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Meta-analysis on the Effect of Differentiated Instruction on Students' Mathematics Achievement

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Meta-analysis on the Effect of Differentiated Instruction on Students' Mathematics Achievement

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DEDICATION

This fruit of hard work is lovingly dedicated
to my dearest parents, Papa Ben and Mama Zarina.
I love you both so much.

There's always a light at the end of the tunnel.

To God be the glory!

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"*Success is a partnership. It is a direct result of the individual and the support and encouragement of another person or persons*."

– Zig Ziglar

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TABLE OF CONTENTS

LIST OF TABLES

TABLE

ABSTRACT

Title	:	META-ANALYSIS ON THE EFFECT OF DIFFERENTIATED INSTRUCTION ON STUDENTS' MATHEMATICS ACHIEVEMENT
Researcher	:	Jean Aiko A. Cutamora-Domingo
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The present study generally aimed to synthesize the findings of research studies on the effect of differentiated instruction to students' mathematics achievement. In this context, the results acquired from the individual studies were combined through Glassian meta-analysis technique. The research studies that were included in the list were purposively selected, and have been subjected to the process of content analysis. A research summary form was developed to gather data from the number of research studies that contain three parts such as: the general data of the study, the methodological characteristics, and the substantive characteristics. Moreover, the methodological characteristics were determined which included the research design, students' profile, number and level of participants, and sampling technique. The substantive characteristics defined and identified were content differentiation, process differentiation, product differentiation, and learning environment differentiation. In addition, the research studies were carefully coded and recorded in the research summary form. The effect size was computed using the Glass' formula. Computed effect sizes were interpreted using Glass and Cohen's interpretation and Sawilowsky's interpretation. Findings showed that in terms of methodological characteristics, the following had exceptionally attained large mean effect sizes: 1) pre-test and post-test design; 2) involvement of regular secondary students; 3) the number of participants involved (61 to 100); and 4) the procedure on simple random sampling. Further, results concerning the calculated effect sizes according to the four types of modifications on differentiated instruction revealed that product differentiation had a huge mean effect size which implies that students' mathematics achievement was significantly higher when product differentiation was employed. Consequently, it was recommended that product differentiation be used more often in the mathematics classrooms, but nevertheless, content differentiation, process differentiation, and learning environment differentiation may also be used as other means to improve students' mathematics achievement.

CHAPTER 1

THE PROBLEM AND LITERATURE REVIEW

Background of the Study

Educators have always been faced with the challenge of meeting the diverse academic needs of their students in the classroom. Responsible to cater to differences of students, they must respect and value the uniqueness of all students. Moreover, schools and teachers are encouraged to adapt to these students' differences. Even policymakers and researchers urge teachers to adjust their instruction and embrace diversity among the students (UNESCO, 2018).

For many years, teachers have recognized and understood differences among their students. However, this led to teachers' difficulty in designing and preparing effective strategies that students could achieve in their own levels. Typically, teachers create lesson plans aligned with direct instruction believing that this is the most effective method of delivering knowledge to the students. But with the current heterogeneity inside the classrooms, Keskin (2018) said that it is nearly impossible for teachers to challenge and reach every student in the same class unless the curriculum is changed.

According to Tomlinson (2015), differentiated instruction is a promising approach for maximizing students' learning abilities. This is based on the idea that students learn better when teachers recognize differences in readiness, interests, and learning profiles among students. This teaching approach is considering the student differences, recognizing their strengths, and accommodating their shortcomings.

In this approach, teachers may differentiate the content of the lesson, teaching process, students' product and learning environment to provide students with various learning opportunities and to get the most out of each student's ability to learn. Evans et al. (2011) explained that it is necessary for the teacher to understand both the strengths and weaknesses of every student in their classrooms, but not teaching each student separately.

The National Council of Teachers of Mathematics (NCTM), as mentioned by Smith et al. (2018), recognized the necessity of differentiation in the mathematics classrooms by emphasizing the importance of accommodating differences among students, considering their readiness and mathematical talent levels, interest, or confidence, to ensure full understanding of mathematical concepts.

Another significant factor in Differentiated Instruction is grounded on the idea that teachers must anticipate student heterogeneity and change their instruction appropriately due to variation among any group of students (Smith et al., 2012). It is essential that the teachers are trained to prepare the lessons from where their students are because they carry with them their skills, knowledge, and experiences they have whenever they attend school (Kanevsky, 2011). This strategy is seen by all students in regular classrooms as the key to academic success. Dee (2010) and Roy et al. (2013) believed that differentiated instruction is crucial to the success and advancement of education.

Recently, differentiating instruction is no longer a new idea because it has been gaining high interests among mathematics teachers. Small et al. (2010) stated that whether a student is struggling, average, or gifted, teachers are expected by educational systems and parents to be mindful on their needs, and to plan instruction to address those needs. Every type of student is capable to shine and work their best regardless of background and culture. This notion must be recognized and understood by all the teachers, school leaders, parents, and even students themselves.

Moreover, Brand et al. (2015) mentioned that mathematics education should provide ways for the students to comprehend and appreciate mathematics' application in real life and avoid giving students' anxiety and distress. As cited by Springs (2014), Finkelstein claimed that there were two kinds of teachers in the classroom during the nineteenth century such as the intellectual overseer and the drillmaster. The former put great emphasis on the significance of memorizing the content, while the latter required students to recite the lesson altogether. Consequently, teachers are incapable to address students' varying needs in the classroom if they will remain the intellectual overseer or the drillmaster type of teacher. Thus, teachers must have content knowledge as well as a wide range of pedagogical and didactic skills to prepare and deliver differentiated instruction effectively (Van Casteren et al., 2017).

Tomlinson et al. (2013) specified that classroom management, effective curriculum, and effective assessment are all necessary with the purpose of achieving maximum academic growth. However, meeting student differences is not easy because these can be attributed to a wide range of student, including learner interests, learning styles, developmental stage, learning speed, abilities, cultural context, language level all of which are factors in Tomlinson's idea of classroom management, effective curriculum, and assessment. Teachers must empower their students to set goals and cultivate individual strengths to build a positive learning atmosphere.

With the introduction of K to 12 in Philippine Basic Education, the most recent curriculum aimed to improve the teaching of mathematics through spiral progression. It enables the students to acquire the skills relevant to their developmental stages that focus on high retention and mastery through constant re-examination and re-visitation of previous knowledge. Critical problem solvers, imaginative, creative people, and wise decision makers are expected to emerge because of this development.

In August 22, 2019, through DepEd Order No. 21 s. 2019, the Department of Education has issued the enclosed policy and guidelines on the K to 12 Basic Education Program. The order stipulates that DepEd shall adhere to the following principles:

a. The curriculum shall be learner-centered, inclusive, developmentally relevant, and appropriate. Learner-centered is an approach to education that places the needs and interests of the students at the center of the teaching-learning process.
b. The curriculum shall use pedagogical approaches that are constructivist, inquiry-based, reflective, collaborative, differentiated, and integrated.

Improving students' performance in mathematics has always been a major concern in the Philippines, as it has been in other countries. In 2018, the Philippines for the first time joined the 2018 Program for International Student Assessment (PISA) of the Organization for Economic Cooperation and Development (OECD) as part of the Quality Basic Education reform plan and a step towards globalizing the quality of Philippine basic education. In the National Report made by the Department of Education on 2018 PISA, the Philippines placed the second lowest in Mathematics. The results revealed that Filipino students scored an average of 353 points on the mathematical literacy category, which is significantly lower than the OECD average of 489 points and is graded below the Level 1 proficiency. The students who were classified below Level 1 can most likely accomplish some direct and simple tasks in mathematics. Most Filipino students (80.70%) had proficiency levels below Level 2, and with 54.4% having proficiency levels below Level 1 proficiency (2018 PISA National Report of the Philippines, 2019).

Several recent studies have found that using differentiated instruction to improve students' mathematics achievement yields positive results. In the studies conducted by Phelps (2012), Mbugua et al. (2014) and Decision (2019), their research findings revealed that differentiated instruction is more beneficial in improving academic scores of the secondary students. From the data collected, it was determined that those students who were taught using differentiated instruction outperformed those who were instructed using the traditional way of teaching.

Quite the opposite results were noted by several researchers on differentiated instruction. The studies conducted by Kestelout (2011), Scott (2012), and Faber et al. (2017) concluded that differentiated instruction did not have an overall effectiveness at a significant level to improve students' academic achievement in mathematics.

In summary, researchers concluded conflicting effects of differentiated instruction on students' mathematics achievement. Even if several meta-analytic research studies that aim at various aspects of differentiated instructions were located, limited results on meta-analysis of students' mathematics achievement were encountered by the researcher. This prompted the researcher to conduct a systematic analysis and synthesis on the findings using the Glass method analysis.

Meta-analysis is a statistical evaluation of a large collection of results from individual studies with the goal of combining the results (Glass, 1976). Glass also called meta-analysis as the 'analysis of analyses" to translate results derived from various studies into a consolidated outcome by means of computing the effect size. Researchers can analyze the findings of numerous studies on a single issue or problem. The chosen portion of the reported results of primary studies are entered into a database, called the “meta-data”. This is “meta-analyzed”, in the same way when working with other descriptive and inferential data to test certain hypotheses (Cajigal, 2011). Researchers can make reasonable generalizations about relationships between variables by using effect sizes from multiple studies that share a common hypothesis.

To date, many educational institutions are embracing differentiated instruction as a tool to personalize education and maximize students’ intellectual growth and development, while researchers are calling for more studies on the effects of differentiation. There is a high number of teachers who are implementing differentiation in the classrooms (Suprayogi et al., 2017). However, one problem encountered by the teachers themselves is the lack of skills and knowledge how to effectively use differentiation in the classroom. Among the difficulties in differentiated instruction faced by the teachers, Aldossari (2018) stated the most common problems such as involving the population of students in the classroom, failure to plan educational equipment and resources, students' lack of confidence, and students’ familiarity with traditional way of instruction.

The researcher hopes that the findings of this study will guide and assist mathematics teachers in deciding which type of differentiation is most appropriate to use in their classrooms. In this manner, students can enjoy and learn mathematics by providing them the appropriate methods to their recognized needs.

Likewise, the Glass Meta-analysis technique used in this study determined which among the modifications on differentiated instruction was the most effective in the improvement on mathematics achievement of students. After different studies were summarized and synthesized the researcher pinpointed the appropriate design used in this study wherein the consolidated result obtained the effect size. Subsequently, this study will benefit teachers to select the most effective type of differentiation appropriate for the needs of their students.

Literature Review

This section contains the reviewed literature and studies on differentiated instruction (DI) and meta-analysis. It discusses the reading sources critically to understand their implication to the present study. Moreover, it assessed previous research materials and evidence that were relevant to the current study.

On Meta-analysis

The development of research activities is characterized by a large volume and intense representation of empirical research. The information overload regarding a certain subject is apparently overwhelming and challenging on the part of the researcher in summarizing these results.

Some problems maybe encountered even with small number of studies and they can be difficult in the attribution of differences of their results. Since it helps researchers to draw conclusions and generalizations from a variety of patterns and circumstances, meta-analysis is really a valuable method in responding to multiple problems in educational studies.

Gene Glass coined the phrase meta-analysis to pertain to a philosophy rather than a statistical technique. Glass stated that writing of literature review should be organized and structured in the same way that primary research is.

In 1976, meta-analysis was formally defined by Glass as the statistical analysis of a broad set of analysis results from individual studies with the goal of integrating the findings. From the Greek word “meta” which refers to after or beyond, and therefore meta-analysis goes beyond individual studies. To put it another way, this is an "analysis of the analyses" because it helps researchers to statistically evaluate results of the studies meta-analyzed and integrate the results. Findings of the studies chosen for meta-analysis were interpreted based on the distribution of findings. Subsequently, meta-analysis had been widely accepted and used to synthesize research findings in a variety of fields.

Another definition of meta-analysis, as cited by Cajigal (2011) referred to a statistical technique for amalgamating, summarizing, and reviewing previous quantitative studies. The objective of meta-analysis is to integrate quantitative data extracted from individual data and then create a general conclusion about a related subject. The researcher enters the individual results of each primary study included into a database, and then these “meta-data” are then meta-analyzed in the same way that other data were used to test a particular hypothesis descriptively and inferentially.

Various areas of Glass's description of meta-analysis are significant:

1) The results of the review are covered in the meta-analysis. It includes the results of objective searches of the research literature; 2) A meta-analysis is a procedure that uses statistical tools to summarize statistics rather than raw data. Means, standard deviations, and results from statistical tests are among the meta-analyst’s observations. Meta-analysis, on the other hand, cannot be described as the analysis of raw scores obtained from primary or secondary analyses; 3) Meta-analysis focuses on not only statistical significance but also the size of treatment effects.

According to Glass's meta-analytic reviews, reviews that do not establish their conclusions on effect sizes and relationship strengths vary in a significant way; and 4) The emphasis of a meta-analysis is on the relationships between research features and outcomes. The goal of a meta-analyst is not just to summarize a large body of research through a single average effect size or overall significance level. A meta-analyst also attempts to figure out what other variables affect the effect sizes of the studies that are meta-analyzed.

Kyriakides et al. (2013) also mentioned two chief reasons for conducting meta-analysis. First, researchers are interested in determining the amount of knowledge that has been accumulated regarding a specific topic. Second, researchers may also be interested in developing a new theory, updating a current theory, or designing new study obtained from the results of the meta-analysis. In this regard, the researcher's objective is to use the findings of this study to help mathematics teachers effectively incorporate DI in their classrooms.

Neuman (2013) outlined the five steps involved in conducting meta-analysis; 1) Collect possible studies regarding a given topic, 2) Develop specified criteria for the inclusion of studies, 3) Determine and record extensively information about each study, 4) Analyze the data gathered, and 5) Draw a conclusion summary based on the results.

Furthermore, meta-analysis on a certain research topic is aimed at quantitatively integrating results from various studies, with each study serving as the unit of analysis. The results of these studies are synthesized by using statistical tools where researchers will translate and interpret findings from the chosen research studies to a unified result called effect size (Franekel et al., 2012). The effect size is a common metric value that measures how strong a relationship between two variables is. It is beneficial in standardizing results and make interstudy comparisons easier (Mertens, 2010; Turgut et al., 2018).

As cited by Swanson (2017), meta- analysis has the following advantages: (1) it organizes and extracts data from large databases using quantitative – statistical methods, (2) it removes study selection bias and makes no assumptions on the quality of a research, (3) it utilize all available data where findings of the study are converted into a comparable expressions of effect magnitude, (4) it investigates study characteristics where findings are measured and their co-variation is studied, and (5) it looks for general conclusions with the goal to enlighten significant interactive result.

On Major Meta-analytic Approaches

For every meta-analysis, it is imperative that researchers specify the approach they utilized in their studies. The following are the various approaches to meta-analysis in terms of procedures, computations, and interpretation of results. These approaches offer a thorough explanation to Glassian Meta-analysis which was used in the present study.

1) **Vote-Counting**– This approach is frequently misunderstood as treatment effect and sample size, even though statistical significance is an essential function of both. It is limited to answering the simple question “Is there any evidence of an effect?” that is why conclusions derived from vote-counting can be very misleading. Vote-counting might be considered as a final resort in circumstances when standard meta-analytical methods cannot be used.
2) **Classic or Glassian Meta-Analysis**– The conventional meta-analysis was patterned after the first meta-analyses conducted by Glass. This entails determining the question to be studied, gathering studies, coding study features and outcomes, and analyzing

relationships between study features and outcomes. Glass's previous meta-analyses established the standard for traditional meta-analysis: determine questions to be investigated, gather studies, code research features and outcomes, and study relationships between study features and outcomes. From all the early meta-analyses conducted, three distinct characteristics were observed. First, this is a type of meta-analysis that uses more lenient inclusion criteria. Furthermore, a meta-analysis will determine whether the quality of the study is linked to variance in observed treatment effect because a research should not be rejected solely based on study quality. Next, the research finding is the unit of analysis. Many similarities between groups and subgroups on various categories can be reported from a single study. Third, although the dependent variables measure different characteristics, researchers applying this technique will average the effects of several dependent variables. Furthermore, when subjected to critical re-analysis. Glassian analysis has been proved to be quite robust. Since it employs traditional statistical tests, this gives educational researchers access to the method and its results.

3) **Study Effect Meta-Analysis -** This modifies the Glassian approach in two ways. First, studies with serious methodological faults are not included because the inclusion rules are more selective. Second, only one effect size is computed for each study, giving the same weight to all studies involved. Apparently, it reduces the number of data points examined during the review.

4) **Tests of Homogeneity** – These tests were designed to determine the possibility that variation in effect sizes is due to sampling error alone. If the homogeneity statistic for a group of studies is significant, analysis of variance can be used. In this approach, studies

are repeatedly split into subgroups based on study characteristics until such time that within-group variation is no longer significant. Even when the variance is of no practical or theoretical significance, homogeneity tests are likely to reveal heterogeneity among effect sizes.

5) **Psychometric Meta-Analysis** - All the best features of other approaches are combined in this approach to meta-analysis. Regardless of quality, all studies related to a certain topic are collected. This approach corrects the effect size distribution for sampling error, measurement error, range restriction, including the other systematic artifacts. Based on study characteristics that have been pre-selected, effect sizes are divided for the second time into subsets. In this way, the remaining variance is checked if it is still significant, and these subsets will be meta-analyzed independently. The individual studies must contain substantial information necessary for the precise correction of effect sizes. Regrettably, this data is not always readily available.

Conducted Related Meta-analyses

The researcher located meta-analyses that used the Glassian meta-analysis approach in the same way as in the meta-analysis conducted by Cajigal (2010) which synthesized 36 theses and dissertations on teaching effectiveness and students' achievement. The experimental studies were aligned to the set of criteria established by the researcher, patterned after Glassian meta-analysis technique, which has gone through the process of content analysis as well. A research summary form was developed which was composed of three parts: the general profile of the study, the substantive characteristics, and the methodological characteristics. To analyze the results, descriptive and inferential statistics were both used. Findings on the meta-analysis revealed that in terms of the number of participants, forty plus got the highest percentage of the total number of studies. In the methodological characteristics for sampling technique, the matched group got the highest percentage among the included studies in contrast to the research design, pre-test, and posttest. In terms of effect sizes, the following got the highest mean: number of participants 30-40, cluster for sampling technique, and Solomon for research design. It was concluded that the students' academic achievement in experimental methods was higher than the students' academic achievement in traditional methods.

Additionally, the meta-analysis of Corbillon (2019) also applied the Glassian meta-analysis technique to describe various studies on improving problem-solving performance of students in mathematics through different teaching approaches. By means of purposive sampling design, the study reviewed 43 research studies that passed the inclusion criteria set by the researcher. The effect size was computed using Glass formula. The results revealed that the Solomon Four Group design had a huge mean effect size of 2.51 compared to other research designs while the level of the secondary students got the largest mean effect size of 1.48. The study concluded that the four teaching approaches included in the study have their own impact to students' problem-solving performance and can be alternative approaches in teaching mathematics.

Numerous studies had also been found which used meta-analysis that explores various topics in education. One example is the study of Chauhan (2016) which meta-analyzed 40 primary studies to investigate the influence of technology on elementary students' learning effectiveness. The study found that technology has a moderate influence on elementary students' learning effectiveness that leads to the recommendation that effective learning of elementary students can be realized if technology is fully integrated into pedagogy.

Another meta-analysis was carried out by Kot (2018) on the influence of the Touch Math technique on the mathematics achievement of students with special needs. The study's descriptive and meta-analytic findings revealed that Touch Math technique is useful in teaching acquisition skills to students with special needs.

Kul et al. (2018) utilized meta-analysis to synthesize the empirical data regarding the effectiveness of educational materials in mathematics classes. Fifty-four experimental studies were included, and fifty-eight effect sizes were calculated. The findings of this study established that using educational materials in mathematics renders a positive and significant impact on students' achievement.

Correspondingly, the study of Jacobse et al. (2012) synthesized 40 primary studies with sixty-nine independent effect sizes extracted to examine the impact of interventions on students' mathematics achievement. The study reported significant difference on the mathematics achievement of the students that utilized non-standard type of tests. However, there was no significant difference noted between students possessing with high or low ability in mathematics, and there was no difference found between direct or guided instruction methods.

Meanwhile, the study of Rosli et al. (2014) used meta-analysis to examine the effect of problem-posing on students' mathematical learning. After screening and careful examination of the collected research studies, only 14 individual studies that satisfied the requirement were selected and synthesized. Results showed high effect sizes that demonstrate problem-posing tasks have a significant positive impact on mathematics achievement.

Kalaian et al. (2014) conducted another meta-analytic review that focused on the effect of small group learning methods on statistics' achievement. The study selected nine published studies which revealed the academic achievement of students who were taught using the inquiry-based approach who were compared to those who were taught using one type of small group learning method. The findings stated that the usefulness of small group learning method in increasing students' achievement is reinforced by both cooperative and collaborative learning methods.

Another meta-analysis by Means et al. (2010) conducted on 50 effect sizes extracted from 45 studies to investigate the effectiveness of online and blended learning. The studies were classified by a coding scheme based on the collections of conditions, practices, and methodological variables. Researchers discovered that the students who learned online performed better than those who received face-to-face instruction.

Furthermore, Bernard et al. (2014) meta-analyzed 96 studies to investigate the effectiveness of blended learning and use of technology in higher education. Results indicated that, in terms of achievement outcomes, blended learning conditions exceeded classroom instructions and the kind of computer support used serve to enhance student achievement.

San et al. (2018) also meta-analyzed 31 studies to calculate the overall effect of traditional methods in Geometry and Number Learning Domains on academic achievement. The data were based on the pretest and experimental and control group designs. The results showed that traditional methods differ by an average of 0.83 standard deviations, and interpreted that traditional methods increase success in mathematics teaching.

Additionally, Toraman et al. (2016) employed meta-analysis to 43 studies that focused on science and technology lessons. The studies fulfilled the criteria that investigated the influence of constructivism on student's attitudes. The findings of the study revealed that students who were instructed using a constructivist approach had a more positive attitude toward the lessons and class activities than those students in the control group who were instructed using traditional methods.

Meanwhile, Turgut et al. (2018) used meta-analysis as well to determine the effect of visualization on mathematics achievement in a thesis conducted in Turkey. The study included 34 studies and 42 effect sizes extracts. Using the random effect model, the computed average effect size value is 0.811, with a standard error of 0.076. The researchers noted a medium effect of visualization on students' mathematics achievement. Therefore, the above-mentioned research studies concur that meta-analysis has been used in research and may support the present study in determining which modifications on DI is most effective in improving students' mathematics achievement.

In addition, the researcher has also located limited meta-analyses exploring the topic on DI. Deunk et al. (2018), synthesized a total of 26 journal articles to determine the effect of differentiation practices over the three stages in the education system while Iterbeke et al. (2020) studied the effects of ability matching and DI on the financial skills of grades eight and nine students. Moreover, Kim (2015) meta-analyzed 49 research articles to examine the effectiveness of DI in mathematics.

These studies were found that they also investigated other aspects of DI but none targeted the effect of content, process, product, and learning environment differentiation on students' achievement in mathematics. This gap prompted the researcher to conduct this meta-analysis on the implementation of differentiated instruction.

Differentiated Instruction

Today’s classrooms are filled with students who have a wide range of cognitive abilities, prior knowledge and learning preferences. As a result, teachers, and schools all over the world have always been challenged with that diversity. Under this condition differentiated instruction is being implemented in many schools to help students learn effectively and maximize their potentials.

Tomlinson’s (2014) concept of differentiated instruction supported the present study. It was founded on the belief that the teachers need to modify the instruction according to the varying needs of the learners. Differentiated instruction conjectured that students learn most effectively when the teachers address students’ differences in terms of readiness, interest, and learning style. In Tomlinson’s view, lessons may be differentiated by content, process, products, and the learning environment. This incorporates the planning and delivery of teaching, classroom management activities, and the prospects of learners' achievement in the class by considering the learners' diversity and varying levels of readiness, preferences, and learning profiles.

Differentiated instruction was first advocated by Dewey (1938) and Piaget (1952) who supported learner-centered approach wherein learner’s personality, talents, skills, and prior experiences are considered as integral parts of the learners’ development. Taber (2012) indicated that learning is a complex process that informs the teacher that every student requires time, space, and skills needed to help them acquire knowledge when students create their real world through their previous experiences, conceptual knowledge, beliefs, attitudes, and methods of learning.

According to Vygotsky's (1978) in the theory of zone of proximal development (ZPD), students learn better if they are given challenging tasks or stimulating learning experiences that are directed by more skilled and experienced peers and teachers. In a constructivist classroom, Bhattacharjee (2015) mentioned that the teacher's role is to act as an expert who can direct learners through cognitive techniques such as self-testing, articulating comprehension, asking probing questions, and reflecting on what they have learned.

Moreover, differentiated instruction should be designed to address the needs of the individual students rather than being a one-size-fits-all solution. Tambaoan et al. (2019) supports the idea that students are more motivated to participate when the teachers employ diverse techniques and tasks in presenting the lessons. In this approach, the learners are also given the opportunities to do and apply what they have learned. Although it can be a tedious task and a huge challenge for the teachers, they must deliver their lessons in innovative ways that focus on the personal interests of learners.

Tomlinson et al. (2013) and Roy et al. (2013) stated the difference between differentiated instruction and individualized instruction. Under differentiated instruction, the teacher does not vary instruction for every student which could be easier and less time-consuming while individualized instruction specifies the purpose to give remediation to students who are facing learning difficulties. Learning objectives are often fragmented to determine and accommodate learners' needs accordingly (Landrum et al., 2010). In fostering accommodation, time, space, resources, and flexible grouping were used in differentiated instruction to target subgroups of the entire class who do not need differentiated lessons daily. On the other hand, the whole class instruction was still used, highlighted with its purpose, and guided by ongoing assessment of students. Lastly, students were not provided with an unbalanced amount of work in differentiated instruction. Instead, every student worked on a task with the appropriate level which challenge critical thinking. Individualized instruction therefore should be implemented only as part of differentiated instruction (Chamberlin et al., 2010).

Moreover, Chesley et al. (2012) suggested that a closer examination of teacher education institutions need to be done. What educators teach and evaluate, use of the same content material, and regard for learners' differences should be examined. This scenario of teacher preparation calls for teacher training institutions to align their programs to meet the challenges and the realities of 21st century schools. One way to do this, as cited by Ireh et al. (2010), is to emphasize differentiated instruction as a fundamental teaching and learning philosophy that all teachers can learn about during their professional training programs.

Definitions of Differentiated Instruction

Over the years, differentiated instruction (DI) has been defined in a different context by experts sharing a common core focus that differentiated instruction attempts to give equal access to high quality instruction for learners with diverse needs.

To increase the probability that each student can learn as effectively as possible, Tomlinson (2014), described DI as a teacher-made proactive plan on what students will know, how they will learn, and how they will communicate. Differentiation, according to Tomlinson, is more than an instructional strategy or a teaching recipe - rather it is a fresh way of thinking about teaching and learning. This implies that in planning instruction, the teacher observes and understands the differences, similarities, and readiness levels among students who will use this information. Considering the students' learning style, interests, and learning pace the teachers are accountable to introduce different learning models and vary instruction.

Anderson et al. (2015) who is another leading expert on differentiation described DI as a teaching philosophy wherein teachers accept discrepancies in their preparation, motivation, and understanding on how students learn better. Likewise, it is also described as an approach to teaching and learning that is adaptable, equitable, and intellectual (Fox et al., 2011). Additionally, Butt et al. (2010) specified DI as a method of planning, that uses a variety of ways, and allows a certain topic be taught to the entire class while considering students' needs. Its major goal is to take full advantage of the intellectual ability of each student.

In support to DI, Howard Gardner made a significant contribution through his concept of multiple intelligences and brain-compatible research. Teachers were empowered to DI activities into three categories such as content, process, and product (Bender, 2012). To maximize learning opportunities, differentiating instruction requires teachers to adjust the curriculum, methods of teaching, learning materials and activities, and student outputs (Hillier, 2011). Additionally, the responsibility of teachers in DI is to ensure good quality of education by helping students construct their own learning and understanding, and nurture talents in an effective manner (Brandt, 2015).

In planning and designing effective mathematics instruction, balancing conceptual understanding with procedural fluency is necessary. Related and engaging activities, including parallel tasks and open questions, a range of representations of mathematics (concrete, pictorial, numerical, and algebraic), access to mathematics learning resources and technology, and regular and varied assessment of student comprehension are all elements of successful mathematics instruction.

According to Christenson et al. (2012), DI is a prevalent teaching strategy employed by teachers to promote learners' varied needs. In a heterogeneously clustered classroom, differentiation offers suitable obstacles at appropriate levels for all learners with different range of skills and preferences. In terms of distinction, designing understanding-focused instruction requires teachers to recognize that their students have varying levels of understanding, require various support systems to enhance their current level, and require a variety of applications to understand real-life experiences.

Similarly, Ricketts (2014) defined DI as a strategy where each student is nurtured as an individual learner and acknowledge the classroom as a learning community. The teacher pays attention on the strengths as well as the weaknesses of every student. Hence, students' needs are identified, and tasks are carefully designed to encourage students' participation.

Furthermore, Logan (2011) emphasized that differentiated learning happens when students participate in activities focused on their individual needs. Student engagement occurs if certain tasks capture students' attention. Learning happens if given assignments are exciting and situations for independent learning are provided. This learning environment gives the students a chance to relate to an expertise, desire, or skills which are personally important to them. Through directing learners to fulfill their own individual expectations, the instructor establishes the basic goals. Once confronted with theoretical challenges, students start to build resilience and independence.

One of the important principles of DI is for the teachers to determine each student's knowledge and skills with the appropriate activities that match learner's abilities. Pre-assessment is vital in the determination of the student's abilities for teachers to plan learning activities.

Tomlinson (2013) proposed that teachers will only begin to effectively establish units of study designed to address student needs once they have identified the results they expect from students. The KUD specifies precisely what the teacher wants students to Know (K), Understand (U), and Do (D) as they plan the unit.

Differentiation encompasses two defining structural features: DI and differentiated assessment (DA). In comparison, DI recognizes and builds on students' readiness, interests, and learning profiles by gathering information through pre formative and summative assessments. However, in DA, teachers adjust content, process, product and leaning environment so that each student can display their understanding and their attainment of specified learning outcomes.

According to Benjamin (2014), differentiation should be understood and practiced as a reflection and extension of best practices in education, but not as a substitute. Unless the changed program and teaching is valid for academically competent students, student outcomes are likely to be misleading. To address a broad variety of readiness levels, interests, and learning styles, curriculum and instruction adaptations need to be appropriately different. A comprehensive definition and model of the scope of successful differentiation is indispensable whenever the teachers are accused of treating individual variance and making slight and infrequent changes in the classroom.

Core Principles of Differentiation

Tomlinson et al. (2011) cited seven fundamental principles of DI. The following below reflect the philosophy behind differentiation and practices necessary for effective differentiation.

1. **Strong Classroom Community** – Pertains to the implication of having a great classroom environment to the students' learning. It is believed that students performed better in a classroom where they sense respect, appreciation, trust, and support.
2. **Quality Curriculum** –This refers to the core of any classroom. There are at least five features of a quality curriculum. First, both the teacher and the students have a clear understanding of the learning objectives—exactly what students should know, understand, and be able to do in each learning chapter. Second, rather than agreeing that the purpose of learning is to absorb huge amount of data in the shortest amount of time, quality curriculum emphasizes on what matters most. Third, quality curriculum enables students to comprehend how material and disciplines make sense, are structured, and contribute to students' own lives and experiences. Fourth, quality curriculum requires students to think critically. In other words, students are encouraged to apply, transfer, and use what they have learned. Lastly, high quality curriculum is created to inspire student to explore their imaginations, recognize their interests, and help them see the value of what they are learning.
3. **Respectful Tasks –**This indicates confidence and appreciation of every learner's capability. They should be able to produce work that is both engaging and welcoming. By assigning such tasks to all students, teachers send a strong message that they believe all students can be achievers and productive thinkers.
4. **Teaching Up-** DI produces excellent outcomes whenever the teacher asks more than the students are capable while providing scaffolding, support, and collaboration that students need to accomplish.

5. **Ongoing Assessment –** As a result of a unit, the teacher determines what students should know, understand, and be able to do, as well as the critical prerequisite knowledge, understanding, and skill that he or she expects students bring to class.
6. **Flexible grouping –** This is a significant factor in achieving both community and academic successes. In a differentiated classroom, students may be asked to work with classmates who have similar readiness levels, similar interests, or similar learning preferences.
7. **Flexible Classroom Management – Good structure and openness are essential** to differentiated classrooms to support every student in a class maximize their full potentials.

Teachers' Guide on Differentiated Instruction

Every time the teachers prepare lesson plans to meet varying students' needs, they must center their planning and delivery on students' current levels of readiness, interests, and learning profiles (Tomlinson et al., 2010). The following discussions focus on the teacher's guide on the implementation of DI.

Readiness

Student's readiness is about students' knowledge, understanding and skills in relation to a specific learning sequence which is affected by cognitive proficiency and past learning experiences, and school attitudes. This is a temporary condition that can vary widely over time, depending on topics and circumstances. Its goal is to provide appropriate learning experience and ensure that no students are left behind. One approach to effectively address readiness is the use of tiered exercises. For instance, all students learn the same definition but will perform activities based on their readiness levels. Small group sessions, one-to-one teaching and peer help or coaching are possible options. Whenever the teacher responds according to varying levels of readiness, this gives students a sense of competence and motivates them to continuously learn.

Student Interest

This pertains to the learner's motivation and their learning environment where students invest time and energy to learn. Addressing student interest is vital to be motivated for them to relate to the lesson that they value. When students' interests are tapped, students are more likely to be engaged and persist to learn (Kahu et al., 2017). Furthermore, it also encourages students to discover new interest.

According to Tomlinson (2013), differentiated learning happens whenever students are assigned with tasks that were created according to their individual level. There is engagement in the classroom when students' attention is drawn to a particular task which is worthy, enjoyable, exciting, challenging, stimulating, requiring them to work independently, and related to their experiences. Marzano et al. (2010) believed that relevance and autonomy are key factors in student engagement, so addressing student interests and learning preferences is critical.

The general incentive of learners to learn and to respond to specific learning tasks varies. Therefore, experts suggest empowering learners to choose their own subjects as assignments and participate in educational conversations with parents and teachers (Phillips, 2011). For example, if students are motivated to choose reading materials that are of value to them, they show meaningful involvement and report increased reading quality. However, if students do not manifest a motivation, their personal interest becomes questionable.

Kanevsky (2011) explained that permitting above-average students to choose their learning preferences is effective to encourage and reduce their feeling of boredom. The teacher shall enlighten students with the advantages and disadvantages of different strategies and allow them to choose what suits them most. This leads students to take control of their learning which is necessary to encourage and help them maintain a positive attitude about learning.

Learning Profile

This refers to a student's preferred method of learning. Students' preferences of learning are affected by learning styles, ability, preferences, background, and gender. Differentiation by learning profile is achieved when teachers provide learning experiences that enable students to demonstrate mastery of learning. More students complete learning activities effectively when various modes of learning are utilized and sustained.

Kesteloot (2011) investigated the effect of differentiation by examining the students' achievement in mathematics. He compared students' mathematics achievements both in the experimental or control groups with no major differences found.

Differentiating teaching can be accomplished more effectively by the teacher to ascertain and determine the students' desired learning styles in the classroom (Othman et al., 2010). By profiling them, the teacher gains a deeper understanding on how students access knowledge. Furthermore, Sarabi et al., (2014) stated that the teacher should know when and how to use learning aids in the resolution of learning difficulties among students and employ strategies on how to motivate students to become better versions of themselves.

Modifications on Differentiated Instruction

Tomlinson (2013) stated that there is not a single way to differentiate instruction. Just like the needs of every student, actual application of differentiation must also be diverse

(Chamberlin et al., 2010). In response to the leaner characteristics of readiness, interest, and learning profile, teachers may choose to differentiate their instruction about a lesson's content, process, product, and learning environment.

Content Differentiation

This refers to the knowledge, understanding, and skills that students need to master from the instruction (Bender, 2012). This is the "*what"* of instruction that involves the use of materials based on individual interest. In the content area, the teacher can vary the level of complexity. In the same curriculum, each student is taught the same concept or skill, but it may differ qualitatively or quantitatively. The teacher may present content in different ways, for example, by showing images of concrete objects illustrating math concepts as a first step in teaching abstract concepts.

Content differentiation implies offering several access points to facts, ideas, generalizations, values, and skills relevant to the subject (Tomlinson et al., 2010). Before assigning activities, the key to effective content differentiation is for the teachers to gauge all students against a common standard to determine the present level of performance. One challenge encountered for this type of differentiation is making sure that the lesson's objective remains central notwithstanding the activities or methods used.

In differentiating content, teachers may use a variety of strategies. One example is the use of the jigsaw puzzle wherein several groups are assigned to concentrate on the different parts of the certain topic. Another strategy is the utilization of varied texts, materials or resources like computer games, tape recorders, and videos as a way of conveying key concepts to varied learners. Another strategy is the use of learning contracts that give independence on the part of the students in learning the lesson. Also, Chamberlin et al. (2010) mentioned that teachers can re-teach some topics before the class through the so called mini-lessons. Students are provided alternative way to learn the lesson.

Joseph et al. (2013) recommends that flexible grouping may also be employed by the teachers for content differentiation. This strategy lets the students to work individually, or work with peers. Books, tapes, or internet are used to develop greater understanding on the lesson. Students are also trained to be responsible to submit assigned tasks on time although they are encouraged to work at their own pace.

Tiered activities are another strategy for differentiating content. Teachers assign varied activities on the chosen concept that serves as the focus of every student. These activities should be designed based on students' level of readiness, interests, or learning profiles. In the study of Nancy (2013), two groups of secondary students were formed to go through two tiers of intervention. The students in the double dose received both the core Algebra 1 curriculum and the Algebra Readiness program, while the students in the single dose only received the Algebra Readiness intervention. Results showed that when compared to students who only joined in a single intervention, students who were double dosed displayed substantial progress.

Process Differentiation

This refers to the "how" of the instruction. Teachers who implement differentiated instruction to the class are also involved in the learning process. Tomlinson et al. (2013) defined process as how the learner made to understand, own, and make sense of the subject's main concepts, skills, and generalizations. When using process differentiation, teachers take into consideration the students' ability level, interests, and learning styles. The students are encouraged to put meanings on what they have been taught (Roberts, 2017). The teacher may differentiate the process by letting students take ownership of their learning and creating sense-making activities for them to realize the relevance of the content they have learned in the world outside the classroom. The teacher may allow students to complete the activity in a different pace, with different aid, in different groups, and using different strategy.

Chamberlin et al. (2010) believed that teachers may apply numerous strategies on process differentiation. Tiered activities and learning stations are helpful in catching students' interest on a particular lesson. Teachers may also introduce journals to the students and let them answer the different prompts written. Moreover, curriculum compacting is a strategy that teachers may also use to determine parts of the lesson that the students have mastered.

Scaffolding is another process-based method for differentiation (Scigliano et al., 2010). The teacher scaffolds an activity consistent with the students' level of ability. It means that every student can navigate the textbook to understand the target lesson for the class. The teachers may design a process to breakdown difficult tasks into smaller segments or permits students to scaffold a given task by working in pairs.

Gordon (2013) claimed that multiple centers are other alternatives to differentiate process in the mathematics classroom. Students were given the chance to enjoy what interest them and take ownership of their learning. In the study conducted, students were tasked to observe and compute for the horizontal distance of water fountains. Subsequently, extra activities that interest the students were also done in addition to the original problem. Result showed that students attained the highest mathematics achievement when multiple-center approach is used with little supervision given by the teacher.

Likewise, collaborative learning is also a strategy to differentiate process that supports students to search for deeper understanding of a certain topic. Students can apply deeper learning strategies by sharing ideas and thoughts with others, by using different resources, and by applying learning in everyday life (Laird et al., 2010). Conversely, superficial learning occurs due to the type of instruction that requires students to memorize, copy, and repeat the lessons whether there is comprehension or none.

The study of Lawson (2018) determined how differentiated instruction using math stations affected students' individual learning progress. The finding demonstrated that the students who took part in the action research study portrayed a positive impact on their mastery of mathematic skills.

Product Differentiation

This pertains to the performances, assignments, and various means for students to show what they have learned, and to do tasks that can be accomplished in the future. According to Tomlinson (2010), the synonym for product is authentic assessment which gives teachers a breeding ground for differentiation. Product refers to students' outputs where they manifest what they have learned, understood, and can do over the course of a long period of study (Tomlinson et al., 2010; Aliakbari et al., 2014).

Numerous ways may be done to encourage students' demonstration of their knowledge on a particular topic. In doing so, teachers may opt to choose alternative products as a replacement for their tests or traditional way of assessment like poster making, visiting museums, crafting brochures, producing skits, listening to podcasts, writing journal articles, or presenting musical performances (Chamberlin et al., 2010).

In product differentiation, the teacher may also offer choices on how a class activity shall be presented and on how they display their learning relative to outlined learning objectives. Likewise, teachers can also allow students to propose possible ways to indicate their level of learning. With this type of differentiation, it is imperative to make sure that all forms of evaluation are equivalent in rigor and that the learning goals are purposefully and explicitly linked to the assessment tool or product.

Reis (2011) noted that the methods utilized in assessing students ' advancement towards learning goals should reflect opportunities for students to show training. The teachers should realize that to address student needs' and increase student' achievement, the teaching and learning practices should be modified and improved (Kanevsky, 2011; Smit et al., 2012; Watts-Taffe et al., 2012). If gaps are apparent, educators can provide DI and student assistance (Gettinger et al., 2012).

Learning Environment Differentiation

This includes both the concrete and intangible aspects of the classroom. This simply refers how the classroom functions to meet student emotional needs. Modifying the learning environment can greatly impact students' comfortability in the classroom and motivation to learn. This is because an individual's emotions and feelings influence one's self-concept, motivation to learn, and ability to collaborate. The tone of any classroom has a significant impact on those who use it and the learning that occurs there. The classroom environment in a place that aims for differentiation is much more important in influencing performance. A differentiated classroom should be able to serve and be embraced by a growing population of learners. That is, the teacher guides his students toward cultivating the kinds of attitudes, values, and behaviors that define a genuinely great neighborhood (Tomlinson et al, 2010).

Hence, to differentiate learning environment, teachers should consider modifying the physical layout of classrooms to create an environment that promotes the expression of new ideas, recognition of diversity, and exploration while respecting each learner's dignity. Similarly, teachers should establish a climate of respect, safety, and security to reduce distraction and promote comfortability. Additionally, teachers can adjust the physical environment and grouping patterns they use in class, as well as vary the distribution of time and resources which are fluid and versatile, approximate real-life conditions, and provide access to a variety of materials and resources in the classroom.

Another way to differentiate instruction is to allow students to choose their environment. In Richardson (2018) study, a class was given a mini-lesson and students were encouraged to remain. They were given options (1) to spend more time and learn with the teacher with limited number of students, or (2) leave for home, and work on their own. Once all students felt individually operating happily, the instructor could bring more challenging work for advanced students. It means that learners achieve the learning objective and are adequately tested. Therefore, if students are thoroughly tested according to their comprehension of the lesson objective, students will meet their maximum potential and achieve progress on their academic achievement.

Classroom differentiation strategies can also be significantly aided by using the internet in several innovative ways. The internet has the potential to extend the learning experience well beyond the four walls of the classroom, and it keeps promise for students in terms of engaging and differentiating content. Finally, teachers may set themselves apart by acting as sports athletes, or drama trainers, stage directors, promotional managers, and academic consultants.

Benefits of Differentiated Instruction

As student demographics become more culturally, socially, and academically different, teaching has become more demanding, and the concept of one-size-fits-all no longer applies (Pham, 2012). Therefore, it is necessary for teachers and students to be equipped with the different teaching and learning strategies respectively to address issues on students' low performance in mathematics (Gaylo et al., 2017).

Studies have shown that DI offers many benefits when practiced correctly with effective and appropriate strategies. Though there are many forms of differentiation, Tomlinson (2014) stated that the delivery of the curriculum which is aligned to the students' level garnered the same results. Furthermore, the primary goal of differentiated instruction to maximize each student's learning potential was highly stressed.

DI was found out to be beneficial to enhance students' motivation and improve students' performance (Konstantinou et al., 2013). Classrooms now have such a diverse population that it is important for educators to adjust the curriculum to accommodate all learners' expectations (Oliver, 2016). Differentiation ensures that all students are learning, regardless of their different abilities and academic readiness. It gives focus on how students think and share what they have experienced and take responsibility for their learning, as well as how educators address the educational needs of students. It was also revealed to be advantageous in terms of improving student's performance, motivation, and commitment.

Another benefit was stated by Polly et al. (2014) that DI means creating multiple paths for learners with different skills. Motivation and interests need to be explored as effective practices of experiencing, utilizing, improving, or communicating ideas of daily learning process. This motivates learners to hold more accountability for their own learning and gives time for peer instruction and collaborative education. It further demonstrates institutional effectiveness and provides students with diverse learning experiences that will enable them to effectively respond to increased challenges in today's world.

In the study conducted by Chamberlin et al. (2010), the outcome showed that when differentiation is designed according to readiness, interests and learning profile, the students improved in terms of achievement, study habits, social interaction, cooperation, attitude toward school. This was confirmed by the study of Thornton (2012) that investigated the use of differentiated instruction as a strategy for assisting struggling young readers in gaining better understanding of their assignments. Differentiation was discovered to provide means of maximizing student learning and thinking. Teachers, when using differentiation in the class, have the greatest power to change the lives of struggling students and help them excel (Lauria, 2010).

Varied Results Studies on Differentiated Instruction

Throughout the years, many studies with varying results on the effects of DI on students' mathematics achievement have been conducted.

The study of Butler et al. (2010) compared the mathematics achievement between students who received differentiation to that of students who did not receive differentiation. The results demonstrated that students who received DI outperformed students who did not.

Leonardo et al. (2015) explored the effects of DI on students' achievement in Trigonometry based on students' identified learning needs. The researchers reported significant high achievement on the group of students who were taught Trigonometry with differentiation than those students who were taught using the lecture-discussion method. However, DI caused no significant change in the attitude of students towards Trigonometry due to the time frame in the conduct of the study.

In Kenya, another study by Mbugua et al. (2014) supported the use of DI in improving the mathematics achievement of secondary students. The study used the quasi-experimental design to compare the mathematics achievement of students taught with differentiation to the mathematics achievement of students taught with the conventional instruction. Results showed that students' mathematics achievement improved significantly in the experimental group when compared with the group that received conventional instruction.

On the other hand, the quasi-experimental research by William (2012) studied the impact of differentiation on grade seven students' performance during on standardized mathematics assessments. No significant difference was reported in comparing the achievement of students taught using the conventional and experimental instructions.

Teachers' Perception and Challenges on Differentiated Instruction

Tambaoan et al. (2017) mentioned that mathematics teachers are motivated to differentiate their instruction to better facilitate learning process and help enhance students' achievement in the class. Successful delivery of DI entails imparting opinions and exchanging ideas about it. Despite its popularity, implementing DI in the classroom has proven to be more difficult and challenging, making the job of teachers more complicated (Tomlinson et al., 2014; Dixon et al., 2014).

According to Richards (2013), teachers who understood DI and received rigorous training about it had a positive attitude toward its implementation in the classroom. This only implies that the introduction of DI in the classroom is linked to both the teacher's perception and in their professional growth.

In the study conducted by Yavuz (2020), results indicated that implementing differentiation caused numerous challenges for teachers. Keeping up with class schedule while also providing differentiation at the same time, being mindful of the students, learning how to differentiate, and meeting institutional curricular standards are only a few examples. The biggest challenge was the lack of adequate time in balancing between differentiation and the daily workload. Teachers need more time for tasks such as lesson planning, accomplishing paperwork, and attending meetings (Robinson et al., 2014; Oliver, 2016; Siam et al., 2016).

However, some teachers hold opposing viewpoints on DI. Teachers were frustrated by the amount of content they were expected to teach without even considering further differentiating teaching. In addition, Whipple (2012) found a gap between teachers' comprehension of DI and its actual application, from a few teachers implementing differentiation in the class.

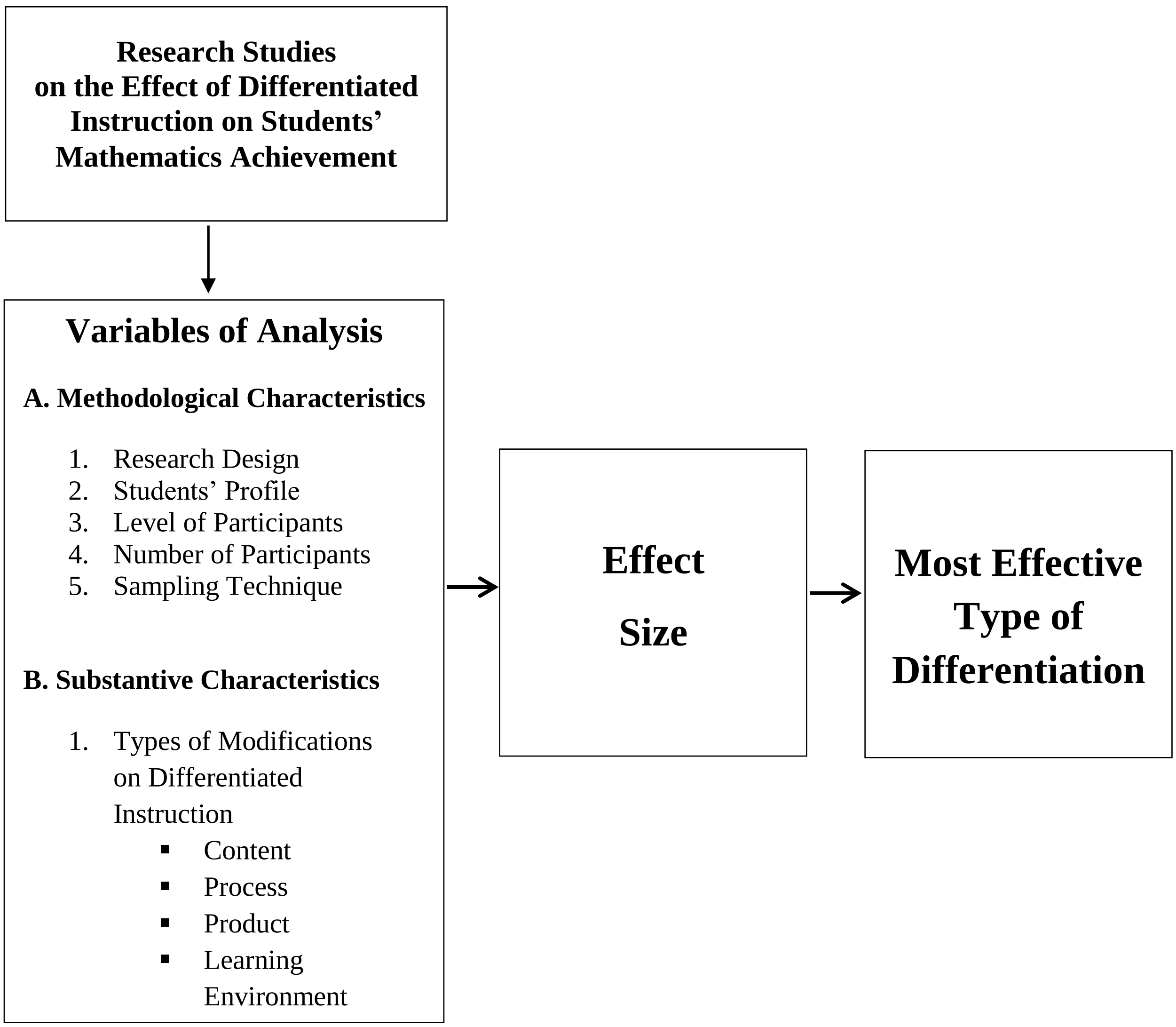
Aldossari (2018) mentioned density or number of students in the classroom, lack of confidence in using differentiated instruction, and students' familiarity with conventional teaching methods as challenges in implementing DI. Although Christopher (2017) reported that in his study the participants demonstrated a good understanding and stated advantages of DI in helping students succeed, additional problems described were lack of materials and resources, unfamiliar with available tools, difficulty to implement without the help of coworkers, and absence of administrative support hampered teachers' ability to execute DI effectively (Rodriguez, 2012; Smit et al., 2012).

Conceptual Framework

The conceptual basis of the study was anchored on the Glassian meta-analysis technique (1976) that highlights three distinguishing features and two variables of analysis. The following are the three characteristics: 1) it applies to a more lenient inclusion criteria; 2) the research finding is the unit of analysis with several similarities between groups and subgroups on various criteria can be made from only one sample, while effect sizes are computed for each comparison; 3) researchers who apply meta-analysis may compute the average of the effects from different dependent variables, although they are not from the same study. Further, the two variables of analysis are the methodological characteristics and substantive characteristics. Figure 1 below depicts said three distinguishing features and variables of analysis (please see next page).

Figure 1

Conceptual Framework



This study considered research studies on the effect of DI in the mathematics achievement of students. The independent variables included in this meta-analysis study were the methodological and substantive characteristics while the dependent variable was the effect size.

The five methodological characteristic variables consist of 1) research design, 2) students' profile, 3) level of participants, 4) number of participants, and 5) sampling technique while the four substantive characteristic variables comprise 1) content, 2) process, 3) product, and 4) learning environment.

An important thing to consider in the meta-analysis was the identification of effect size. The effect size is a general measure of the treatment effect on the dependent variable, expressed as the standardized difference between the results of experimental and control groups. Subsequently, the effect size was significant in this study to identify the most effective type of differentiation in improving the mathematics achievement of students. Using the Glass formula, the effect size was computed by subtracting the mean of the control group from the mean of the experimental group, and then divided by the control group's standard deviation.

Accordingly, if the computed effect size is positive or higher, it means that it is more valid. It also connotes that the type of differentiation applied in the experimental group has a higher difference than the mean of the control group. Similarly, the lesser the effect size means less significant or there is only little effect on the performance of the pupils in 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.

Ultimately, the researcher assumed that the four types of differentiation have different effect sizes. Among these types of differentiation, there could be one approach more effective than the other. This means that one must have the highest mean effect size while the rest could possibly have a lesser effect. This is significant to know so that mathematics teachers can use it as a reference when preparing lessons to help students improve their mathematics skills.

Statement of the Purpose

The main purpose of this study was to synthesize the findings of research studies on the effect of DI on students' mathematics achievement by using the Glass' meta-analysis design. This study aimed to answer the following:

1. Describe the methodological characteristics of the researches reviewed in terms of:
   1.1. Research Design
   1.2. Students' Profile
   1.3. Level of Participants
   1.4. Number of Participants
   1.5. Sampling Technique
2. Describe the substantive characteristics of the primary studies reviewed in terms of the types of modifications on DI used in improving students' mathematics achievement.
3. Determine the effect size of the different types of modifications on DI in improving achievement of students in mathematics when grouped according to methodological and substantive characteristics.

Scope and Limitations

The study focused only the effect of DI to students' mathematics achievement. Findings from online theses and dissertations within 2000-2020 were included in the study. The duration of the study depended on how many published or unpublished journals, articles, theses, or dissertations were found.

Definition of Terms

The following terms were conceptually and operationally defined to aid in a clear understanding of the study:

Differentiated Instruction. It is a philosophy of teaching that is based on the premise that students learn best when the teacher accommodate their differences in readiness levels, interests, and learning profiles. The teacher proactively plans what students will know, how they will learn, and how they will communicate (Tomlinson, 2010). In this study, this refers to the type of differentiation used by the teacher such as content, process, product, and learning environment in order to address students' needs.

Effect Size. This refers to the standard mean difference between the outcome scores of control and experimental groups (Glass 1976). In this study, this is the dependent variable of the study which is used to describe the difference between the mean of the experimental group and mean of the control groups. The statistical value showing each effect size calculated from each research is used to estimate the value of the effect size of the population.

Mathematics Achievement. According to Pandey (2017), it is the competency shown by the student in the mathematics subject. This is measured using scores in the achievement test in mathematics. In this study, this pertains to the summative grades, mathematics performance of the students that were used in the research studies.

Meta-analysis. This pertains to the statistical analysis of a broad set of analysis results from individual studies with the goal of integrating the findings. In this study, it is used as the analysis of the analyses.

Methodological Characteristics. This refers to the characteristics that are more general pertaining to the steps, methods, and procedures of conducting the study (Glass, 1976). In this study, this included research design, students' profile, level of participants, number of participants and sampling technique.

Substantive Characteristics. This refers to the characteristics of studies that are specific to the problem studies (Glass, 1976). In this study, this refers to the four types of modifications on differentiated instruction such as content differentiation, process differentiation, product differentiation, and learning environment differentiation.

CHAPTER 2

METHODOLOGY

This chapter explains the research methodology used to perform the meta-analysis on the relationship between DI and students' mathematics achievement. This also provides a thorough description of the research design, sampling and participants, instruments, data gathering procedure, data analysis, and potential ethical issues.

Research Design and Method

The main objective of this study was to synthesize the findings of the research studies on the effect of differentiated instruction to students' mathematics achievement. Applying the Glassian meta-analysis technique, this study used the descriptive-documentary analysis method which involves gathering of information by examining records of the documents.

Applying the meta-analysis technique in the study involved a statistical summary or integration of the results of several studies on the same topic. It analyzed and synthesized experimental research studies to determine how much effect the manipulations of independent variables had upon the dependent variables, as well as how much is the difference of each type of manipulation variable.

Meta-analysis was used to examine which among the DI techniques considered in the studies analyzed was most effective in improving mathematics achievement of students. This was the most appropriate design in this study to arrive at a unified result after the effect size was obtained. Thus, this study can guide teachers to choose the most effective type of differentiation appropriate for their students.

Selection and Inclusion Criteria for the Meta-analysis

The synthesized research studies examined in the present study were selected through purposive sampling. According to Etikan et al. (2016), purposive sampling is a nonrandom technique that does not need underlying theories or a set number of participants. It was used to select samples according to the researcher's goal and preferences.

First, a survey on both unpublished and published online dissertations and theses about improving students' mathematics achievement through differentiation were made.

In this study, the researcher selected research studies that compared the results of the traditional and DI in mathematics. These research studies must contain the following information: research design, number and level of participants, sampling technique, and findings of the study. The studies had to be conducted in an actual classroom setting and had to report measured study outcomes for improving mathematics achievement.

The researcher reviewed 20 research studies both unpublished and published online dissertations, theses, and journal articles from 2000 to 2020. Based on the literature, below are the criteria set by the researcher for analysis and synthesis patterned after the Glass meta-analysis (1981) technique:

Studies from both international and national literature which took differentiated instruction and mathematics achievement into account.

1. Studies should come from both international and national literatures which take on DI and mathematics achievement into account.
2. Studies only on theses, dissertations, or journal articles unpublished or published online are included in the reading list.

3. Studies on comparison between students in experimental groups using differentiated instruction and students in control groups using traditional method of teaching are included.
4. Studies must be an open access theses, dissertations and journal articles through Google and other related search engines.
5. Studies must involve students from kinder to college.
6. Studies should be conducted between 2000 to 2020.
7. Studies must contain the following information:
   7.1 Research Design
   7.2 Students' Profile
   7.3 Level of Participants
   7.4 Number of Participants
   7.5 Sampling technique
   7.6 Data on mean and standard deviation
8. Studies must have been conducted within the actual classroom setting.
9. Studies had to be measured and reported outcomes on the effect of DI.

Research Instrument

A Research Summary Form was developed to collect data from the researchers. The survey form was patterned on the meta-analyses conducted by Cajigal (2011) and Corbillon (2019). However, the researcher made revisions on some parts of the instruments which are appropriate for the study. The approval of the adviser and some experts was considered for the purpose of content validation. An initial examination of the studies and a review of previous meta-analyses were done on similar topics containing common characteristics which were included in the final instrument of the summary form.

The Research Summary Form (please see Appendix B) is composed of three parts. The first part includes the general data of the study such as title and researcher's name or author of the study. The second part was designed to gather methodological characteristics such as: (1) research design, (2) students' profile, (3) level of participants, (4) number of participants, and (5) sampling techniques. The third part was designed to gather substantive characteristics of the study. This includes the following: mean of the control and experimental groups, control group's standard deviation, and the type of differentiation used.

To clearly present the summary of the data collected including the effect size, a Research Summary Survey Results (please see Appendix C) was also created. The research instrument was further based on the given research characteristics used by Glass' studies in 1981 as well as the other research studies which used the same meta-analysis procedure.

Data Gathering Procedure

This meta-analysis focused on the impact of differentiated instruction on students' mathematics achievement. Though the studies found by the researcher were silent regarding the required number of studies that must be considered in conducting a meta-analysis, several meta-analyses (Kot (2018); Rosli et al., 2014; Kalaian et al., 2014; and Bicer et al., 2020) which reviewed less than twenty studies had been located. Hence, the researcher used twenty research studies in conducting this study. Likewise, the researcher guaranteed the confidentiality of the information about the participants by getting only the information indispensable for the study.

In this study, the researcher performed the following steps in gathering data for this study. First, using print and electronic resources, the researcher gathered data by collecting as many studies as possible including relevant published and unpublished theses, dissertations, and journal articles and determine their inclusion in the study. The researcher accessed several electronic databases such as Proquest, EBSCO Host, IG Library, ERIC, ScienceDirect, ResearchGate, Academia, and Google Scholar.

After identifying relevant studies, the researcher examined the research findings as objectively as possible following the criteria for inclusion set by the researcher. A research summary form (See Appendix B) and research summary survey results (See Appendix C) were drawn up for this purpose. The research summary form was validated by the researcher's adviser and some experts to check the information considered in the instrument.

With the use of the accomplished Research Summary Forms, the researcher cautiously coded and recorded the studies that have met the entire standard for inclusion to ensure the objectivity and reliability of the coding. The coding method of the characteristics of the research studies that utilized by the researcher is shown in the tables that follow.

Substantive Characteristics

Characteristics	Type	Code
Types of Modifications on Differentiated Instruction	Content	1
	Process	2
	Product	3
	Learning environment	4

Methodological Characteristics

Characteristics	Type	Code
A. Research Design	Pre-test and Post-test	1
	Post-test only	2
	Solomon Four Group Design	3
	Factorial Design	4
B. Students' Profile	Regular Students	1
	Advanced/Gifted Students	2
C. Level of Participants	Kinder to Grade 3	1
	Grade 4 to Grade 6	2
	Grade 7 to Grade 12	3
	Tertiary Students	4
D. Number of Participants	1-20	1
	21-40	2
	41-60	3
	61-100	4
	101 or more	5
E. Sampling Technique	Simple Random Sampling	1
	Stratified Sampling	2
	Cluster Group Sampling	3
	Matched Group Sampling	4
	Purposive Sampling	5
	Convenience Sampling	6

Data Analysis

Steps were followed before the data were analyzed. After the data collection, tabulation, and coding were undertaken, the researcher used the descriptive analysis to analyze the data using Microsoft Excel in the computations. Here are the statistical techniques that were used in the study:

a. Descriptive statistics for the computation of the means, frequencies, and percentages. This was used for the description of both the methodological and substantive characteristics.
b. The Glass formula was used for the computation of the effect size as shown below:

$$\Delta = \frac{\bar{x}_e - \bar{x}_c}{S_c}$$

where:

$\bar{x}_e$ =mean of the experimental group

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

S_c =standard deviation of the control group

The researcher interpreted the effect sizes by using the convention for appraising the magnitude of effect sizes which was developed by Glass (1976) and Cohen (1992) and was later extended by Sawilosky (2009).

The following tables present the data gathered in the study. Table 1 below shows the interpretation of the 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

According to the interpretation of Glass and Cohen, if the computed mean ranges from 0.01 to 0.2 the effect size is small. It means that the effect of the methodological and substantive characteristics on students' mathematics achievement is less significant. Likewise, this signifies that the effect of differentiation in the experimental group has a little difference from the effect of the teaching approaches in the control group.

Furthermore, if the computed mean ranges from 0.21 to 0.5 the effect size is medium. It means that the effect of the methodological and substantive characteristics on students' mathematics achievement is moderately significant. This implies that the effect of differentiation in the experimental group has a medium difference from the effect of the teaching approaches in the control group.

Moreover, if the computed mean ranges from 0.51 to 0.8 the effect size is large. It means that the effect of the methodological and substantive characteristics on students' mathematics achievement is highly significant. This suggests that the effect of differentiation in the experimental group has a high difference from the effect of the teaching approaches in the control group.

Correspondingly, as extended by Sawilowsky, if the computed mean ranges from 0.8 to 1.19 the effect size is also large. It means that the effect of the methodological and substantive characteristics on students' mathematics achievement is highly significant. This indicates that the effect of differentiation in the experimental group has a high difference from the effect of the teaching approaches in the control group.

Also, if the computed value ranges from 1.2 to 1.99 the effect size is exceptionally large. It means that the effect of the methodological and substantive characteristics on students' mathematics achievement is significantly higher. This indicates that the effect of differentiation in the experimental group has a higher difference from the effect of the teaching approaches in the control group.

Likewise, if the computed mean is 2 the effect size is huge. It means that the effect of the methodological and substantive characteristics on students' mathematics achievement is significantly highest. This also signifies that the effect of differentiation in the experimental group has a huge difference from the effect of the teaching approaches in the control group.

Conversely, if the computed mean is 0 it means that the performance of the students in the experimental group is the same as the performance of the students in the control group. This implies that the teaching approaches have the same effect or no effect at all. Similarly, if the calculated effect size is negative, it signifies that the effect of the teaching approach is better or higher in the control group than in the experimental group.

Potential Ethical Issues

In the conduct of this study, the researcher ensured to observe the ethical guidelines on research of the Philippine Normal University. With the help of her adviser, the researcher did not compromise the integrity of the research by following the necessary procedures required by Philippine Normal University.

The primary objective of this meta-analysis was to synthesize numerous studies on the effect of DI on mathematics achievement of the students. Careful planning, coding, and constant checking were done to avoid biases in the interpretation of the results. Conduct of the study and the data gathering procedure were clearly defined under the methodology section to ensure that no biases arise from its implementation. The researcher planned to publish the findings of this report in the field of mathematics education.

Furthermore, the researcher avoided academic dishonesty by making sure that all studies included in this study were publicly available data published on the numerous online journal databases on the internet.

CHAPTER 3

RESULTS AND DISCUSSIONS

This chapter presents the findings found by the researcher in conducting this meta-analysis. The discussion covered the results on (1) methodological and substantive characteristics of the research included herein, and the (2) effect sizes.

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

1.1. Research Design

Table 2

Methodological Characteristics Based on Research Design

Research Design	Frequency	Percent
Pre-test / Post-test	17	85.00
Post-test only	3	15.00

Table 2 shows that most of the studies meta-analyzed employed the Pre-test/Post-test research design with a frequency of seventeen. Among these seventeen studies, sixteen studies employed the quasi-experimental design, specifically the non-equivalent control group design where the number of participants for the experimental and control groups are different.

Further, there is one study that used quasi-experimental design, particularly the equivalent/parallel method where the numbers of participants in each group are equal, and pairs were being matched based on their abilities.

The same result was yielded in the meta-analysis conducted by Corbillon (2019) where most of the research reviewed used the pretest-posttest design. Out of forty-three studies that the researcher synthesized, forty studies 93.02% used pretest-posttest design.

On the other hand, post-test only design was employed by the three studies meta-analyzed to examine the cause-and-effect relationship of standardized assessment and DI in the classroom.

In view of the results of the meta-analysis conducted, it shows that pretest-posttest design is the preferred type of research design to test the effectiveness of DI on students' mathematics achievement. It can also be noted that pretest-posttest design is appropriate to test the effectiveness of any educational innovations or interventions. This conforms with Knapp (2016) that pretest-posttest designs are the favored approach for comparing groups and measuring the degree of progress taking place because of treatments or interventions conducted in countless true experimental designs.

1.2. Students' Profile

Table 3

Methodological Characteristics Based on the Students' Profile

Students' Profile	Frequency	Percent
Regular	19	95.00
Gifted	1	5.00

Table 3 indicates that among the students' profile, regular students have the highest frequency of nineteen.

One study involved in this meta-analysis used gifted students as respondents. The capability to perform significantly above average for a particular age is described as giftedness (National Association for Gifted Children, 2018). As explained by McWilliams (2018), gifted and talented refers to exceptional achievement in intelligence, creativity, artistry, and leadership demonstrated by students who needed special programs and activities to fully develop their abilities in an academic environment.

Furthermore, mathematically gifted students also show an inconsistent pattern of mathematical understanding and progress because some are better grasping the concepts than in computation. They are usually more fascinated in the *hows* and *whys* of mathematical concepts rather than the computational *how-to* processes (Al-Zoubi, 2014).

It can be noted that in the meta-analysis most of the research included herein used regular students as respondents to study the impact of DI on students' mathematics achievement. This supports Caldwell (2012) statement that despite efforts in professional development, studies constantly report that little differentiation occurs for gifted learners in regular classrooms, a trend that has remained relatively unchanged over the last ten years. Though addressing a variety of learners can be challenging, teachers must teach the gifted and grade-level students at the same time (Dixon et al., 2014). This result may guide mathematics teachers to adequately address the needs of gifted students through the implementation of DI. Differentiation allows for more personalized learning because gifted students can go beyond what is learned and can be challenged by concentrating on a certain task that is appropriate to their level.

1.3. Level of Participants

Table 4 presents the secondary students the highest frequency on the level of participants. Out of these twelve studies on DI, four studies had Grade 7 as their respondents, two studies had Grade 8, one study had Grade 9, four studies had Grade 10, and one study had Grade 11. Moreover, four studies had used pre-school students from Kinder to Grade 3 as their respondents. Out of these four studies, one study had Grade 1, one study had Grade 2, and two

Table 4

Methodological Characteristics Based on the Level of the Participants

Level of the Participants	Frequency	Percent
Kinder to Grade 3	4	20.00
Grade 4 – Grade 6	2	10.00
Grade 7 – Grade 12	12	60.00
Tertiary Education	2	10.00

two studies had Grade 3. Also, two studies had used Grade 4 to Grade 6 as their respondents. Out of these two studies, one study had Grade 4, and one study had Grade 5. Finally, two studies had used tertiary students as their respondents. Specifically, these two studies both used freshmen or first year college students.

On the level of participants, the finding of this study was consistent with the meta-analyses performed by Corbillon (2019). Out of forty-three studies, twenty-seven had been on secondary students while the study of Batdi et al. (2019) shows that out of forty-four studies twenty-six had been secondary students. Turgut et al. (2018) has also noted a different result which reveals that secondary students got the third highest percentage of 52.94 while Capar et al. (2015) noted that secondary students got the second highest.

From the result of this study, it can be observed that secondary students were the most-chosen participants of the studies on DI included herein. According to the French psychologist Jean Piaget, the formal operational stage of the cognitive development of children is from 11 years old and beyond. Children at this age can use logic to solve problems, observe the world around them, and make plans. In addition, the youth can think in a more abstract way, going beyond the limits of concrete mental operations. This new skill was regarded as "Formal Operations" by Piaget. The formal operational stage lasts from about the age of 12 to adulthood. At this point, the children can think abstractly on how to solve problems (Bergin et al., 2014).

Hence, it can also be noted that the researchers of the studies included in the meta-analysis conducted perceived secondary school students were more capable to do and finish the required activities. They can easily follow when teachers gave instructions whenever DI was applied in the learning process.

1.4. Number of Participants

Table 5

Methodological Characteristics Based on the Number of Participants

Number of Participants	Frequency	Percent
21-40	3	15.00
41-60	5	25.00
61-100	3	15.00
101 and above	9	45.00

Table 5 shows that among the number of participants, the sample size of 101 and above got the highest frequency. Out of these nine studies, six studies have a sample size greater than 100 but less than 200, two studies have a sample size greater than 200 but less than 300, and one study had a sample size of exactly 700. Thus, it can be concluded from the studies reviewed that the ideal number of participants when DI is being used is 101 and above, specifically around 101 to 200. This was contrary to the results of the meta-analyses done by Means et al. (2010) and Capar et al. (2013) that the number of participants of one hundred and above had the second and third highest sample size, respectively.

Moreover, the number of participants ranging from 41 to 60 attained the next highest frequency. Five studies reviewed had sample sizes ranging from 41 to 60. Two studies have 56, while three studies have 60. However, the study of Turgut (2018) reveals a sample size that ranges from 41 to 60 got the highest frequency.

Lastly, the number of participants ranging from 21 to 40 and 61 to 100 ranked the third highest as they both got a frequency of three. Specifically, the sample size ranging from 21 to 40 have 28, 32, and 40 participants. Despite their small sample sizes, these three research studies were still included because all the requirements set by the researcher for the selection and inclusion criteria were met.

On the other hand, the sample size ranging from 61 to 100 have 68, 96, and 100 participants. This differs with the result concluded in the meta-analysis conducted by Talan (2020) because the sample size with a range of 100 and above got the third highest frequency.

Based on the result from the preceding data, it can be said that most of the research on DI that were conducted had more than 101participants. This could be attributed that using large sample size helps in determining the mean value of a quality among tested values. It provided a more accurate estimate of the treatment effect, easily determine the sample' representative, and generalize the results. Also, a study with large number of participants was a powerful test of the null hypothesis which resulted to a smaller standard error. Thus, it can be concluded that the larger sample size, the more precise the mean (Delice, 2010).

1.5. Sampling Technique

Table 6 shows that the first highest sampling technique used was in the case of nine studies using the simple random sampling. For a variety of purposes, it was the most commonly used

Table 6

Methodological characteristics Based on the Sampling Technique

Sampling Techniques	Frequency	Percent
Simple Random Sampling	9	45.00
Stratified Sampling	2	10.00
Purposive Sampling	4	20.00
Convenience Sampling	5	25.00

tool for selecting a sample from a population since it is the most simple and the most straightforward probability sampling technique. The rationale behind simple random sampling is to eliminate partiality from the selection process. Thus, every member has an equal chance of being selected as a participant in the study (Gravetter et al., 2011). In another study, the lottery method was used, wherein, the researcher picked samples by assigning a number to each member of the population and the numbers were chosen at random. On the contrary, Cajigal (2011) obtained a different result in terms of sampling technique, with simple random sampling as the second highest frequency.

Further, the second highest sampling technique was convenience sampling. Five studies reviewed in this meta-analysis on DI used convenience sampling. This is a non-probability sampling method that collects data from members of the population. With no additional requirements, samples for the study were taken from the first primary data source available to the researcher. All subjects were invited to participate without any inclusion criteria identified prior to the selection. This sampling technique entails bringing together participants wherever is most convenient. This contrasts with the findings of a meta-analysis conducted by Corbillon (2019), which found convenience sampling to be the third highest frequency.

Also, table 6 revealed that purposive sampling obtained the third highest frequency among the sampling techniques. Four studies reviewed employed purposive sampling. Another name for purposive sampling is the judgmental sample. Its primary goal is to generate a sample that can be representative of the entire population. The researcher selected the sample according to their knowledge regarding the study. The requirement of the study was the basis in choosing participants. In other words, samples which do not meet the profile were rejected.

Finally, there were two studies reviewed that utilized the stratified sampling procedure. In this type of sampling method, the researcher divided a population into a stratum based on specific characteristics such as age, gender, roles, locality, and others. Everyone in the population should belong to only one stratum. After that, the researcher sampled the strata again by using another probability sampling method.

Each stratum was then sampled using another probability sampling method, such as cluster or simple random sampling, allowing the researcher to estimate statistical measures for each sub-population. This allowed the researcher to calculate statistical measures for each subdivision. One study divided the population into groups using a gender criterion, and then a given number of cases were randomly selected for each population subgroup. If the characteristics of a population were complex, Thomas (2020) recommended that researchers used stratified sampling to ensure that every characteristic is adequately represented in the sample.

Thus, the findings of this meta-analysis can be a great guide for future researchers when choosing the appropriate sampling technique to be used in their study. Undoubtedly, it was essential to apply the most relevant and useful sampling method to achieve the desired credible results.

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

2.1. Types of Modifications in Differentiated Instruction

Table 7

Substantive Characteristics Based on the Types of Modifications in Differentiated Instruction

Type of Modification	Frequency	Percent
Content	5	25.00
Process	11	55.00
Product	2	10.00
Learning Environment	2	10.00

Content Differentiation

Content differentiation is a type of modification wherein the teacher can vary the level of complexity of the knowledge, understanding, and skills that students need to master from the instruction. Likewise, the teacher can differentiate the methods on how students can acquire and understand the key content. Content refers to the “what” of instruction which involves the use of materials based on individual interest. It is important to understand that all students in a differentiated classroom should have the same learning goals. One example of content differentiation is assigning similar activity to all students with different levels of difficulty (Christenson, 2012). Each student is taught the same concept or skill based on a common curriculum, but it may also be quantitatively or qualitatively not the same. Chien (2012) stated that teachers may differentiate content by providing leveled material in compliance with pre-assessments that evaluate students’ preparation for content. Mathematics teachers can challenge every student with varying levels by assigning tasks with different levels of difficulty. For instance, when mastering subtraction of numbers, one practice worksheet may involve signed numbers, another set may contain decimals, and a third set may also include fractions.

Table seven shows that there were five reviewed studies that employed content differentiation. One study reviewed differentiated content to look at the effects of problem-based learning of complexity on the processing of Analytical Geometry. The experimental program was built on the foundation of problem-based learning, with three levels of achievement for the selected content. The students' problem-based situation and requirements were tailored to their capabilities and skills.

Mnemonics was also used in one of the studies included herein. Mnemonics are memory aids that assist students in remembering specific information through a process, strategy, or technique to improve one’s memory. It is a memory-improving technique in which students are trained to make connections between new knowledge and what they already know. Students with a wide range of abilities (gifted, naturally performing, and those with mild and moderate disabilities) in all grade levels found this to be effective. Mnemonics are especially useful when teaching students with disabilities who have trouble remembering verbal and content-area information.

Math-Island game was used in one study reviewed by the researcher to differentiate content. The Math-Island system restructures the curriculum as an information chart, allowing students to see the entire structure of knowledge, remember what they have learned, and apply what they have learned. This uses the metaphor of an “island” to describe the information map where a virtual city is set. Furthermore, the island consists of regions, paths, and structures, which represent the curriculum's domains, subdomains, and concepts, respectively. A learning activity in Math-Island is an interactive page-turning game with video clips and interactive activities for cooperative learning. The learning process for each task primarily consists of three stages: 1) to watch demonstrations, 2) perform illustrations, and 3) accept prizes. Students first learn a mathematical principle by watching videos in which the teacher shows examples, describes the logic, and gives guidance. Second, students must obey the instructions to respond to a set of questions about the illustrations shown in the video. Students get direct feedback after they answer questions. In addition, if students enter incorrect responses, the system offers multilevel hints to help them find out solutions on their own. The virtual money may be spent in buying structures to create their own islands (Yeh et al., 2019).

Another study used graphic organizers, illustration aids, representative models, visual presentations, and vocabulary terminology to differentiate content. As mentioned by Antoine (2013), a graphic organizer is a diagram that depicts graphical relationships among the essential concepts in a topic. This is helpful to teachers in assisting students in organizing and structuring knowledge and linked it to other concepts. As a visual tool, graphic organizers helped students process and remember content by facilitating the development of images. From the results of various researchers conducted in the past, it was found out that using graphic organizers can help students learn more effectively and using them improved students' critical thinking and higher order thinking skills (Owolabi et al., 2015; Delisio, 2014; Ilter, 2016).

Lastly, one study used cubing and compacting in content differentiation. A cube is a six-sided figure that has various tasks written on each side. The student rolls a cube, and then completes the task that appears. Cubing is a method of instruction in which students are required to study a concept from different viewpoints. As students work with cubes, they also use what they have learned in innovative ways. Likewise, it also allows teachers to provide six concepts or ideas to students in a simple way (Gregory et al., 2013). On the other hand, compacting is a technique that allows teachers to make curriculum changes for students who have already mastered the content. The practice or repetition of those skills is replaced with new content, by more challenging opportunities, or other tasks (Renzulli, 2014). Teachers should first compose lesson's objectives based on content, abilities, or standards that students must attain before evaluating students to check who among them have already mastered these objectives.

From the meta-analysis on DI conducted by the researcher, it can be noted that it was crucial to differentiate content since students vary in readiness, interest, and learning profile. Before the class begins, the teacher must establish goals and expectations for all students and present them to everyone. The objectives must be in line with the students' previous knowledge and learning profiles, whether they were taught individually or as a group. Teachers must ensure that each student was given opportunities to advance academically (Smit et al., 2012).

Moreover, effective content differentiation entails identification of significant understandings, benchmarks, goals, expectations, and learner outcomes (Warner, 2010) before moving forward with the curriculum. Students must understand and appreciate the purpose of every lesson in real-life. By doing so, the students establish a sense of connection between the school and real world which improves performance (Landrum et al., 2010). Chamberlin et al. (2010) mentioned that teachers may differentiate content by providing activities in which different groups of students can concentrate on other areas of the subject. Although students can work at their own speed, it is important to remember that students are responsible for meeting project deadlines.

Process Differentiation

Process differentiation refers to the "how" of the instruction. Tomlinson et al. (2013) defined process as how the learner comes to understand, own, and make sense of the subject's main concepts, skills, and generalizations. The process is critical because this is where students learn and work at different speeds, need enough support in different groups and in different modes of learning.

Table seven shows the ten reviewed studies that employed the process of differentiation. One study differentiated process by using manipulatives. One of the studies looked at using money, number cubes and capacity containers. Mathematical manipulatives are characterized as concrete and tangible objects that students can see and touch to present abstract ideas in mathematics. In the mathematics classroom, the use of manipulatives had been shown to improve students' comprehension of challenging and perplexing concepts, most especially among students with diverse needs.

Meanwhile, another study used a manipulative called algebra tiles in differentiating process. Algebra tiles are typically rectangular figures with two sides that are used to model constants and variables in algebra. Each side represents either a positive or a negative number. These are often used to solve math problems involving integers that can also be used to solve more complicated problems involving equations. Algebra tiles are beneficial for the students to establish relation between concrete and abstract ideas that allows them to gain better understanding of the lesson.

Subsequently, flexible grouping was also used in one of the studies included. Park et al. (2017) characterized flexible grouping as a form of grouping that is not permanent, wherein every member of the group is changed frequently. Students are constantly placed in different groups based on certain goals, activities, and individual needs. To supervise students' development, the teachers kept track of their records and systematically grouped and regrouped them. The experimental group's pre-assessment was completed with compacting which included giving acknowledgement to students' progress and encouraging them to continue completing their tasks.

Furthermore, one study used an inquiry-based approach to teaching mathematics called Math Out of the Box (MOOTB). As cited by Gamble (2011), each MOOTB lesson comes with a set of manipulatives that can be used to effectively teach the lesson. The aim of this program is to help teachers realize every student's greatest potential by supporting teachers with a rigorous mathematics curriculum, new materials, and high-quality professional growth. Additionally, the use of manipulatives throughout the whole learning process offers an effective way in assessing students as they explore mathematical concepts.

Another study included herein focuses on differentiated process by using news reports and role play associating the lesson on derivatives in real-life applications. Role play exercises allow students to act out a specific situation or take on the role of another person, and they can be done alone, in pairs, or in groups. Role plays require students to scrutinize personal feelings toward other individuals and their conditions that immerse students in a variety of difficult scenarios that they unfamiliar with resulting to traumatic experiences (Martin, 2013).

On the other hand, another study used small group instruction to differentiate process.

Small group instruction is a strategy that allows teachers to divide large group of students into smaller learning sub-groups. Subdividing the class allows the teacher to consider student differences and build groups that address those differences. As a result, this provides opportunities to meet with students and help them as they strive to gain new skills and achieve self-sufficiency. It also lets students observe as the teacher demonstrates and practice with the teacher's support. Allowing students to work in smaller groups in a conference-type setting provides a one-on-one attention and adjustments on the lesson to meet students' needs (Seravallo, 2010).

One study taught the experimental group through tiered activities. A Tiered lesson, according to Tomlinson (2010), is the essence in DI. It is a strategy used for differentiation which allows students to achieve learning key concept and lesson standards through multiple pathways designed according to their readiness, interests, and learning profiles.

Additionally, differentiated process indicated that the strategy on think-pair-share can be applied. Think-pair-share, as defined by Usman (2015), is a strategy that allows students to think about a certain topic by articulating individual ideas and thoughts with their classmates. The following steps were taken by the researcher to put the think-pair-share cooperative strategy into action: first the teacher poses a question, preferably one demanding analysis, evaluation, or synthesis, then gives students about one minute to think through the appropriate answers to the teacher's questions. Then, students turn to a partner and convey their answers. In the last step, students' share their answers and reactions within a group of four. Lastly, the student joins a larger group, or with an entire class for the additional discussion.

Activity-based instruction integrated with peer instruction was also done in one of the studies reviewed. This type of instruction acts as a dynamic problem solver for the learners since activities promote active engagements among learners. Under this strategy, the key focus is on the student who is expected to learn based on his or her ability. In the study being reviewed, students were asked to point out geometrical terms like line, segment, ray, angles etc. from the objects around them. Students were also asked to give examples of the shapes using straw, ice-cream sticks, and other things around them. At times, body parts such as the arms, fingers, and elbows are used to illustrate geometrical shapes.

One study utilized series of music-mathematics integrated activities in the classroom. The teacher incorporated playing musical compositions into the lessons. Consequently, students had the opportunity to study mathematics using graphical notations, such as color-cards representing musical notes, as well as a variety of musical instruments, such as handbells, drums, musical stick, and keyboards. Students were given pre-written musical pieces that they used to practice the lesson. The benefit of integrating mathematics and music in the classroom is that it enhances students' attitudes toward mathematics and increases their performance because they are given several ways to grasp the concepts (An et al., 2011).

Still in one study, math stations were also used. Math stations are a strategy for meeting students' needs according to learning preferences. It is a form of differentiation in which several places, or stations, are set up in the same classroom. This allows students to work on multiple activities related to the same lesson at once. Students benefit from differentiated math stations because they recognize ways on how students demonstrate in understanding the lesson (Andreasen et al., 2012). Teachers should include a variety of opportunities for students to explore educational content and give opportunities to understand lessons in the ways that are most natural to them or that present the greatest challenge. For instance, some students may choose to read or listen while manipulating objects presented in the lesson.

Some of the examples of effective process differentiation are by tiering activities, giving instructions at different levels, changing students' speed in finishing the task, offering several alternatives for expressions, providing substitute topics, and designing activities that are enjoyable for students. This is referred as "sense-making" activities as they enable students to gain a deeper comprehension and appreciation of the subject (Tomlinson, 2013). It is extremely important to highlight that process differentiation encompasses not just how the teacher decides to teach, but also to the strategies used to encourage students to explore the lesson in depth (Joseph et al., 2013).

Product Differentiation

Product differentiation is a strategy for students to show what they have learned and understood (Tomlinson et al., 2010). Product opportunities are used to assess and evaluate students' understanding. Specifically, this pertains to the assignment that demonstrates what the students learned over the course of a unit. Authentic assessment is the alternative term for product. The teachers acknowledge that each activity presented to the learner should be interesting, challenging, and accessible to develop the essential skills and promote understanding among students.

Two types of assessments are implemented formally or informally that provide different range in giving scores to the students' academic performance.

One study reviewed differentiated product by giving performance assessments to the students. It is a form of assessment that allows students to show mastery of skills and competencies by participating in an activity that demonstrates what they have learned (Arhin, 2015). Unlike the traditional test, performance assessment requires students to finish a task rather than select a response from a ready–made list. Additionally, it gives a chance to the students to apply their knowledge and skills from several areas to show that they can achieve a learning target and create their own solutions. Performance assessments are more engaging and interesting for students since it provides a stronger proof of effective instructional activities.

Moreover, another study on differentiated instruction is by means of giving assessment using open-ended questions. According to Al-absi (2013), open-ended task assessments encourage students to respond in a multitude of ways, allowing all students to succeed and generate lively classroom discussions. This form of assessment offers students with innovative and creative learning opportunities to develop comprehension on the lesson by measuring higher-order thinking skills quickly and efficiently. The students' who worked on open-ended tasks were assessed using a scoring rubric that differed depending on the type of question asked and the type of answer expected of the students. According to Attali et al. (2010), students should revise their answers after receiving immediate feedback on the correctness of their answers to open-ended questions. As a result, students' mathematics performance can improve.

Smit et al. (2012) argues that to differentiate a product, teachers should allow students to create a variety of outputs. Students should be able to critically think, implement, and demonstrate what they have learned through product assignments which are usually performance focused. Teachers must create a variety of product assignments depending on students varied needs. The complexity, scale, and type of product assignments can vary. Alternative products can also be used by teachers to alter some of their evaluations or other traditional assessments.

Students may encourage demonstrating their learning through presentations or role-plays instead of written tests. Teachers will be able to choose suitable assignments and assessments for each student because of this.

Teachers may use a variety of strategies to differentiate products. They can do flexible grouping for projects, differentiating levels of difficulty, creating rubrics according to students' needs, engaging with students' interests, enabling students to communicate and express their knowledge by providing a variety of product formats. The role of the teacher is to scaffold, model, and assist so that the strategies they employ become a skill sometime. One of the most important goals for any teacher is for students to take control of their learning and have it developed in autonomy (Warner, 2010).

Learning Environment Differentiation

Learning environment pertains to the physical and the affective aspects of the classroom. This is linked to the tone of the classroom, and it pertains to how time, resources, and space are arranged. Creating a quiet space and workstations for groups, as well as providing a classroom that allows for movement, are strategies to differentiate the learning environment. To ensure effective learning, modifying the classroom's learning environment is an important factor in shaping success. A differentiated classroom should be able to serve and be embraced by a growing population of learners. Thus, the teacher's position is critical in guiding students toward the kinds of attitudes, values, and activities that define a genuinely great neighborhood (Tomlinson, 2013).

One study included herein examined the correlation between students' academic growth in mathematics and a differentiated physical learning environment of the classroom. The physical layout of the classroom was distinguished from the start of the school year. Students could choose a lamp for their desk from the room's back counter. A stack of cushions was available for students to use on the floor or in their seats. Some students used their own mp3 player or the class iPod to listen to music during class. Students were also given class time to experiment and try sitting in various areas of the classroom at the start of the school year, but once the study started, students sat in their predetermined positions or used objects set by the research, such as lighting, music, and pillows.

Another study differentiated learning environment by utilizing group competition among the students in the experimental group. The class was classified into six small groups. As a general mark, there were five levels of scores: 60, 70, 80, 90, and 100. The order of the group competition was determined by drawing random numbers, with the first group assigning one student to solve the problem, followed by the second group for the next round, and so on. If the three groups were all incorrect, the final contestants were the last two groups, which included students who did not participate in the competition. But if both groups quit at the same time, the teacher will solve the problem and ask another question before a winner is determined. As a result, the process of group competition increased the participants and students' desire to learn.

Santangelo et al. (2012) cited that a learning environment must be both healthy and stimulating for the students. The learning atmosphere is characterized by class routines, procedures, physical layout of the classroom, including the general feelings and attitudes among and between students and teacher. Differentiated learning environment is effective when carefully planned to support students' needs for encouragement, contribution, strength, goal, and challenge. Chamberlin et al. (2010) stressed that teachers can differentiate the physical environment of the classroom in terms of seat plans, and locations of resources that are easily accessible such as well as lighting, ventilation, and noise levels, among other things.

Similarly cited by Thiessen (2012), the social and physical aspects of creating a friendly classroom environment are both necessary. Respect, motivation, acceptance, and joy must all be fostered in the classroom. These four social characteristics can have the greatest impact on the classroom environment, and they should be the primary focus of any inclusive classroom. When students prefer a certain setting, the teacher may make important adjustment to sound, light, temperature, and design. Making changes to the classroom's atmosphere takes time but implementing changes can be beneficial in all subject areas. Knowing and considering the various facets of the learning environment and planning to accommodate the diverse needs of students can be helpful to all students.

Considering that each student responds uniquely to the learning environment, this must be observed and understood by the teacher. Students, for example, respond to sound in multiple ways. Some students can deal effectively with noise so they can ignore it; others need complete silence; and still others need types of sounds to work effectively (Thiessen, 2012).

In an article published by Hakimi (2011), light is another aspect that influences students. Some students are light sensitive and need dim lighting, while others need bright lighting. Some students, on the other hand, focus better when the room is cool because they get drowsy when it is too warm while others find it difficult to concentrate when it is too cold, and they need a warmer environment because a cooler environment can cause physical or emotional discomfort.

Some students also desire for a more relaxed work environment. They tend to work in coaches and comfy seats, believing that a formal workspace will stifle their inspiration and imagination while other students prefer a more formal workspace. To focus, these students need a hard chair, a table, or a desk. For some students, their workspace is either determined by the task assignment they are working on or it does not matter at all (Thiessen, 2012).

Differentiating the learning environment is a simple task that can provide significant benefits to a student during the entire school year. Researchers have noted that the learning environment was one of the classroom issues chosen for differentiation while others have mentioned how the learning environment affects effective teaching and learning. If the classroom environment is not conducive to learning, even the best lesson taught with an effective learning method will fail (Evans et al., 2010; Thiessen, 2012; Tomlinson, 2014).

3. Effect size of the different types of modifications on differentiated instruction when grouped according to methodological characteristics and substantive characteristics

Table 8

Effect Size and Research Design

Research Design	Mean Effect Size	Interpretation
Pre-test / Post-test	1.31	Very Large
Post-test only	0.13	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 large effect sizes.

Table 8 shows that Pre-test and Post-test design has a very large effect size of 1.31 according to Sawilowsky's interpretation. This indicates that Pre-test and Post-test design is significantly the highest among the other research designs included in the study. A very large effect size can be interpreted that Pre-test and Post-test design is highly significant. When Pre-test and Post-test design was used as a research design, the effect of the four modifications on DI was very evident. Since seventeen studies utilized the said research design, it greatly shows that the effect of the four modifications on DI was highly significant as manifested by the performance of the students belonging in the experimental group that is better than the performance of the students in the control group.

A Pre-test and Post-test design is a quasi-experiment where participants are studied before and after the experimental manipulation. This design was employed both in experimental and quasi-experimental research and may be used with or without control groups. Its purpose was to help the researcher to see the effects of some type of treatment in a group. This research design employed two groups, one for control group and the other for the treatment group. The control group has been subjected to the same test but receives no treatment. The results were gathered at the end. The pre-test and post-test design was analyzed using difference scores, analysis of covariance, or a statistical technique called analysis of variance that was based on a mixed model to determine whether the independent variable produced an effect.

Meanwhile, Post-test design resulted to a small effect size of 0.13 based on Glass and Cohen's interpretation. A small effect size can be interpreted that Post-test only design is less significant. Out of three studies that were in used this design; the result implied that the effect of the four modifications on differentiated instruction on students' mathematics achievement was less significant when Post-test design was used.

Therefore, Table 8 shows that the research designs used by the researchers in the meta-analysis conducted that focused on DI was highly significant across research studies revealed by the evidence presented when these research designs were used. The evidence revealed that the effect of the four modifications on differentiated instruction on students' mathematics achievement was observed which was proven by the computed effect size.

The result of this study confirmed the meta-analyses conducted by Cajigal (2011), Ding et al. (2011), and Corbillon (2019) wherein the research design was concluded to be significant. On the contrary, opposite result was noted by Ergen et al., (2017) and Arik et al. (2020) where it was discovered that the research design did not differ significantly in terms of overall effect size.

Consequently, future researchers may be guided to make decisions on the appropriate research design to be used in their studies. From the result of this study, researchers may choose to employ pre-test and post-test design. Being the most convenient to use, it provided control for rival hypotheses that can threaten the internal validity of the experiment.

Table 9

Effect Size and Students' Profile

Students' Profile	Mean Effect Size	Interpretation
Regular Students	1.20	Very Large
Advance/Gifted Students	-0.17	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 large effect sizes.

Table 9 shows that among the students' profile, regular students have very large effect size of 1.20 according to Sawilowsky's interpretation. There were nineteen studies that have regular students as the participants. When the effect sizes of these nineteen studies were averaged, the result was 1.20. This implies that the mean effect size of regular students was highly significant. It showed that the effect of the modifications on differentiated instruction was evident when regular students were used by the researchers. Moreover, this result seemed to imply that differentiated instructions may be more effective in teaching regular students.

Consequently, gifted students have a mean effect size of -0.17. According to Glass and Cohen's interpretation, this reveals that the mean effect size of gifted students was not significant. It also shows that the effect of the modifications on DI was not evident when gifted students were used by the researchers. On the other hand, this result may be attributed to the limitation of this meta-analysis that only one study was included based on the qualifications set by the researcher.

Table 10

Effect Size and Level of Participants

Level of Participants	Mean Effect Size	Interpretation
Kinder to Grade 3	0.54	Large
Grade 4 – Grade 6	0.26	Medium
Grade 7 – Grade 12	1.55	Very Large
Tertiary Education	0.71	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 large effect sizes.

Table 10 reveals that the level of participants from Grade 7 to Grade 12 obtained a very large mean effect size of 1.55 according to Sawilowsky's interpretation. This indicates that the mean effect size of secondary students was highly significant. Similarly, the result implies that the experimental group' secondary students' mathematics achievement has a high difference than the control group' secondary students' mathematics achievement.

In other words, this implies that differentiated instruction may probably be most effective to improve mathematics performance when used with Grades 7 to 12 than with students of other grade levels. Corbillon (2019) mentioned that secondary students have already established strong foundation in mathematics and can easily follow teacher's instruction. Correspondingly, this clearly reflects that most researches are focused on improving secondary education.

Also, participants from the tertiary level attained a large mean effect size of 0.71 according to Sawilowsky's interpretation. From the two studies, the effect sizes are 0.67 and 0.76. This means that the effect size of the tertiary students is moderately significant. Additionally, the result also indicates that the performance of tertiary students in the experimental group has a large difference compared to the performance of tertiary students in the control group.

Similarly, participants from Kinder to Grade 3 got a large mean effect size of 0.54 according to Sawilowsky's interpretation. Of the four studies, the effect sizes are 0.19, 0.24, 0.41, and 1.30. This implies that the effect size of the participants from Kinder to Grade 3 is moderately significant. It also suggests that the performance of the primary students in the experimental group has a large difference than the performance of those in the control group.

Whereas participants from Grade 4 to Grade 6 attained a medium mean effect size of 0.26 according to Glass' and Cohen's interpretation. Out of the two studies, the effect sizes are -0.07 and 0.59. It can be said that the mean effect size of participants from Grade 4 to Grade 6 was moderately significant. Thus, the performance of Grade 4 to Grade 6 participants in the experimental group was not as high compared to the performance of the primary students in the control group.

The result of this study concurred with the results found on the meta-analyses of Cajigal

(2011), Sokolowski (2015), Kul et al. (2018), Corbillon (2019), and Talan (2019). These studies established that secondary students have the highest effect size. However, different results were noted by Ergen et al (2017), Turgut et al. (2018), and Arik et al. (2020). They ascertained that primary students got the highest effect size of 1.08 and 1.35 respectively.

From the result of the meta-analysis conducted, mathematics teachers may consider high performance in mathematics could be achieved when DI is employed in teaching secondary (Grades 7 to 12) students.

Table 11

Effect Size and Number of Participants

Number of Participants	Mean Effect Size	Interpretation
21-40	0.06	Small
41-60	1.15	Very Large
61-100	1.62	Very Large
101 and above	1.32	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 large effect sizes.

Table 11 shows that the number of participants ranging from 61 to 100 has an exceptionally large mean effect size of 1.65 according to Sawilowsky's interpretation. Out of the three studies, the effect sizes are -0.07, 1.15 and 3.79. Even though one effect size is negative, the result was 1.62 when these effect sizes were averaged. This indicates that the mean effect size of the number of participants was highly significant. It can be interpreted that when the number of participants ranges from 61 to 100, the effect of the four modifications on differentiated instruction was evident. Likewise, the students' mathematics achievement in the experimental group was higher than the students' mathematics achievement in the control group when there are 60 to 100 participants in the study.

Similarly, the number of participants ranging from 101 and above had an exceptionally large mean effect size of 1.32 according to Sawilowsky's interpretation. Among these nine studies, the effect sizes were -0.71, 0.24, 0.32, 0.40, 0.41, 0.60, 1.70, 1.97, and 6.96. When these effect sizes were averaged, the result was 1.32. The result was highly significant which means that the effect of the four modifications on DI in improving students' mathematics achievement was obvious when there were more than 100 participants in the study.

Subsequently, the number of participants ranging from 41 to 60 had a large mean effect size of 1.15 according to Sawilowsky's interpretation. Out of these five studies, the effect sizes were 0.67, 0.76, 1.30, 1.49, and 1.55. This shows that the finding was highly significant when the mathematics achievement of the students in the experimental group was compared to the mathematics achievement of those students in the control group when there are 41 to 60 participants.

Nevertheless, the number of participants ranging from 21 to 40 had a small mean effect size of 0.06 according to Glass and Cohen's interpretation. This implies that the result was less significant. It means that the effect of the types of modifications on DI of students' mathematics achievement was not evident when the number of participants ranges from 21 to 40.

On the contrary, the studies conducted by Means et al. (2010), Turgut et al. (2018) and Akar (2020) concluded that statistically, there was no significant difference found between the groups in terms of sample size.

Accordingly, the results of this meta-analysis indicated that the effect of the modifications on differentiated instruction was highly significant in those studies with the number of participants ranging from 61 to 100. This result may guide future researchers in determining the number of participants that they must include in their studies. It is suggested that the number of participants ranging from 61 to 100 is the ideal number to get better results.

Table 12

Effect Size and Sampling Techniques

Sampling Techniques	Mean Effect Size	Interpretation
Simple Random Sampling	2.01	Huge
Stratified Sampling	0.08	Small
Purposive Sampling	1.12	Large
Convenience Sampling	-0.004	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 large effect sizes.

Table 12 reveals that simple random sampling technique attained a huge mean effect size of 2.01 according to Sawilowsky's interpretation. Among the nine studies, the effect sizes are 1.70, 0.59, 1.55, 3.79, 1.15, 6.96, 1.30, 0.41, and 0.67. The result was 2.01 when all these effect sizes were averaged. This means that simple random sampling is significantly the highest among the other sampling techniques included in the study. A huge effect size indicates that simple random sampling technique is incredibly significant. When a simple random sampling technique was used, the results of this meta-analysis show that the effect of differentiated instruction on students' mathematics achievement is very evident.

Consequently, purposive sampling technique attained a large effect size of 1.12 based on

Sawilowsky's interpretation. The effect sizes of these four studies are 0.24, 0.76, 1.48, and 1.97. A large effect size means that purposive sampling technique is highly significant. When the researchers used a purposive sampling technique, the effect of differentiated instruction on students' mathematics achievement was also significant.

Conversely, stratified sampling technique has small effect size of 0.08 based on Glass and Cohen's interpretation. The effect sizes of the two studies that utilized this sampling technique are -0.16 and 0.32. When these two effect sizes were averaged, the result was 0.08. A small effect size means that stratified sampling technique is less significant. The result signifies that the effect of differentiated instruction on students' mathematics achievement is less obvious when stratified sampling technique was used by the researchers.

Additionally, convenience sampling had a computed mean effect size of -0.00. This is even though there are five studies that used this sampling technique. This indicates that when the convenience sampling technique was used, the modifications to differentiated instruction had no effect on the students' mathematics achievement. The result also implies that when convenience sampling was used, the performance of the students in the experimental group is lesser than the performance of the students in the control group.

Related study of Corbillon (2019) was located yielding same result that simple random sampling got the highest mean effect size. On the other hand, Cajigal (2011) noted different result and found out that simple random sampling technique got the fourth highest effect size among all the sampling techniques include in the study. Moreover, Means et al., (2010) concluded that effect sizes did not vary significantly with sampling technique used.

Table 12 reveals that the type of sampling technique used by the researchers in the meta-analysis conducted is significant across reearch studies as shown by the evidence presented when these sampling techniques were applied. This may guide future researcher to decide the type of sampling technique appropriate to use in their studies. From the result of this study, researchers may use the simple random technique because of its simplicity and because it is the most straightforward sampling technique (Gravetter, et al., 2011).

Table 13 shows the results of the computed effect sizes in terms of the four types of modifications on DI such as content, process, product, and learning environment to determine their effect on students' mathematics achievement.

As presented in Table 13, the result reveals that product differentiation has a huge mean effect size of 2.19 according to Sawilowsky's interpretation. There were two studies that employed product differentiation which had the effect sizes of 0.59 and 3.79. The result was 2.19

Table 13

Effect Size and Types of Modifications on Differentiated Instruction

Types of Modifications on Differentiated Instruction	Mean Effect Size	Interpretation
Content	0.09	Small
Process	1.53	Very Large
Product	2.19	Huge
Learning Environment	0.54	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 large effect sizes.

when the effect sizes were combined. Even if there were only two studies that employed product differentiation, the result implies that product differentiation had the highest significance on students' mathematics achievement. Thus, it can be expected that students' mathematics achievement would be higher when product differentiation was used.

The result of this meta-analysis was supported by several research like Chamberlin et al. (2010), Little (2010), Tomlinson (2010), Kanevsky (2011), Decovsky (2012), Smit et al. (2012), Kelly (2013), Aliakbari et al. (2014), and Parsons et al (2014). They all agreed that product differentiation helps students to show what they have learned and allows them to utilize different modes of expression.

Effective product differentiation, as cited by Joseph et al. (2013), should provide students with clear and suitable criteria, emphasize relevance in real-life situation, and promote creative thinking. Teachers must also provide sufficient scaffolding and guidance for students, as well as opportunities for peer and self-evaluation. Maluleke (2019) suggested that differentiating the product allows students to self-select a way to show they have learned the material that was taught. When students self-select their product, they normally choose a method that will provide them success which most likely will coincide with their own learning profiles.

Subsequently, Table 13 also shows that process differentiation has an exceptionally large mean effect size according to Glass and Cohen's interpretation. There were eleven studies that differentiated process. When their effect sizes were combined, the result was 1.53. The result of the mean effect size says that process differentiation had a higher significance on students' mathematics achievement. It implies that when process differentiation was used, students' mathematics achievement in the experimental group was higher than students' mathematics achievement in the control group.

Several researchers support the finding of this study. Chamberlin et al. (2010), Scigliano et al. (2010), Gordon (2013), Lawson (2018), Roberts (2017) noted the importance of process differentiation by allowing students to take ownership of their learning and creating sense-making activities for the students to realize the relevance of the content they have learned in the real world outside the classroom.

According to Tomlinson (2010), differentiating the process within a lesson refers to “how the learners come to understand and assimilate facts, concepts, or skills”. Strategies for effective process differentiation include: tiring activities to various levels of complexity to optimize every student’s classroom experience; providing directions at varied levels of specificity; varying the pace of work; offering multiple options of expression; giving students alternative topics on which to focus; creating activities that are harmonious with students’ preferred modalities of learning.

According to Gregory et al. (2013), learners learn and process information in different ways. Some students prefer certain methods of learning, and it is important that teachers utilize a wide variety of teaching activities to address learning preferences of the students. Being able to identify the various learning styles of students and teaching them with an informed awareness of those differences can assist students to achieve a better academic result and improve their attitudes towards learning.

Further, it is essential to note that the process is differentiated not only by how the teacher decides to teach but by the strategies the teachers encourage students to use to facilitate thorough exploration of the content taught. This can be done by way of higher-order thinking, open-ended thinking, discovery, reasoning and research (Taft, 2012).

Meanwhile, Table 13 also reveals that learning environment differentiation had a large mean effect size according to Glass and Cohen’s interpretation. There were two studies that differentiated the learning environment which produced the effect sizes of 0.32 and 0.76. When these two effect sizes were averaged, the calculated mean effect size was 0.54. This implies that learning environment differentiation had a high significance in improving students’ achievement in mathematics.

Related studies were also conducted by Thiessen (2012), Hannah (2013), Ghazali (2017), and Demir-Yildiz et al. (2019) that supported the finding of this study. They all realized that differentiating the learning environment can significantly improve students’ achievement in mathematics. According to Bosworth (2014) and Farrie et al. (2016), class size is an important factor in learning, thus, the number of students in a class should be reduced. Nobody would be left behind because everybody is part of the learning process and receives adequate attention from the teacher.

According to Hannah (2013), the classroom environment plays a crucial role in keeping students engaged and allowing them to be successful. The teacher can modify the environment to achieve these results. There is a multitude of ways in which to do this. They can arrange the desks in different patterns.

Finally, Table 13 shows that content differentiation had a small effect size according to Glass and Cohen’s interpretation. Five studies applied content differentiation which attained the effect sizes of -0.16, -0.71, 0.40, 0.67, and 0.24. When these effect sizes were averaged, the calculated mean effect size is 0.09. This implies that the use of content differentiation was less significant in improving students’ achievement in mathematics.

Tomlinson (2010) explains that content comprises not only what is taught, but how students access the material taught. She suggests that to a large extent, what is taught should remain relatively constant across learners, with teachers varying how students get access to specified content to address learners' needs. Some strategies for content differentiation include: providing text materials at varied reading levels of complexity; curriculum compacting; using small group instruction to re-teach or reinforce content; providing text on audiotape; supplementing oral presentations with videotapes and visual demonstrations; providing note-taking organizers; highlighting or summarizing key portions of text; and using manipulative.

Clearly, differentiating content requires teachers to either modify or adapt how they give students access to the material they want the students to learn. One way teachers can differentiate the content or curriculum they teach is by providing students with the opportunity to choose a subtopic within a main topic or unit. As each student presents the information on their sub-topic, the whole class learns more about the topic in general. Anderson (2015) stated that teachers may choose to differentiate content by using flexible grouping where students can work in pairs, small groups or alone, using books or tapes or Internet as a means of developing understanding and knowledge of the topic or concept. It is important to note that while all students should be encouraged to work at their own pace, each student has the responsibility for meeting specified deadlines for class projects.

The result implies that teachers may use several techniques to effectively differentiate content, such as jigsaw exercises in which different classes can focus on different aspects of the lesson. Another common practice is the used of varied texts, materials or resources like computer games, tape recorders, and videos as a way of conveying key concepts to varied learners. They can also utilize learning contracts to give students more flexibility in learning the content. Mini-lessons can also be held in which teachers re-teach concepts to students in order to provide a different perspective on a concept or to expand on a subject as well as extend a topic (Chamberlin et al., 2010).

Implications of the Study

Present classrooms are getting more diverse than ever. As a result, teachers have always faced a significant challenge in addressing student diversity. Classroom's nowadays, as described by Koehler (2010) may have students with the following personalities: possess a variety of interests, unable to remain seated, academically advanced, and unmotivated to name a few. Hence, teachers are constantly encouraged to embrace and modify their instruction in response to student diversity (Katz et al., 2011).

Relatedly, improving students' achievement in mathematics has always been a great concern that needs to be addressed. DI is a promising approach in to address student's differences in the classroom. Tomlinson (2014) described it as "where the teacher proactively plans what students will know, how they will learn it, and how they will communicate it". Differentiation is more than an instructional strategy or a teaching recipe: rather it is a fresh way of thinking about teaching and learning. Numerous studies have reported that using differentiated instruction to improve students' achievement in mathematics yields to positive results (Phelps, 2012; Mbugua et al.; 2014; Decision, 2019).

Hence, the result of this meta-analysis which examined the effective type of modifications on differentiated instruction in improving students' mathematics achievement will help different groups of people. The result of this study implies for its contribution on the discussions and conversations about DI. Inputs from the study can advance professional growth and better mathematical pedagogies of the teachers and resulting to learning of diverse students. The findings of this study can also be shared with school administrators, teachers, and practitioners to provide opportunities to improve instructional methods for teaching at all grade levels.

Most importantly, this study can provide guidance to mathematics teachers on the types of differentiation that they may use in their classrooms. Since the results of this study indicate that the four modifications on differentiated instruction have a significant impact on the mathematics achievement of the regular students at different grade levels, it is now up to the teacher as to which type of differentiation to use.

CHAPTER 4

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

The main purpose of this study is to describe several research studies on the effect of four modifications of differentiated instruction on students' mathematics achievement using the Glass Meta-analysis technique. This meta-analysis specifically aimed to (1) describe the methodological characteristics of each research reviewed in terms of research design, students' profile, level of participants, number of participants, and sampling technique; (2) describe the substantive characteristics of each research reviewed in terms of the types of differentiated instruction used in improving achievement of students in mathematics; and (3) determine the effect size of the different types of DI in improving achievement of students in Mathematics when grouped according to methodological and substantive characteristics.

The researcher found the answers to the problems using a descriptive-documentary analysis method called the Glassian Meta-analysis technique. Twenty researches which are unpublished and published online dissertations and theses, and journal articles from 2000 to 2020 were included in the study. These studies were selected according to 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 data and collected data were encoded and consolidated in Microsoft Excel. The first part of the survey was about the general data of the study such as the title of the study and name of the researcher/s. The second part is composed of the research design, students' profile, level of the participants, number of participants, and sampling techniques which serves to gather information about the methodological characteristics of the study. The third part was made to gather information on the substantive characteristics of the study such as the effective type of modifications on differentiated instruction on students' mathematics achievement. The researcher's instrument was patterned from the given research characteristics variable used by Glass (1981) as well as the researcher who have conducted meta-analyses. Descriptive analysis was used to examine the data. The data were gathered, coded, tabulated, and analyzed. The means, frequencies, standard deviation, percentages were used for the description of the research characteristics. Glass formula was used to compute the effect size to determine the significant effect sizes of the variables when grouped according to substantive (effective type of modifications on differentiated instruction) and methodological characteristics (research design, students' profile, level and number of participants, and sampling technique).

Summary of Findings

The following are the results of the analyses on the data presented in the previous section of the study:

1. Methodological characteristics were more general pertaining to the steps, methods, and procedures in doing the research. In this meta-analysis, there were five methodological characteristics involved: (1) research design, (2) students' profile, (3) level of participants, (4) number of participants, and (5) sampling techniques.

   1.1 In terms of research design, most of the researchers used Pre-test and Post-test design in conducting study.

   1.2 In terms of students' profile, it was found out that most of the researchers preferred the use of regular students in conducting the study.

1.3 In terms of the level of participants, it showed that most of the researchers preferred secondary students as participants of their study.

1.4 In terms of the number of participants, it showed that most of the researchers used more than one hundred students as participants of their study.

1.5 In terms of sampling techniques, it was found out that most of the researchers preferred to use simple random sampling technique as their method in selecting participants of their studies.

2. Substantive characteristics refer to the characteristics of the studies that are specific to problem studies. In this study, this referred to content differentiation, process differentiation, product differentiation, and learning environment differentiation. In content differentiation, researchers used mnemonics, graphic organizers, problem-based activity, Math Island Game, cubing and compacting. On the other hand, the process differentiation utilized by the researchers included in this meta-analysis were Math Out of the Box, cooperative learning, flexible grouping, learning stations, algebra tiles, tiered activities, activity-based with peer instruction, and think-pair share. Consequently, the product differentiations utilized in the study were performance assessment and assessment using open-ended questions. Finally, the learning environment differentiations were the use of group competitions in the classroom, and conducive classroom environment with optimum class size.

3. The effect sizes of the four types of modifications on differentiated instruction when grouped according to methodological characteristics and substantive characteristics are stated below.

3.1 In terms of research designs, the effect of the four types of modifications on differentiated instruction in improving students' mathematics achievement was very evident when Pre-test and Post-test design was used as a tool in the study.

3.2 In terms of students' profile, the effect of the four types of modifications on differentiated instruction in improving students' mathematics achievement was very evident when regular students were used in the study.

3.3 In terms of the level of participants, the effect of the four types of modifications on differentiated instruction in improving students' mathematics achievement was very apparent among secondary (Grades 7 to 12) students. The mathematics achievement of the secondary students in the experimental group had a high difference compared to the mathematics achievement of the students in the control group.

3.4 In terms of the number of participants, the effect of the four types of modifications on differentiated instruction in improving students' mathematics achievement was very evident when the number of participants used is sixty-one to one hundred students.

3.5 In terms of the sampling techniques, the effect of the four types of modifications on differentiated instruction was very evident when simple random sampling was used.

3.6 Among the four types of modifications on differentiated instruction considered in this study, product differentiation had a huge mean effect size. This implies that product differentiation had the highest significance on students' mathematics achievement. Thus, it can be expected that students' mathematics achievement would be higher when product differentiation is used. Subsequently, process differentiation had an exceptionally large mean effect size. The computed effect size indicated that process differentiation had a higher significance on students' mathematics achievement. It signified that students' achievement in mathematics in the experimental group would be higher compared to that students' achievement in mathematics in the control group when process differentiation is used. On the other hand, learning environment differentiation had a large mean effect size. This means that learning environment differentiation had a high significance in improving students' achievement in mathematics. However, results revealed that content differentiation had a small mean effect size. This implies that the use of content differentiation was less significant in improving students' achievement in mathematics. Hence, the results revealed that the four modifications on differentiated instruction considered in this study had a positive impact on the mathematics achievement of students.

Limitations of the Study

Although the researcher employed a rigorous methodology, however, there are still several limitations in conducting this study that should be considered.

Thus, the findings of this study should be interpreted within the context of those limitations. Although there were lots of studies considered, in the end there were only twenty studies qualified according to the criteria set by the researcher. The result of this meta-analysis will not be greatly changed even if there will be more than twenty studies involved for as long as these studies will meet all the requirements set by the researcher. Additionally, the researcher made only a thorough analysis of the defect sizes of each methodological and substantive characteristic using mean and percentage but did not include the connection of the effect sizes to the other variables.

Conclusions

The following results were taken from the findings of this meta-analysis.

1. In conducting an experiment to improve students' mathematics achievement, the methodology that includes research design, level and number of participants, and sampling technique had an impact on the validity of the results.
2. The four types of modifications on DI had their respective effect on the mathematics achievement of the students. Product differentiation yielded the huge impact. Nonetheless, content differentiation, process differentiation, and learning environment differentiation helped the students improved students' mathematics achievement.

Recommendations

Based on the findings of this study, the researcher presents the following recommendations for improving the processes for students' achievement in mathematics.

1. Product differentiation may be used more often in mathematics classrooms. Nevertheless, content differentiation, process differentiation, and learning environment differentiation may also be used to improve students' mathematics achievement.
2. Curriculum writers and developers may use the findings of this study to evaluate and improve the existing curriculum by including the use of the four modifications on differentiated instruction.
3. Future researchers may consider using Pretest and Posttest design as the research design, secondary students as their level of participants, sixty-one to one hundred

participants as their sample size, and simple random sampling as their sampling technique.

4. Similar meta-analyses may be conducted using other meta-analyses technique. Also, meta-analysis on the other types of differentiated instruction may also be conducted.

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APPENDICES

Appendix A

Annotated Bibliography

Adeneye, Awofala O., Lawani, Abisola O. ***Increasing Mathematics Achievement of Senior Secondary School Students through Differentiated Instruction*****. (2020)**

This study examined the effect of differentiated instruction on senior secondary school students' achievement in mathematics in Nigeria within the blueprint of the pre-test, post-test non-equivalent control group quasi-experimental research design. The sample comprised 220 students in which three research questions and three null hypotheses guided the study. The experimental group was taught with the differentiated instruction while the control group received instruction with the conventional teaching method for eight weeks. Three valid and reliable instruments, Mathematics Achievement Test (KR-20=0.89), Felder-Soloman Index of Learning Styles (Cronbach α=0.92), and McKenzie Multiple Intelligences Inventory (Cronbach α=0.90), were used for data collection. Results revealed that students in the differentiated instruction group performed significantly better than students in the conventional teaching method group. Also, male students performed slightly better than female students with differentiated instruction, although no significant difference existed between the achievement of male and female students taught mathematics using differentiated instruction. There was no significant main effect of gender on students' achievement in mathematics. Also, there was no significant interaction effect of treatment and gender on students' achievement in mathematics. The differentiated instruction made lesson more fascinating, stress-free and created co-operation among students. It was thus, recommended that differentiated instruction be adopted by mathematics teachers in teaching mathematics at the senior secondary school level in Nigeria.

Al-Absi, Mohammad. ***The Effect of Open-ended Tasks –as an assessment tool- on Fourth Graders' Mathematics Achievement, and Assessing Students' Perspectives about it.*** **Yarmouk University, Irbid, Jordan, 2013.**

The open-ended task constitutes an effective type of assessment. This study aimed at investigating the effect of open-ended tasks on fourth graders' mathematics achievement and assessing students' perspectives about it. The sample of the study consisted of (135) fourth grade students, from four sections, distributed randomly to an experimental group who were assessed during the "9-digit Numbers" unit by exposing them to open-ended tasks, and a control group who were assessed using the traditional method of instruction. Results of the study revealed that open-ended tasks had a positive effect on improving students' mathematics achievement, and assessing their perspectives toward using the tasks in learning mathematics.

Al-Absi, Mohd Mustafa, Nofal, Mohd Baker. ***The Effect of Using Manipulatives on the Mathematical Achievement of the First Grade Students*****. Amman, Jordan, 2010.**

This study aimed at examining the effect of using manipulatives in the mathematical achievement of the first graders at UNRWA schools in Jerash area in Jordan. The sample of the study consisted of 155 students representing four sections, who were divided into two groups: An experimental group which was taught "numbers from 0-9" subjects using manipulatives, and a control group which was taught by the traditional method. After the completion of the study application, an achievement test was applied and a 2-way ANOVA analysis was used to test the hypotheses of the study. The study results revealed that there were statistically significant differences between the two groups in favor of the experimental group, which was taught by using manipulatives; whereas there were no significant differences between students' marks due to sex or the interaction between group and sex.

An, Song A., Tillman, Daniel A., Boren, Rachel, Wang, Junjun. ***Fostering Elementary Students' Mathematics Disposition through Music-Mathematics Integrated Lessons*****. International Journal for Mathematics Teaching and Learning, 2014.**

Two classes of third grade students (n = 56) from an elementary school located on the western coast of the United States participated in this research study. A pretest-posttest control group design was utilized to examine changes between two groups of participating students' in mathematics achievement and dispositions, including beliefs about success, attitude, confidence, motivation, and usefulness. The students in the music group received music-mathematics integrated lessons, while the students in the control group received traditional lecture and textbook based mathematics instruction. Analysis of the results demonstrated that despite statistically equivalent pretest scores prior to the intervention, after the intervention the music group students had statistically significantly higher positive mathematics dispositions scores than their non-music group peers. These findings provide empirical evidence that there are advantages to teachers utilizing music-themed activities as a context for offering students the opportunity to learn mathematics in a challenging yet enjoyable learning environment.

Anaduaka, U. S., Sunday, A. O., Olaoye, A.E. ***Effect of Think-Pair-Share Cooperative Strategy on Mathematics Achievement of Attention-Deficit Hyperactive Students*****. University of Abuja, Abuja, Nigeria, 2018.**

This study investigated the effect of think-pair-share cooperative strategy on the mathematics achievement of attention-deficit hyperactive students. It also determined the level of gender bias in the method as compared with conventional method of teaching. Purposive sampling technique was used to select two secondary schools, classes and students for the study. Quasi-experimental research design was adopted for the study and intact classes of 105 JS2 and

86 SS2 students identified as attention-deficit hyperactive were assigned into think-pair-share cooperative teaching strategy and conventional teaching method groups in Kuje Area Council of FCT Abuja. Mathematics Achievement Test (MAT) was the instrument used for data collection. The data were analyzed using mean, standard deviation and ANCOVA. Findings indicated that attention-deficit hyperactive students taught mathematics using think-pair-share cooperative strategy achieved better in posttest than those taught with conventional method for both JS2 and SS2 classes. There was no significant difference between the mathematics achievement of attention-deficit hyperactive students taught with think-pair-share cooperative learning strategy at both junior and senior secondary levels. It was also discovered that think-pair-share cooperative strategy was not gender biased for both junior and senior students. It was recommended that teachers of mathematics should be encouraged to use think-pair-share cooperative learning strategy to teach attention-deficit hyperactive students at all levels of secondary education.

Bikić, Naida, Maričić, Sanja M., Pikula, Milenko. ***The Effects of Differentiation of Content in Problem-solving in Learning Geometry in Secondary School*. University of Zenica, Zmaja od Bosne 56, 72000 Zenica, Bosnia and Herzegovina, 2016.**

The aim of the study was to examine the effects of problem-based learning which was established on differentiation of content at three levels of complexity in the processing of the content of Analytical geometry in the plane. In this context, an experimental research was conducted, on a sample of secondary school students (N = 165) in order to examine whether methodical approach designed on the principles of problem-based learning based on differentiation of content gives better effects in learning compared to the traditional mode. The results of the final measurement shown that the experimental group achieved better overall success than control group. The results suggest that the proposed methodical approach contributes to better student performance in teaching geometry and that the most significant progress is achieved in the group of students who are average in terms of success and with ones below the average.

Cannon, Melinda A. *Differentiated Mathematics Instruction: An Action Research Study* (2017). University of South Carolina.

The purpose of this action research study was to evaluate the relationship between two third grade mathematics classroom; one with differentiated pedagogy and other with traditional pedagogy. To fulfill these purposes, the study tested the hypothesis utilizing an independent t-test. The t-test was used to identify statistical differences among variables. The participant-researcher utilized a differentiated mathematics instructional strategy of small group instruction, collaborative group instruction, and online instruction with one classroom and traditional lecture style pedagogy with the other classroom over a five week period in preparation for a Post-Assessment. Quantitative data included Mathematics Pre- and Post-Test scores which were given to students to gage their mathematical problem solving abilities before and after the comparison study.

Gamble, Valerie D. *The Impact of Differentiated Versus Traditional Instruction on Math Achievement and Student Attitudes* . Walden Dissertations and Doctoral Studies, 2011.

With the implementation of the No Child Left Behind (NCLB), all schools are held accountable for student achievement. One southern US Title I school failed to meet NCLB mandated math standards for several years and was placed on program improvement. The purpose of this study was to compare math achievement of 34 students in fifth grade using differentiated instruction via Math out of the Box (MOOTB) and math achievement of 34 students in fifth grade using traditional textbook instruction. A second purpose was to determine if there was a difference between student attitudes toward math relative to confidence, value, enjoyment, and motivation. The theoretical base for this study is rooted in the works of Gardner's theory of multiple intelligences, Vygotsky's sociocultural theory, Bruner's psychological theory, Piaget's concrete operational theory, and Tomlinson's differentiated instruction theory. In order to examine the differences in math achievement based on the two instructional approaches, a quasi-experimental nonequivalent (pretest-posttest) control group design was implemented with scores analyzed using the one-way analysis of covariance. The univariate analysis of variance was used to compare the differences between MOOTB and traditional fifth grade students' attitudes toward math relative to confidence, value, enjoyment, and motivation. The findings from the study showed improvements in both instructional groups on MAP posttest, but differences between the groups on math scores were not significant. The main effect for socioeconomic status was significant. A significant difference in students' attitudes toward math relative to enjoyment was noted. This study has the potential to provide school systems with alternative ways to increase student achievement which is an important implication for social change.

Jing-Hua Chen, Yi-Chou Chen. *Differentiated Instruction in a Calculus Curriculum for College Students in Taiwan*. General Education Center, Army Academy R. O. C., Taiwan, 2017.

To explore differentiated instruction within a calculus curriculum. For college students to learn concentration, motivation and the impact of academic achievement; explore the attitudes and ideas of students on differentiated instruction within a calculus curriculum; build up the diversity of mathematics education within varied educational settings. Participants: Sample data were collected from freshman students of the Army Academy: total sample = 60, experimental and control group each had 30. Methods: Quasi-experimental design. Study tested whether differentiated instruction would enhance calculus instruction, compared with a traditional teaching method. Results: As hypothesized, results showed a significant difference in calculus achievement between experimental and control groups. Conclusions: Results supported the effectiveness of differentiated instruction on calculus curriculum. Finally, depending on the research results, the researcher provided practical suggestions for the educational research.

Larbi, Ernest, Mavis, Okyere. *The Use of Manipulatives in Mathematics Education*. Catholic University College of Ghana, Fiapre, 2016.

The study was designed to investigate the efficacy of using algebra tile manipulatives in junior high school students' performance. The study sample comprised 56 students from two schools purposely selected from two towns within the Komenda Edina Eguafo Abirem municipality. The students were made up of two groups; the experimental and the control group. Each group was taught the same algebra units over a period of four weeks. However, the experimental group was taught using algebra tile manipulatives whilst the control group was taught using the conventional 'talk and chalk' method. The instruments used for data collection were mathematics achievement pretest and posttest. Students' achievements on the posttest were analysed using percentages, mean, standard deviation and the independent t-test. The findings of the study were that, those who were taught through extensive use of algebra tiles performed significantly better. Thus the use of the algebra tiles proved very effective and promising approach to teaching and learning algebra, and that the tiles also improved students' thinking process as they solved problems in algebra. On the basis of these findings, it is recommended that algebra tiles should be used as a tool to introducing students to algebraic concepts.

Leonardo, Rainilyn R. ***Differentiated Instruction Its Effects on Students Achievement and Attitude Towards Trigonometry***

The study made a comparative analysis of the effectiveness of differentiated and traditional instructions of teaching on the Mathematics achievement and attitude of college freshmen. The quasi-experimental method of research particularly the non-equivalent group design was used in the study. In the differentiated instruction group, varied instructional materials and formats were provided to the students in each lesson based on their identified learning needs- readiness level, interest, and learning style. Differentiated instruction recognizes the students as individuals with unique learning needs. Flexible grouping was consistently used in the instruction. Students were grouped according to their pre-test results. Some students were also given the chance to work alone when it was deemed their best modality of learning. On the other hand, students in the control group were taught using the traditional method of lecture-instruction. The achievement posttest results of the two groups revealed that the students in the differentiated instruction group obtained a significantly higher posttest mean score than the students in the traditional instruction group. On the other hand, the attitude of the students in both groups remained the same even after the experiment. However, the learning journal of the students in the differentiated instruction revealed more positive learning experiences after using this instructional strategy. Based on the findings of the study, it was concluded that differentiated instruction can better improve students' achievement in Mathematics than the traditional method of teaching. Furthermore, using differentiated instruction will improve students' Mathematics achievement regardless of their attitude towards Mathematics.

Maghy S. J. *Effectiveness of Mnemonics on Achievement of Students in Mathematics at Highschool Level*. Academy of Science and Technology, University Of Kerala, India, 2015.

This research is an experimental study which is intended to find out the effectiveness of mnemonics in teaching mathematics. The method adopted here is pretest posttest nonequivalent group experimental design .To conduct the study two groups were selected from an intact class room one was treated as experimental group and other as control group. Both groups were pretested before the start of experiment. The experimental group was taught by mnemonics strategy and control group was taught by lecture method. Then they were given a post test. The result shows that mnemonic strategy is more effective than the lecture method.

Ndidi, Meremikwu Anne., Effiong, Ibok Ekpenyong. *Influence of classroom environment on senior secondary school students' academic achievement in mathematics in Calabar, Nigeria.* University of Calabar, 2020.

This study examined classroom environment and mathematics achievement of senior secondary school (SS2) students' in the Calabar Cross River State, Nigeria. Ex-post facto quasi-experimental research design was used to test two hypotheses on the influence of two classroom variables, class size and instructional materials on students' academic achievement in mathematics. A sample of 700 students was selected from public secondary schools for the study using stratified and simple random sampling procedures. Two instruments used for data collection were a questionnaire on classroom environment and test items on mathematics achievement. The reliability estimate of the instrument was established through Cronbach Alpha reliability estimate and Kuder – Richardson K-R-20 formula which gave the reliability indices to range from 0.75 to 0.78. Independent t- test was the statistical technique adopted to test the hypotheses at 0.05 level of significance. The result of the analysis revealed that class size and availability of instructional facilities significantly influenced students' academic performance in mathematics among SS 2 students in Calabar Nigeria. Based on this finding, increased government funding for provision of conducive classroom environment, with optimum class sizes is recommended. Instructional materials for teaching mathematics should be made available in public schools.

Noreen, Razia, Abdul Majid Khan Rana. *Activity-Based Teaching versus Traditional Method of Teaching in Mathematics at Elementary Level*. Bulletin of Education and Research, 2019.

The aim of this research was to study the effect of activity-based teaching and traditional method of teaching on students' achievement in the subject of Mathematics at elementary stage. The research was experimental based on pre-test, post-test control group design. Two units of geometry were selected from seventh grade Mathematics for this research. Population of the study was the 120 students of seventh grade from GGHS Bhedian Pattoki, District Kasur, Punjab (Pakistan). Sixty students of class seventh were taken randomly from Govt. Girls High School Bhedian Pattoki, District Kasur. A pre-test was administered on them for equalizing the groups. Students were randomly divided into two groups (experimental and control) according to the results of pretest. Both tests were developed from the seventh class Mathematics book for the compilation of data. Tests were administered keeping cognitive domain in view. Selected unit 10 (exercise 10.1 to 10.4 and revision exercise) and unit 12 (12.1 to 12.6 and revision exercise) from seventh class Mathematics book prescribed by Punjab Text Book Board were taught to both groups (experimental and control) for a period of eight weeks. Activities were used for experimental group only and other group was taught traditionally. Time for the teaching Mathematics was 40 minutes daily to each group. Independent sample t-test was applied on the pre-test and post-test scores to check whether there is a difference in the performances of two groups. It was also concluded that students taught through activity based teaching performed better in post-test. It is recommended that in future Mathematics may be taught with activities at elementary level. Mathematics kit containing material for activities may be provided to Mathematics teachers.

Ogunkunle , R. A., Henrietta , Onwunedo Azuka. *Effect of Differentiated Instructional Strategies on Students' Retention in Geometry in FCT Senior Secondary Schools, Abuja, Nigeria*. Bachudo Science Co. Ltd Printed in Nigeria, 2014.

The effect of differentiated instructional strategies on students' retention in geometry in senior secondary schools was examined. The study employed experimental research design of pretest, posttest control group. The area of this study is Abuja Municipal Area Council, the Federal Capital Territory. The target population was the entire mathematics student in senior secondary class 2 (SS2) in the area. The simple random sampling technique was adopted and used to select two senior schools and 100 subjects for the study. Researcher-designed Geometry Achievement Test (GAT) containing 25 multiple choice items with reliability coefficient of 0.90 was used to measure students' academic achievement before and after treatment. The researcher taught the experimental and control groups for six weeks. At the beginning and end of the six weeks GAT was administered as a pre-test and post-test to the students in the two groups. The result shows among others that differentiated instructional strategies was more effective in promoting meaningful learning and enhancing mathematics students' achievement than the conventional method (Z98=11.320, p<.05). The result of the post-post-test administered to the experimental and control group students' four weeks after the first post-test also show that retention ability was significantly higher in the experimental group students than in the control group student (z98= 13.876, p<.05). Conclusion from these findings led to the recommendation that Mathematics teachers and educators should adopt the Differentiated instructional strategies as an innovative, efficient and effective strategy in teaching geometry concepts in Mathematics.

Tambaoan, Rebysarah S., Gaylo, Derren N. *Differentiating Instruction in a Mathematics Classroom: Its Effects on Senior High School Learners' Academic Performance and Engagement in Basic Calculus*. Bukidnon State University, Malaybalay City, Bukidnon, Philippines, 2019.

A quasi-experimental study was conducted to investigate the effects of differentiated instruction, a strategy that may cater to learners' diversity, towards their academic performance and engagement in Basic Calculus. It was participated by sixty Grade 11 learners in the Science, Technology, Engineering and Mathematics (STEM) strand of Bukidnon State University Secondary School, Malaybalay City during the second semester of the school year 2017-2018. Lessons on differentiation and its applications were developed. Researcher-made academic performance test and engagement scale were evaluated by a panel of experts and underwent validity and reliability analysis. The gathered data were analyzed and interpreted using appropriate statistical techniques: mean, standard deviation, frequency, percentage, one-way analysis of covariance (ANCOVA) and paired t-test. The results revealed that the learners' academic performance when taught using differentiated instruction was Very Satisfactory; while learners taught with the conventional instruction was Fairly Satisfactory. There was a statistically significant difference in the academic performance between the two groups of learners, in favor of those taught with differentiated instruction. Moreover, the engagement level of the learners in the experimental group was Moderate before and after the intervention, and there was a statistically significant difference between them attributed to differentiated instruction.

Thurmon, Elijah. *The Impact of Learning Stations on High School Students Ability to Solve Linear Systems of Equations*. Goucher College, Graduate Programs in Education, 2019.

The purpose of this study was to determine the impact of learning stations on high school students' ability to solve linear systems of equations. The measurement tool was a performance assessment aligned with the Anne Arundel County Public Schools' Algebra 2 curriculum. The study was a true experimental design with 22 participants in group A receiving the treatment and 18 participants in group B receiving the control over a two-week period. A pretest posttest design was used for comparison between group A and group B. The null hypothesis states that learning stations have no impact on high school students' ability to solve linear systems of equations which was supported. Regarding the achievement gains between group A and group B, there was not a statistically significant difference. Research in the area of learning stations impacting math achievement should continue given the importance of engagement and differentiated instruction.

Williams, Kimberly Gail. *The Effect of Differentiated Instruction on Standardized Assessment Performance of Students in the Middle School Mathematics Classroom*. Liberty University, 2012

Changing demographics, student diversity, and increased accountability have compelled educators to challenge the uniform constraints of traditional instruction and create an environment focused on individual achievement. Differentiated instruction empowers teachers to target multiple learning styles through varied themes, adapted content delivery, and assessment options. This quantitative quasi-experimental research study examined the effects of differentiated instruction on seventh grade student performance on standardized mathematics assessments using a repeated-measures design. Two independent research trials, controlling for initial group differences with 2011 Texas Assessment of Knowledge and Skills (TAKS) scores, provided inconclusive assessment results. Significant differences between students who received differentiated instruction compared to students who were instructed using traditional lecture-based strategies were inconsistent for each research trial. All learning groups, including special education, economically disadvantaged, English language learners, and gifted were included to determine if strategies were successful based on specific learning needs. Evidence obtained through classroom observations revealed deficiencies in effective instructional delivery of differentiated strategies, emphasizing the need for ongoing, quality professional development and support for educators.

Yeh, Charles Y. C., Cheng, Hercy N. H., Chen, Zhi-Hong, Liao, Calvin C. Y., Chan, Tak-Wai. Enhancing achievement and interest in mathematics learning through Math-Island. Taiwan, Republic in China, 2019.

Conventional teacher-led instruction remains dominant in most elementary mathematics classrooms in Taiwan. Under such instruction, the teacher can rarely take care of all students. Many students may then continue to fall behind the standard of mathematics achievement and lose their interest in mathematics; they eventually give up on learning mathematics. In fact, students in Taiwan generally have lower interest in learning mathematics compared to many other regions/countries. Thus, how to enhance students' mathematics achievement and interest are two major problems, especially for those low-achieving students. This paper describes how we designed a game-based learning environment, called Math-Island, by incorporating the mechanisms of a construction management game into the knowledge map of the elementary mathematics curriculum. We also report an experiment conducted with 215 elementary students for 2 years, from grade 2 to grade 3. In this experiment, in addition to teacher-led instruction in the classroom, students were directed to learn with Math-Island by using their own tablets at school and at home. As a result of this experiment, we found that there is an increase in students' mathematics achievement, especially in the calculation and word problems. Moreover, the achievements of low-achieving students in the experimental school outperformed the low-achieving students in the control school (a control group in another school) in word problems. Moreover, both the low-achieving students and the high-achieving students in the experimental school maintained a rather high level of interest in mathematics and in the system.

Appendix B

The Research Summary Form

Part I: General Data

A. Title of the Study:____
B. Researcher/s: ____

Part II: Methodological Characteristics

A. Research Design

_____ Pre-test or Post-test Design
_____ Post-test only Design
_____ Solomon Four Group Design
_____ Factorial Design

B. Students' Profile

_____ Regular Students
_____ Advanced / Gifted Students

C. Level of Participants

_____ Kinder – Grade 3
_____ Grade 4 – Grade 6
_____ Grade 7 – Grade 12
_____ Tertiary Students

D. Number of Participants

_____ 1-20 participants
_____ 21-40 participants
_____ 41-60 participants
_____ 61-100 participants
_____ 101 or more participants

E. Sampling Technique

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

Part III: Substantive Characteristics

A. **Type of Modifications in Differentiated Instruction**

_____ Content Differentiation

_____ Process Differentiation

_____ Product Differentiation

_____ Learning Environment Differentiation

B. **Mean of the Control Group** _______

C. **Mean of the Experimental Group** _______

D. **Standard Deviation of the Control Group** _______

Appendix C

Research Summary

		Methodological Characteristics					Substantive Characteristics				
Study	Year	Research Design	Students' Profile	Level of Participants	Number of Participants	Sampling Technique	Type of Differentiation	Mean of the Control Group	Mean of the Experimental Group	Standard Deviation of the Control Group	Effect Size
		1-Pre-test/Post-test	1-Regular	1-Kinder to Grade 3	1-(1-20)	1-Simple Random Sampling	1-Content				
		2-Post-Test only	2-Gifted	2-Grade 4 to Grade 6	2-(21-40)	2-Stratified Sampling	2-Process				
		3-Solomon Four Group Design		3-Grade 7 to Grade 12	3-(41-60)	3-Cluster Group Sampling	3-Product				
		4-Factorial Design		4-Tertiary Education	4-(61-100)	4-Matched Group Sampling	4-Learning Environment				
					5-(100 and above)	5-Purposive Sampling					
						6-Convenience Sampling					
1 Study A	2011	1	1	2	4 (68)	6	2	215.94	215.12	12.09	-0.06782
2 Study B	2017	1	1	1	2 (28)	6	2	82	84.15	11.1	0.193694
3 Study C	2019	1	1	3	5 (220)	1	2	23.94	32.81	5.21	1.702495
4 Study D	2015	2	2	3	2 (32)	2	1	72.44	70.19	13.64	-0.16496
5 Study E	2020	2	1	3	5(700)	2	4	14.12	16.23	6.52	0.32362
6 Study F	2015	1	1	3	5 (120)	6	1	14.33333	12.01667	3.280614	-0.70617
7 Study G	2016	1	1	3	5 (165)	6	1	17.3	22.11	12.021	0.400133
8 Study H	2012	1	1	2	5 (135)	1	3	13.75	15.37	2.75	0.589091
9 Study I	2019	1	1	3	2(40)	6	2	57	60	19	0.157895

10 Study J	2019	1	1	3	3 (60)	1	2	19.57	23.27	2.39	1.548117
11 Study K	2017	1	1	4	3 (60)	5	4	31.03	51.7	27.164	0.760934
12 Study L	2016	1	1	3	3 (56)	5	2	20.35	32.16	7.94	1.487406
13 Study M	2014	1	1	3	4 (100)	1	3	34.98	60.42	6.72	3.785714
14 Study N	2015	1	1	3	4 (96)	1	2	1.47	2.22	0.65	1.153846
15 Study O	2019	1	1	3	5 (120)	1	2	20	48.8	4.136	6.96325
16 Study P	2018	1	1	3	5 (191)	5	2	57.1	70.5	6.8	1.970588
17 Study Q	2014	1	1	1	3(56)	1	2	3.64	4.33	0.53	1.301887
18 Study R	2010	1	1	1	5(155)	1	2	11.83	13.32	3.61	0.412742
19 Study S	2011	1	1	4	3 (60)	1	1	22.2	26	5.71	0.665499
20 Study T	2019	2	1	1	5(215)	5	1	25.34	27.23	7.809	0.242028

PHILIPPINE NORMAL UNIVERSITY
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GRADUATE TEACHER EDUCATION FACULTY

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

This is to certify that the Thesis of **JEAN AIKO C. DOMINGO** entitled**, "*Meta-analysis on the Effect of Differentiated Instruction on Students' Mathematics Achievement*"**, submitted as fulfillment of the requirements for the degree Master of Arts in Education with specialization in Mathematics, has been proofread and edited by the undersigned.

This certification is issued on the 14th day of May 2021 upon the request of Ms. Domingo for whatever legal purpose this may serve.

Maria Jhona B. Acuňa, PhD
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- August 11, 2011 - Present
  Florentino Torres High School
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VOLUNTARY WORK

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CLUB ADVISORSHIPS

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- TorreSHINE in Math, Adviser

AWARDS / RECOGNITIONS RECEIVED

- Florentino Torres High School Outstanding Teacher Award 2020 (Mathematics Department)
- Writer-Contributor for PSM Supplemental Materials for Junior High School

SEMINARS AND TRAININGS ATTENDED

- Virtual In-Service Training for Public School Teachers, DepEd Central Office, March 15-19,2021
- Teach On: Keeping the Passion Alive, Southeast Asian Ministers of Education Organization (SEAMEO), May 18 - July 15, 2020
- Modern and Transformational Leadership for Quality Education, Sun Star Hotel, October 26 - November 24, 2019
- Mathematics Gears toward Digital Education, Manuel G. Araullo High School, September 28 - October 5, 2019
- Mathematics Teachers: Keeping up with the Global Trend, Manuel G. Araullo High School, September 24, 2019, Manuel G. Araullo High School, September 24, 2019
- Enhancing Mastery of Content in Mathematics to Meet the Needs of 21st Century Learners, Manuel G. Araullo High School, September 7, 2019
- Education Law for Public School Teachers, De La Salle University, June 9, 2018
- Good Research Practice Seminar, Philippine Christian University, April 26, 2019
- Enhancement Program for Mathematics Teachers Part 5, Manuel G. Araullo High School, December 16, 2017
- MTAP- Deped – NCR – Seminar Workshop in Mathematics with the theme: "Empowering Math Teachers for K-12", Ramon Magsaysay High School, October 14-15, 2017
- 2017 MTAP DepEd NCR Annual Convention for Elementary and Secondary Mathematics Teachers, Cuneta Astrodome, October 7, 2017
- Microsoft Education Ambassador's Teaching with Technologies Batch 1, National University, June 10, 2017