiliar or unusual situations. Teachers now at all disciplines or levels are challenged to develop the process of mathematical thinking of the students through simple routine and non – routine problems. Ersoy (2016) cited that problem solving should really be part of the lesson to develop the students' high – level thinking. In addition, it plays a key role in learning mathematics since the foundation of mathematical activities is problem solving. It is also an important component of mathematics education because it is a single vehicle that enables the school to help learners realize the functional, logical, and aesthetic values of Mathematics (De Guzman, 2009).

Since teachers cater 21st century learners and problem solving is one of the skills that needs to be developed among them, they should find ways on how to make meaningful connections and understanding on the concepts of problem solving. The learners should develop a deeper understanding of word problems because it is a prerequisite skill so the learner can perform the correct mathematical computations (Anton, Boonen, De Fries, Jolles, Schoot, & Wesel, 2013; Thevenot,

2010). One challenge for problem solvers is that enough understanding of the problem statement should be honed.

Researches have been conducted for the past years on utilizing varied approaches in teaching Mathematics to improve problem solving performance but there is only limited studies that summarizes the results. Most of these studies that were summarized were conducted abroad. There were only few conducted in the Philippines. Hence, a meta – analysis is done to answer the question: What really is the best or the most effective teaching approach to use in helping students improve their problem solving performance?

The drive of this study is to analyze the results of different experimental studies that have not been summarized or relatively compared since no definite conclusions have been made as to which teaching strategies or approaches help students learn. With this, a systematic analysis and synthesis of findings is necessary using Glass method of Meta – analysis.

From the business dictionary, meta – analysis has been applied in the field of mathematics and logic since before Aristotle (384 – 322 B.C). Analysis means loosening and breaking up the pieces of context to come up with the best findings (Beaney, 2012).

There are varied definitions of meta – analysis mentioned by some authors. According to Kalaian and Kasim (2008) meta-analysis tests the same research questions and hypotheses using a quantitative statistical method to summarize and integrate descriptive statistics from different researches. Meanwhile, Maksimovic (2011) cited that meta – analysis as a summary or synthesis of researches that

enables the researcher to create a general conclusion based from the results or findings of the study. It also has been widely used in researches. It also synthesizes evidence across many studies and samples that yields a better estimate of the strength and stability of an intervention or a relationship that could be gained in any single study.

Moreover, the results of a single study cannot be used as a basis of the utility of an intervention or the validity of a hypothesis because the results from a study is different from another study. So, Meta – analysis is needed to synthesize data across studies. It is used for different purposes such as: (1) to create statistical significance with studies that have disagreeing results (2) to have a more accurate estimate of effect magnitude; (3) to give a more complex analysis of harms, safety data, and benefits and (4) to inspect subgroups with individual numbers that are not statistically significant.

It is believed that the result of this study may be very helpful and a reliable source of feedback from which improvements of the Mathematics program may be drawn. This may serve also as a tool for mathematics educators to address the needs of students. Hence, the researcher conducted this study to address the issue of which teaching approach is best or effective to use in improving students' problem solving performance in Math.

Significance of the study

The study primarily used Meta – analysis by Gene Glass (1976) in identifying the best or the most effective teaching approaches in improving problem solving performance. The main goal of this study is to upgrade the teachers on the best or

the most effective teaching approaches to use in their instruction. As a result, people from schools to different work places may gain benefits from this study, which may help attain certain goals in their respective field of endeavors.

The findings of this study may be beneficial to teachers, school heads, curriculum planners and implementers, seminar/workshop organizers, parents and most especially the students. Moreover, teachers may gain better learning of the ways on how to improve the problem solving performance of the students. Being equipped with the knowledge about their students' development in terms of academic achievement, they may be guided effectively to rely on their teaching approaches or strategies. This study may also provide an in – depth analysis of the roles they need to perform which may eventually lead to better performance and a more effective use of their professional services. It may also serve as a basic source of information from which the students can attain maximum development of their potentials and be prepared to adapt to the needs of passing the next level of study.

The findings of this study may be instrumental in awakening and guiding the school heads to plan and make decisions necessary in upgrading the teaching and learning process in education. The result too, may make them realize that there is a need to improve the Mathematics program. Based on several studies, knowing the limitations that may affect students' performance would give way in providing materials suited to the needs of the students. Furthermore, they may be able to give suggestions for the improvement of the mathematical skills of the students and teaching style for the teachers.

The result of this study may serve as a means of providing the parents, who also act as teachers, on what kind of assistance and guidance they may provide to their children to develop their maximum potentials. The information that may be obtained from the result of this study may provide vital data to the curriculum planners/implementers in the preparation of instructional materials suited to the needs of the students, as well as to the seminar/workshop organizers so they could include in their plan of informing the teachers the best approach or strategy in teaching math and the use of meta – analysis in educational research.

Literature Review

Below are some of the relevant literatures that guided the research. The first part reviews on the problem solving performance. Meanwhile, the second part reviews on meta – analysis technique as it has been widely used in research particularly in education.

Mathematical Problem Solving Performance

Difficulty in problem solving is when a problem solver cannot find a solution or a method to use in solving a problem (Mayer and Wittrock 2006). When a person does cognitive processing to achieve a solution to a problem, problem solving is evident. Zen and Cook (2011) stated that problem solving is one of the areas of mathematics that requires students to analyze content, transfer words into mathematical equation or representation. Students find it more difficult compared to other components of learning. It requires more time and effort to develop the conceptual understanding so that the students may apply what methods or strategies they learned to be able to create a new solution. Problem solving model

should also be practiced or be remembered by the students on how they would answer and show the solution. That is, a problem – model – strategy should be introduced to the problem solvers in which they translate the problem statement into a quantitative mental representation of the problem hidden in the text (Van der Schoot, Bakker Arkema, Horsley & Van Lieshout, 2009).

Learners take an active role in producing ideas to solve problems. Their ability to produce ideas further augments the understanding that problem solving requires higher order, critical thinking because solutions are not immediately seen (Kuzle 2013). In order to solve problems, the learners need to know the process of problem solving to come up with varied solutions (Marzano, 2014). Fülöp (2015) agreed that, in problem-solving, students cannot directly apply methods and algorithms to solve it or it is a task with multiple solutions where the students are asked to come up with different ways of solving the problem.

One factor that makes the students solve problems inaccurately is due to their low reading comprehension abilities. This is proven by research evidence. Reading comprehension is so important in solving problems because students must be able to understand and find the hidden message or keys that would help them find the answer (Anton, Boonen, De Fries, Jolles, Schoot, & Wesel, 2013)

A study was conducted by Fuchs, Seethaler and Powell (2008) on the effects of preventive tutoring on mathematical problem solving of third grade students with math and reading difficulties. They found out that tutoring protocol is effective for preventing word problem deficits among third grade students with math reading deficits. Meanwhile, Boonen, de Koning, Jolles, and Schoot (2016) conducted a

study on word problem solving in contemporary education. They found that even those who are very good problem solvers had a low performance on complex problems. It was revealed that reading comprehension skills should be developed and be given attention in order for the pupils to improve their problem solving ability.

Learning does not only involve internal or mental representations but also involves how the students interact with each other and their way of life. It provides the learners opportunities to gain understanding and achieve higher levels of achievement (Rigelman, 2007). According to Hiebert and Grouws (2007), students construct their own mathematical information by combining ideas, procedures and mathematical facts, while Giganti (2007) believed that the world of the universe needs a good problem solver that is why problem solving must be taught to students.

Effects of Problem Solving Heuristics Approach

Problem solving heuristics or approaches are what people work in their heads as they make sense and solve problems. They are their tools for simplifying problems and revealing the possible paths to solutions (O'Connell, 2007). Problem solving skills can be developed through varied approaches that requires learners' mathematical skills and thinking skills however, developing students' problem-solving abilities can be a challenging task. That is why many authors identified some problem solving heuristics that improved the problem solving performance of students in Math.

George Polya (1945) developed a strategy known as FOUR STEP PLAN IN PROBLEM SOLVING. The first step is "Understand the Problem." In understanding

the problem, the teachers should ask the students if they understood the problem by giving some guide questions leading to the second step, which is “Devise a Plan.” In devising a plan, the students are encouraged to think of the appropriate strategies to solve the problem. Some of the strategies under this principle are: Guess and check, Look for a pattern, Make an orderly list, Draw a picture, Eliminate the possibilities, Solve a simpler problem, Use symmetry, Use a model, Consider special cases, Work backwards, Use direct reasoning, Use a formula, and Solve an equation. After the students devised a plan they need to “Carry out the Plan,” the third step. The students may now try to show solutions using a strategy to solve the problem and check if it works, if not, choose another one that will give the correct answer. Then finally, when a solution is correct, the students need to “Look Back,” the fourth step. This is done to let the students reflect and examine if they did answer the problem correctly. This is to reassure that the chosen strategy or method applied is appropriate.

In order to solve word problems, students must apply previous knowledge of a concept to the word problem. Solving math word problems involves several processes (James, 2015) and calculation is one of the many steps to reach the correct answer. Therefore, students need to master all the mathematical skills for them to be able to perform the correct procedure in finding the correct solution and answer to the problem. They have the choice or option of what problem solving heuristic approach to be applied in their solution.

Similar thoughts and ideas on problem solving was mentioned in the study of Montague and Dietz (2009). There are seven cognitive processes that are

necessary to solving word problems in math: (a) understanding the problem, (b) translating the problems in own words, (c) creating a representation, (d) developing a plan, (e) guessing or predicting the answer, (f) computation, and (g) checking the answer. Accomplishing success in math problem solving, leads to overall achievement in math (Krawec, Huang, Montague, Kressler, & de Alba, 2013).

Similarly, Montague, Morgan, and Warger (2006) examined "Solve It," which is designed to help students learn how to understand a mathematical problem situation, develop reasonable plans to solve a problem, analyze story problems information, and assess solutions. The program was intended to help improve the problem-solving skills of middle and secondary students who have adequate reading and computational skills, but still have difficulty in solving math word problems. "Solve It" also provides mathematics teachers the chance to use proven instructional techniques in the classroom that help their students acquire and effectively use cognitive processes and self- regulation. Prior to attempting to solve word problems, students must first memorize the cognitive processes and self-regulation strategies necessary for solving them (Montague, 2006).

Freeman (2013) also used SOLVE strategy. SOLVE strategy is a combination of explicit instruction and integrating a recognized approach to eight stage of instruction: model, pretest, posttest, verbal practice, advanced practice, describe, controlled practice and generalization. SOLVE is an action problem solving introduced by Enright (1987) and the acronym stands for its procedure. S pertains to see the sign. O stands for observe and answer. If unable to answer the problem, the student should keep working on it. L stands for line up a plan or look

and draw. V stands for verifying the answer with computation, and E stands for examining or entering the answer. This strategy is known as a mnemonic strategy particularly a letter word strategy. This is taught to let the students remember the steps on how to solve a problem. Explicit instruction on the other hand is where the teacher provides clear modules for solving a problem using different sets of examples and students receive extensive practice and training in the use of newly learned approaches. They are provided to think aloud and with extensive feedback on their work. It was found out that the SOLVE strategy provided students who are struggling in Math understand math just like how efficient learners had.

Another mnemonic device was created by Montague (2006) to help students remember in solving word problems. The acronym was RPVHECC which stands for the following: R (Read for understanding), P (Paraphrase), V (Visualize by draw a picture or diagram), H (Hypothesize), E (Estimate), C (Compute), and C (Check). The purpose of having students use acronyms is that they will be able to say the words and the process needed to solve word problems effectively. Putting labels in the drawing helps pupils better identify the problem type and allow them to solve more complex or difficulty problems. Van Garderen's research (2006) has also shown that with practice, students are able to become more proficient in generating correct diagrams. Relevant mathematics concepts and procedures are best enhanced and taught to the students through problem solving (Van De Valle (2007).

Sulaka (2010), conducted a study on the effect of problem solving strategies on problem solving achievement in primary school mathematics. The study used pretest and posttest design. It was revealed that participants in the experimental

group was significantly successful in using the strategies they learned such as drawing a diagram, making a table, writing mathematical sentences, looking for a pattern, making a list, using logical reasoning and guess-check strategies.

In the same vein, Klinger (2012) conducted a study on Mathematics strategies for teaching problem solving. His study was an action research and the objective is to teach five different problem solving strategies. These are drawing pictures, making a chart or table, looking for a pattern, working backwards, and guess and check. He found out that the attitude of the students and their performance improved. Therefore, teaching strategies is an influential tool for improving pupils' performance.

Moreover, Locke (2016) conducted a study on the effects of the RIDE teaching strategy on teaching word problem solving skills to students with learning disabilities. RIDE is a mnemonic device created for helping middle school students with learning disabilities. RIDE stands for remember the problem correctly, identify the relevant information, determine the operations and unit for expressing the answer and enter the correct numbers, calculate and check the answer. It was found out that such strategy helps students with learning disability recall the steps/process of solving problems. Their responses to problem solving were positive as well as their confidence level. With the related studies on the effects of problem solving heuristics approach on the performance of students, the researcher took this a guide and a proof that indeed it is very beneficial to the learner in terms of solving routine and non - routine problems.

Effects of Technology - Oriented Approach

Problem solving performance of the students in Math really needs to be addressed due to poor performance as stated by some of the researchers. One way to improve this is by incorporating the use of technology in the teaching instruction, especially that this is the new trend of how students grasp mathematical concepts. Different researchers conducted a study on the different effects of technology on the performance and academic achievement of learners.

A study was conducted by Enchang, TingSung and Feng Lin (2006) on computer – assisted learning for mathematical problem solving. MathCAL, a computer – assisted system was assessed by the researchers. It has four problem solving strategies similar to George Polya's (1945) four step plan in problem solving POLYA such as (1) Understand the problem (2) Make a plan (3)Execute the plan and (4) review or double check the solution. The results indicated that MathCAL is effective in improving the performance of the students who are performing very low in Math.

Meanwhile Jin – Seo (2008) conducted a study on the effects of "Math Explorer" multimedia software on word problem-solving performance for students with mathematics difficulties. The findings of the study suggested all the participants were able to apply their cognitive and metacognitive strategies to solve problems involving addition and subtraction. The participants' accuracy performance improved on the computer – based tests. In general, the findings of the study clearly gives evidence that Math Explorer is an effective method or tool for teaching addition and subtraction with word problems to students who are having a hard time

in Math. It was also suggested that CAI program was successfully designed is to help the students with mathematical difficulties improve their mathematical performance.

Parallel study on improving problem solving was conducted by Schoppek and Tulis (2010) about enhancing arithmetic and word problem solving skills efficiently by individualized computer – assisted practice. The researchers suggested individualization of practice to improve the efficiency of computer – assisted instruction to learners on their arithmetic and problem solving skills. Adaptive training software was created to help the teachers in selecting problems and giving feedback to students. The software was evaluated first before it was used by nine third grade classes. The findings of the study show that a moderate amount of individualized practice was associated with higher improvements on the problem solving skills and arithmetic of the participants.

Another study on problem solving performance was conducted by Leh & Jitendra (2013) on the effects of computer – mediated versus teacher – mediated instruction on the mathematical word problem solving performance of third grade students with mathematical difficulties. Computer – Mediated Instruction (CMI) and Teacher – Mediated Instruction (TMI) were the two methods used in the study. These two methods were compared on the problem solving performance of students with mathematics difficulties. Cognitive modeling using visual representations was taught in both conditions. It was found out that there was no significance between the two methods/conditions as shown in the pupils' posttest problem solving performance. These related studies on the impact of using

technology, show that indeed, technology is very helpful in helping the students improve their problem solving performance.

Effects of Cooperative Learning Approach

Cooperative learning is an approach that most of the teachers choose to apply in their instruction. Many researchers claimed that it has a positive impact on the performance of the students. Poore (2008) conducted an action research on cooperative learning in relation to problem solving in Mathematics classroom. The participants of the study were 5th grade students. She found out that cooperative learning has a positive influence on students' skills in problem solving and their thoughts in mathematics as a subject. Participants' communication skills showed greater improvement in explaining their work orally.

Meanwhile, Johnsen (2009) conducted a study on improving achievement and attitude through cooperative learning in math class. This is an action research to investigate the use of cooperative learning groups and whether working in groups changed student's individual achievement towards mathematics. The participants of the study were secondary students. The study revealed that the kinds of groupings have an effect on the attitudes of the students and how they interact and work well with their groupmates. But it was also found out that the students' achievement did not change but when they worked longer with their group, they gained better performance.

Similarly, Weimer (2010) wrote an article on improving students' problem solving skills. He said that to have a better problem solving performance, teachers need to utilize group work in the classroom. He also mentioned that problem solving

is “what students do when they don’t know what to do.” In addition to this, students’ problem solving performance improved when they were asked to work collaboratively in groups.

Indeed, cooperative learning approach, as compared to conventional teaching, greatly influenced the performance of the students. This is supported by the study conducted by Aziz and Hossain (2010) where sixty two students from grade-IX at the Sreepur Adarsha Girls’ High School participated in quasi – experiment. The teacher guided both the experimental and control groups in single academic session for fifteen weeks. The findings revealed that students who worked together with their peers significantly outperformed those students who work individually. They also mentioned that cooperative learning has been one of the approaches being chosen by the researches to include in their study. It has been three decades already since CL has been a subject of interest by the researchers because they believed that cooperative learning can improve secondary students’ achievement in Math.

A similar study on improving problem solving performance was conducted by Jitendra, Dupuis, and Rodriguez (2012). The study focused on the effectiveness of schema based instruction (SBI). It was found out that students under SBI performed better than the students in the control group. It was also revealed that SBI is effective to varied sets of students or learners either individual instruction or group instructions.

The study of Mutakinati, Mudzakir, and Supriyanti (2015) on cooperative learning Think Pair Share (TPS) for improving students’ problem solving skills in

Buffer Solution concept had proven also that cooperative learning approach is an effective tool. The findings of this study that was conducted in Bandung City, Indonesia, showed that cooperative learning TPS can enhance high school student's problem solving skills significantly compared with the conventional model.

Meanwhile, Titsankaew (2015) also conducted a study on the effects of using cooperative learning on students' achievement and attitude toward mathematics. The participants were forty – nine Thai students from Grade 11 at Satrinonthaburi School. Think Pair Share (TPS) cooperative learning strategy was employed. The findings of the study revealed that TPS cooperative learning strategy has a positive impact on students' achievement and attitude in learning mathematics. Given that cooperative learning is an effective approach, it is hoped that teachers would utilize it as part of their teaching instruction.

Effects of Practical Work Approach

Students need to work hard to understand varied mathematical concepts. They need to be exposed to real life situations and tasks. However, learning mathematical concepts does not only happen in using textbooks and supplementary materials. The use of manipulatives could also help the students' gain conceptual understanding that would lead a better problem solving performance. Moreover, the use of manipulative and modeling technique, and hands on activities make them more productive and develop their critical and problem solving skills.

A study on using manipulatives in Mathematical problem solving was conducted by Kelly (2006). The article focuses on problem solving in elementary classrooms on how the students use manipulatives while solving the given

problems. Teachers used a performance – based tool to assess the students' learning. It was revealed that the use of manipulatives helps the students perform better in showing their solutions and answers. Teachers should consider the use of manipulatives in teaching new concepts and skills to the students. A similar study on problem solving performance was conducted by Moreno, Ozogul and Reisslein (2011) on teaching with concrete and abstract visual representations. They found out that problem solving is nurtured when students get to experience solving using concrete visual representations that make them connect what they already know to their previous knowledge and are able to apply abstract visual representations.

On the other hand, Garforth and Siegel (2015), wrote an article on the usefulness of Concrete Pictorial Abstract Approach. They found out that Concrete Pictorial Abstract (CPA Approach) is very effective in teaching mathematical concepts/skills to achieve a higher rate of academic and problem solving performance. Students who joined in CPA instruction outperformed the students who joined in traditional abstract instruction. Therefore, it is believed that concrete manipulatives are effective because they allow the students to work on mathematical tasks without understanding written arbitrary symbols.

Morevoer, Kim, Michaels and Wang (2015) wrote an article on using explicit C – R – A instruction to teach fraction word problem solving to low – performing Asian English learners. Multiple probe design across participants was used in the study. It was found out that all participants reached grade – level mastery solving different types of problems through the use of concrete representation approach.

Based on the different studies, it is hoped that teachers should utilize practical work approach as it helps a lot in improving students' problem solving performance.

Effects of Problem Solving or Word Problems

The use of word problems is helpful in honing the students' analytical skills. With this approach, they are more aware of how problem solving affects their performance. Eduafo (2014) conducted a study on the effects of Problem – Solving Approach on Mathematics achievement of Diploma in Basic Education Distance Learners at the University of Cape Coast, Ghana. The findings of the study revealed that problem solving approach significantly changed most of the new elementary mathematics teachers. Their views on teaching mathematics through problem solving changed after given some training workshops. Thus, a problem solving approach to teaching mathematics lets the teacher act as facilitator of learning rather than a transmitter of knowledge and the learners are the managers and directors of their own learning.

Pongsakdi, Laine, Veermans, Hannula-Sormunen and Lehtinen (2016) conducted a study on improving word problem performance in elementary school students by enriching word problems used in mathematics teaching. The participants of the study were fourth and sixth graders and elementary teachers from one of the schools in southwest Finland. The authors developed a Word Problem Enrichment (WPE) program to inspire teachers to use advanced self – created word problems to enhance students' mathematical modeling and problem solving skills. The findings revealed that the enriching word problems used in

mathematics is very successful method to enhance students' problem solving skills when solving routine and non – routine problems. Truly, problem solving is said to be the partner of everybody. Teachers should not neglect this and should help everyone hone his or her problem solving skills.

Effects of Combined Problem Solving Heuristics Approaches

Some teachers would also prefer to use combined problem solving strategies. This is very evident in the studies included herein. Mancl (2011) investigated the effects of a combined problem solving strategy for students with learning difficulties in mathematics. He examined the impact of READER Strategy on the problem solving performance of students with mathematics difficulties and disabilities. It was found out that the use of Concrete – Representational Abstract instruction sequence, schema – based diagrams and cognitive strategy (i.e. READER) may be used in improving the students' ability to solve problems. The study implied that teachers who want to use the combined problem-solving strategy should allow more time for lessons that involve the use of manipulative devices.

Moreover, Odegaard (2015) conducted a study on using graphic organizers, cooperative learning, and written reflection to improve mathematics problem solving skills. It was found out that graphic organizers are useful tools to help students unify their thoughts, work on a problem, and think of a strategy to solve the problem. It was also found out that cooperative learning strategy aided pupils to deliberate, clarify and defend their method of solving the problem. It allowed the students to find out how the other group go about the process of problem solving. Also, it was revealed in the study that the writing process permitted students to improve their

metacognitive skills by letting the students evaluate their own work and justify why their answer was correct. In general, these three strategies aided students to become more effective or successful problem solvers and more assertive in solving word problems.

Effects of Other Teaching Approaches

Aside from the approaches mentioned previously, there are also other approaches that may be utilized in improving problem solving performance of the pupils. Palmay (2015) conducted a study on improving the problem solving of struggling learners in mathematics. Cognitive Strategy Instruction (CSI), through the use of graphic organizers, was examined in the study. It was found out that students who had cognitive strategy instruction with the support of graphic organizers improved the performance of Grade Eight students with mathematics difficulties. There was also a big improvement on students' attitude toward mathematics and application of the problem solving approaches.

James (2015) conducted a study on the effects of Schema-Based Instruction on word problem solving in pupils with disabilities. Problem solving is one of the toughest skills in mathematics especially to pupils with learning difficulties. In order to help the pupils cope with their problem solving performance, schema based instruction as an intervention was used. The use of diagram and quality was fair and played a role in increasing word problem solving ability in the study.

In the study conducted by Voyer (2010) on pupils' performance in mathematical problem solving as a function of comprehension and arithmetic skills, it was found out that students with low or weaker foundation in math construct

different mathematical representations based on the information stated in the problem. Students who have higher mathematical foundation or those who give greater importance to situational information in a problem have higher performance in math.

Another study on problem solving was conducted by Lai, Zhu, Chen, and Li (2015) on the effects of Mathematics anxiety and mathematical metacognition on word problem solving in children with and without mathematical learning difficulties. They claimed that mathematics is one of the most practical, logical and objective among other disciplines. The result of the study indicated that anxiety during learning mathematics should be looked into in mathematical learning difficulty interventions or programs. Mathematics should be a subject that does not threaten the lives of the learners and pupils should be motivated more to learn and love the subject.

Bortoli and Macaskill (2014) wrote an article about creative problem solving. Creative problem solving involves different ways on solving problems just like the use of tickets, exit pass, robot cleaner and others. It allows the students to solve different problems using their creativity or own approach to come up with the right solution. Also, some of the authors like Autor, Levy and Murnane (2003), and Hanushek, Jamison, Jamison and Woessmann, (2008), mentioned that students who could solve difficult problems easily adapt to changes in society and learn from their mistakes. These students will have a brighter future and will contribute for the betterment of the country's economic growth.

Furthermore, the use of other teaching approaches is highly encouraged for the teachers to use as an instructional tool. With the different sets of students that are being catered today, it is not enough to use just one approach. An approach might be applicable to one student but may not be applicable to others. So, the teachers are challenged to be more creative and more innovative in improving their teaching instruction.

Meta – analysis in the Field of Education

Nowadays, meta – analysis is in demand as a new tool in conducting research to see the effects of a certain intervention or approach. It helps the researcher come up with a unifying result based from the results and findings of different studies. One of the advantages of using meta – analysis is that it helps the researchers draw relative inferences across different areas of education research. It is a method of combining the findings of related studies to provide an overall quantitative or "pooled estimate effect." The purpose of doing meta – analysis is to help the researcher identify clearer conclusions about which teaching approaches are effective in improving students s problem solving performance. It has been widely used too in other fields of education as many researchers claimed that meta – analysis is an effective tool.

Bas, Senturk, and Cigerci (2017) conducted a meta – analytic review of research on homework and achievement. It was found out that homework or assignments had positive effect size (d = 0.229) on pupils academic achievement levels. This means that giving of homework enhances students' performance in Math.

On the other hand, Demirel and Dagyar (2016) conducted a meta – analysis study on the effects of Problem – Based Learning (PBL) on attitude of the students. In the analysis of their study, it was revealed that problem – based learning (PBL) has a low positive effect on students' attitude. It means that PBL is still effective in helping the students gain a positive outlook towards mathematics.

Similarly, Bernard, Abrami, Borokhovski, Waddignton, Wade and Person (2015) conducted a meta – analysis on strategies for teaching students think critically. The authors synthesized the available empirical evidence on the effect of instruction on the improvement and development of critical thinking skills, outlooks and students' achievement. It was revealed that the strategies employed were useful and effective. The ability for the students to talk with their peers and discuss the problems given to them helped them nurture their critical thinking skills.

Klassen and Tze (2014) conducted a Meta – analysis on teacher's self – efficacy, personality, and teaching effectiveness. The objective of the study was to thoroughly analyze the researches exploring two psychological characteristics and teaching effectiveness. There were forty – two studies included in the study. It was found out that there was a small positive effect size of d = 0.10 between overall psychological characteristics and teaching effectiveness. Self – efficacy on evaluated teaching performance has the strongest effect size of 2.58.

A similar study was done by Lloyd (2013) on the effects of math intervention on elementary students' math skills. He evaluated the usefulness of hierarchical math interventions to enhance math skills. It was revealed that math fluency interventions were more effective than math acquisition interventions in improving

students' basic math skills. It was also found out that generalizations interventions have greater effect on word problem solving skills compared to math fluency and math acquisition interventions.

Relatedly, a study was conducted by Kyriakides, Christoforou, and Charalambous (2013) on exploring factors of effective teaching. It revealed that the dynamic model was moderately associated with student achievement. Therefore, teachers need to use varied methods in order to bring out the best of the students' ability in solving problems.

Similarly, another meta – analysis was conducted by Jeynes (2012) on the efficacy of different types of parental involvement programs for urban students. Fifty – one studies were included in this meta – analysis. It was found out that there is a significant relationship between academic achievement and parental involvement for pre – elementary and elementary and secondary students. Hence, programs involving parents were associated with higher achievement.

On the other hand, another study was done by Loren (2012) on meta – analysis of experimental research studies on mathematics teaching. She mentioned that to attain good performance, correct strategy and how the strategy is established are very important. It was found out that teaching strategy is significant on the achievement of students in mathematics.

A parallel study on meta – analysis was done by Zhang and Xin (2012) on word problem solving interventions for students with mathematics difficulties. The authors analyzed the influence of education reforms as moderator variables on intervention effects. Single - subject design and group – design studies were part of

the study. It was found out that there was a huge positive effect size (d= 1.848) for word problem solving instruction across the studies. Therefore, problem solving interventions is necessary to aid students with mathematics difficulties.

Picho, Rodriguez and Finnie (2012) also conducted a meta – analysis study on exploring the moderating role of context on the mathematics performance of females under stereotype threat. It was revealed that females in stereotype conditions had a low performance on Mathematics tests than the control group counterpart with an effect size of 0.24. But stereotype is more effective for middle and high school students compared to tertiary students.

Meanwhile, Sudkamp, Kaiser, and Moller (2012) conducted a meta – analysis on accuracy of teachers' judgments of students' academic achievement. There were seventy – five studies included in the meta – analysis. The study focused on different school types, grade levels, and subject areas. It was found out that there is a positive effect size of 0.63 on the accuracy of teachers' judgement of students' achievement.

A Meta – analysis study was also conducted by Jacobse and Harskamp (2011) on the effects of instructional interventions on students' Mathematics Achievement. There were forty studies included in this meta – analysis study. These studies used non – standardized test to measure mathematics achievement of students. This is reported to have larger effects of instructional interventions compared to studies that used standardized tests. It was also found out that there was no difference on the effects found between students of higher or lower

Mathematics ability, as well as with direct instruction methods or indirect instruction methods.

Another meta – analysis study was done by Codding, Burns, and Lukito (2011) on mathematics based – fluency interventions. It was found out that drill and practice with modeling create large effect size. In teaching mathematical concepts and skills, it is imperative to give students lots of drills and practices to develop their skills. In doing so, their problem solving skills will also be enhanced.

A related meta –analysis also was done by Cajigal (2011) on experimental studies on teaching effectiveness. The study used the descriptive – documentary analysis method using the Glass' Meta – analysis technique. The reviewed studies are composed of thirty - six researches using graduate theses and dissertations. The findings of the study revealed that for the number of participants, forty and above got the highest percentage of the total number of included studies aside from the other characteristics. Moreover, in the methodological characteristics, for sampling technique, the match group got the highest percentage among the included studies; for research design, pre-test and posttest. In terms of effect sizes, the following got the highest mean: number of participants under 30 – 40, cluster for sampling technique and Solomon for research design. The academic achievement of students in the experimental teaching methods is better compared with the achievement of students in the traditional group in the three educational levels in the different subject areas. The effect sizes were affected by subject area, duration of instruction and number of participants in the study, statistical treatment and sampling technique used. It is recommended that review in appropriateness of the

experimental teaching methods for the students in all levels and subject areas must be done and employed in the classroom to improve the students' achievement.

Lindberg, Hyde, Petersen, and Linn (2010) also conducted a meta – analysis on new trend in gender and mathematics performance. There were two hundred forty – two studies that were included in the study. It was found out that gender does not affect the mathematics performance. Both males and females equally performed well, hence, gender does not matter - what matters is how the students understand and gained the concepts and applied the skills they learned.

Burns, Codding, Boice, and Lukito (2010) conducted a meta – analysis of acquisition and math fluency interventions with instructional frustration level skills. It was found out that the skill – by – treatment paradigm is relevant for matching the skill level in math. There is a need of additional research investigating the articulacy interferences particularly for students with instructional level skills.

In addition, a study was conducted by Rakes, Valentine, and McGatha (2010) on methods of instructional improvement in algebra. There were eighty – two relevant studies with one hundred nine effect sizes included in the study. Technology curricula, instructional strategies, non – technology curricula, technology tools and manipulative were the categories considered for improvement. It was found out that these five categories were statistically significant. A positive effect size was also noted on the pupils' achievement. Interventions focusing on the development of conceptual understanding had an average effect size almost twice that of interventions focusing on procedural understanding.

Similarly, Gersten, Chard, Jayanthi, Baker, Morphy, and Flojo (2009) conducted a study on mathematics instruction for students with learning disabilities. Forty studies were included in this meta – analysis. Randomized control trial and quasi experimental studies were chosen as part of the study. There were four categories that were examined like approaches to instruction and/or curriculum design, formative assessment data and feedback to teachers on students' mathematics performance, formative data and feedback to students with LD on their performance, and peer-assisted mathematics instruction. It found out that student feedback with goal setting and peer – assisted learning within a class has no significant effects while the rest of the components/categories result to significant mean effects. It was found out through multiple regressions that teaching students using heuristics and explicit instruction is effective and statistically significant.

Meanwhile, Walker and Leary (2009) conducted a meta – analysis on differences across problem types, implementation types, disciplines, and assessment levels. Problem based learning (PBL) is most widely used today in developing students' critical thinking and problem solving performance. Students are exposed to varied types of problems. It was revealed in the study that PBL has positive effects on the performance of the students.

Subsequently, Murphy, Wilinson, Soter, Hennessey, and Alexander (2009) conducted a meta – analysis on the effects of classroom discussion on students' comprehension of text. Its findings revealed that discussion approach impacts students' performance. Students are able to comprehend the test when they say it aloud or when they discuss it among their peers. In terms of study design and

academic ability, effects were moderate. The range of the ages of the participants in the included studies was large.

Another meta – analysis was conducted by Ritter, Barnett, Denny, and George (2009) on the effectiveness of volunteer tutoring programs for elementary and middle school. It was found out that volunteer tutoring increased students' achievement. Students who have tutors performed better on assessments related to letters and words, oral fluency and writing as compared to other students who do not have tutors.

Importantly, Browder, Spooner, Ahlgrim – Delzell, Harris, and Wakeman (2008) conducted a meta – analysis on teaching mathematics to pupils with significant cognitive disabilities. It was revealed that pupils with significant cognitive disabilities have the ability to learn mathematics. Teachers should give assistance and use systematic instruction and prompt fading in teaching mathematical concepts. Giving feedback about their performance also can help them boost their confidence and develop the skill on problem solving.

Another meta – analysis study was done by Dignath, Buettner, and Langfeldt (2008) on how primary school students learn self – regulated learning strategies most effectively. The findings showed that self – regulating learning training programs proved to be effective, even at primary school level. Templeton, Neel, and Blood (2008) conducted a meta – analysis on math interventions for students with emotional and behavioral disorders. They found out that the need for development of interventions for higher level Mathematics and additional research is necessary to help students learn better in Math.

Meanwhile, meta – analysis was also used by Clayson (2008) on students' evaluations of teaching. In some areas of learning, students are asked to give feedback about what they learned from their teachers or instructors. They are asked to evaluate the performance of their teachers. It was found out in the study that when learning is objectively measured, it does not show any relationship to evaluation.

In addition to that, a meta – analysis study was conducted by Cornelius-White (2007) on learner – centered teacher – student relationships. The study focuses on the relationship of teachers and students. Many claimed that learning should not only be done solely by the teacher rather pupils should be acting or doing the activities. Teachers are guide on the side, they mainly give and assign what to be done. After giving some facts and teaching concepts, they let the students explore and learn on their own. It was revealed in the study that there was a positive effect on the performance of the students when they are tasked to work by themselves and be involved in the activity.

Meta – analysis on the Effects of Cooperative Learning Approach

Some researchers utilized meta – analysis in their studies on the effects of cooperative learning. Capar and Tarim (2015) conducted a study on efficacy of the cooperative learning method on mathematics achievement and attitude. They found out that the effect size for cooperative learning on academic achievement was 0.16. This means that cooperative learning has a medium positive and significant effect but for attitude, the effect was small. Therefore, cooperative learning is still the more

effective method than the traditional method in improving achievement and attitudes of students towards problem solving.

A similar study was also conducted by Ugwuanyi (2015) on the effectiveness of cooperative learning method in mathematics in Nigeria. It was found out that cooperative learning approach has a positive effect on students' achievement in Mathematics. It is also significant at 0.5 level. Thus, cooperative learning is an effective method in teaching Mathematics.

Another study was conducted by Bowman-Perrott, Davis, Vannest, Williams, Greenwood and Parker (2013) on academic benefits of peer tutoring. Five potential moderators were analyzed which include dosage, grade level, reward, disability and content area. It was found out that peer tutoring is an effective intervention across five moderators. Students with emotional and behavioral disabilities benefitted the most in the study.

Lastly, Kyndt, Raes, Lismont, Timmers, Cascallar, and Dochy (2013) conducted a meta – analysis on the effects of face to face cooperative learning. Fifty – four articles were included in the study with one hundred twenty – one findings were used for this meta – analysis. It was revealed that cooperative learning has a positive effect on students' achievement and attitude towards learning mathematics. It was also revealed that the study domain, the age level, and culture in which the study took place were associated with variations in effect size.

Meta – analysis on the Effects of Technology – Oriented Approach

Studies also revealed that there are authors who utilized meta – analysis on the effects of technology on the performance or achievement of students. Tokac (2015) conducted a meta – analysis on the effects of game – based learning on students' mathematics achievement. The results showed heterogeneity among studies both in magnitude and in direction. They found out that Math video games might have contributed to higher learning as compared to traditional instructional methods.

Another study was conducted by Sokolowski and Willson (2015) on the effects of using exploratory computerized environments in Grades 1 to 8. It was revealed that the use of computers to support the process of problem solving and exploration has a positive effect on the performance of grade 1 to 8 students. They mentioned that the process of problem solving is difficult for students, thus mathematics educators have made multiple attempts to seek ways of making this process more accessible to learners.

A parallel study was done by Belland, Walker, Olsen, and Leary (2014) on a pilot meta – analysis of computer – based scaffolding in STEM education. The authors examined the impact of computer – based scaffolding characteristics on the cognitive outcomes of students in the STEM level. It was found out that there were no significant differences based on variables included in their study like study design, generic versus specific, paired intervention, assessment level, or intended learning outcome.

Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, Surkes, and Wood (2014) conducted a meta – analysis on the effects of technology in postsecondary education. It was mentioned that the overall weighted average effects of technology and attitude outcomes and moderator variables to explain how technology affects learning had positive and negative effects.

A similar meta – analysis was conducted by Merchant, Goetz, Cifuentes, Keeney – Kennicutt and Davis (2013) on the effectiveness of virtual reality – based instruction on student's learning outcomes in K – 12 and higher education. The findings of the study showed that games, simulations and virtual worlds were effective in improving learning outcome gains of the students. It was also revealed that though the studies were different from each other, the homogeneity analysis of the effect sizes was seen to be statistically significant.

A paralell meta – analysis was conducted by Cheung and Slavin (2013) on the Effectiveness of educational technology applications for enhancing mathematics achievement in K- 12 classrooms. Seventy - four qualified studies were involved in the final analysis. It was found out that educational technology has a positive effect of 0.05 compared to traditional method on the achievement of students.

In the study of Li and Ma (2010) on the meta – analysis of the effects of computer technology on student's mathematical learning, It was revealed that the use of computer technology has a positive impact on the mathematics achievement of students. They also found out that the use of computer technology has advantage in promoting mathematics achievement of elementary over secondary school students.

Meanwhile, Steenbergen-Hu and Cooper (2013) conducted a meta – analysis on the effectiveness of intelligent tutoring systems on K – 12 student's mathematical learning. It was found out that intelligent tutoring systems (ITS) had a small positive effect on students' mathematical learning. ITS is found to be effective when it is used only for less than a year rather than using it for more a year. It helped more average students than low achiever students. Therefore, the authors drew their attention to the issue of whether computerized learning contributes to the achievement gap between students with different aptitudes. This is probably dependent on the type of learners receiving the intervention. There might be some factors that contribute why CAI is not effective to low achievers.

Another meta – analysis of recent studies was conducted by Girard, Ecalle and Magnan (2012) on Serious Games as new educational tools. Serious Game refers to video games specifically to serve a valuable purpose. It was found out that serious games or video games yielded a positive effect on students' achievement.

A similar meta – analysis study was done by Wu W-H, Wu Y-C, Chen, Kao, Lin and Huang (2012) on review of trends from mobile learning studies. It was found out that most of the included studies focus on effectiveness of mobile learning devices. The most globally used learning devices were mobile phones and personal digital assistant.

Meanwhile, Sosa, Berger and Saw (2011) conducted a meta – analysis on the effectiveness of computer – assisted instruction in statistics. They investigated some factors that influence the effectiveness of CAI such as the level of learner engagement, learner control, and the nature of feedback. The findings suggest that

there was a larger effect in which treatment groups had more instructional time than control groups. Thus, the use of CAI in teaching statistics is effective.

In addition, Yesilyurt (2010) conducted a meta – analysis on computer assisted studies in science and mathematics in Turkey. It was revealed in the study that CAI is important in teaching Mathematics and Science. It has a great impact on the performance of the pupils. Meanwhile, Liao (2007) conducted a meta – analysis on the effects of computer assisted instruction (CAI) on students' achievement in Taiwan. In the study, results reveal that computer assisted instruction is more effective than traditional instruction. Truly, technology creates a big change in the lives and performance of the learners.

A parallel meta – analysis study was conducted by Bernard, Abrami, and Borokhovski (2009) on three types of interaction treatments in distance education. Various types of interaction treatments were compared with other distance education instructional treatments. Interaction treatments are the instructional media types designed into distance education. It was primary to facilitate student to student learning, student and student, or student and content. It was found out that the three types of interaction treatments have a positive effect on achievement.

Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, Surkes, and Lowerison (2009) conducted a meta – analysis on the effect of technology on achievement in higher education of classroom applications. There were 231 studies included in the meta – analysis. It was found that research design was not significant across true, quasi and pre – experimental designs while the degree of

technology was found to be significant. So, technology has a great impact in helping the students increase their achievement.

Rosen and Solomon (2007) also conducted a meta – analysis on the differential learning achievements of constructivists' technology – intensive learning environments as compared with traditional ones. They found out that learning in a constructivist's environment has greater impact than traditional environment on the performance of students. Traditional method environment allows students to have a limited source of learning. Students are just confined with procedural method unlike in constructivist method, pupils are given the chance to build their own understanding, ideas and solution to the problem.

Meanwhile, Vogel J., Vogel D., and Cannon – Bowers (2006) conducted a meta- analysis on computer gaming and interactive simulations for learning. It was found out that in order to achieve higher cognitive outcomes, games and simulations should be used in teaching. However, when teachers are in control of the programs, results favored those in the traditional teaching method over the games and interactive simulations.

In addition to that, Sung, Chang and Liu (2016) also conducted a meta – analysis on the effects of integrating devices with teaching and learning on student's learning performance. They found out that there was a moderate mean effect size of 0.523 for the use or application of mobile devices to teaching mathematical skills and concepts. The advantages and disadvantages of mobile learning in different levels of moderator variables were summarized based on content analysis of specific studies.

To that end, the use of mobile learning device (MLD) is another tool to aid student's problem solving performance.

On the other hand, a meta – analysis study was conducted too by Sitzmann, Kraiger, Stewart and Wisher (2006) on the comparative effectiveness of web – based and classroom instruction. Web – based instruction was found to be effective than classroom instruction. Teaching pupils involving the use of applications and programs related to technology has greater impact on the performance of students.

Moreover, Ellington (2006) conducted a meta – analysis on the effects of non – CAS graphing calculators on students' achievement and attitude levels in mathematics. It was found out that the use of calculators during tests and instructions created a significant effect on the procedural, conceptual and achievement skill of students. Additional meta – analysis was conducted by Means, Yukie, Murphy, Bakia and Jones (2009) on evaluation of evidence – based practices online learning. It was revealed that students in online conditions gained a positive result on their assessment scores than those pupils having face to face instruction. The authors mentioned that the blended set up of learning should not be attributed to media alone.

There are many other instructional materials that can be used to continue the use of blended learning. Indeed, a lot of schools are trying to incorporate this in their learning plans and modules. Thus, in todays' generation, the students needed this type of learning but teachers should know how to balance the use of technology and other related instructional tools.

Meta – analysis on the Effects of Problem Solving Heuristics

Problem solving heuristic has a positive effect on the problem solving performance of the students. This was proven by the studies included herein. Khashefi, Alias, Kahar and Mirzaei (2015) conducted a meta – an analysis on visualization in mathematics problem solving. Visualization among students should be enriched in order to boost their acquired skills in Mathematics. A study must be conducted to see the vast transformation of visual usage today to suit the 21st century learners and learning environment. Learning how to solve problems accurately would make the students good speakers and transmitters of knowledge. They can assimilate ideas to the real world more than just memorizing facts.

Another meta – analysis was conducted by Friso-van de Bos, Van der Ven, Kroesbergen, and Van Luit (2013) on working memory and mathematics in primary school children. It was found out that working memory components are associated with mathematical performance. Teachers may do some variations in improving students' recall on basic concepts in mathematics.

Meta – analysis on the Effects of Practical Work Approach

A meta – analysis study was also used to find the effects of practical work approach. Holmes (2013) conducted meta – analysis on the effects of manipulative use on PK – 12 Mathematics. It was revealed that students who had manipulatives outperformed those students without manipulatives in math instruction.

A similar study was done by Carbonneau, Marley and Selig (2013) on the efficacy of teaching mathematics with concrete manipulative. They said that the use of manipulative is often prescribed as an efficacious teaching strategy. It was

revealed that concrete manipulative are powerful tools in helping students improved their mathematical performance.

Lastly, Codding, Burns, and Lukito (2011) conducted a meta – analysis on Mathematics Based – fluency Interventions. It was found out that drill and practice with modelling create large effect size. In teaching mathematical concepts and skills, it is imperative to give students lots of drills and practices to develop their skills. In doing so, their problem solving skills will also be enhanced.

Meta – analysis on the Effects of Other Teaching Approaches

There are some other teaching approaches that can be applied in teaching. Some of the researchers conducted a meta – analysis on the effects of teaching strategies. Schroeder, Scott, Tolson, Huang and Lee (2007) conducted a meta – analysis on the effects of teaching strategies on student achievement in science in the United States. Eight categories of teaching strategies or approaches were included in the meta – analysis. The first category is questioning strategies where the teacher asks questions to the students to let them think and evaluate the solution to the problem. It was found that it has a positive effect size of 0.74 on the performance of the students. The second category is manipulation strategy which also has a positive effect size of 0.57. Letting the students touch or hold objects using their sensory motors make them visualize the concepts and this helps them create new meaning and alternative solution to the problem. The third category is enhanced material strategies with an effect size of 0.29. Sometimes teachers create materials which only cater specific skills but to make it more helpful and challenging to the learners, it would be better if teachers could add more exercises

targeting the required skills. The fourth category is assessment strategies with an effect size of 0.51. Assessment strategies pertain to how the teachers administer either the summative or the formative assessments. This would allow the students to show how far they have learned the skills or concepts taught to them. The fifth category is the inquiry strategies with an effect size of 0.65. This is somehow related to questioning strategies but differ in terms of how it delivered by the teachers. This is more on probing the students to think deeper of their solutions. The sixth strategy is enhanced context strategies with an effect size of 1.48. This is found to have a very large effect size. Enhancing context strategies would mean teaching the students find the hidden messages and clues found in the problem to arrive at the appropriate method. Their skills on contextual clues should be developed and be given importance to attain better performance. The seventh category is instructional technology strategies with an effect size of 0.48.

Students nowadays can be identified as “DIGIZEN”, digital generation Z or digital natives. It means that connecting or integrating lessons through technology is an effective tool in helping the students gain better performance. The last category is collaborative learning strategies with an effect size of 0.98. Collaborative learning strategies help the students hone their social competence. They get to learn and share ideas among their peers. All these categories included in the study projected a very positive effect on the performance of the students. It can be concluded that alternative learning strategies are effective.

Hence, the different researches and studies cited agree that meta – analysis have been used in research and could help in identifying which teaching

approaches is the most effective in teaching mathematics. With these theoretical bases, findings, and review of related literature, the researcher chose meta – analysis and problem solving performance as the focus of this paper.

Conceptual Framework

The conceptual basis of the study is anchored on Glass (1976) Meta – analysis technique. Meta – analysis refers to the analysis of the analyses. Below is the conceptual framework of the study.

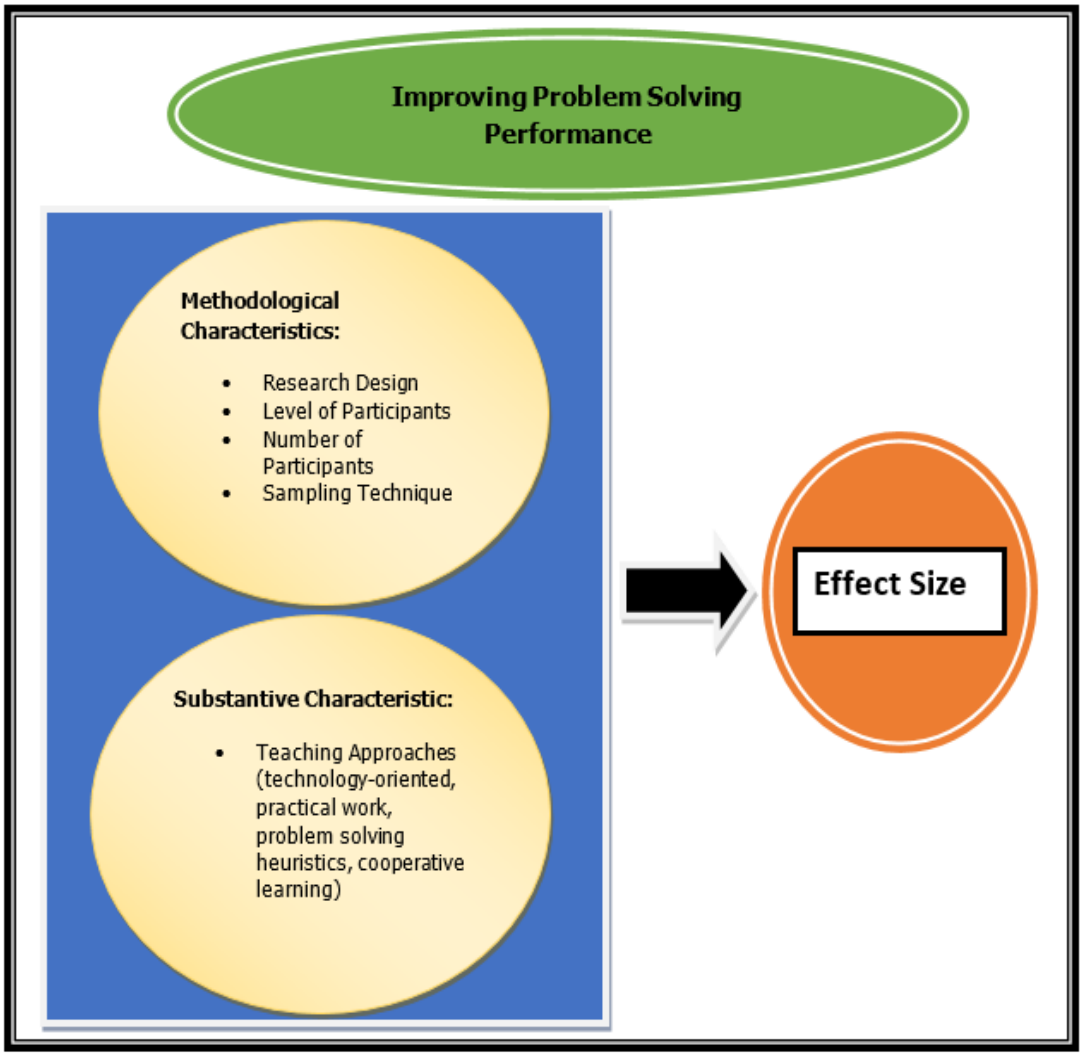

Figure1. Conceptual Framework on Meta – analysis on the Effect of Varied Teaching Approaches

One of the most important things to consider in conducting a meta – analysis is the effect size because it is the most identifiable in the conversion of each research study outcomes to common matrices called standardized mean difference of the effect size in itself. Effect size has a very important role in this study. It is a quantifiable measure of the magnitude of any occurrences that is used for addressing a certain question of interest (Kelley &Preacher, 2012). While, Cheung (2015) cited that effect size has to be scaled properly and accurately because it represents or summarizes the result or findings of studies.

Effect size can either yield to a positive or a negative effect. It reflects the magnitude or strength of an intervention or teaching approaches. It is computed based on the type of study a researcher is conducting. There are four well known authors on the computation of the effect size. They are Glass, Cohen, Hedge and Sawilowsky. Since this study is anchored on Glass, effect size is computed by getting the difference of the mean of the experimental group and the control group divided by the standard deviation of the control group. It can be computed manually or through the use of effect size calculator accessible online. To have a better interpretation, Glass, Cohen and Sawilowsky interpretation were adapted.

Effect size is significant in the study in identifying the most effective or best teaching approach in improving the problem solving performance of students in Math. If the computed effect size is positive or higher, it means that it is more valid. It also connotes that the teaching approach applied in the experimental group has a higher difference than the mean of the control group. The lesser the effect size means less significant or there is only little effect on the performance of the pupils

between the two groups. If the computed effect size is zero it means that the teaching approach is not significant or the effect is just the same as the traditional approach. In addition, if the effect size is negative it means that the performance of the students in the control group is far better than the performance of the students in the experimental group.

There are many definitions of meta – analysis as cited by different authors. But one of the best definitions is that it is a method or an analytical tool used in synthesizing data. It has two important features. These are methodological characteristics and substantive characteristics (Glass, McGaw & Smith, 1981). These two features are factors that influence the results on the effect of the teaching approaches used in the reviewed studies.

Methodological features are more general pertaining to the steps, methods and procedures of conducting the study. There are four methodological characteristic variables concerned in the study: (1) research design; (2) level of the participants; (3) number of participants; and, (4) sampling techniques. These four methodological characteristics are the independent variables of the study. Research design in this study includes Pretest and Posttest, Posttest only, Solomon Four Group design and Factorial design. The level of participants includes primary pupils, secondary pupils and tertiary pupils. Since there are different numbers of participants used in the reviewed studies, the researcher devised a range to group the participants. The number of participants is ranging from 1 to 80, 81 to 160, 161 to 240, 241 to 320 and 321 to 400. In addition, the sampling techniques included in

the study are simple random, multi – stage, cluster group, matched group, purposive, and convenience sampling.

Meanwhile, substantive features are characteristics of studies that are specific to the problem studies. There is only one substantive characteristic variable concerned in the study which is the research findings of the different researches on which teaching approach is best or most effective in improving problem solving performance of students in Math. This is also one of the independent variables of the study. Cooperative learning approach, technology oriented approach, problem solving heuristics approach and practical work approach are the teaching approaches included in the study.

These four teaching approaches are the common or most used approaches by some teachers. Cooperative learning approach refers to having students perform or do tasks in small groups who work together in order to achieve the desired learning goals. Technology oriented approach refers to the use of computer – assisted instruction, online applications, e-learnings that would help the students improve their performance. Problem solving heuristic approach is a technique used to help students solve problems independently and accurately like using patterns, pictures/drawing or representation to solve problems. Practical work approach refers to instructions that utilized the use of concrete manipulative materials or activities done by the students in order to develop their conceptual understanding and improve their problem solving performance.

The effect sizes of these four teaching approaches were computed because the reported means in the reviewed studies are just the p-values or the confidence

intervals which do not give the exact strength or effect of the teaching approach. The teaching approaches included in the study were practically significant.

Therefore, the researcher assumed that the four teaching approaches have different effect sizes. Among these four different teaching approaches, there could only be one effective approach. One of them, has the highest mean effect size while the rest could possibly have a lesser effect. This is significant to know so that teachers and practitioners have a guide in planning their lessons in order to improve the problem solving performance of the students.

Statement of Purpose

The main purpose of this study is to describe the different researches or studies on improving the students' problem solving performance in Mathematics through varied teaching approaches using Glass Meta – analysis technique. Specifically, the study aims to:

1. Describe the methodological characteristics of the researches reviewed in terms of:
    1.1 Research Design
    1.2 Level of Participants
    1.3 Number of Participants
    1.4 Sampling Technique
2. Describe the substantive characteristics of the researches reviewed in terms of teaching approaches used in improving problem solving performance.

3. Determine the effect size of the different teaching approaches in improving problem solving when grouped according to methodological characteristics and substantive characteristic.

Scope and Limitations

This study covered only researches on improving problem solving performance through varied teaching approaches found online, published and unpublished journals, articles, theses and dissertations from 2002– 2017 (for the past 15 years). The duration of the study depended on how many published or unpublished journals articles, thesis or dissertations were found. The researcher took about 4 months in searching these studies to be used.

Definition of Terms

In enhancing understanding of the major terms in the study, the following terms were conceptually and operationally defined:

Meta – Analysis. This means a synthesis of a research project, including a summary of the results of other studies that enables the derivation of general conclusions (Maksimovic, 2011). In this study, it is used as analysis of the analyses of the researches.

Problem Solving Performance. Acording to Polya (1957), it is a measurement of ability to do mathematical problem solving. In this study it refers to how the students performed in their test about problem solving. The problem solving performance is

reflected on the results of their scores in their assessment given before and after the treatment.

Teaching Approaches. This refers to the principles, and methods used by teachers to enable student learning (Linde, 2018). In the study, it is used as the styles or techniques employed by the teachers in improving students problem solving performance such as the use of technology, manipulative, concrete objects, models or representations and group works.

Effect size. It is simply a way of quantifying the size of the difference between two groups (Coe, 2002). In the study, it is computed by getting the difference of the mean of the experimental group and the control group divided by the standard deviation of the control group.

Substantive characteristics. This refers to characteristics of studies that are specific to the problem (Glass 1976). In the study, substantive characteristic is one of the features of meta – analysis. This includes the teaching approaches such as technology oriented approach, cooperative learning, practical work and problem solving heuristics approach.

Methodological characteristics. This pertains to characteristics that are more general pertaining to the steps, methods and procedures of conducting the study (Glass, 1976). In the study, it is also one of the features of meta – analysis. This includes research design, level and number of participants and sampling technique.

Sampling technique. This refers to the specific process by which the entities of the samples have been selected (Trochim, 2004). In this study, it refers to how the researchers identified the respondents of their study such as simple random

sampling, multi - stage sampling, cluster group, matched group, purposive or convenience.

Research design – This refers to the set of methods and procedures used in collecting, measuring and analyzing data (Cavana, Delahaye and Sekaran, 2001). In this study, it refers to the strategy that the researchers used in answering the questions and the hypothesis of their research. The researches were particularly experimental studies that utilized either posttest or pretest design, posttest only design, Solomon Four Group design and factorial design.

Cooperative Learning Approach – This is a strategy that lets the students play a vital role of helping one another achieve one common goal. It begins with the formation of groups into teams of students (Johnsen, 2009). In the study, it refers to having students perform or do tasks in small groups who work together in order to achieve the desired learning goals.

Technology – Oriented Approach – Technology - oriented approach refers to activities that involve the use of computer, mobile learning devices like smartphones, and tablets, presentation and media (Cracraft, 2015). In the study, it refers to the use of computer – assisted instruction, online applications, e-learnings that would help the students improve their performance.

Practical Work Approach – From the article written by the Nuffield Foundation (2018), practical work approach is used when students observe or manipulate real objects or materials or witness a teacher doing a demonstration. In this study, it refers to instructions that utilized the use of concrete manipulative materials or

activities done by the students in order to develop their conceptual understanding and improve their problem solving performance.

Problem solving Heuristic Approach – From Romhilde (2018), problem solving heuristic approach employs a practical method not guaranteed to be perfect but sufficient for the immediate goals. It can be done using graphs, models and mental shortcuts that helps the cognitive load of making a decision. In the study, problem solving heuristic approach is a technique used to help students solve problems independently and accurately like using patterns, pictures/drawing or representation to solve problems.

CHAPTER 2

METHODS

Research Design

The main purpose of this study is to summarize the findings of the experimental research studies on improving problem-solving performance through varied approaches. This study used the descriptive – documentary analysis method using the Glass' Meta – analysis technique. Glass' Meta – analysis technique involves systematically synthesizing many studies conducted on similar research topics to determine how much effect the manipulation of independent variables have upon the dependent variables and how much is due to the difference of each type of manipulation variable. Meta – analysis is used in the study to determine which among the primary studies on improving problem solving performance through varied approaches give the teachers the effective strategies or approaches to use in mathematics instruction. It is the appropriate design or tool in this study because different researches was summarized or synthesized. A unified result by means of getting the effect size was produced to determine which among the included teaching approaches is the most effective.

Documentary analysis is a technique used to gather information. It describes the act of reviewing the existing documentation of different studies in order to extract pieces of information that are relevant to the study. It is also often referred

as content analysis because the content of each studies was carefully examined and thoroughly read.

Selection and Inclusion Criteria for the Meta - analysis

The samples of the study were selected through purposive sampling. According to Crossman (2017), purposive sampling is a sampling technique that is used to select samples based on the researchers' choice. It is subjective or selective sampling because the researcher's preference is being considered. A survey of both unpublished and published online dissertations, theses and journal articles on improving problem solving performance through varied approaches was done.

The selected samples used for the study were those experimental studies that compare the results of the traditional teaching and experimental teaching influencing the improvement of the problem solving performance of the learners. The researches on the experimental studies had the following basic information: research design, participants, sampling technique and findings of the study on which effective teaching strategy helps improve problem solving performance. The studies had to be conducted in an actual classroom setting and had to report measured outcomes for improving problem solving performance.

The reviewed studies were 43 experimental studies both unpublished and published online dissertations, theses and journal articles from 2002 to 2017. These were qualified based on the criteria set by the researcher and patterned after Glass (1981). The following were the criteria set for research studies to be analyzed and synthesized patterned after the Glass Meta – analysis technique:

1. The studies must be experimental comparing the results and findings of both substantive and methodological characteristics included in the study.
2. The study must be an open access theses, dissertations and journal articles through Google and other related search engines.
3. The study was conducted from 2002 to 2017.
4. The study used test of difference as its statistics.
5. The studies must include the following information as mentioned or set by the author:
   5.1 Research Design
   5.2 Participants (level and the number)
   5.3 Sampling Technique
   5.4 The Mean of the control group and the experimental group and their Standard Deviation needed for the computation of the effect size
6. The studies were conducted within actual classroom setting.
7. The studies were either theses, dissertations or journal articles unpublished or published online.
8. The studies had to report study outcomes on improving problem solving performance of the learners.

Research Instrument

A Research Summary Form was developed to collect data from the researches. The survey form was patterned on the research study conducted by Cajigal (2011). Some parts of the instrument were revised. The approval of the adviser and some experts were considered for the content validation. The research

summary form was presented to the panelist during the colloquium to validate the content. The initial validation of the studies and a review of the previous meta – analyses were done on similar topics containing common characteristics in the final instrument of the summary form.

The Research Summary form (see Appendix A) is composed of three parts. The first part pertains to the general data of the study such as the title of the study and the researcher's name or the author of the study. The second part is created to gather methodological characteristic such as: (1) research design: if it is a pretest/posttest, posttest only, Solomon four group design or factorial design, (2) level of participants: primary, secondary or tertiary, (3) number of participants: if it ranges from 1 to 80, 81 to 160, 161 to 240, 241 to 320 or 321 to 480, and (4) sampling techniques: simple random sampling, multi – stage sampling, cluster group, matched group, purposive sampling and convenience sampling. The third part was designed to gather the substantive characteristic of the study. It includes the following: mean of the control group, mean of the experimental group, standard deviation, and the teaching approaches in improving problem solving performance in math.

A Research Summary Survey Results (See appendix C) was made to clearly show the summary of the data gathered as well as the effect sizes. The research instrument was further based from the given research characteristic variables by Glass' studies in 1981 as well as other researches which used meta – analysis procedure.

Data Gathering Procedure

The focus of this research was experimental studies, theses and dissertations published and unpublished online pertaining to improving problem solving performance of learners through varied approaches. The information about the participants were not disclosed in this study for confidentiality purposes. It is a guarantee that only the pertinent information needed for the study was gathered, analyzed and synthesized.

To gather the data needed for the study, first the researcher identified relevant researches, journal articles, theses, and dissertations published and unpublished online. Electronic and print resources were used to determine which studies to include in the analysis. Electronic databases and manual search used include ERIC. Edu.Gov., SAGE Publication, Psych Info, Academic Search Elite, ProQuest for Dissertations, Math and Science Journals, Educational Technology and Society, Journal of Educational Psychology, International Conference on Social Sciences Research, Journal of Education and Learning, PubMed, Research Gate, Review of Educational Research, Slide Share, Educational Psychology Review, Taylor and Francis Online, Remedial and Special Education. This was done to determine if there are enough studies on improving problem solving performance to have meta – analysis possible. In order to use the technique there should be at least 30 experimental studies to conduct the analysis.

After locating a pool of studies, the researcher characterized the studies as objective as possible and criteria for inclusion was set in the study. A research summary form (see Appendix A) and a research summary survey results (See

appendix C) were drawn up for this purpose. The research summary form was presented to the panel during the colloquium and was validated by the researcher's adviser to check the information included in the said instrument.

The researches on the experimental studies must include the following basic information: (1) research design: if it is a pretest/posttest, posttest only, Solomon four group, or multiple probe design (2) participants: pre-school, primary, secondary, tertiary (3) sampling technique: simple random sampling, stratified sampling, cluster group, matched group (4) mean of the control group, mean of the experimental group, standard deviation, effective teaching strategy or approach in improving problem solving performance of leaners in math. The studies had to be conducted in an actual classroom setting and measured outcomes for improving learners' problem solving performance.

The existing meta – analysis literature on relevant studies provides direction on which study features to code. The studies that met the criteria for selection was carefully coded and recorded in the research summary form to ensure the objectivity and reliability of coding. The initial research was 75 but was later trimmed down to 43 because of incomplete data. The collection and gathering of data lasted for 4 months. An annotated bibliography was included to provide the readers with summary and evaluation of the research studies.

The coding method of the characteristics of the studies used by the researcher is shown below:

Substantive characteristics:

Characteristics	Code	Types
Teaching Approaches	1	Technology – Oriented Approach
	2	Practical Work Approach
	3	Problem Solving Heuristics Approach
	4	Cooperative Learning Approach

Methodological Characteristics:

Characteristics	Code	Types
Research Design	1	Pre – test /Post Test
	2	Post – Test only
	3	Solomon Four Group Design
	4	Factorial Design
Level of Participants	1	Primary Students (Gr.1 – Grade 6/6 – 12 years old)
	2	Secondary Students (Gr.7 – Gr. 12/12 – 18 years old)
	3	Tertiary Students (College/18 years old and up)
Number of Participants	1	1 – 80
	2	81 – 160
	3	161 – 240
	4	241 – 320
	5	321 – 480
Sampling Technique	1	Simple Random Sampling
	2	Multi – stage sampling
	3	Cluster Group
	4	Matched Group
	5	Purposive
	6	Convenience

Data Analysis

Descriptive statistics was utilized to analyze the data. The data was collected, coded, tabulated, and analyzed. Since the study is descriptive, the researcher used MS Excel for the computation and for the analysis.

The following statistical techniques were used in the study:

a. Descriptive statistics for the computation of the means, frequencies and percentages. This was used for the description of the methodological characteristic such as research design, participants, and sampling technique as well as the substantive characteristics on which teaching approaches is more effective.

b. The effect size was computed using the Glass formula as follows:

$$\Delta = \frac{\overline{x_e} - \bar{x}_c}{s_c}$$

Where:

$\overline{x_e}$= mean of the experimental group

$\bar{x}_c$= mean of the control group

s_c= standard deviation of the control group

Since one of the reviewed studies used Solomon four group design, the effect size was computed differently. The formula above was used to get the effect size of each group. The four effect sizes were combined then the sum was divided by four to get the mean effect size of the reviewed study.

For the interpretation of the effect size, the researcher used the convention for appraising the magnitude of effect sizes, which was established by Glass (1976), Cohen (1992) and Sawilowsky (2009).

The interpretation of the effect size is shown in Table 1. Glass and Cohen's interpretation was extended by Sawilowsky's interpretation to describe better other effect sizes because there were studies that had more than 0.8 effect size.

Table 1

Interpretation of the Effect Size

Effect Size Range	Glass and Cohen's Interpretation	Meaning	Effect Size Range	Sawilowsky's Interpretation	Meaning
0.01 to 0.2	Small	Less significant			
0.21 to 0.5	Medium	Moderately significant			
0.51 to 0.8	Large	High significant			
			0.8 to 1.19	Large	high significant
			1.2 to 1.99	Very Large	higher significant
			2	Huge	highest significant

Based on Glass and Cohen's interpretation, an effect size is small if it ranges from 0.01 to 0.2. It means that the effect of the methodological characteristics and substantive characteristics on the problem solving performance of the pupils is less

significant. This also signifies that the effect of teaching approaches in the experimental group has a little difference from the effect of the teaching approaches in the control group.

Based on Glass and Cohen's interpretation, an effect size is medium if it ranges from 0.21 to 0.5 which is moderately significant. This means that the effect of teaching approaches in the experimental group has a medium difference from the effect of the teaching approaches in the control group.

Based on Glass and Cohen's interpretation, the effect size is large if it ranges from 0.51 to 0.8 and was extended by Sawilowsky up to 1.19. It means that the effect of the methodological and substantive characteristics on the problem solving performance is significantly high. It also signifies that the effect of teaching approaches in the experimental group has a high difference than the control group.

Based on Sawilowsky's interpretation the effect size is very large if it ranges from 1.2 to 1.99. It means that the effect of the methodological and substantive characteristics on the problem solving performance is significantly higher than 1.99. It also signifies that the effect of teaching approaches in the experimental group has a higher difference than the control group.

Furthermore, based on Sawilowsky's interpretation, the effect size is huge if the computed mean is 2. It means that the effect of the methodological and substantive characteristics on the problem solving performance is significantly highest among the rest. It also signifies that the effect of teaching approaches in the experimental group has a huge difference than the control group.

Lastly, if an effect size is 0 it means that the performance of the pupils in the experimental group is the same as the performance of the pupils in the control group. This implies that the teaching approaches have the same effect or no effect at all or no difference at all. If the effect size is negative, this means that the effect of the teaching approach is better or higher in the control group than the experimental group.

Ethical Considerations

Conducting a meta – analysis study has already been used in many fields of profession. A researcher needs to consider the following in conducting a meta – analysis: the design and the analysis strategies. A researcher really has to be very keen to find all the necessary things that he needs to look into the studies. All the criteria set by the researcher must be met to avoid such problems.

Bartolucci, Katholi, Singh and Alarcon (2005) cited that one of the issues in conducting a meta – analysis is heterogeneity. It happens when the size as well as variance between the two treatments (experimental and control) vary across the studies being measured. One more problem is the issue of completeness or extensiveness. Researchers would consider how complete or extensive the data is, findings and suggestions stated by the authors of the studies.

There are quite limited number of studies to be included in the meta – analysis, thus researchers need to search more related studies or articles. Since there are insufficient materials to be able to conduct a meta – analysis, careful planning and checking of the studies should be done by the researchers so that the

best findings and results will be derived. Finally, to have a better output of any meta – analytic reviews or researches, all the necessary data should be available so that there would be no any biases into the interpretation of the results due to incomplete information or data.

CHAPTER 3

RESULTS AND DISCUSSION

1. Methodological characteristics of the researches reviewed in terms of:

1.1 Research Design

Table 2 shows that most of the studies reviewed utilized the Pre-test/Post-test research design with a frequency of forty.

Table 2

Methodological Characteristics according to Research Design

Research Design	Frequency	Percentage
Pre – test /Post Test	40	93.02
Post – Test only	1	2.33
Solomon Four Group Design	1	2.33
Factorial Design	1	2.33

Of these forty studies, nineteen studies used randomized pretest and post-test control group design to test the cause and effect relationship of two groups. Nine studies used quasi - experimental design, particularly the equivalent/parallel method where the number of participants in each group is the same or equal and where the pairs were being matched according to their abilities. Similarly, seven studies also used quasi – experimental method, particularly the non – equivalent where the number of participants for the experimental group is not the same as the number of participants in the control group. A quasi – experimental design is

necessary when participants cannot be randomly assigned to an intervention thus, there are multiple threats to validity.

There is one study that used mixed method research. A mixed method research is a combination of qualitative and quantitative research. The static group comparison design was also utilized by another study in which the students may leave a question blank in the test if they do not know the answer.

In addition to that, one study had a group within treatment design. A within treatment design is an experiment in which the same group serves in more than one treatment. Another study used ex post facto causal comparative design that sought to identify potential cause – effect relationships by forming groups of individuals in which the dependent variable is present or absent followed by comparing the groups on the basis of one or more dependent variables. Pretest and posttest questions from a Program for International Student Assessment (PISA), an international assessment that devotes time to study the standards between countries pertaining to international standards was also used by one more study. Pretest was used for ascertaining the proficiency level on the subject matter then posttest was used to measure the result of the instruction.

The same result was yielded in the meta – analysis study conducted by Cajigal (2011) where most of the researches in his study used pretest – post-test design. Among those studies that he reviewed, twenty – nine out of thirty studies with a percentage of 80.55 used pretest-posttest research design. On the other hand, Table 2 shows that there is only one reviewed study that used post – test only

design. The study used quasi – experimental method wherein two elective classes were selected as intact groups.

Meanwhile, one study also used the Solomon four group design particularly the non – equivalent pre-test/post-test control group design. Solomon four-group design is the extension of the pretest and posttest control group design. It is the combination of pre-test/post-test control group design and post-test only. Two groups are pre- and post- tested, two groups are post-tested, two groups have treatments and two groups do not have experimental treatment.

Lastly, one study used the factorial design particularly the 2 x 3 factorial design. This is done to see how the independent variable affects the dependent variable and how the combination of the independent variable affects the dependent variable. Study AA used 2 x 3 factorial design with 2 levels in factor A and 3 levels in factor B. Factor A consisted of the methods of instruction involving explicit problem solving strategy and the traditional method while factor B consisted of three types of pupils based on their mental ability such as high mental ability, average mental ability and low mental ability. Quasi – experimental method was also utilized since the absence of random assignment was observed. The design is usually done in a natural arrangement such as intact classes in a school setting so as not to disrupt the schedule of the participants in the study.

From the result of the meta – analysis done, it implies that pretest – posttest design is the most used research design to test the effectiveness of a certain intervention or approaches. It may be inferred that among the research designs, pretest – posttest design is best suited to test the effectiveness of any educational

innovations or interventions. This agrees with Shuttleworth (2018) who mentioned that future researchers who wish to conduct true experimental research can adopt or use pretest and post – test design because it appears to be valid in comparing participant groups and in measuring the degree of change occurring as a result of treatments or interventions. The relevance of this finding to the Mathematics education and research is that it gives the choice or option to the educators and researchers on what kind of research design can be utilized in their study.

1.2 Level of Participants

Table 3 shows that among the level of the participants, secondary students with an age range of 12 to 18 years as respondents have the highest frequency of twenty - seven.

Table 3

Methodological Characteristics according to the Level of the Participants

Level of the Participants	Frequency	Percentage
Primary students	10	23.26
Secondary students	27	62.79
Tertiary students	6	13.95

Of these twenty - seven studies, eight studies had grade twelve as their respondents, six studies had grade seven, four had grade nine, four studies had grade eleven, three had grade eight, and two had grade ten. On the other hand, studies with primary students from grades one to six with age range of six to twelve years as respondents have a frequency of ten. Of these ten studies, five had grade

six, two had grade four, one had grade five, one had grade three and one had grade one with emotional and behavioral disorder. Meanwhile, studies with tertiary students with age eighteen years old and above as respondents have a frequency of six. Of these six studies, three were from the educational statistics class, two were from the engineering class and one was from the first year college students.

In contrast to the meta – analysis study conducted by Bas, Senturk and Cigerci (2017), the primary/elementary level has the highest percentage of 64, while secondary and university levels have the same percentage of 18. While in the meta – analysis conducted by Capar and Tarim (2015), secondary pupils have the highest percentage of 52.77, primary pupils are next with a percentage of 27.77, and university or tertiary has a percentage of 13.88.

It can be derived from the results of this study that secondary students were favored as respondents or participants of the researches included herein. Hence, it may be considered to have it as the participants of the future researchers in conducting any study particularly experimental studies. As Pennington (2009) mentioned, secondary learners are qualitatively different from preschool and primary learners. Most secondary students have achieved the formal operational stage as described by Piaget. They can already think abstractly and need lesser concrete examples to comprehend complex thought patterns and ideas.

It can also be noted that the researchers of the studies included in the meta – analysis done believed that high school students too are more responsible in terms of handling gadgets and using computers when technology oriented approach is applied in the teaching process. They should be reminded and informed that too

much use of technology like using gadgets will not make them good problem solvers. High school students too can easily follow the instructions of the teachers when cooperative learning approach, practical work approach and problem solving heuristics approach are applied in the learning process.

1.3 Number of Participants

Table 4 shows that among the reviewed studies, twenty - nine had a sample size ranging from 1 to 80.

Table 4

Methodological Characteristics according to the Number of Participants

Number of Participants	Frequency	Percentage
1 to 80	29	67.44
81 to 160	6	13.95
161 to 240	4	9.30
241 to 320	1	2.33
321 to 480	3	6.98

Of these twenty - nine studies, fourteen studies preferred to use 41 to 60 as sample size, nine studies used 21 to 40, four studies used 61 to 80 and two studies used 1 to 20 only. Thus, it can be derived from the result that the ideal number of participants used by the researchers of the studies included herein is ranging from 1 to 80, particularly around 41 to 60. This is in contrast to the meta – analysis of Lloyd (2013) that the number of participants with a range of 1 to 80 is the second highest sample size.

The number of participants ranging from 81 to 160 is the second highest. Four reviewed meta-analysis studies had sample sizes of 81 to 160. Of these four studies, two studies had a sample size of 160, one study had 153 and another had a sample size of 106. The same result was found in the meta – analysis study conducted by Carbonneau, Selig and Marley (2013); Gersten, Chard, Jayanthi, Baker, Morphy and Flojo (2009); and Sokolowski, Li, and Willson (2015) with seventeen studies. However, this is in contrast with the meta – analysis study conducted by Lloyd (2013) because the sample size with a range of 81 to 160 is the third highest.

The number of participants ranging from 321 to 480 is the third highest. There are three reviewed studies that are included in the meta – analysis done. Of these three studies, one had 366 participants, another had 380 participants, while the third study had 461 participants. In the meta – analysis conducted by Lloyd (2013), the number of participants is the highest. Sixteen studies were involved in the meta – analysis conducted by Lloyd (2013).

The number of participants ranging from 161 to 240 is the fourth highest. Two reviewed studies were included in the meta – analysis. One study had 173 participants and the other study had 180 participants. Similar result was found in the meta – analysis conducted by Carbonneau, Selig and Marley (2013) with three studies, Lloyd (2013) with one study, and Sokolowski, Li, and Willson (2015) with one study too. These authors found out in their studies that participants ranging from 161 to 240 is the fourth highest. The number of participants ranging from 241

to 320 is the least. There is only one study that is included in the meta – analysis done. This study had a sample size of 267.

From the result of this meta – analysis study and the related studies included herein, it can be derived that the most number of participants used is participants ranging from 1 to 80. This may be due to the fact that conducting a study with lesser sample size is easier to handle. This result also implies that in the field of research, this maybe a source for the future researchers in selecting their number of samples or participants. With lesser number of participants, it is much easier to manipulate or conduct a study rather than having big number of participants.

Barkhuizen (2014) cited that there may be different factors on having less number of participants such as the purpose or the nature of the study. The purpose of the study is to represent an in-depth analysis of the intervention. Participants are determined by availability, accessibility, suitability and class size. It can also be outside the control of the researcher. This includes the specific requirements of the research design and methods, constraints of time, human resources and timetabling. Consequently, this finding implies that for future researchers, said range may be considered as basis for selecting sample size.

1.4 Sampling Techniques

Table 5 shows that most of the reviewed studies included in the meta – analysis done used simple random sampling technique. Of these twenty – three studies, twelve studies used grades of the participants in selecting the samples of the study. Their mathematical performance (high, medium and low ability) from previous level was also used as criteria for selection.

Seven studies included herein assumed that the participants have similar characteristics and were selected from the intact group. One study applied tossing of a coin to choose which section or class will be included either in the experimental group or in the control group. Then, random sampling was done through fish bowl technique in order to have an equal number of participants in each group.

Table 5

Methodological Characteristics according to Sampling Techniques

Sampling Techniques	Frequency	Percentage
Simple Random Sampling	23	53.49
Multi-stage Sampling	1	2.33
Cluster Group	1	2.33
Matched Group	13	30.23
Purposive Sampling	2	4.65
Convenience Sampling	3	6.98

Lottery sampling without replacement was utilized in one of the studies. This was used for the purpose of confidentiality and sampling codes were assigned to the participants of the study. Another study employed random assignment with matching to ensure the group equivalence on the variables of each matched pair. Then these pairs were assigned to either experimental group or control group.

The use of an IPad with a name selector app to determine the sample was used in one study. Simple random sampling was used because it is an unbiased way of choosing the samples from the given population since every member was given an equal chance to be part of the study. Random sampling is the cornerstone of sampling theory. It is a sampling technique wherein each member of the

population has an equal chance of being selected. It is based on the concept of probability and it is noted to produce good samples of the population.

Result in Table 5 also reveals that the second highest sampling technique is the matched group sampling. It uses discrete experimental groups for each particular treatment but depends upon matching every subject with one group, which is equivalent to one another. This technique ensures that the groups are equivalent on one important variable before the start of the study. There are thirteen studies included in the meta – analysis done that used matched group sampling technique.

Of these thirteen studies, four studies employed matched pair to ensure the group equivalence. The member of each matched pair was then assigned to the experimental or control group. Four studies took the participants from two intact groups which were eventually matched according to their IQ score and pretest score. These groups then were randomly assigned to either experimental or control group to come up with a comparable group. Also, two studies had intact groups or group matching to come up with a comparable group. Fishbowl technique was used to determine the participants assigned to the two groups. An example of this was done by De Guzman (2009), where letters F to J were written on identical strips of paper and placed in a container. The researcher picks a slip in the container without looking and the chosen slip will be assigned in the experimental group then next to the control group.

The other three studies that employed matched group had varied ways of utilizing it. In the first study, matched group was used to avoid extraneous variables

using ranking method. The pupils were ranked using their entrance test scores as the basis from the rank order list, the first two subjects were drawn, and then one is assigned to the experimental group and another one to the control group. In the second study, matched group was used based on the previous grades of the participants. While in the third study, the same was used to determine who will be part of the experimental or the control group. Tossing of a coin was then applied. A fair distribution of the learners' mathematical ability such as being an above average, average, and below average was considered in selecting the samples. In contrast to the meta – analysis study conducted by Cajigal (2011), matched group technique is the most used technique of the researches being reviewed. There were seventeen studies that utilized this technique.

The third highest sampling technique is convenience sampling. There were three studies included in the meta – analysis done. Convenience sampling is a non – probability sampling technique where participants are selected because of their convenient accessibility and proximity to the researcher. The participants are selected because they are closest and easiest to recruit. The researcher did not anymore consider the entire population in selecting the samples.

Meanwhile, the fourth highest is purposive sampling. There were two studies included in the meta – analysis done that used purposive sampling. Crossman (2017) cited that purposive sampling is a non – probability sample where the researcher selects the samples based on what he likes. His preference or choice is considered.

On the other hand, cluster sampling and multi – stage sampling are the least among the sampling techniques. Both have a frequency of one. From the Statistics Dictionary (2018), cluster sampling is a process of selecting samples where the researcher splits the population into certain groups called clusters. It is also a process of randomly selecting intact groups or individuals within the defined population sharing similar characteristics. Meanwhile, in the study of Cajigal (2011), there were three studies that utilized cluster sampling.

Study AF used multi – stage sampling. The researcher combined purposive and random sampling techniques. In the first stage, the researcher purposively selected eight colleges then from the eight colleges it was trimmed down to three colleges using random sampling technique. Then from the three colleges, intact classes were grouped or used as either experimental or control group. Based from the result of the meta – analysis done and the related studies included herein, it implies that the most used sampling technique is the simple random sampling. Most of the researchers prefer to use simple random sampling technique.

Choosing a sampling technique depends on the type of study a researcher is conducting. Sampling techniques has its own purpose that is to provide various types of information of a qualitative or quantitative nature about the whole population. The relevance of these findings to future researchers is that it may serve as a guide or basis for selecting which sampling technique should be used in their study.

2. Substantive characteristics of the researches reviewed in terms of:

2.1 The effective teaching strategy/approach in improving problem solving performance

Table 6 shows the different teaching approaches included in the study.

Table 6

Substantive Characteristics according to Teaching Approaches

Teaching Approaches	Frequency	Percentage
Technology – Oriented Approach	14	32.55
Practical Work Approach	10	23.25
Problem Solving Heuristic Approach	11	23.58
Cooperative Learning Approach	8	18.60

Technology Oriented Approach

Technology – oriented approach refers to the activities or to the instruction that involves the use of computer, mobile learning devices like smartphones, and tablets, presentation and media (Cracraft, 2015; Tareef 2014; Karnasih, Sinaga 2014). Technology is essential in teaching 21st century where pupils are considered as digital natives (Abdon, 2014). Teachers should optimize the potential of technology to increase students' access to information, ideas and interactions to strengthen learning experience.

Table 6 shows that there are fourteen reviewed studies that applied technology – oriented approach in teaching mathematics. Of these fourteen studies, seven studies used Computer – Assisted Instruction (CAI) but with varied style or types of mathematical skills and competencies. One researcher used a Geometer's Sketchpad to teach different concepts of geometry. Another researcher used

personalized and non – personalized computer – assisted instruction. In the personalized group, preferences were used to create the math instruction while non – personalized group were taught using the standard lesson given by a computer program.

Computer – assisted instruction with a hyperlink was used in the two studies included in the meta - analysis. Hyperlink is a command in a computer that enables the use to click one slide to another slide using action button where the browser can go to specific target by clicking the mouse. A Dynamic Software Autograph in teaching Statistics in grade XI was utilized in one study included herein. This was used to improve pupils' problem-solving ability. Autograph helps the students and teachers visualize Math by just pointing and clicking on animated objects or figures on the computer. It is a student-driven exploration where students can explore how to understand statistics.

An Authorware was also used in one of the studies. It is used if one wants to create interactive programs that can integrate a range of multimedia content particularly electronic educational technology (also called e – learning) applications. An example of the application that was used by one researcher is the MobyMax application. It is an online resource free "Math, Language and Reading" for K – 8. It provides engagement of all students, pacing of the lesson, checking for understanding, modeling, providing feedback and student monitoring.

Aside from the above mentioned software, one study used the "I Can Learn" computer software program to improve adolescent's mathematics achievement. "I Can Learn" is a computer program with software and hardware intended to provide

a series of interactive lessons to each individual. It allows students to learn and study Mathematical concepts at their own pace of learning. Students need to repeat the entire lesson if they did not pass the comprehensive test until mastery of the lesson is achieved.

With the vast changes of technology as well as of the curriculum, teachers do not stop in finding ways on how to improve the performance of the students. Another technology-oriented approach was utilized by two studies included herein. They used blended learning. Blended learning is a mixture of an online and a face to face instruction. Teachers are encouraged to use social media, and other computer programs to help students do well in their academics. An example of the program that was used was DreamBox and Reflex Math. Yushau (2006) mentioned that blended learning combines practical life activities, including live e – learning, self – paced learning and face to face instruction.

A kind of blended learning that was used in one study is the flipped model of instruction. It is one of the newest strategies to improve student involvement and academic performance. The idea of having flipped classroom is to let the students access their homework and activities in the house through teacher created videos, applications, playlists and interactive lessons. Another blended learning style that was used by one researcher is the Moodle online teaching. It is an e-learning based, free education web application. It enhances, educational interaction and helps teacher understands students' aptitudes and academic achievements to improve teaching quality and efficiency.

Related meta – analyses on utilizing technology in teaching math was conducted by Enchang, TingSungand Feng Lin (2006), Jin – Seo (2008), SchoppekandTulis (2010), and by Leh&Jitendra (2013). All of them believed that technology should not be used to work out problems without gaining understanding. Thus, it helps students think critically and use their skills in solving problems using varied applications.

The meta – analyses conducted by Sung, Chang, Liu (2016); Tokac (2015); Belland, Walker, Olsen, and Leary (2014);Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, Surkesand Wood (2014); Merchant, Goetz, Cifuentes, Keeney – Kennicuttand Davis (2013); Cheung and Slavin (2013); Girard, Ecalleand Magnan (2012); Wu W-H, Wu Y-C, Chen, Kao, Lin and Huang (2012); Sosa, Berger and Saw (2011); Qing Li (2010); Yesilyurt (2010); Rakes, Valentine, andMcGatha (2010); Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, Surkes, andLowerison (2009); Means, Yukie, Murphy, Bakiaand Jones (2009); Schroeder, Scott, Tolson, Huang and Lee (2007); Liao (2007); Vogel J., Vogel D., and Cannon – Bowers (2006); and, Sitzmann, Kraiger, Stewart and Wisher (2006) favored the use of technology in improving problem solving performance. All the authors believed that integrating technology in mathematics instruction can produce high achievement and boosts interests in learning mathematical concepts.

Problem Solving Heuristics Approach

Problem solving heuristics approach are techniques that help students solve problems independently and accurately through patterns, pictures/drawing or representation to solve problems. Table 6 shows that there are eleven reviewed

studies that used problem solving heuristics. Problem solving method was used in two studies included herein. It helped students enhance their achievement or performance in math. These two studies claimed that problem solving is an essential element in teaching mathematics because it heightens the logical thinking, curiosity, organization, perseverance and analysis to interpret communication of facts or data (Ali, Hukamdad, Akhter, Khan, 2010; Dannawi, 2013).

POLYA's (1945) strategy was used also in two studies included herein. This strategy includes four steps: (1) Understand the problem (2) Devise a plan (3) Carry out the plan and (4) Look back. It is believed that up to now, this has been widely used by mathematics teachers in teaching problem solving.

Similar to POLYA's strategy is the Rusbult's problem solving strategy. There were two studies included herein that utilized this strategy. Rusbult's problem solving strategy has four phases. The first phase is ORIENTATION. In this phase, students translate the story problems, symbols, pictures and information into a clear idea of now (a situation that is definitely the problem statement) and the target. Students read carefully and understand the problem. They draw and sketch a diagram when this is not given and look for data that is not given in the picture. The second phase is PLANNING. In this phase, students figure out how to get from where they are now to the target. They may predict what will happen in a given situation and explore possible strategies. The third phase is ACTION. In this phase, students begin or carry out their plan and continue until they reach the target. Students may decompose the problem into sub-problems when the problem is large and complex. The last phase is CHECKING. In this phase, students may ask

themselves: “Did I answer the question given in the problem?” “Have I reached the target?” The result of the studies claimed that Rusbult’s problem solving strategy enhances students’ achievement in Math (Nfon 2013; Dedel 2002).

Another problem solving heuristics that was employed in one study is problem – based learning strategy. Problem – based learning is used as an alternative instructional strategy in the teaching and learning of mathematics effectively. Previous research had discovered that it enhances students’ teamwork, problem solving skills and communication skills. The use of Polya’s strategy is still included in the execution of the problem - based learning (PBL). Several effects of PBL was mentioned in the study such as learners/students became better problem solvers, better in written and oral communication skills, and worked collaboratively with peers (Abdullah, Tarmizi, Abu, 2010)

One more problem solving heuristic approach used in one study is the use of Higher Order Thinking Skills learning strategy. Students were given problems that needed analysis so that their critical thinking and problem-solving skills will be honed. The strategy allows the pupils to reflect on how they performed the steps in each thinking skill in order to find the correct answer (Villarey, 2002).

Likewise, one of the studies included herein utilized problem solving contexts strategy. This includes 6 stages. (Stage 1) Students begin with individual reading and understanding a problem’s context. If the student still did not understand the problem, they are allowed to reread it. (Stage 2) Students make a situation model to represent the problem. (Stage 3) Students make a mathematical model using graphs, pictures, symbols, tables and verbal statements, and do some analysis

technique. (Stage 4) Students derive a possible outcome from the analysis made on the procedures and mathematical representation of the problem. (Stage 5) After deriving from the analysis, the students may now interpret the result. (Stage 6) The last stage is reporting a solution. Students will then share the solutions and answers to their peers, when they effectively answer the problems. The findings of the study conducted by Bostic (2011) suggest that this type of instruction supports students' problem-solving performance regardless of the grade level and content embedded within a problem-solving task.

Problem solving really makes students twist their individual brains. Some students feel sad when they do not find the answer to the problem. Their conceptual understanding should also be improved. Thus, conceptual and procedural learning strategy was created and utilized in one of the studies included herein. Procedural learning is learning how to execute actions sequences to solve problem. It is applying the rules learned on how to solve the problem. While, conceptual learning strategy enables students to describe with understanding the rule governing equations and their solutions (Adeleke, 2007).

Another technique to hasten problem solving performance under problem solving heuristics approach is the use of mathematical modeling. One study applied this, wherein students made more significant and meaningful connections when mathematical ideas are represented in various models such as manipulatives, verbal symbols, pictures and written symbols to make concepts more meaningful. Students are encouraged to make/draw a model or a representation of the problem

so that they could easily find the accurate solution and answer to the problem (Santos, Belecina, Diaz, 2015).

Related studies conducted by Zhang and Xin (2012), and Walker, and Leary (2009) agreed that problem solving heuristic approach could yield a positive output in solving mathematical problems. The use of adequate heuristics support efficient and appropriate mathematical thinking leading towards a solution. Students need these representations to solve word problems because it clearly shows the correct solution to the problem.

Related studies conducted by Montague and Dietz (2009); Montague et.al (2006); Freeman (2013); Montague (2006); Sulaka (2010); Mancl (2010); and Palmay (2015), all claimed that problem solving heuristics approach were effective in improving problem solving performance. It helps students who are struggling in Math understand the basic concepts and learn how to understand a mathematical problem, analyze the problem, develop sensible plans to solve the problem, and evaluate or assess solutions.

From the meta – analysis done by the researcher and the related studies included herein, it can be derived that problem-solving heuristics approach can be applied to improve the performance of the pupils. Teachers in the field of education need to consider modifying and revising modules/lesson plans and integrate the different problem-solving heuristics mentioned in the study. Students need to be given different ways on showing solutions to find the correct answer. There is no single solution to every problem. Students are encouraged to think and find many ways on how to arrive at the correct solution. In Math, there is only one correct

answer but with varied solutions. Thus, teachers and students should work hand in hand to attain better performance.

Practical Work Approach

Practical work approach in this study refers to instructions that utilized the use of concrete manipulative materials or activities done by the students in order to develop their conceptual understanding and improve their problem solving performance. Practical work approach helps the learners to find out information and understand concepts through appropriate activities and demonstration.

There are ten reviewed studies included in the meta – analysis study. Of these ten studies, four used the project – based learning/authentic performance task which made the pupils the center of the learning and teachers were only the facilitators of students learning experiences. Students worked on a project that focuses on a specific learning objective that were aligned with content standards and important 21st century skills. The project had a real world connection which allowed them to demonstrate knowledge through published presentation or displayed products or performances (Intel Corporation, 2009).

Concrete models or manipulatives were utilized in seven studies included herein. Kontas (2016) cited that manipulative came from an Old French word “manipule” which means “handle,” It also connotes movement, control, operate or to manage with the use of hands. The use of manipulatives allows pupils to grasp abstract concepts because they get to touch or to manipulate concrete objects to demonstrate the problem they are solving. It empowers students to connect the

information they have in mind and integrate their thoughts to fully understand mathematical ideas.

There are three different models of manipulative materials mentioned in the reviewed study done by Bayram (2004). First is the concrete models which is used to illustrate mathematical concepts and principles through three dimensional figures. Second is the symbolic model which is used to illustrate mathematical concepts or principles using numbers and signs that specify operation or relationship in Math. The third model is pictorial. In this model, concrete and symbolic are being combined to come up with the pictorial view. This view is similar to Bruner's model. He states that children gather information through three different ways. They are enactive (concrete), iconic (pictorial) and symbolic (abstract). In the enactive stage, children gather information through interacting with objects and concrete experiences. In iconic stage, pictorial representation is very important. In symbolic stage, language and symbol are important.

The use of magnetic coins to teach the concepts of money to first graders was utilized in one of the studies included herein. Another study also used cubes, stamps, dice, spinners, balls, coins, shapes, gifts/boxes, lemon candies, music, blocks and sandwiches to teach the concepts of probability was also used.

On the other hand, in one of the studies included herein, geometry was taught using concrete models like cutting of the plane and solid figures and making a model of the figures. The use of materials like measuring tools, shapes of a circle to teach the concepts of a circle and its parts like the angle, arc, radius and diameter was adapted in another study. One local study used the block model

approach. De Guzman (2009) cited that the Block Model Approach is a series of instruction that helps students gradually understand mathematical concepts and construct a significant connection among concrete, representational and abstract level of understanding.

In the same vein, related studies on applying practical work approach was conducted by some researchers. Holmes (2013) used virtual manipulatives. Carbonneau, Marley and Selig (2013); Rakes, Valentine, and McGatha (2010); Schroeder, Scott, Tolson, Huang and Lee (2007); Ellington (2006); Kelly (2006); and Moreno, Ozogul, Reisslein (2011) had concrete manipulatives too as part of their studies. Garforthand Siegel (2015), and Kim, Michaels, and Wary (2015) anticipated that manipulatives have a significant effect on the performance of the pupils because it lets the pupils do mathematics without understanding arbitrary symbols.

From the result of the meta – analysis done by the researcher and the related studies included herein, it can be noted that practical work approach has been applied in the mathematics instruction to improve the problem-solving performance of the students. It is considered by many researchers as an approach to enhance the conceptual understanding and mathematical skills of the pupils. In the field of education, teachers might want to use this as part of their medium of instruction. Students gain better problem-solving performance when exposed to practical work approach like the use of manipulative materials (Garforth and Siegel, 2015). In the article written by the Nuffield Foundation (2018) on teaching and learning using practical work approach, it was mentioned that practical work

approach can motivate students, stimulate interest and enjoyment and can improve problem solving performance. It can also be used to achieve certain learning goals.

Cooperative Learning Approach

Subsequently, cooperative learning approach used in the study refers to having students perform or do tasks in small groups who work together in order to achieve the desired learning goals. Johnsen (2009) quoted that in cooperative learning, each students has a crucial role of working together to achieve a common goal. It has been practiced by many teachers to let the students discuss and share their thoughts to their peers. Not only has their confidence been developed but also their social relationship among their teammates.

There are eight studies included herein that utilized cooperative learning approach. Of these eight studies, one used the Jigsaw puzzle technique where students learn on their own. They are arranged into groups and each member has an assigned task to work on or has a different piece of information. Then the members will join with the other group to work on the same task or piece of information by doing a research and sharing their ideas about the information they got. Eventually, students would go back to their original group to try to put together or connect the ideas to create a clear picture of the topic/problem at hand.

Similarly, group work or collaboration among students in solving varied problems was utilized in seven studies included herein. Cooperative learning allows students to learn from each other by discussing and justifying ways on how to solve the problem. They do not only learn and take what was presented or shown by the

teacher but they learn the process as well from other students (Mutakinati, Mudzakir, Supriyanti, 2015).

The studies included herein found out that cooperative learning approach can enhance students' problem solving performance in mathematics as well as improve students ' positive attitude towards mathematics. It was also mentioned in the studies that it was the most liked strategy of the students because of its benefits such as (a) stimulates deeper learning of mathematics, (b) helps gain better grades, (c) enhances social skills and values, (d) develops students higher order critical thinking skills (e) supports personal growth, and (f) develop students positive attitudes towards autonomous learning.

In addition to that, Nyunt and Myint (2009) claimed that in cooperative learning, students work together and are responsible for learning process. It gives more space and opportunities for students to discuss, solve problems, create solution, provide ideas and help each other. Cooperative learning has five principles such as (a) positive interdependence, (b) individual accountability, (c) group processing, (d) social skills, and (e) face-to-face interaction. These five principles should be the reason why teachers need to apply this approach.

Truly, there is no doubt that every teacher can utilize this technique to develop students' social skills and ability to share their thoughts and justify their answers. Alshammari (2015) mentioned that cooperative learning enables students to have comprehensive understanding of the topics or lessons since they are able to work together in the learning process. Sofroniou and Poutus (2016) also believed that group work as a form of cooperative learning approach helps students learn

mathematical concepts and problem solving techniques, overcomes students' hesitation to learn or anxiety Math, and enhances self – confidence.

Related studies conducted by Poore (2008); Johnsen (2009); Weimer (2010); Aziz and Hossain (2010); Jitendraet. al (2012); and Titsankeaw (2015) agreed that problem solving is developed, honed and nurtured when students get to solve problems with their peers.

From the result of the meta – analysis done by the researcher and the related studies included herein, it can be noted that cooperative learning approach has been applied in the mathematics instruction to improve the problem-solving performance of the students. Teachers, practitioners, and administrators should adapt this strategy because in every aspect of life, teamwork and cooperation is needed to enhance individuals' productivity towards learning.

3. Effect size of the different teaching approaches in problem solving when grouped according to methodological characteristics and substantive characteristic.

Results in Table 7 on the effect size and research design reveal that Solomon Four Group Design has a huge mean effect size of 2.72 based on Sawilowsky's interpretation. This means that Solomon Four Group design is significantly the highest among the other research designs included in the study. A huge effect size means that Solomon Four Group design is very significant. The result also shows that the effect of the four different teaching approaches in improving the problem solving performance of students is very evident when Solomon Four Group design is used as a tool in the research design. Even if there

is only one study that utilized this research design, it greatly shows that the effect of the four different teaching approaches is very significant because the performance of the students in the experimental group is far better than the performance of the students in the control group.

Table 7

Effect Size and Research Design

Research Design	Mean Effect Size	Interpretation
Pre – test /Post Test	1.17	Large
Post – Test only	0.38	Medium
Solomon Four Group Design	2.51	Huge
Factorial Design	0.50	Large

Note. Glass (1976) and Cohen's (1992) interpretation use only three criteria (0.01 to 0.2 = small; 0.21 to 0.5= medium, 0.51 to 0.8 = large) but Sawilowsky (2009) modified it by adding three more criteria (0.8 to 1.19 = large; 1.2 to 1.99 = very large; 2 and above = huge) to better interpret larger effect sizes.

Shuttleworth (2018) quoted that Solomon Four Group Design, which is developed by Richard Solomon in 1949, permits the researcher to have a complete control over the variables and check that the pretest did not influence the results. Though the use of Solomon Four Group is very complex and challenging, it is said to be valid and reliable. Meanwhile, in terms of pretest and posttest design, there were four studies included herein that have 0 and below effect size. It means that the effect size is not significant. Thirty studies have effect sizes ranging from 0.01 to 1.99. Four studies have effect sizes ranging from 2.00 to 4.99. Two studies have effect sizes ranging from 5.00 to 7.99. But when the effect sizes of these forty

studies were computed, the mean effect size was 1.17. The effect size is large based on Sawilowsky's interpretation. It means that pretest and posttest design is highly significant. This implies that the effect of the four teaching approaches in improving the problem solving performance of students is evident when the pretest posttest design is used.

On the other hand, factorial design has a medium effect size of 0.5 and posttest only design has a medium effect size too of 0.38 based on Glass and Cohen's interpretation. This means that the effect sizes of factorial design and posttest only design are moderately significant. This implies that the effect of the four teaching approaches in improving the problem solving performance of students when these research designs are utilized is somehow evident.

Moreover, Table 7 reveals that the research designs used by the researchers in the meta – analysis done is significant across experimental studies because of the evidence shown when these research designs were utilized. The evidence was that the effect of the four different teaching approaches in improving the problem solving performance of students is highly observed and obviously seen among the research designs considered in this study. This is proven in the computed effect size.

This is in contrast to the meta – analysis conducted by Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, Surkes, andLowerison (2009) where research design was found to be not significant across the experimental designs. The same is also found on the meta – analysis conducted by Bas, Senturk and Cigerci (2017) where research design were seen not to be significantly different from the others.

While in the meta – analysis conducted by Harskamp and Jacobse (2011), the experimental and quasi – experimental design has a medium effect size of 0.58 which is also significant.

Similarly, the meta – analysis conducted by Zhang and Xin (2012) claimed that the weighted mean effect size for word problem solving performance was positive across the research designs of the studies. Meanwhile, Slavin and Cheung (2013) used matched control studies. The pretest – posttest design had an effect size of 0.20 while post-test only design had an effect size of 0.15. Future researchers and practitioners may consider Solomon Four Group design as basis for choosing research design to be part of their experimental studies. David (2018) claimed that researchers who want to control testing effects, Solomon Four group design is appropriate to use because the participants are randomly assigned to four different learning conditions such as (a) intervention with pre-test and post- test, (b) pre-test and post – test with no intervention, (c) intervention with post – test, and (d) post – test with no intervention.

Results in Table 8 on the effect size and level of participants reveal that secondary students have a very large mean effect size of 1.48 based on Sawilowky's interpretation. Of these effect sizes, there were two studies that had 0 and below effect size. It means that it is not significant. There are eighteen studies that had an effect size ranging from 0.1 to 1.99, five studies had effect size ranging from 2.00 to 4.99, and two studies had effect size ranging from 5.00 to 7.99. When the effect sizes of these studies were combined, the result was 1.48. This implies that the mean effect size of the secondary pupils is highly significant. This also

signifies that the performance of the secondary students in the experimental group has a high difference than the performance of the students in the control group. It can be noted that the effect of the teaching approaches can be seen comparably in the secondary level.

Table 8

Effect Size and Level of Participants

Level of participants	Mean Effect Size	Interpretation
Primary Students	0.76	Large
Secondary Students	1.48	Very Large
Tertiary Students	0.28	Small

Note. Glass (1976) and Cohen's (1992) interpretation use only three criteria (0.01 to 0.2 = small; 0.21 to 0.5= medium, 0.51 to 0.8 = large) but Sawilowsky (2009) modified it by adding three more criteria (0.8 to 1.19 = large; 1.2 to 1.99 = very large; 2 and above = huge) to better interpret larger effect sizes.

This may be due to the fact that the researchers of the reviewed studies believed that secondary students have strong foundation in Math and that they can already solve problems accurately and that secondary students can easily adapt to any kind of teaching approaches given to them. On the other hand, primary students have a large mean effect size of 0.76 based on Glass and Cohen's interpretation. Of these effect sizes, there were seven studies that had effect size ranging from 0.01 to 1.00 and three studies that had effect sizes ranging from 1.01 to 2.00. This means that the mean effect size of primary students is moderately significant. This implies that the performance of the primary students in the

experimental group has a large difference than the performance of the students in the control group.

Meanwhile, tertiary students had a small mean effect size of 0.28 based on Glass and Cohen's interpretation. Of these effect sizes, there were three studies that had an effect size ranging from 0.01 to 1.00 and two studies ranging from 1.01 to 2.00. This means that the mean effect size of tertiary students is less significant. The result signifies that the performance of the tertiary students in the experimental group has a small difference than the performance of those tertiary students in the control group.

This is in contrast to the meta – analysis conducted by Schroeder, Scott, Tolson, Huang and Lee (2007). In their study, secondary students had an effect size of 0.76, while Harskamp and Jacobse (2011) found in their study that primary students had a an effect size of 0.58. This is also in contrast with the study of Gersten, Chard, Jayanthi, Baker, Morphy, andFlojo (2009); Slavin and Cheung (2013). They found out that studies catering older students had generally smaller effects than those for younger students. Future researchers may consider having secondary pupils in their research as it was revealed in the meta – analysis done that the effect of teaching approaches in improving the problem solving performance of students is very evident when secondary students are considered in a research study.

Results in Table 9 on the effect size and number of participants reveal that the number of participants ranging from 161 to 240 has a very large effect size of 1.45 based on Sawilowsky's interpretation. Of these effect sizes, two studies had an effect size ranging from 0.01 to 2.00 and another two studies had an effect size ranging from 2.01 to 4.00. This means that the mean effect size of the number of participants is highly significant.

Table 9

Effect Size and Number of Participants

Number of Participants	Mean Effect Size	Interpretation
1 to 80	1.28	Very Large
81 to 160	0.51	Large
161 to 240	1.45	Very Large
241 to 320	0.84	Large
321 to 480	0.84	Large

Note. Glass (1976) and Cohen's (1992) interpretation use only three criteria (0.01 to 0.2 = small; 0.21 to 0.5= medium, 0.51 to 0.8 = large) but Sawilowsky (2009) modified it by adding three more criteria (0.8 to 1.19 = large; 1.2 to 1.99 = very large; 2 and above = huge) to better interpret larger effect sizes.

It signifies that when the number of participants ranges from 161 to 240 in a research study, the problem solving performance of students in the experimental group has a high difference than the problem solving performance of students in the control group. This also implies that the effect of the four different teaching approaches is obviously observed when the number of participants ranges from 161

to 240. Meanwhile, the number of participants ranging from 1 to 80 has a very large mean effect size of 1.28 based on Sawilowsky's interpretation. Of these effect sizes, three studies had an effect size of 0 and below. It means that it is not significant. There were twenty – one studies that had an effect size ranging from 0.01 to 1.99, three studies ranging from 2.00 to 4.99, and two studies ranging from 5.00 to 7.99. When the effect sizes of these studies were combined, the result was highly significant which means that the effect of the teaching approaches in improving the problem solving performance of students is very evident when the number of participants ranges from 1 to 80.

On the other hand, the number of participants ranging from 81 to 160 has a large mean effect size of 0.51 based on Glass and Cohen's interpretation. Of these effect sizes, one study had a negative effect size. It means that it is not significant and the performance of the participants in the control group is higher than that of the performance of the participants in the experimental group. But there were five studies that had an effect size ranging from 0.01 to 1.30. When these effect sizes were combined, the result was highly significant. This implies that when asked to solve math problems, the experimental group would tend to perform much better than the control group when the number of participants ranges from 81 to 160.

Alternately, the number of participants ranging from 241 to 320 and 321 to 480 has a large mean effect size of 0.84 based on Sawilowky's interpretation. It means that it is highly significant. This implies that the effect of the teaching approaches on the students' problem solving performance is very evident when the number of participants ranges from 241 to 320 and 321 to 40.

The related meta – analysis conducted by Bas, Senturk and Cigerci (2017) found out that there is significant difference between studies with small number of participants and the ones with large number of participants. Meanwhile, Cheung and Slavin (2013) found out that the number of participants above 250 has a lesser effect size than the number of participants below 250. This finding suggests that small sample size produce much larger effect sizes than large studies.

Based on the findings, it can be noted that the effect of the teaching approaches in improving the students' problem solving performance is highly significant in those studies with the number of participants ranging from 161 to 240. This finding may serve as basis of the future researchers in determining the number of participants they need to include as their samples. It is believed that the number of participants ranging from 161 to 240 is the ideal number to get better results or findings. It can be gleaned from the meta – analysis done that the reliability of the results of the teaching approaches applied in the experiments depends on the number of participants.

Results in Table 10 on the effect sizes of sampling technique reveal that simple random sampling technique has a very large mean effect size of 1.51 based on Sawilowsky's interpretation. Of these effect sizes, eighteen studies had an effect size ranging from 0.01 to 1.99, three studies had an effect size ranging from 2.00 to 4.99 and two studies had an effect size ranging from 5.00 to 7.99. This result connotes high significance among the other sampling techniques. This means that the effect of the four different teaching approaches is very evident when simple

random sampling technique was utilized by the researchers. It also signifies that the effect of the four different teaching approaches on the problem solving performance of the pupils is very evident when this technique of sampling was used. Meanwhile, purposive sampling technique also has a very large mean effect size of 1.22 based on Sawilowsky's interpretation.

Table 10

Effect Size and Sampling Technique

Sampling Technique	Mean Effect Size	Interpretation
Simple Random Sampling	1.51	Very Large
Multi-stage Sampling	1.11	Large
Cluster Group	-0.26	Not significant
Matched Group	0.96	Large
Purposive Sampling	1.22	Very Large
Convenience Sampling	-0.34	Not significant

Note. Glass (1976) and Cohen's (1992) interpretation use only three criteria (0.01 to 0.2 = small; 0.21 to 0.5= medium, 0.51 to 0.8 = large) but Sawilowsky (2009) modified it by adding three more criteria (0.8 to 1.19 = large; 1.2 to 1.99 = very large; 2 and above = huge) to better interpret larger effect sizes.

There are two studies included herein that utilized this sampling technique with an effect size ranging from 1.00 to 1.50. This means that the mean effect size of purposive sampling technique is highly significant. It showed that the effect of the four different teaching approaches in improving the problem solving performance of students is evident when simple random sampling technique was utilized by the researchers.

On the other hand, multi – stage sampling technique has a large mean effect size of 1.11 based on Sawilowsky's interpretation. This means that the mean effect size of multi – stage sampling technique is highly significant. One study utilized this technique. It showed that the effect of the four different teaching approaches on the problem solving performance of students is also evident when multi - stage sampling technique was used by the researchers.

Alternately, matched group has a large mean effect size of 0.96 based on Sawilowsky's interpretation. Of these effect sizes, one study had an effect size from zero and below. This means that it is not significant. Ten studies had an effect size ranging from 0.01 to 2.00 and two studies had an effect size ranging from 2.00 to 4.00. When these effect sizes were combined, the result was 0.96 and it is found to be highly significant as well. This means that the problem solving performance of the students in the experimental group would tend to be better than the performance of the students in the control group when matched group sampling technique was utilized.

In addition to the findings about the sampling techniques, cluster group had an effect size of -0.26 and convenience sampling had an effect size of -0.34. This means that the four different teaching approaches have no effect on the problem solving performance of the students. It also gives an idea that the performance of the pupils in the control group is higher than the performance of the students in the experimental group when these two techniques were used in choosing the population or samples of the study.

The findings discussed above are in contrast to the meta – analysis conducted by Cajigal (2011). He found out in his study that the cluster sampling technique has the highest effect size of 1.33. The other two samplings techniques that ranked next were stratified sampling technique with an effect size of 1.24, and simple random sampling technique with an effect size of 0.71.

Based on the findings and the related meta – analysis it can be gleaned that the kind of sampling technique used is not a factor that contributes to the effect of teaching approaches on the problem solving performance of the pupils in math. However, this result may be an input to the researchers on deciding what kind of sampling technique they can use or adapt in their study. The use of simple random sampling technique maybe adapted because it is an easier method to use in extracting a small population from a larger population. DePersio (2018) cited that simple random sampling is very simple and accurate to use. It has advantages over other sampling techniques especially when a researcher chooses to have a larger population.

Results in Table 11 reveal that among the teaching approaches, **cooperative learning approach** has a very large effect size of 1.46 based on Sawilowsky's interpretation. Of these effect sizes, one study had an effect size of 0 and below. This means that in that study it was revealed that cooperative learning approach has no difference with the traditional approach in improving the students' problem solving performance. Meanwhile, five studies had an effect size ranging from 0.01 to 1.99, one study had an effect size ranging from 2.00 to 4.99 and one study had an effect size ranging from 5.00 to 7.99.

Table 11

Effect Size and Teaching Approaches

Teaching Approaches	Mean Effect Size	Interpretation
Technology – Oriented Approach	1.09	Large
Practical Work Approach	1.03	Large
Problem Solving Heuristic Approach	1.10	Large
Cooperative Learning Approach	1.46	Very Large

Note. Glass (1976) and Cohen's (1992) interpretation use only three criteria (0.01 to 0.2 = small; 0.21 to 0.5= medium, 0.51 to 0.8 = large) but Sawilowsky (2009) modified it by adding three more criteria (0.8 to 1.19 = large; 1.2 to 1.99 = very large; 2 and above = huge) to better interpret larger effect sizes.

When these effect sizes were put together, the result was 1.46. It means that cooperative learning approach has a higher significance on the problem solving performance of the pupils. It implies that when the cooperative learning approach would be used, the performance of the students in the experimental group would seem to be far better than the performance of the students in the control group.

This finding is supported with the related study conducted by Poore (2008), Johnsen (2009), Weimar (2010), Aziz and Hossain (2010), Mutakinati et. al (2015), Titsankaew (2015), and Odegaard (2015). They all claimed that cooperative learning approach has a positive effect on the problem solving performance of the students. This finding is also consistent with the meta – analysis conducted by Capar and Tarim (2015). It was found out in their study that cooperative learning is

most effective in the university or tertiary level in terms of problem solving performance or achievement with a very large effect size of 1.33.

Similarly, the related meta – analysis conducted by Kyndt, Raes, Lismont, Timmers, Cascallar, and Dochy (2013) also found out that cooperative learning has a positive effect on the problem solving performance of the students and that the age level of the students are associated with the variations in effect size. This is also similar to the meta – analysis study conducted by Ugwuanyi (2015), Schroeder, Scott, Tolson, Huang and Lee (2007). It was found out in their study that cooperative learning improves problem solving performance in Math.

Truly, cooperative learning is more powerful on the mathematics achievement in contrast to the traditional method. Teachers in the field of Mathematics education need to apply this approach. This may somehow help them deliver the lessons better in order to improve the pupils' performance.

Meanwhile, result in Table 11 also reveals that **problem solving heuristic approach** has a large mean effect size of 1.10 based on Sawilowsky's interpretation. Of these effect sizes, nine studies had an effect size ranging from 0.01 to 1.99 and two studies had an effect size ranging from 2.00 to 4.99. The result of the mean effect size tells that problem solving heuristic approach has a high significance on the problem solving performance of the students in math. It reveals that when the problem heuristic approach would be used, the performance of the students in the experimental group would tend to have a large difference from the performance of the students in the control group.

This is supported with the related meta – analysis conducted by Gersten, Chard, Jayanthi, Baker, Morphy, andFlojo (2009), Montague and Dietz (2009), Montague et.al (2006), Sulaka (2010), Mancl (2011), Klinger (2012), James (2015), and Locke (2016). It was revealed in their study that the use of heuristics has a very large mean effect size of 1.56. Indeed, problem solving heuristics approach help students who struggle in Math to improve their problem solving performance.

On the other hand, results in Table 11 show that **technology - oriented approach** also has a large mean effect size of 1.09 based on Sawilowsky's interpretation. Of these effect sizes, one study had an effect size ranging from 0 and below which means that in this study, the students in the control group performed better than the pupils in the experimental group. However, there are ten studies that had an effect size ranging from 0.01 to 1.00, two studies ranging from 1.01 to 2.00 and one study ranging from 5.00 to 7.99. When these effect sizes were combined the mean was 1.09. The result implies that technology - oriented approach has a high significance in improving the problem solving performance of the students.

This finding is supported with the related studies conducted by Enchang et. al (2006), Jin – Seo (2008), Schoppek and Tulis (2010), Leh and Jitendra (2013), (2011), Cheung and Slavin (2013), Yesilyurt (2010), SokolowskiandWillson (2015), Merchant, Goetz, Cifuentes, Keeney – Kennicuttand Davis (2013), Tokac (2015), Liao (2007), and Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, Surkes and Wood (2014). They all agreed and found out that using technology – oriented approach helps the pupils improve their problem solving performance. Cheung and

Slavin (2013) cited that technology must be incorporated or must be used as an instruction because it supports learning process in K – 12 classrooms in improving academic learning goals.

The use of virtual reality technology based approach like virtual words, games, and simulation, and mobile learning devices such as tablets, laptop and mobile phones are influential tools that can be used in classrooms and outdoor learning. These are also considered as significantly more effective than traditional method that uses paper and pencil. Yesilyurt (2010) cited that the use of computer assisted instruction as a teaching method lets the learners learn on their pace. They are given to work or do their task anywhere using technologies or perform online activities prepared by their teachers. It was also mentioned that computer is a medium that allows learning to happen.

On the other hand, Table 11 also reveal that **practical work approach** has a large mean effect size of 1.03 based on Sawilowsky's interpretation. Of these effect sizes, two studies had an effect size ranging from 0 and below which means that the students in the control group outperformed the students in the experimental group. There are six studies that had an effect size ranging from 0.01 to 1.99 and two studies ranging from 2.00 to 4.99. But when the effect sizes were combined, the result was 1.03. It means that practical work approach has a high significance on the problem solving performance of the students. The scores of the in the experimental group are higher than the scores of the students in the control group. Thus, it gives an impression that practical work approach is an effective method in improving the problem solving performance of the students in math.

This is supported with the related meta – analyses conducted by Holmes (2016) with an effect size (ES) of 0.22, Schroeder, Scott, Tolson, Huang Lee (2007) with ES = 0.86, Carbonneau, Marley and Selig (2013) with ES = 0.45, and Ellington (2006) with ES = 0.29. It was found out that practical work approach has appositive effect on the performance of the students. These students who used manipulatives during math instructions had statistically higher mathematics achievement or performance than pupils who did not use manipulatives. Based on the findings and the related meta –analysis, it can be noted that practical work approach increases students' achievement or performance in Math.

Implications to the Teaching Approaches

Mathematics is one of the most challenging subjects for the students. Most teachers are aware of it. In the study of Siyepu (2013) he mentioned that mathematics is a requirement for various jobs in every discipline and it is a core subject in basic educational setting. Hence, learning mathematics using different approaches prepares the students to be good in solving problems in their daily lives. The result of the meta – analysis done by the researcher which identified the teaching approach that is best to use in improving the problem solving performance among learners will help the teachers, practitioners, researchers, and the school administrators in planning and implementing the curriculum.

The four learning interventions yielded significance or positive effect, which means that the students in the experimental group, or those who had a treatment, outperformed those students who are in the control group. The reason for the increase of students' achievement and/or performance is due to the following: (a)

students' participation in the discussion; (b) students are using manipulatives to gain conceptual understanding; (c) students are using different online applications and other related computer assisted instruction; and (d) students are using different problem solving heuristics .

In teaching mathematical concepts, the use of cooperative learning approach gives more time and opportunities for students to solve problems, form solutions, justify, argue or comment, and help each other improve their output. Capar and Tarim (2015) mentioned that traditional methods of teaching are more on discussion done by the teacher, therefore there is a less chance given to students to collaborate and share their ideas. Teachers are encouraged to practice these methods regularly and effectively because cooperative learning approach does not only improve the performance of the students but it can also improve the attitude of students towards the mathematics subject. In cooperative learning, students acquire the correct ways or strategies to be used in attacking the problems. They work as a team to obtain a common goal, which is to get the correct solution and answer. There is a feeling of contentment when they function effectively in the group work.

The meta – analysis done also revealed that problem solving heuristics has a positive effect on the problem solving performance of the students. It means that it is a more effective method of instruction for teaching and learning math as compared to traditional (lecture) method. Hence, mathematics teachers may use problem solving heuristics method such as POLYA's strategy, SOLVE strategy, Rusbult's strategy and other mentioned problem solving heuristics included in the meta – analysis study. In the study of Freeman (2013) he said that instruction using

different problem solving heuristics helped the pupils improve problem solving skills by looking into the critical elements such as finding the unknown, looking for the key or hidden information, carrying out the plan and solving accurately mathematical word problems.

With regard to technology – oriented approach, teachers/instructors all over the world are applying technology as a tool and aid to instruction. Hence, teachers/instructors are encouraged to use social media, apps, and other computer programs to help their pupils succeed. Cracraft (2015) mentioned that it is imperative that students are given opportunities to demonstrate what they know using multiple tools. Many researchers have embedded different technologies in mathematics to motivate students to learn and to assist pupils in conquering the difficulties of learning math word problems. In the study of Chen and Liu (2007), they mentioned that from the end of 1950s to the early 21st century up to the present, technological media such as films, photographs, slides, sound recordings, radio broadcast, motion pictures televisions and computers (online applications) have been used to help pupils learn and increase their problem solving performance.

Meanwhile, it was also revealed in the meta – analysis done that practical work approach has a positive effect on the problem solving performance of the pupils. Koko (2008) cited that practical work approach helps the learners to find out information and understand concepts through appropriate activities and demonstration. The findings of the meta – analysis done suggest that teachers need to recognize the importance of hands on activities and manipulatives for

students because these can help enhance the students conceptual understanding. This is supported with the study conducted by Kelly (2006), Garforth and Siegel (2015) and Kim, Michael and Wang (2015). Ado and Abasi (2014) also cited that manipulatives have many uses such as to provide varied educational activities, give time to practice solving problems, enable pupils to concretize abstract ideas, let the pupils participate actively, empower the differences of each other, and to heighten the motivation of students towards mathematics.

Moreover, with the trends and changes happening in the K – 12 curriculum and the type of students that are being catered today, all these teaching approaches can be applied in the teaching instruction. Since the findings suggest that the four teaching approaches have a positive effect on the performance of the students in Math, it is now on the preference of the teacher as to which teaching approach should be used. It is recommended, however, that these four teaching approaches must be applied.

Learning is a continuous process, it does not stop. Therefore, for teachers, known as transformers, facilitators, mentors, coaches, instructors and counselors, there is a need to look back on the practices or strategies being employed to achieve good quality education and better problem solving performance of the pupils. The success of the students lies in the hands of every educator. Thus, to be able to accomplish the dream of everyone, effective and efficient teachers need to apply varied teaching approaches to help improve students' problem solving performance.

CHAPTER 4

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the study

The main purpose of this study is to describe the different researches or studies on improving the students' problem solving performance in Mathematics through varied teaching approaches using Glass Meta – analysis technique. Specifically, the study aims to: (1) describe the methodological characteristics of the researches reviewed in terms of research design, level of participants, number of participants and sampling technique; (2) describe the substantive characteristics of the researches reviewed in terms of teaching approaches used in improving problem solving performance; and (3) determine the effect size of the different teaching approaches in improving problem solving when grouped according to methodological characteristics and substantive characteristic.

To find the answers to the problems, a descriptive – documentary analysis method using the Glass' Meta – analysis technique was conducted. The reviewed studies were 43 experimental studies both unpublished and published online dissertations, theses and journal articles from 2002– 2017. These were qualified based on the criteria set by the researcher and patterned after Glass. The content of each study was analyzed to find the answers to the problems. A research summary form was created to gather or collect data. This was then encoded in Microsoft Excel and a matrix of the data was developed. The first part of the survey pertains to the general data of the study such as title of the study and researcher/s name. The second part was made to collect information on the methodological

characteristics such as research design, level of the participants, number of participants and sampling techniques. The third part was developed to gather information on the substantive characteristic of the study such as the effective teaching approach in improving problem solving performance. The researcher's instrument was then based from the given research characteristics variable utilized by Glass' studies in 1981 as well as other researchers who used meta – analysis. Descriptive analysis was used in analyzing the data. The data were collected, coded, tabulated and analyzed. The means, frequencies, standard deviation, percentages were used for the description of the research characteristics. Glass' formula was utilized to compute the effect size to determine the significant effect sizes of the variables when grouped according to substantive (effective teaching approach) and methodological characteristics (research design, level and number of participants, and sampling technique.

Summary of Results

1. Methodological characteristics are more general pertaining to the steps, methods and procedures of conducting the study. There are four methodological characteristic variables concerned in this study: (1) research design (2) level of the participants (3) number of participants and (4) sampling techniques.

    1.1 In terms of research design, Pretest and Posttest design, Solomon Four Group design, Factorial design and Posttest only design are the research designs utilized by the researchers. Most of the

researchers were in favor of using Pretest and Posttest design in conducting experimental studies.

1.2 In terms of the level of participants, primary students, secondary students, and tertiary students were the chosen levels of the researchers. The researchers of most of the reviewed studies preferred secondary students to be the participants in their study.

1.3 In terms of the number of participants, it showed that the researchers used varied number of participants in their study. Most of them preferred to have one to eighty students as participants of their study.

1.4 In terms of sampling techniques, the researchers of the reviewed studies utilized simple random sampling technique, multi – stage sampling technique, cluster group sampling technique, purposive sampling technique, matched group sampling technique, and convenience sampling technique. Most of the researchers preferred to utilize simple random sampling technique as their tool in choosing the participants in their experimental study.

2. There are four different teaching approaches included in the meta – analysis. These are technology - oriented approach, problem solving heuristics approach, practical work approach, and cooperative learning approach. In this technology - oriented approach students were taught using computers and mobile learning devices like smartphones, IPADs and tablets, specifically, computer assisted instruction (CAI), geometer's sketchpad, and

personalized and non – personalized computer instruction, CAI with hyperlink, soft wares and applications. Meanwhile, the practical work approach considered in this meta-analysis utilized the use of concrete manipulative materials or activities that would let the pupils do or perform in order to develop conceptual understanding and improve problem solving performance. Apparently, the problem solving heuristics approach encouraged students to use patterns, pictures/drawing or representation in solving math problems. On the other hand, the cooperative learning approach in this meta-analysis utilized teaching mathematics by having small groups in classes. .

3. The effect sizes of the four different teaching approaches in improving problem solving when grouped according to methodological characteristics and substantive characteristic are stated below.

    3.1 In terms of research designs, the effect of the four different teaching approaches is very evident when Solomon Four Group design is used as a tool in the study.

    3.2 In terms of the level of participants, the effect of the four teaching approaches is very evident and observable among secondary students. The problem solving performance of the secondary students in the experimental group has a high difference than the problem solving performance of the students in the control group.

3.3 In terms of the number of participants, the effect of the four teaching approaches is obviously observed when the number of participants ranges from one hundred sixty – one to two hundred forty.

3.4 In terms of sampling techniques, the effect of the four teaching approaches is very evident when simple random sampling technique was utilized by the researchers in their study.

3.5 Among the four different teaching approaches, cooperative learning approach has very large mean effect size. It means that when cooperative learning approach is used, the problem solving performance of students in the experimental group has a very large difference than the problem solving performance of the students in the control group. Meanwhile, problem solving heuristics approach has a large mean effect size. It means that it has a high significance on the problem solving performance of the students. On the other hand, technology – oriented approach also has a large mean effect size which means that it has a high significance on the problem solving performance of the students. Similarly, practical work approach also has a large mean effect size which means that it has a high significance on the problem solving performance of the students. Thus, results revealed that the different teaching approaches included herein have a positive effect on the problem solving performance of the student. This indicates that the four teaching approaches brought

a high significance on the problem solving performance of the pupils. However, cooperative learning approach is the most effective.

Limitations of the Study

Although the researcher has produced the results that answers the research problems or objectives, several limitations related to the study still exist. First, there are only limited studies that met the criteria for inclusion. Probably more time to gather data should be considered so that the sample size of the study will increase. Consequently, a minimum sample size was only included per teaching approach. Lastly, the researcher made only a thorough analysis of the effect sizes and description of each methodological characteristics and substantive characteristics using mean and percentages but did not include anymore the interaction of the effect sizes to the other variables. Probably, this concern maybe addressed or done by future researchers to extend or add more research problems and use other statistical analysis treatment and analysis.

Conclusions

Based on the findings derived from the study, the following conclusions were drawn.

1. In conducting an experiment to improve the problem solving performance of students, the methodology that includes the research design, level and number of participants, and sampling technique to be considered would impact validity of the results. However, beyond the experiment, qualitative study may also be considered for deeper analysis of results.

2. The four different teaching approaches have their own impact to the problem solving performance of the pupils. While the use of cooperative learning approach would yield the greatest impact, technology – oriented approach, practical work approach and problem solving heuristics approach could also help the students to improve their problem solving performance. Therefore, these approaches may be used as alternatives in teaching mathematics.

Recommendations

In view of the findings and conclusions of the study, the researcher presents the following recommendations:

1. Cooperative learning approach may be used more frequently in mathematics classrooms. However, the problem – solving heuristic approach, technology – oriented approach, and practical work approach may also be used to improve the problem solving performance of the students at any level.
2. Curriculum writers and developers can use the findings of this study to evaluate, improve and enrich the existing curriculum in the school by incorporating the use of the four different teaching approaches.
3. Future researchers on conducting experimental studies may consider to use Solomon Four Group design as the design of their studies, secondary level as their level of participants, 161-240 participants as their sample size, and simple random sampling technique as their sampling technique. They may also include pre –school pupils as their participants in

conducting experimental studies on varied teaching approaches in improving problem solving performance.

4. A meta – analysis on the different teaching approaches across the other disciplines such as Science, English, Filipino, Music Arts and PE (MAPE), and Social Studies may also be considered. A similar study may also be conducted utilizing other meta – analysis technique and increase the number of studies to be included in the meta – analysis.

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APPENDICES

Appendix A
Annotated Bibliography

ABDULLAH, NUR I., AHMAD, TARMIZIA, ROHANNI A., ABDUB, ROSINI. ***The Effects of Problem Based Learning on Mathematics Performance and Affective Attributes in Learning Statistics at Form Four Secondary Level*** (Laboratory of Innovations in Mathematics Education, Institute for Mathematical Research, Faculty of Educational Studies Universiti Putra Malaysia, 2010)

The challenge of globalization today requires students to acquire problem solving and communication skills besides good procedural and conceptual knowledge of mathematics. This study was conducted to explore the effects of Problem Based Learning (PBL) as an alternative instructional strategy in the teaching and learning of mathematics effectively in Malaysian secondary schools. Previous research had discovered that that PBL enhances students' team work, problem solving skills and communication skills. In addition, interest in the subject significantly improved. A quasi experimental study with non-equivalent control group posttest only design was conducted to investigate the effects of PBL on form four Malaysian students' mathematics performance, instructional efficiency and affective attributes. The experiment was carried out for six weeks involving 53 Form Four students randomly selected from the district of Port Dickson. The experimental (PBL) group (n=29) were exposed to the PBL instruction whereas the control (CT) group (n=24) were taught conventionally. There were five instruments used in this study namely, mathematical learning worksheets, a posttest, Paas Mental Effort Rating Scale, a questionnaire on perception towards group work, interest in

mathematics and perception towards mathematics learning experience and a rubric evaluating students' effective use of Polya's problem solving procedures, mathematical communication and teamwork. The data were analysed using analysis of covariance (ANCOVA) and independent t-test. Students' response to the questionnaire and researcher's observations based on the rubric were described using means, standard deviations and percentages. The findings of the study indicated that PBL is just as efficient as the conventional teaching strategy in enhancing Form Four students' mathematics performance. Even though both groups of students showed positive perception towards group work, interest in mathematics and perception towards the learning experience they went through, the PBL group used the Polya's problem solving procedures more effectively, displayed better mathematical communication skills and showed stronger teamwork compared to the CT group.

ADELEKE M. A ***Strategic improvement of mathematical problem- solving performance of secondary school students using procedural and conceptual learning strategies*** (Department of Special Education and Curriculum Studies, Faculty of Education Obafemio Awolowo University, 2007)

The paper examined the possibility of finding out if improvements in students' problem solving performance in simultaneous linear equation will be recorded with the use of procedural and conceptual learning strategies and in addition to find out which of the strategies will be more effective. The study adopted a pretest, post test control group design. A total of 166 science students drawn from

four schools in four local government Areas in Osun state of south-western Nigeria were involved in the study. The students were in Senior Secondary Class Two. These students were assigned to four groups of Conceptual Learning Strategy (CLS), Procedural Learning Strategy (PLS) and Conventional Method (CM) while the fourth group was not taught at all. The first two groups were the experimental groups and the control groups were the last two groups. Treatment was administered for a period of eight weeks. A mathematical achievement test was used as pretest and posttest after validation and was found to have reliability coefficient of 0.76 and item difficulty level ranging between 0.42 and 0.46. Three mathematics teachers who were university graduates were engaged to administer the treatment. The study recorded a significant difference between the problem-solving performance of students in the CLS group and those in the CM group (X_1=30.71, X_2 = 15.66, df =78, t = 16.56, $p<0.05$).Significant difference in performance was also recorded between PLS group and CM group (X_1 = 24.07, X_2 = 15.66, df =80, t = 10.95, $p<0.05$). Likewise performance of students in CLS group and those in PLS group differed significantly (X_1=30.71, X_2 = 24.07, df = 84, t = 7.98, $p< 0.05$). The study therefore concluded that both CLS and PLS were effective in enhancing students problem-solving performance and that conceptual learning strategy was more effective.

ADO, ISAAC B., AND ABASI, ANDREW U. ***Effect of Practical Approach on Basic 7 Mathematics Students' Interest and Performance in Fraction in Uyo Akwa Ibom State of Nigeria*** (Department of Science Education,University of Uyo, Uyo, Nigeria, Department of Curriculum and Instructional Technology,Cross River University of Technology, Calabar Nigeria, 2014)

This research was an experimental study carried out to determine the effect of practical approach on mathematics students' performance in fraction in Uyo Local Government Area of Akwa Ibom State. Two (2) research questions were raised to guide the study. The Pretest-posttest non-randomise control design was adopted for the study. A sample of 173 Basic 7 students was randomly selected for the study. Two instruments, Mathematics Performance Test on Fraction (MAPF) and Student Interest Questionnaire (SIQ) were used for the study. MATF and SIQ reliabilities were found to be 0.76 and 0.83 using Kuder-Richardson Formulae 21 and Cronbach Alpha respectively. The data were analysed using mean and the independent t-test. The result showed that students taught using practical approach performed significantly better than those taught using conventional method. Students in the practical approach group developed interest that was significantly better than their counterparts in the conventional group. It was concluded that practical approach significantly enhances students' performance and interest in fraction.

ALI, RIASAT., HUKAMDAD., AKHTER, AQILA., KHAN, ANWAR. ***Effect of Using Problem Solving Method in Teaching Mathematics on the Achievement of Mathematics Students*** (University of Science & Technology, Bannu, (NWFP) Pakistan, National University of Modern Languages Islamabad, Pakistan, Regional Institute of Teacher Education, Bannu, Pakistan, COMSATS Institute of Information Technology, Attock, Pakistan, 2010)

The major purpose of study was to investigate the effects of using problem solving method on students' achievement in teaching mathematics at elementary level. Pre-test post-test design was used in the study. Results were analyzed using mean, standard deviation and t-test. From the findings it was observed that the use of problem solving method enhanced the achievement of the students in mathematics. The result showed that there was significant difference between the effectiveness of traditional teaching method and problem solving method in teaching of mathematics at elementary level. The study recommended that the teachers should be encouraged to employ problem solving method in teaching mathematical concepts like set, information handling and geometry etc. Regular training, workshops and seminars should be arranged for teachers to give them knowledge and understanding of problem based learning.

BAYRAM, SIBEL. ***The Effect of Instruction with Concrete Models on Eight Grade Students' Geometry Achievement and Attitudes Toward Geometry*** (Middle East Technological University, Master of Science in Secondary Science and Mathematics Education, 2004)

The purpose of the study was to investigate the effects of concrete models on eighth grade students' geometry achievement and attitudes toward geometry. The study was conducted on 106 eighth grade students in one of the private school in Ankara. The subjects of the study received instruction with concrete models, and by the traditional method. Cooperative learning method and discovery learning method were also used to provide better classroom environment and to create exciting classroom atmosphere for the use of concrete models. The following measuring instruments were used to collect data: The Geometry Attitude Scale (GAS), Geometry Achievement Test (GAT) and open ended questions. The present study was a matching-only pre-test- post-test control group design. The data of the present study were analyzed by Analysis of Co-Variance and by two-way Analysis of Variance. The results of the study indicated that: (1) There was a statistically significant mean difference between students received instruction with concrete models and those received instruction with traditional method in terms of the GAch; (2) there was no statistically significant mean difference between girls and boys in terms of GAch; (3) there was no statistically significant interaction between treatment and gender on GAch; (4) there was no statistically significant mean difference between students received instruction with concrete models and those received instruction with traditional method in terms of ATG; (5) there was no

statistically significant mean difference between girls and boys in terms of ATG; and (6) there was no statistically significant interaction between treatment and gender on ATG.

BOSTIC, JONATHAN D. ***The Effects of Teaching Mathematics through Problem – Solving Contexts on Sixth Grade Student's Problem Solving Performance and Representation Use*** (Doctor of Philosophy, University of Florida, 2011)

This study examined sixth-grade students' problem-solving performance and representation use as a result of an instructional intervention. It responds to recently adopted mathematics standards (i.e., Next Generation Sunshine State Standards (Florida Department of Education, 2007); Standards for Mathematical Content and Standards for Mathematical Practice (Chief of Council State School Officers, 2010)) that indicate problem solving needs more prominence within mathematics instruction. The instructional intervention aims to supplement current efforts to enhance students' problem-solving performance and number of representations used to solve word problems. Multiple scholars designed instructional interventions intending to improve K-8 students problem-solving performance (e.g., Charles & Lester, 1984; Sigurdson, Olson, & Mason, 1994; Verschaffel et al., 1999) or their facility with representations (Verschaffel & De Corte, 1997; Klein, Beishuizen, & Treffers, 1998). A literature review indicated that investigators have not concurrently examined students' problem-solving performance and representation use. Three sections of sixth-grade mathematics

were sampled from a school in Florida; one section was randomly assigned to experience the instructional intervention. The author developed mathematics lessons intended to support students' mathematics learning of rates, ratios, and data analysis by working on word problems and engaging in content-focused and problem-solving discourse. These lessons were enacted for one month while two comparison classrooms received their typical instruction. Participants completed a pretest, posttest, and a unit test. Data analyses within groups indicate that the intervention had a positive effect on students' problem-solving performance (d = .48) and number of representations used on the posttest (d = .42) whereas the comparison group experienced no changes. Results from multiple regression analyses indicate that intervention students solved more word problems (d = .26) and used more representations on the posttest (d = .18) than their peers. The comparison group had a higher average unit test score than the intervention group (d = .34). Implications for these results as well as limitations of this study and future research are discussed.

CAMLI, HANDE. ***Mathematical problem solving and computers: Investigation of the effect of computer aided instruction in solving lowest common multiple and greatest common factor problems*** (International Journal of Human Sciences, 2009)

This paper aims to determine the effect of computer aided instruction on students' academic performance in solving Lowest Common Multiple and Greatest Common Factor problems and multiplicative structures. The study was held in the

second semester of 2008 for five weeks with a total number of 102 sixth grade students. The research was carried out experimentally and a post test control group design method was used in this experimental study. An academic level test was used at the beginning of the study to compare the existing knowledge of experimental and control groups; and a post test and software developed by the researchers about the topic were used as data collection instruments in this study. The means of scores received in academic success test and post test were analyzed using t-test technique. The results of the study show that the use of computer support in teaching and learning Lowest Common Multiple and Greatest Common Factor problems and multiplicative structures in mathematics lesson may increase students' academic success.

CASQUEJO, CECILIA C. ***Project Based – Learning: Effects on Problem Solving Skills, Critical Thinking skills and Attitude Towards Math*** (MA.Ed., Master of Education, 2012)

This study zeroed in on the effects of project – based learning (PBL) on the following variables: problem solving skills, critical thinking and attitude toward mathematics. Perceptions of the students regarding PBL were likewise noted. PBL Action was prepared to set the direction of students' activities. The study was conducted at Tanauan City High School during the First Quarter of the School Year 2011 – 2012. Thirty (20) students from the Engineering and Science Education Program (ESEP) section in the first year level were the subjects of this research. Fifteen (15) students underwent PBL and 15 underwent the traditional approach.

The two groups were comparable in abilities as revealed in the t – test analysis results of their pre- test mean scores. The posttest mean scores of both groups were higher compared with their pre-test mean scores. However, results of the t – test showed that the control group's differences in the pre – test and post – test mean scores are significant only in two variables: problem solving skills, and attitude toward mathematics. While the results of the t – test analysis of the pre-test and post-test mean scores of the experimental group are significant in all three variables: problem solving skills, crtical thinking skills and attitude toward mathematics

CERVANTES, BERNADINE M. ***The Impact of Project – Based Learning on Mathematics and Reading Achievement of 7th and 8th Grade Students in a South Texas School District*** (Doctor of Education in Educational Leadership, Texas A&M University-Corpus Christi Corpus Christi, Texas, 2013)

Since the introduction of A Nation at Risk (1983), considerable efforts have been made to address the need for more innovative teaching and learning to prepare students to meet the changing demands of the 21st century. Project-Based Learning (PBL) serves as an instructional approach to classroom teaching and learning that is designed to engage students in the investigation of real-world problems to create meaningful and relevant educational experiences. The study examined the impact of PBL on reading and mathematics achievement of 7th and 8th grade students and tested the hypothesis that PBL is effective in impacting academic achievement. The ex post facto study employed a causal-comparative

research design. The characteristic-present sample was the group in which the PBL was utilized. The comparison group did not receive the PBL. The outcome measures were the State of Texas Assessments of Academic Readiness (STAAR) mathematics and reading achievement scores. The 7th grade participants consisted of a characteristic-present group (n=87) and a comparison group (n= 140). The 8th grade participants consisted of a characteristic-present group (n=84) and a comparison group (n=150). Multivariate and univariate analysis of the data showed that the PBL groups performed at a higher achievement level on the majority of the tested Reporting Categories than did the nonPBL students on the basis of observed and adjusted scores for the outcome measures. The study did demonstrate that student participation in the PBL positively impacts academic achievement in 7th and 8th grade reading and mathematics based on STAAR outcome measures. Participation in the PBL, as the curriculum, would likely benefit students in other school districts. The implementation of PBL would have implications for teacher professional development of innovative teaching and learning. The study revealed that student participation in the PBL favors academic achievement and would likely hold up to high stakes testing and accountability.

CHEN, CHIU-JUNG AND LIU, PEI-LIN. ***Personalized Computer-Assisted Mathematics Problem-Solving Program and Its Impact on Taiwanese Students*** (The Journal of Computers in Mathematics and Science Teaching, 2007)

This study evaluated the effects of a personalized computer-assisted mathematics problem-solving program on the performance and attitude of

Taiwanese fourth grade students. The purpose of this study was to determine whether the personalized computer-assisted program improved student performance and attitude over the non-personalized program. One-hundred-sixty-five (165) Taiwanese fourth-grade students participated in the study. The research used the results to determine if the computer-assisted program was effective between the two groups. The results of the study showed that the personalized computer-assisted program on mathematics improved student performance and attitude. The achievement of students in the personalized group was significantly higher than those in the non-personalized group. The posttest score of the personalized group was significantly higher than the posttest score of the non-personalized group. The attitude of the personalized group was significantly more positive than that of the non-personalized group.

CLARK, KEVIN R. ***The Effects of the Flipped Model of Instruction on Student Engagement and Performance in the Secondary Mathematics Classroom*** (Midwestern State University, Wichita Falls, Texas, USA, 2013)

In many of the secondary classrooms across the country, students are passively engaged in the mathematics content, and academic performance can be described, at best, as mediocre. This research study sought to bring about improvements in student engagement and performance in the secondary mathematics classroom through the implementation of the flipped model of instruction and compared student interaction in the flipped classroom with a traditional format. The flipped model of instruction is a relatively new teaching

strategy attempting to improve student engagement and performance by moving the lecture outside the classroom via technology and moving homework and exercises with concepts inside the classroom via learning activities. Changes in the student participants' perceptions and attitudes were evidenced and evaluated through the completion of a pre- and post-survey, a teacher-created unit test, random interviews, and a focus group session. In addition, the researcher documented observations, experiences, thoughts, and insights regarding the intervention in a journal on a daily basis. Quantitative results and qualitative findings revealed the student participants responded favorably to the flipped model of instruction and experienced an increase in their engagement and communication when compared to the traditional classroom experience. The student participants also recognized improvements in the quality of instruction and use of class of time with the flipped model of instruction. In terms of academic performance, no significant changes 92 were demonstrated between the flipped model of instruction students and those taught in a traditional classroom environment.

CRACRAFT, LINDSEY. ***Effect of Blending Learning on Student's Percent Increase in Assessment Scores*** (Northwest Missouri State University Missouri, Research Paper, 2015)

Educators everywhere are implementing technology as a resource and aid to instruction in their classrooms. Teachers are encouraged to use social media, apps, and other computer programs to help their students succeed. It's imperative that students are given opportunities to demonstrate what they know using multiple

tools. The question is can educators implement technology consistently in the classroom to assist in the academic and social achievement of all students? One school district chose to implement this idea in one 5th grade elementary classroom. These teachers and students were each presented with a Chrome Book to use as their device to support blended learning in the classroom. Within this study, data was collected and analyzed to see the effects on student success rate with blended learning and the traditional classroom. MAP data was collected from 5th grade classrooms. One classroom implemented blended learning for a year and another a traditional model. The purpose of the study was to see if student achievement increased with adding blended learning into daily classroom instruction. A t-test was administered and assessed to see the possible effect on student achievement with an added blended learning component. The t-test results indicated that there isn't a significant change in student achievement when a blended learning model is added in the classroom. Blended learning is an increasingly popular systematic philosophy on instruction that adds in technology components to support the daily instruction in the classroom.

DANNAWI, DANA M. ***A Study on Effect of Problem solving on student's achievement*** (Dissertation, MEd of International Management and Policy Studies, 2010)

The investigation is about the importance of teaching problem solving and critical thinking in schools and including it in the curriculum, to prepare students achieve the best quality of thinking in the society and be more involved in the

society. The study focuses on the gender difference and the use of cooperative learning in teaching problem solving, how it effects on their performance. The study was on 10th graders in U. A.E., Dubai private school, under the implementation of cooperative learning. A comparative data collected by pre-test and a post-test to study the student's achievement as well as a questionnaire to study the cultural background of the students. The study showed there is significance in performance in aspects, gender and student's achievement, but no significance in culture.

DEDEL, ERNEST *JR. The Effect of Orientation, Planning, Action and Checking (OPAC) Problem Solving Strategy on Student's Problem solving skills and Conceptual Understanding* (DLSU Master in Science Teaching Major in Physics, 2002)

This study focuses on the effect of OPAC problem solving Strategy on student's problem solving skills and conceptual understanding in teaching selected topics in mechanics. The study used the non – equivalent pretest-posttest control group design. This design consists of an experimental and control group but subjects are not randomly assigned (quasi – experimental). Six intact classes of 153 first year college science and engineering students were used as the subjects of the study. Out of these 153, 69 students were in the experimental group and 84 students were in the control group. These students were enrolled in Physics 21/L (Elementary Physics I) during the second semester of school year 2001 – 2002 in Palawan State University. Student's achievement was measured in terms of their performance scores in a teacher – made test consisting of 20 items multiple –

choice test and 5 items word problem. The 60 items mental ability test and 98 items math anxiety (MARS – A) test were also used as the instruments in the study.

DE GUZMAN, NINO JOSE P. ***Block Model Approach in Problem Solving: Effects on Problem Solving Performance of the Grade V Pupils in Mathematics*** (PNU, M.A.Ed., Mathematics Education, 2009)

The study in general attempts to examine the effect of the use of block model approach in problem solving of the grade five pupils on problem solving performance in mathematics. This study employed Pretest-Posttest Control Group design. The participants of the study were taken from ten heterogeneous sections. The control and the experimental groups were given pretests, exposed to different treatments and then given a posttest. It was concluded that the use of Block Model Approach helps improve the pupils' the problem solving skills. Thus, Block Model Approach helps the pupils to perform better in the problem solving performance. There is no interaction effect of problem solving approach and mathematical ability on problem solving performance. There is no interaction effect of problem solving approach and the types of problems on problem solving performance. Likewise, block model approach as perceived by the pupils is useful and easy to use in solving word problems in Mathematics. It is recommended that Block Model Approach be introduces as early as grade 1 to master the said approach.

DELA CRUZ, LAURA B. ***The effectiveness of using Computer – Based Instructional Material on the Achievement towards Mathematics of Fourth Year High School Students*** (PNU, MA. Ed, Mathematics education, 2004)

The objective of the study is to determine the effectiveness of using computer – based instructional material on the achievement and attitude towards mathematics of the selected fourth year high school students. The study made use of the true experimental design particularly the randomized pretest – posttest control group design using matched subjects, There were two groups namely: the experimental group (with computer - based instruction) and the control group (without computer - based instruction). The two groups were equated in terms of mental ability. Mental ability was determined using the Manila Self – Administering Test Mental ability. The participants were classified as above average, average and below average using the local norms of the school. Another equating variable was the Mathematics III final grade. Each group consisted of 25 participants. A total of 50 students using random assignment with matching participated in the study. The study was conducted at Fort Bonifacio High School, Makati City in the school year 2003 – 2004. A teacher made achievement test was validated and was administered as a pretest and posttest to both groups. The result shows that there was a significant difference between the pretest and posttest mean scores of both experimental and control groups in the mathematics achievement test. Both groups, even when they were grouped according to ability level remarkably improved in the mathematics achievement regardless of the treatment. The use of computer –

based instructional material is an effective method in improving the students; achievement and attitude towards mathematics.

DELERA, FLORINDA B. The Effectiveness of Video – Based Strategy in the Development of Mathematics Achievement and Attitude of Junior Students of Arellano High School (NTC, MAED – Mathematics Education, 2004)

This study was designed to determine the effectiveness of video – based instruction in teaching selected topics in Mathematics III. The equivalent or parallel method was used to determine the effectiveness of the method employed in the process of teaching and learning in order to improve the present educational practice. The subjects involved were heterogeneously grouped third year students who were enrolled and took up Mathematics 3 for the school year 2002 – 2003. The control group was exposed to conventional method of teaching while the experimental group was treated with video – taped lessons. Both groups were given a pretest prior to the study and a posttest after the experimental period. Attitude of students were collated from questionnaires answered by both groups, then analyzed and interpreted through an instrument for the purpose. The teacher used the same lessons, activities and written evaluation. The only difference was the use of video – based group and the use of textbook for the traditional group. It was revealed that significant interactions were noted among students' attitudes, teaching strategy and achievement of both experimental and control subjects. Thus, the researcher arrived at the conclusion that students can best learn Mathematics 3 with the aid of educational television.

DHAMIJA, NEELAM DR., AND KUMARI, MUNNI. ***Effectiveness of Computer-Assisted Instruction on the Academic Achievement in Mathematics for Secondary School Students*** (Yamuna Institute of Education Yamuna Nagar, India and K.U.Kurukshetra, India, 2016)

This experimental study aimed at comparing the effect of Computer Assisted Instructional (CAI) and Lecture Method of teaching on the performance of IX class students in Mathematics. The significance of academic achievement scores for experimental group (using CAI) and control group (using lecture method) were examined in this study. A Pre-test - Post-test control group experimental design was used on forty five students of IX class. The results showed that the experimental group was significantly higher than the control group in academic achievement of students in Mathematics. Findings supported that experimental group (CAI) where students performed better than control group (lecture method) in Mathematics.

GUBBAD, ABDULLAH ABBAS MOHAMMED AHMED. ***The Effect of Cooperative Learning on the Academic Achievement and Retention of the Mathematics Concepts at the Primary School in Holy Makkah*** (Umm Al-Qura University, Makkah, Saudi Arabia, 2010)

The purpose of this study was to identify the effect of cooperative learning on the academic achievement and retention of the mathematics concepts learning of sixth grade students at primary school in Holy Makkah in Saudi Arabia. The study sample was 59 students divided into two groups: the control group (29 students)

which have been taught the mathematics concept using the traditional method, and the experimental group (30 students) which have been taught using the strategy of cooperative learning. An achievement test was used as an instrument to collect information and study data. Frequencies, percentages, means, standard deviations as well as t-test were used for the analysis of the study data and information. The results of the study showed that there is a statistical significance difference at the level (0.05) between the means of the performance of the experimental and control groups on the achievement and retention test for the benefit of the experimental group.

HOSSAIN, ANOWAR., TARMIZI, ROHANI A. ***Effects of cooperative learning on students' achievement and attitudes in secondary mathematics*** (Institute for Mathematical Research, Universiti Putra Malaysia, 2013)

The main purpose of this study was to identify the effects of cooperative learning on students' mathematics achievement and attitudes towards mathematics in selected secondary schools in Bangladesh. A total of 80 students (40 from Boys' school and the other 40 from Girls' school) of grade nine participated in this study where quasi-experimental design was administered. Data were analyzed using independent-sample test. The results showed that cooperative learning had significant effects on mathematics achievement and attitudes towards mathematics. It was found that students' performance in mathematics and attitudes towards mathematics were affected by exposure to the cooperative learning. The findings of this study have shown a great improvement in mathematics achievement and

attitudes towards mathematics. Therefore, cooperative learning can be successfully used to promote student' performance in mathematics in secondary schools in Bangladesh.

KARNASIH, IDA AND SINAGA, MARIATI. ***Enhancing Mathematical Problem Solving and Mathematical Connection Through the Use of Dynamic Software Autograph in Cooperative Learning Think-Pair-Share*** (Pascasarjana, Universitas Negeri Medan, UNUIMED, 2014)

Numerous studies have been conducted in analyzing the impact of integrating technology in teaching and learning mathematics. The purpose of this study was to investigate students' mathematical problem solving (MPS) and mathematical connection ability (MC) in cooperative learning setting using Dynamic Software Autograph for students in Grade XI, in Medan, Indonesia. This experimental study was conducted to 34 high school students in the School Year 2009/2010. The collection of the data was done using observation sheets, documentation, attitude scale, and performance tests. Repeated measure tests was delivered to students for four times, in the first class session (first measurement), after 2, 4 (second measurement) and 6 class session (fourth measurement). The result of the test showed that: (1) Cooperative learning using Dynamic Software Autograph in teaching Statistics in Grade XI improved students' problem solving ability. This can be shown from the results, that there were significant improvement in students' problem solving ability of the four tests given; (2) Cooperative learning using Dynamic Software Autograph in teaching statistics; (2) Students activity

during teaching learning processes improved, shown by the observations conducted during the lessons. Compared to the second measurement, the students' activity improved 37% on the third measurement and 56,3% in the forth measurement. The result of analysis of the questionnaire given to the students showed that: 20 students (58.8%) like using Cooperative Learning methods, 31 students (91.2%) like using Dynamic Software Autograph, and 27 students (79.4%) like using cooperative learning with Dynamic Software Autograph. Based on this positive result, it is hoped that mathematics teachers have to consider the use of Dynamic Software Autograph in teaching and learning secondary mathematics, especially in teaching statistic and teaching other units of mathematics such as Algebra, Geometry, Trigonometry, and Calculus.

KONTAS, HAKKI. ***The Effect of Manipulatives on Mathematics Achievement and Attitudes of Secondary School Students*** (Faculty of Education, Adıyaman University, Adıyaman, Turkey, 2016)

The purpose of this study is to investigate the effect of manipulatives (concrete learning materials) both on the academic achievement of secondary school students in mathematics and on their attitudes towards mathematics. Pretest-posttest control group experimental model, which is one of the quasi-experimental research designs, was used in the study. The study group consisted of 48 seventh grade students (24 in experiment group and 24 in control group) studying in a state school in the Southeastern Region of Turkey in 2014-2015 school year. The ages of students range between 13 and 14. Mathematics

achievement test and mathematics attitude scale were applied in order to collect the research data. As a result of the research, posttest mathematics academic achievement scores of experiment and control groups were found to differ significantly in favor of posttests in both groups. The scores of attitude towards mathematics for experiment and control groups were significantly different in posttests in favor of the experiment group.

LAURETO, MARLYN M. The effectiveness of Practical Work Approach on the Mathematical Achievement of Elementary Global and Analytical Learners. (NTC, MAED – Mathematics Education, 2004)

This study was conducted in order to find out the effectiveness of Practical Work Approach on the Mathematical achievement of the global and analytical learners. The researcher used the experimental method of research. This study was composed of forty experimental group - twenty global and twenty analytical learners. The control group was composed of forty pupils - twenty global and twenty analytical learners. The result of the pretest and posttest served as the main instrument used by the researcher in gathering pertinent data. The data from the test were tabulated and organized, after which were treated statistically using percentage, mean standard deviation, t – test and correlated t – test. It was revealed in the study that the experimental and the control groups had a positive attitude towards the Mathematics subject; pupils exposed to the whole class discussion method; and Practical Work Approach is more effective to the analytical learners than the global learners in the experimental group.

LIN, YA-WEN, TSENG, CHIH-LUNG, CHIANG, PO-JUI. ***The Effect of Blended Learning in Mathematics Course*** (National Kaohsiung University of Applied Sciences, TAIWAN, 2015)

With the advent of the digital age, traditional didactic teaching and online learning have been modified and gradually replaced by “Blended Learning.” The purpose of this study was to explore the influences of blended learning pedagogy on junior high school student learning achievement and the students’ attitudes toward mathematics. To investigate the outcomes of the combination of Moodle online teaching platform and traditional instruction, a quasi-experiment was conducted using a pre-test–post-test control group design. ANCOVA and MANCOVA analyses showed that the blended learning experience benefitted students in the experimental group by having a positive effect not only on the learning outcomes, but also on their attitudes toward studying mathematics in a blended environment. Preliminary results indicated that male students and high-ability students were more motivated in the blended learning environment. Students gave positive feedback on the use of the Moodle learning platform for mathematics after experiencing blended learning.

MARTIN, MARILOU M. ***The Effect of Using Varied Problem Solving Heuristics on the Mathematics Achievement of Students at IMUS National High School – Manila*** (PNU, MA.Ed., Master of Education, 2003).

This study was undertaken to determine the effectiveness of using varied problem solving heuristics in teaching Mathematics. The research site was Imus National High School, Imus, Cavite where 100 regular first year high school students under sections Akle and Apitong were used as samples. Fifty students were placed under the control group. While the other fifty were placed in the experimental group. The students were equated on the basis of mathematics performance reflected on the subjects ' Math I grade during the first grading period. The study followed the pretest – posttest control group design. The pretest and posttest of the students of both groups were statistically analyzed using t – test or independent samples across groups and the t – test for dependent samples within groups. The test of hypothesis on the pretest result had not shown any significant difference in the mean scores of the students in both groups based on t – test. Based on the results, the posttest means were significantly higher than their pretest means in both groups. This means that the students in both groups learned the lesson regardless of the method used. And also, the posttest result revealed sufficient evidence to indicate a significance difference in the mean scores of the students in both groups based on t – test in favor of the experimental group. This implies that using problem solving heuristics is an effective tool in teaching mathematics.

MASHOUJ, ALSHAMARI. Effects of Cooperative Learning on Academic Performance of College Students in Saudi Arabia (State University of New York at Fredonia, 2015)

The purpose of this study was to investigate the effects of cooperative learning on academic performance of college students in Saudi Arabia. This experimental quantitative study sought to answer the research question: How would jigsaw cooperative learning strategy affect college students' academic performance in Saudi Arabia compared to the traditional teacher- centered approach? The study involved 40 females ranging in age from 20 to 25, in an education course in Hail City. Over a period of four weeks, the researcher conducted the study in two classes: one class was the control group, and the other was the experimental group. The experimental group was taught by using a jigsaw strategy while the control group was taught by using a traditional teacher-centered lecture. The results showed students who were taught by the jigsaw strategy had a better understanding of the content as compared to the students who were taught by lecture. Therefore, the conclusion of this study is that the cooperative learning had a positive impact on students' academic performances in Saudi Arabia.

MYERS, RON Y. ***The Effects of the Use of Technology in Mathematics Instruction on Student Achievement*** (Florida International University, Doctor of Philosophy in Curriculum and Instruction, 2009)

The purpose of this study was to examine the effects of the use of technology on students' mathematics achievement, particularly the Florida

Comprehensive Assessment Test (FCAT) mathematics results. Eleven schools within the Miami-Dade County Public School System participated in a pilot program on the use of Geometers Sketchpad (GSP). Three of these schools were randomly selected for this study. Each school sent a teacher to a summer in-service training program on how to use GSP to teach geometry. In each school, the GSP class and a traditional geometry class taught by the same teacher were the study participants. Students' mathematics FCAT results were examined to determine if the GSP produced any effects. Students' scores were compared based on assignment to the control or experimental group as well as gender and SES. SES measurements were based on whether students qualified for free lunch. The findings of the study revealed a significant difference in the FCAT mathematics scores of students who were taught geometry using GSP compared to those who used the traditional method. No significant differences existed between the FCAT mathematics scores of the students based on SES. Similarly, no significant differences existed between the FCAT scores based on gender. In conclusion, the use of technology (particularly GSP) is likely to boost students' FCAT mathematics test scores. The findings also show that the use of GSP may be able to close known gender and SES related achievement gaps. The results of this study promote policy changes in the way geometry is taught to 10th grade students in Florida's public schools.

NFON, NEKANG F. ***Effect of Rusbult's Problem Solving Strategy on Secondary School Students' Achievement in Trigonometry Classroom*** (University of Buea, Cameroon, 2013)

The study investigated the effect of Rusbult's Problem Solving Strategy (RUPSS) on secondary school students' achievement in trigonometry in Fako Division in Cameroon. A sample of 366 form four students consisting of 186 males and 180 females were drawn from three colleges in the division by a multi-stage sampling technique. The Trigonometry Achievement Test (TAT) was used for data collection. Five experts, three in mathematics education and two in measurement and evaluation validated the instrument. The findings showed that Students exposed to the RUPSS achieved higher than those exposed to CPSS; Males in the RUPSS obtained a higher POSTTAT mean score compared to their female counterparts. The study recommends the teaching/learning of trigonometry via problem-solving strategies; Problem-solving should be incorporated into the curriculum in all institutions including teacher-training colleges and faculties of education in all universities in Cameroon.

NYUNT, NU NU., MYINT, AYE AYE. ***Enhancing Students' Mathematical Problem Solving Performance by Using a Cooperative Learning Model*** (Yangon Institute of Education Research Journal 2009, Vol. 1, No. 1)

The primary purpose of this study is to investigate the students' mathematical problem solving performance by using a cooperative learning model especially for Student-Team Achievement-Division (STAD). Students' attitude towards

mathematics was also examined. This study was conducted at Basic Education High School No (3) Kyeeyindine in Yangon, Myanmar. Sample of thirty-two Grade 9 students participated in this study. This study used a pre-experimental design to observe the changes in students' problem solving performance and students' attitude towards mathematics. This is a pioneer study which applied the cooperative learning model in Myanmar. Both qualitative and quantitative data were collected and analyzed. Two versions of mathematics performance assessment teacher-made (pre-test and post-test) tests, 14 items mathematics attitude test, 9 items problem solving observation rating scale, 8 items rating scale for students' cooperation, and reflective journals were used to assess the changes after intervention. The results of this study showed a definite increase in improvement both on the pre-test and post-test performance assessment and the attitude towards mathematics. Students earned the mean score of 12.06 on mathematics performance pre-test and that of 33.75 on mathematics performance post-test. Similarly, in the pre-attitude test, scores for 32 students has a mean of 30.62 and standard deviation of 6.40. In the post-attitude test, scores for 32 students has a mean of 32.62 and standard deviation of 4.24. The results showed that cooperative learning model can enhance students' problem-solving performance and students' attitude towards mathematics.

OCAMPO, IVY GAY. Cooperative and Competitive Learning Strategies: Effects on the Achievement and Attitude of Students in Mathematics. (PNU, MAED – Mathematics Education, 2005)

The study was conducted to make a comparative analysis of the effectiveness of cooperative, competitive and traditional learning strategies on the achievement and attitude of the freshmen college students of Pampanga Agricultural College towards mathematics. The quasi – experimental method of research particularly the non – equivalent control group design was used in the study. The study made us of an achievement test and an attitudinal questionnaire as the instruments. The achievement test prepared by the researcher, consisted of 40 - multiple choice item, each of which had 4 options. The test was administered before the experiment as pretest and at the end as posttest. The test covered topics on the following: the six trigonometric functions, angle complements, special angles, quadrantal angles, and solution of right angles. The students were given one and a half hour to take the test. The statistical techniques used in the study were means, standard deviations, U – L, Index Method, Kuder – Richardson, Formula 21, Pearson Product Moment Correlation, t – test for independent samples, and Analysis of Covariance (ANCOVA). Microsoft Excell and SPSS for windows version 9.0 were used in all statistical analyses of data. The 5 percent level of significances was used in all level of significance. It was concluded that the use of cooperative, competitive and traditional teaching learning strategies could help improve mathematics achievements of the students. However the use of cooperative learning strategy is the most effective among the three learning

strategies in improving mathematics achievement. Cooperative learning could also help improve mathematics attitude of students. Despite the improvement on the mathematics attitude of the students in the cooperative group after the experiment, the findings of the study concluded that there was no interaction in the attitude of the students in the cooperative, competitive and traditional learning strategies.

OJOSE, BOBBY AND SEXTON, LINDSEY. ***The Effect of Manipulative Materials on Mathematics Achievement of First Grade Students*** (University of Redlands, California, USA, Redlands Unified School District, California, USA, 2009)

This study investigated the effect of manipulative materials on the achievement of first grade students in mathematics. The data of scores obtained from students in the pretest and posttest were crunched and analyzed with the aid of Statistical Packages for the Social Sciences (SPSS) program. Using a pre-test posttest single group design and the t-test for dependent samples for analysis, it was found that students (n=18) achieved significantly higher scores on the end- of-unit test administered by the researchers, with $t(17) = 4.310$, $p < .001$. It was concluded that the instruction that incorporates manipulative materials in the form of money (magnetic coins) aided the achievement of students. Implications for teaching were discussed.

PEREYRA, MARIA LINDA C. ***The Effect of Computer – Aided Instruction on the Performance in an Attitude toward Problem Solving in Mathematics*** (PNU, M.A.Ed., Mathematics Education, 2009)

This study was conducted to determine the effect of the computer – aided instruction on the performance in and attitude towards solving word problems in Mathematics of selected fourth year students of Bonifacio Javier National High School the School year 2007 – 2008. Pretest and Posttest experimental design was employed in this study involving an experimental group and a control group. The experimental group was exposed to the use of computer – aided instruction with Hyperlink feature while the control group was exposed to the conventional method. Both groups were given pretest before the treatment and a posttest after the treatment. It was revealed that the use of CAI was proven to have a positive effect on improving the performance of fourth year students in solving word problems.

PERVEEN, KOUSAR. ***Effect of the Problem-Solving Approach on Academic Achievement of Students in Mathematics at the Secondary Level*** (Kohat University and Science Technology, Pakistan, 2010)

This study sought to determine the effect of the problem-solving approach on academic achievement of students in mathematics at the secondary level. The secondary school students studying mathematics constituted the population of this study. The students of 10th class of Government Pakistan Girls High School Rawalpindi were selected as a sample for the study. Sample size consisted of 48 students who were equally divided into an experimental group and a control group

on the basis of pre-test. Treatment of the planned problem-solving approach is the guideline of Sherreen (2006) and Polya's (1945) heuristic steps of the problem-solving approach. After the treatment, post-test was used to see the effects of the treatment. A two-tailed t-test was used to analyze the data, which revealed that both the experimental and control groups were almost equal in mathematics base at the beginning of the experiment. The experimental group outscored the control group significantly on the post-test.

POQUIZ, JUICYLEEN C. ***The Effects of Cooperative Learning Approach on Pupils Achievement and Attitude towards Math*** (PNU, MA Ed., Mathematics Education, 2005)

This study investigates and compares the effects of cooperative learning approach against the traditional method of teaching Mathematics to Grade 3 pupils at Paco Catholic School during the second grading period, school year 2004 – 2005. The study used experimental design, specifically the equivalent control group design to ascertain the initial equivalence of the intact groups. In this study, the experimental and the control groups were given pretest, underwent different treatments and then were given posttest at the end of the experimental period. It was found out that the achievement in Mathematics of pupils exposed the cooperative learning approach is higher than those exposed to traditional approach. The cooperative learning approach has more positive effect in the attitude of students towards mathematics than the traditional method. The cooperative learning approach is an acceptable and effective instructional method in teaching grade 3

Mathematics. The grade 3 pupils in the experimental group enjoyed learning mathematics and at the same time, they learned about mathematical concepts an acquired mathematical skills more easily than those in the traditional group. The cooperative learning approach has a higher achievement than the traditional method of teaching mathematics.

SANTOS, MA. LIAN KAMYL P., BELECINA, RENE R., DIAZ, ROSEMARIEVIC V. ***Mathematical Modeling: Effects on problem Solving Performance and Math Anxiety of Students*** (PNU, MA. Ed., Mathematics Education, 2015)

This study determined the effects of the integration of mathematical modeling on the problem solving performance and math anxiety level of Grade 9 students. Two groups of students were exposed to different strategies: the control group was taught using guided practice while the experimental group was taught using the integration of mathematical modelling. Pretests and Posttests were given to measure the performance of both groups in terms of their problem solving skills and their math anxiety level. T-test of independent and dependent were used to determine whether there exists significant difference between the performance of the two groups in terms of their pretest and posttest scores. Questionnaire and Interview Method were implemented were used to elicit students' reactions on the integration of mathematical modeling in the classroom. Findings showed that there is a significant difference between the pretest and posttest mean scores of both groups in terms of their problem solving performance test and their mathematics anxiety test. However, when their posttest mean scores were compared, the

experimental group made a large improvement in terms of their problem solving performance and a reduction in terms of their mathematics anxiety level, thus, the integration of mathematical modeling was effective in improving the problem solving performance and reducing the math anxiety level of students.

SOFRONIOU, ANASTASIA., POUTOS, KONSTANTINOS. ***Investigating the Effectiveness of Group Work in Mathematics*** (School of Computing and Engineering, University of West London, St. Mary's Road, London, 2016)

Group work permits students to develop a range of critical thinking, analytical and communication skills; effective team work; appreciation and respect for other views, techniques and problem-solving methods, all of which promote active learning and enhance student learning. This paper presents an evaluation of employing the didactic and pedagogical customs of group work in mathematics with the aim of improving student performance as well as exploring students' perceptions of working in groups. The evaluation of group work was carried out during tutorial time with first year civil engineering students undertaking a mathematics module in their second semester. The aim was to investigate whether group work learning can help students gain a deeper understanding of the module content, develop improved critical and analytical thinking skills and see if this method of pedagogy can produce higher performance levels. The group work sessions were conducted over four weeks whilst studying the topic of integration. Evaluation surveys were collected at the end of the intervention along with an investigation into the examination results from the end of semester examinations. In order to derive

plausible and reasonable conclusions these examination results were compared with analogous cohort of first year mathematics students, also studying integration in their engineering-based degree. The investigation into the effectiveness of group work showed interesting and encouraging positive outcomes, supported by a combination of qualitative and quantitative analysis.

SUBONG, RYAN. The Effect of Authentic Performance Tasks on Grade Six Pupils Problem Solving Abilities and Attitude towards Mathematics (PNU, M.Ed. – Mathematics Education, 2013)

The study aimed to investigate the effect of authentic performance tasks on the problem solving abilities and attitude towards mathematics of Grade VI students and the correlate problem solving abilities and attitude towards mathematics. The respondents are 3o Grade VI students of Blessed Sclarabini Institute for the School Year 2012 – 2013 coming from an intact class and were randomly assigned to form the experimental and control group. The experimental group was exposed to authentic performance tasks while the control group was exposed to traditional forms of assessment. Pretests and posttest were administered. The data were obtained using the Mathematics Attitude Scale for Pupils (MASP) and the Problem Solving Test (PST) which was scored using a rubric. The mean, standard deviation, t – test for dependent and independent samples, effect size and the Pearson Product Moment Coefficient were used to analyze the data obtained. It was found out that the authentic performance tasks

had significant effect on the experimental group as shown by the posttest scores both in the problem solving test.

TAREEF, ATIF BIN. ***The Effects of Computer – Assisted Learning on the Achievement and Problem Solving Skills of the Educational Statistics Students*** (The University of Jordan, Faculty of Education, 2014)

The basic aimed of this study is to investigate the effects of Computer Assisted Learning on the achievements of the educational statistic students the measurements related to the experimental and control groups. The result showed that, the difference is on behalf of the experiment group. This fact shows that the Computer-assisted learning method and traditional education methods have a clear different effect on the student's educational statistics achievements. This result leads that experiment group's students with computer-assisted learning methods increase their achievement level and show a higher performance more than the control group students.

TIENKEN, CHRISTOPHER H. AND WISLON, MICHAEL J. ***The Impact of Computer Assisted Instruction on Seventh-Grade Students' mathematics achievement*** (Planning and Changing Vol. 38, No. 3&4, 2007)

The perceived problem of low mathematics achievement is a concern to education leaders at all levels of PK–16 education. Reflecting this problem, the Third International Mathematics and Science Study–Repeat (TIMSS-R) showed the weaknesses of mathematics in the U.S. compared to other industrialized countries

when eighth grade U.S. students performed lower than those from 14 of the 38 participating nations (NCES, 2000). In addition, 15-year-olds from the U.S. ranked between 16th and 23rd out of 31 countries that participated in the 2000 administration of the Programme for International Student Assessment (PISA) (OECD, 2004). On the national level, the 2005 administration of the National Assessment of Education Progress (NAEP) mathematics test indicated only 36% of Grade 4 students scored “at or above proficient” and only 30% of Grade 8 students scored “at or above proficient” (NCES, 2005). These results raise concerns about the mathematics learning of U.S. middle school students. Education leaders search for interventions to address issues related to improving mathematics achievement. This article presents findings from a middle school mathematics intervention implemented to improve students’ mathematics performance. The purpose of this empirical study was to determine if there was a measurable difference in achievement on the mathematics section of the TerraNova Full Battery standardized test by a sample of seventh-grade students whose teachers taught them to use mathematics websites and presentation software as tools to practice basic mathematics skills (e.g., recall, comprehension, and application; Bloom, 1956) related to their curriculum compared to students whose teachers did not teach the use of such tools.

VALENCIA, BRENDA. ***Impact of Computer Assisted Instruction on Achievement in Seventh Grade Mathematics*** (California State University, Monterey Bay, 2016)

Increasing mathematical skills in American students has been a top priority. To increase these skills, an effective and easy to implement intervention is sought. Computer Assisted Instruction (CAI) is frequently used as an intervention with promising results. MobyMax, a CAI application was used in this study. This study used two groups and a pretest/posttest to compare students' achievement scores. The control group (n=28) received traditional Direct Instruction (DI) and the treatment group (n=29) received CAI through MobyMax. Independent sample t-tests were completed to determine the difference in student achievement scores. The results suggest the use of MobyMax increased student achievement compared to those who received traditional DI. Future research could examine the use of MobyMax with other populations.

VILLAREY, TERESA E. Effects of Higher Order Thinking Skills Learning Strategy on the Mathematics Achievement and Attitude of Grade 6 Pupils. (PNU, MAED – Mathematics Education, 2002)

The specific objective of the study was to determine the effects of the Higher Order Thinking Skills Learning Strategy (HOTSLS) on the mathematics achievement and attitude towards learning mathematics and towards reflective thinking of grade six pupils. The research was conducted at the North Fairview Elementary School in Quezon City with two heterogeneous groups of grade six

pupils as the participants of the experiment. The quasi – experimental design was employed. The experimental group were exposed to Higher Order Thinking Skills Learning Strategy while the control group was exposed to the traditional strategy. The two – way analysis variance was used to determine if there was a significant difference in the Mathematics achievement between the experimental group and the control group and between boys and girls after they were exposed to the HOTSLS and traditional strategy. It was found out that the performance between the two groups did not differ significantly, thus both groups were still comparable after the treatment. However, the HOTSLS seemed to have an impact on the kind of problems the pupils formulated and made a significant difference on the pupil's performance in analytical thinking. The attitude towards learning Mathematics and towards reflective thinking improved significantly in the experimental group. It was concluded that the HOTSLS was more effective in terms of improving the attitude of the pupils towards learning mathematics and reflective thinking.

YAGCI, FATMAGUL. ***The Effect of Instruction with Concrete Models on Eight Grade Students' Probability Achievement and Attitudes Toward Probability*** (Middle East Technological University, Master of Science in the Department of Elementary Science and Mathematics Education, 2010)

The main purpose of the study was to investigate the effect of instruction with concrete models on eighth grade students' probability achievement and attitudes toward probability. Another aim was to examine students' views about instruction with concrete models. The study was conducted in a private school in a big city in Central Anatolia Region with 12 eighth grade students. Both quantitative and

qualitative research designs were used. The treatment was applied by the mathematics teacher for 4 hours per week throughout 4 weeks. Probability Achievement Test and Probability Attitude Scale were administered to collect data. In order to analyze the data, Friedman and Wilcoxon tests were used. Also, the interview was carried out with 11 students to determine their views about the instruction. It was found that there was a statistically significant change in probability achievement of eighth grade students participated in the instruction with concrete models across three time periods. In other words, it was found that there were statistically significant positive changes in students' probability achievement from pre-intervention through post-intervention and from pre-intervention through follow-up. It was also found that there was no statistically significant change in students' probability achievement from post-intervention through follow-up. The results also revealed that there was no statistically significant change in students' attitudes toward probability across three time periods. Moreover, according to findings of the interview it was determined that most of the students had positive views about the effects of instruction with concrete models on their cognitive processes and on their attitudes toward concrete models and probability lessons.

ZAKARIA, EFFANDI., CHIN, LU CHUNG., DAUD, YUSOFF MD. ***The Effects of Cooperative Learning on Students' Mathematics Achievement and Attitude towards Mathematics*** (University Kebangsaan Malaysia, 2010)

The purpose of this study was to determine the effect of cooperative learning on mathematics achievement and attitude towards mathematics. Approach:

This quasi-experimental study was carried out on two form one classes in Miri, Sarawak. One class (n = 44) was assigned as an experimental group and the other (n = 38) was assigned as a control group. The two groups were pre-tested prior the implementation. At the end of the study, post-test was given, while daily quiz was used as a tool for formative testing. Teaching and learning process was carried out for two weeks. Data were analyzed using the t-test to determine performance by comparing the mean of the post test for treatment and control group. Results: The results of this study showed that cooperative learning methods improve students' achievement in mathematics and attitude towards mathematics. Conclusion: The researchers concluded that cooperative learning is an effective approach, which mathematics teachers need to incorporate in their teaching.

Appendix B

The Research Summary Form

Part 1. General Data

A. Title of the Study: _____

B. Researcher(s)/Author (s): _____

Part 2. Methodological Characteristics

A. Research Design

_____ Pre – test /Post Test
_____ Post – Test only
_____ Solomon Four Group Design
_____ Factorial Design

B. Participants:

B.1 Level

_____ Primary students (Gr.1 – Grade 6/6 – 12 years old)
_____ Secondary students (Gr.7 – Gr. 12/12 – 18 years old)
_____ Tertiary students (College/18 and up)

B2. Number of participants: _____

C. Sampling Technique

_____ Simple Random Sampling
_____ Stratified
_____Cluster Group
_____ Matched Group
_____ Purposive Sampling
_____ Convenience Sampling

Part 3. Substantive Characteristics

A. Learning Interventions

_____ Technology Oriented Approach
_____ Practical Work Approach
_____ Problem Solving Heuristics Approach
_____ Cooperative Learning Approach

Mean of the Control Group: _____

Mean of the Experimental Group: _____

Standard Deviation: _____

Appendix C – Research Summary Survey Results

Study	Year	Research Design	Participants	Number of Participants	Sampling Technique	Learning Interventions	Mean of the Control Group:	Mean of the Experimental Group:	Control Group Standard Deviation:	Effect Size	
		1-Pre – test /Post Test		1* -1 - 80	1 - Simple Random Sampling	1- Technology – Oriented Approach					
		2-Post – Test only	1-Primary Pupils (Gr.1 – Grade 6/6 – 12 years old)	2* - 81 - 160	2- Multi - stage sampling	2-Practical Work Approach					
		3-Solomon Four Group Design	2-Secondary Pupils (Gr.7 – Gr. 12/12 – 18 years old)	3* - 161 - 240	3- Cluster Group	3-Problem Solving Heuristics Approach					
		4 - Factorial Design	3-Tertiary Pupils (College/18 years old and up)	4* -241 - 320	4- Matched Group	4- Cooperative Learning Approach					
				5* -321 - 480	5 -Purposive Sampling						
					6 - Convenience Sampling						
1. Study A	2004	1	2	1 (50)	4	1	23.76	28.16	5.93	0.741989882	0.74
2. Study B	2009	1	2	1 (60)	1	1	15.97	26.5	1.43	7.363636364	7.36
3. Study C	2004	1	2	1 (74)	4	1	40.2	42.97	10.79	0.256719184	0.26
4. Study D	2009	1	2	2 (95)	1	1	4.02	5.22	2.99	0.401337793	0.4

5. Study E	2009	1	1	2 (106)	1	1	33.33	51.07	14.44	1.228531856	1.23
6. Study F	2014	1	3	3 (180)	1	1	42.1	44.3	7.3	0.301369863	0.3
7. Study G	2016	1	2	1 (45)	5	1	10.59	13.655	3.08	0.99512987	1
8. Study H	2007	1	2	4 (267)	1	1	53.73	64.57	12.94	0.837712519	0.84
9. Study I	2013	1	2	1 (42)	1	1	80	80.38	11.56	0.032871972	0.03
10. Study J	2016	1	2	1 (57)	3	1	21.07	19.45	6.13	-0.264274062	-0.26
11. Study K	2007	1	1	3 (165)	1	1	22.53	26.4	5.84	0.662671233	0.66
12. Study L	2014	1	2	1 (34)	1	1	74.66	84	6.71	1.39195231	1.39
13. Study M	2015	1	1	5 (380)	1	1	657.774	661.246	3.47	1.000576369	1
14. Study N	2016	1	2	1 (54)	1	1	54.7	64.3	28.58	0.33589923	0.34
15. Study O	2009	1	1	2 (84)	4	2	18.79	22.71	5.03	0.779324056	0.78
16. Study P	2012	1	2	1 (30)	4	2	33	35.4	7.74	0.310077519	0.31
17. Study Q	2004	1	1	1 (60)	1	2	9.15	12	3.5	0.814285714	0.81
18. Study R	2016	1	2	1 (48)	5	2	53.75	77	16.31	1.425505825	1.43
19. Study S	2014	1	2	3 (173)	1	2	24.18	38.95	6.35	2.325984252	2.33
20. Study T	2010	1	2	1 (12)	1	2	5	17	3.219	3.727865797	3.73

21. Study U	2004	1	2	2 (106)	4	2	10.68	8.82	5.02	-0.370517928	-0.37
22. Study V	2013	1	2	5(461)	1	2	0.339	0.422	0.203	0.408866995	0.41
23. Study W	2009	1	1	1 (18)	6	2	3.61	6.39	3.202	0.86820737	0.87
24. Study X	2013	1	1	1 (30)	1	2	51.93	52	28.954	0.002417628	0
25. Study Y	2002	1	1	1 (40)	4	3	12.005	12.745	4.355	0.169919633	0.17
26. Study Z	2003	1	2	1(30)	1	3	29.87	35.4	8.32	0.664663462	0.66
27. Study AA	2002	4	3	2 (153)	4	3	22.1	25.7	7.25	0.496551724	0.5
28. Study AB	2011	1	1	1(22)	1	3	2.22	2.83	1.17	0.521367521	0.52
29. Study AC	2010	1	2	1(76)	1	3	43.95	54.92	14.3	0.767132867	0.77
30. Study AD	2013	1	2	1(57)	4	3	41	41.25	17.77	2.321328081	2.32
31. Study AE	2010	2	2	1 (53)	1	3	60.58	67.38	17.9	0.379888268	0.38
32. Study AF	2013	1	2	5 (366)	2	3	23.12	39.29	14.55	1.111340206	1.11

33. Study AG	2010	1	2	1 (48)	4	3	37.92	57.17	10.35	1.859903382	1.86
34. Study AH	2007	3	2	3 (166)	1	3					
Grp 1							8.45	15.66	3.71	1.943396226	
Grp 2							15.66	30.71	3.71	4.056603774	
Grp 3							15.66	24.07	3.71	2.266846361	
Grp 4							24.07	30.71	3.71	1.789757412	
									Mean Effect Size =	2.514150943	2.51
35. Study AI	2015	1	2	1 (50)	4	3	22.7	29.83	5.37	1.327746741	1.33
36. Study AJ	2005	1	3	1(57)	4	4	17.857	24.643	5.489	1.236290763	1.24
37. Study AK	2005	1	3	1 (70)	4	4	13.69	17.83	3.61	1.146814404	1.15
38. Study AL	2010	1	2	2 (82)	6	4	50.18	56.18	11.18	0.53667263	0.54
39. Study AM	2012	1	2	1 (80)	1	4	35.31	47.56	1.89	6.481481481	6.48

40. Study AN	2015	1	3	1 (40)	6	4	6.0875	5.1496	0.38618	-2.42866021	-2.43
41. Study AO	2016	1	3	1 (39)	1	4	0.863	1.807	0.281	0.944	0.94
42. Study AP	2009	1	2	1 (32)	4	4	12.06	33.75	9.93	2.18429003	2.18
43. Study AQ	2010	1	1	1(59)	1	4	18.5	23	2.85	1.578947368	1.58

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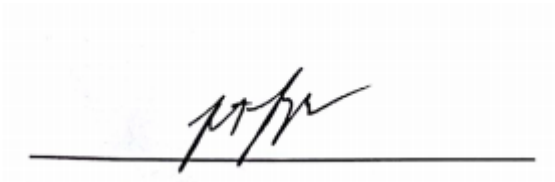
CERTIFICATION

This is to certify that the thesis entitled: "Improving Problem Solving Performance through Varied Teaching Approaches: A Meta – analysis" was prepared by Angelita V. Corbillon in partial fulfillment of the requirements for the degree of Master of Arts in Education with specialization in Mathematics Education has been checked and edited.

Issued upon request of Mrs. Corbillon, this 18th of September 2018 at the De La Salle Santiago Zobel School.



Robert Reyes
Language Editor

From the Desk of
Heidi Barcelo-Macahilig, Ph.D.
Faculty of Education Sciences
College of Teacher Development

C E R T I F I C A T I O N

This is to certify that the Thesis of **Angelita V. Corbillon** entitled, "***Improving Problem Solving Performance through Varied Teaching Approaches: A Meta-Analysis***," submitted as fulfillment of the requirements for the degree Master of Arts in Education with specialization in Mathematics Education, has been proofread and edited by the undersigned.

This certification is issued on the 4th day of March 2019 upon the request of Ms. Corbillon for whatever legal purpose this may serve.

Heidi Barcelo-Macahilig, Ph.D.
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EDUCATIONAL BACKGROUND:

June 2014 – April 2019	Philippine Normal University – Manila College of Graduate Studies Master of Arts in Education with Specialization in Mathematics Education
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2001 – 2005	Philippine Normal University - Manila Bachelor of Elementary Education with English: Concentration; Mathematics: Specialization Cum Laude Academic Excellence
1997 – 2001	The Sisters of Mary School - Manila Top 2, Leadership Award
1991 – 1997	Andarayan, Elementary School - Cagayan 2nd Honor, Best in Religion

ELIGIBILITY: Professional Teacher – October 2005

WORK EXPERIENCES:

June 2009 – present De La Salle Santiago Zobel School

Mathematics Teacher (Singapore Math)

(taught grades 1 to 6)

Science Teacher (taught grade 1 students)

Dance Club, Tippy Toes, Rainbow, Busy Hands

Moderator

Creative Team Member, ICONS director (2014)

MTAP Trainer

April 2005 – March 2009 Montessori De Manila

Class Directress II

taught Mathematics, Geometry and Filipino to grade school students

April 2008 – March 2009 Montessori De Manila

Area Facilitator

responsible in circulating information, observing colleagues and giving recommendations/suggestions for better implementation or execution of the lesson

April 2008 – March 2009 Montessori De Manila

Program Coordinator

responsible for planning all programs per area, disseminating information to colleagues, check and secure the venue and the flow of the program, evaluate the effectiveness of the over – all program with

	the other CDs and note some points for future improvement.
June – Oct. 2008	Alabang Elementary School Department of Special Education **Practicumer/Intern** taught students with disabilities under the following program (Mainstream, Early Education A-C, Behavior Modification Therapy (BMT)., Pre-vocational, Vocational)
July 21 – 25, 2008	Alabang, Elementary School **Organizer/Facilitator** responsible for organizing the celebration of the National Disability Week
October 27, 2007	Department of Education **Organizer** organized a seminar – workshop on Individualized Educational Plan (IEP)
June 2005 – March 2009	Montessori De Manila **Dance Club Adviser** taught students different kinds of dances, instilled good values, and inculcated nationalism choreographed varied dances in different activities/programs

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Mar. 2005 Philippine Normal University

Office of Admission

Student Assistant

responsible for receiving calls, evaluating students' requirements for admission, encoding data and answering queries of local and foreign students

SCHOLARSHIPS:

2002 – 2005 **International Bazaar Foundation**

Department of Foreign Affairs

2001 – 2002 **Student Government Scholarship**

Philippine Normal University – Manila

1997 – 2001 **The Sisters of Mary Foundation**

Sisters of Mary School – Manila

1992 – 1997 **Green Meadow Foundation**

Andarayan Elementary School – Cagayan

AWARDS RECEIVED:

- Perfect Attendance Awardee
- Exemplary in Teaching Portfolio (Runner Up)
- Exemplary in Instructional Materials (Runner Up)

SEMINARS AND TRAININGS ATTENDED:

REX Bookstore

Curriculum Construction and Teaching Methods (Singapore Math)

Summit Ridge Tagaytay

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The Mathematics Teachers Association of the Philippines Inc.

Empowering Math Teachers for K – 12

Doña Josefa SHS Las Piñas City

September 23 – 24, 2017

STEM Educ Training Hub

Critical Content and Pedagogy Training for Elementary Math Teachers

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March 4, 11, 2017

REAP Training Center,

Curriculum Construction and Teaching Methods (Singapore Math)

Quezon City

August 20, 2016

Phoenix Publishing House

International Seminar on Developing Mathematics Coaches

Manila Grand Opera Hotel, Sta. Cruz Manila

October 21 – 23, 2015

MTAP Congregation

Making K – 12 Succeed

Pinaglabanan Elementary School, San Juan

October 3 – 4, 2015

Philippine Normal University - Graduate Studies

Mathematical Investigation as an Approach in Enhancing Critical Thinking in Mathematics Learning

"Resource Person"

Magsaysay National High School, Dinalupihan Bataan

March 15, 2015

MTAP Congregation

Equipping Teachers for K – 12

San Francisco High School, Misamis St. Bago Bantay, Quezon City

September 27 – 28, 2015

C and E Publishing

Ready Minds Development Center

International Forum on Assessment and Explicit Instruction K to 12

Quezon Hall, Quezon City Sports Club, Quezon City

November 5, 2013

Teacher Training Workshop on Effective Strategies for Teaching Mathematics and Science: An Introduction to the Singaporean Approach

Eastwood Richmonde Hotel

November 29, 2013

Mathematics Association of the Philippines

Annual Convention and 2013 MTAP – DepEd Seminar Workshop : "Meeting the Challenges of K – 12"

Pitogo Elementary School

August 17 – 18, 2013

EdCrisch International
"Developing Problem Solving Skills in Learners"
Treston International College, Bonifacio Global City Taguig
February 2, 2013

EdCrisch International
"Developing Problem Solving Skills in Learners"
Treston International College, Bonifacio Global City Taguig
February 2, 2013

Rex Publishing House
"Pedagogies of Singapore Math"
Crowne Plaza Hotel, Ortigas, Mandaluyong City
January 11, 2013

Phoenix Publishing House Educational Foundation
"Unpacking Standards and Standards – Based Assessment and Grading in the K to 12 Curriculum"
De La Salle Santiago Zobel School
April 1 and 3, 2012

De La Salle Santiago Zobel School
"Item Analysis Using the Item Response Theory"
December 5, 2009
MTAP Congregation
"2009 MTAP Annual Convention and Seminar: Mathematical Excellence for Progress"
Pasig Central Elementary School
October 18, 2009