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Research Article

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Enhancing Mathematical Critical Thinking and Problem-Solving Skills through Emergenetics® as a Grouping Mechanism

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ABSTRACT

Mathematical critical thinking and problem-solving skills are needed to be enhanced during a group activity through a new mechanism. This study aimed to enhance students' mathematical critical thinking and problem-solving based on Emergenetics® as a grouping mechanism. This is a practical action research design wherein the researchers made profiling to identify the dominant thinking attributes of each student followed by the formation of the group. Then, a pre-test was used to assess the level of critical thinking and problem-solving skills of the students. After that, the formation of a group with a complete set of four thinking attributes. Moreover, four group learning tasks were given at regular intervals wherein the students must collaboratively find the solutions to the given Statistics and Probability problems by combining their thinking attributes. After three months, the post-test of validated test materials and interviews were administered. Based on the findings, the students enjoyed group activity because of the collaboration and a combination of abilities in doing the task. A significant increase exists from pre-test to post-test scores of the students. Through Emergenetics® as a grouping mechanism helps the students to combine their attributes and work collaboratively towards the accomplishment of the group task.

Keywords: critical thinking, Emergenetics®, grouping, problem-solving

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INTRODUCTION

Critical thinking and problem-solving are the two 21st century learning and thinking skills needed to develop among the students (Bellanca et al., 2010). With loads of changes, challenges, and a rapid increase in technological advancement, these two skills are necessary and vital to living in modern society. The 21st-century critical thinking and problem-solving for learners define the process to prepare learners for the international arena that has characterized by having rapid communications with complex and accelerated change and rising diversity (New York State United Teachers, 2015). It caters to engaging students to apply multiple strategies when dealing with a problem, to take into account different perspectives, and to explore with possible ways. It opens opportunities to explore possibilities in dealing with challenges in life due to human activities and natural phenomena.

In the Philippine setting, the mathematics curriculum of K to 12 Basic Education Program under the Enhanced Basic Education Act of 2013 (RA 10533) intends to build critical thinking and problem-solving skills among the students. The said two skills are the common interest for both local and international education settings as learning and innovation skills are needed to cope with the fast-changing modern world. Despite different endeavors of the teachers, it is not yet known how these skills of students can be promoted in daily practice and how teachers can implement teaching problem-solving in their lessons (Hanegem, 2017). It implies that still in the present time, teachers are trying to innovate and invent new methods and strategies on how these two skills can be incorporated in their teaching practices. This calls for action research in the field of mathematics education at the classroom level.

Critical thinking skills are required when someone tries to comprehend some information that is useful for the sparking of ideas (Ennis, 1996). Similarly, it is using prior knowledge or new information of the students to formulate equitable action to novel problems (Lewis & Smith, 1993; Perkins & Murphy, 2006). A different definition of critical thinking skills are stated, but the most accepted in mathematics education is from Scriven and Paul (1987) who argued that critical thinking skills are the intellectual process of conceptualization, application, analysis, synthesis or evaluation of information actively and skillfully as a framework to action and belief. This definition calls for higher-order thinking skills that are needed to live in this fast-changing society with complexity. Facione (2011) stated that the most core skills of critical thinking are the capability to analyze, evaluate, explain, infer, interpret, and self-regulate.

Critical thinking skills need to be developed in Mathematics (Aizikovitsh & Amit, 2010; Rajendran, 2010). Mathematical critical thinking skills are the processes of crucial thinking concerning mathematical reasoning, knowledge, and proofs regarding problem-solving (Krulik & Rudnick, 1995). It has three components in Mathematics, namely identification and interpretation of information, information analysis, and evaluation of evidence and argument (Ennis, 1996; Facione, 2011; Glazer, 2001; Krulik & Rudnick, 1995). The statement above shows the importance of mathematical critical thinking skills concerning the problem-solving skills of the students. If critical thinking skills are developed among students, this will promote the progress of their problem-solving skills.

On the other hand, mathematical problem solving is considered one of the most vital lessons to study and also one of the most complexes to develop among the students (Dendane, 2009). The reason for teaching this skill is to develop among the students the capability to deal with real-life situations and make use of mathematical concepts in real-life problems (Dendane, 2009). On the other hand, Doorman et al., (2007) reported: "problem-solving in secondary mathematics education has only a marginal position" (p. 411) and more work needs to be done. It means that it must be developed through the guidance of teachers by using different strategies and techniques in delivering the lesson. Teachers may still develop a way or mechanism in classroom activities that promote problem-solving skills of the students. This is one of the reasons why this study is utilizing a mechanism that promotes problem-solving in classroom activities.

Different studies show that better conceptual learning and higher order-thinking are the benefits of collaborative learning (Gillies, 2000; Yiping, Abrami, & D'Apollonia, 2001). Collaborative learning helps each member of the group to lean on each other by combining different abilities to perform a group task. It may enhance achievement, self - efficacy, and motivation if the students with different expertise and attributes are grouped to learn from each other by bringing the diverse types of expertise and knowledge (Davies, 2009). It implies that diversity in group formation is a vital principle for the process of collaborative learning. Group diversity may create convenience and advantages for team effectiveness through the sharing of various knowledge, expertise, skills, and cognition which may produce better decisions and solutions to the problem (Harrison & Klein, 2007). The great questions are how group diversity can be established in the formation of the group and what basis of diversity would it be. These questions served as a guide in this study in formulating grouping mechanism.

Cooperation within the group enhances the interdependence of each member towards the common goal. Social interdependence theory posits that interdependence unites group members into a dynamic whole group working together towards the attainment of a common goal (Johnson & Johnson, 2019). The theory supports the cooperative learning yields better outcomes and the process of doing tasks working in a small group of people. It produces active learning when every member of a group is working collaboratively to perform a task. Also, members are motivated to accomplish tasks derive from their intrinsic tension from each member.

This study was conducted in San Pedro Relocation Center National High School (SPRCNHS) - Main Campus, which is a public high school located at Old Tenant Imelda Avenue Langgam, City of San Pedro, Laguna, the Philippines occupying 5.2-hectare lot near Iglesia ni Cristo. SPRCNHS, now on its 40 years of existence, has its Senior High School (SHS) Program implemented since 2013 as one of the pilot testing schools of Senior High School under the K to 12 Basic Education Program. It has three campuses in the City of San Pedro such as the main campus located in Langgam, Cuyab campus, and Landayan Campus. It offers both Junior and Senior High School program committed to delivering the basic education services to the youth of San Pedro and the nearby municipalities as a technical-vocational school.

The SHS in Langgam Campus under Technical-Vocational Livelihood (TVL) track has three strands such as Home Economics (HE), Industrial Arts (IA), and Information and Communication Technology (ICT), while the Academic Track has two strands, namely Science, Technology, Engineering and Mathematics (STEM) and Humanities and Social Sciences (HUMSS). As of June 1, 2019, it has 5, 840 students, of which 766 are Grade 11 students with TVL and academic tracks. There are eight sections under TVL track, while six sections under the academic track with an average of 45 students per class. Moreover, the TVL and HUMSS students were struggling in academic subjects, particularly Mathematics. Based on the quarterly test, two TVL and one HUMSS sections got the low mean per section of below 40% to compare to other academic track. This is a manifestation of poor student's critical thinking and problem-solving skills that caught the attention of the teacher to conduct action research on how the academic performance of the said students be increased. For this reason, this action research was conducted.

LITERATURE REVIEW

Grouping students with diverse dominant thinking ability is the principle of Emergenetics® profiling which studied and conducted to effectively implement group tasks (LaPrairie, 2007; Mitchell, 2016). Instead of just counting numbers to group the students during group tasks, it is better to use the tenet of Emergenetics® theory. A group which is composed of a complete set of analytical, structural, social, and conceptual thinkers comprised the grouping of the students in dealing with tasks or activities. Through diversity and collaboration in mind, the researchers decided to bring together groups of students with diverse thinking preferences to improve their mathematical critical thinking and problem-solving skills. They used the principle of Emergenetics® profiling which served as the basis in the formation of groups since it has been used by different organizations in the business world like Citibank, Microsoft, Siemens, and Nanyang Technological University in forming groups effectively within the organization (Torino, 2018). Needless to say, this profiling was widely used around the world by big companies which results in better organizational culture among a group of workers but new to the education sector. This calls for an application in the education sector specifically inside the classroom to achieve the target objectives of basic education under K to 12 programs.

Schmuck and Schmuck (2015) argued that heterogeneous groups improved the social competencies of the students by respect for human differences, improved self-esteem within the cooperative, and a sense of responsibility for the general welfare. It shows that students sharing something despite their differences and capabilities may produce better outcomes than groups with the same characteristics. This calls for the utilization of different abilities in forming a group or team.

Figure 1. Component of Emergenetics® Profile Attributes

In the study of LaParairie (2007) with ninety-five students, participants enrolled in six multimedia production courses formed learning groups based on Emergenetics® profiling. He found that Emergenetics® profiling is a useful approach in grouping the students; group process engagement improved, and the learning group seems to be less effective when one or more thinking attributes are missing or not represented in a group. These findings inspire researchers to use Emergenetics® profiling as the basis of group formation in group activity.

Torino (2018) investigated how Emergenetics® increase the computational thinking of Grade 11 students in Mathematics. She used causal-comparative design to determine the cause of differences between the two groups. Two groups were compared - Emergenetics® group and non-Emergenetics® group - using their group output and she found that the use of Emergenetics® profiling is an effective grouping strategy when facilitating problem-solving using computational thinking skills. Students' engagement in the learning task was found to be satisfactory. They were more proficient in the middle steps of problem-solving rather than the initial and final phases. Thus, it is inevitable to say that Emergenetics® is novel in the Philippine classroom setting as a grouping mechanism. Needless to say, there is only one study that has been conducted in a private school but has not yet been proven in public schools.

Emergenetics® is based on the behavior and learning theory as emergenesis flourished by David Lykken in 1982 (Emergenetics International, 2019). The Emergenetics® proposes that individuals have various genetic tendencies to think and act in different ways, and behaviors may have been modified through socialization. It means people are born with thinking and behavioral traits already which may alter by the environment and society that molds them to become a better one. The Emergenetics® concept is based on the concept that a person is the emergence of genetics, behavior, and life experience which is developed by Dr. Geil Browning and Dr. Wendell Williams (Emergenetics® International, 2019). The combination of different people with different thinking and behavioral attributes may maximize their potentials on the realization of group objectives. It provides a better understanding of each member of a group and working diversely in collaboration. As depicted in **Figure 1** the group composition proposed by Emergenetics® profiling is used in the study composed of four dominant thinking preferences.

Figure 1 shows the composition of groups based on the Emergenetics® theory. The figure shows a complete set of four thinking and three behavior attributes in which group comprising of analytical, structural, social, and conceptual as diverse learning groups work collaboratively in the group task. Each attribute shows different characteristics and norms that develop at various levels for each individual.

The four thinking attributes are listed as analytical, structural, social, and conceptual (Browning, 2006). Analytical thinkers think rational, factual, and skeptical. They have a steady inclination, often prefer to work independently, and may be seen as not emotional or less caring people. On the other hand, structural thinkers have a practical and cautious way of thinking. These people follow a sequence of steps in thinking combine with a usual inclination for pragmatic application. Students who are eminently structural thinkers are mostly learners, who prefer to go hands-on activity after the methods or procedures step-by-step, which makes them unimaginative.

Social thinkers are socially aware and like to interact with other people. People with strong preferences for social thinking are usually emotional but appreciative of others' opinions. These people may be interpreted as sensitive; but, not all are extrovert. On the other side, conceptual thinkers are imaginative and focused on conceptual ways of thinking situations or problems. They prefer intuitive thoughts combined with a desire for abstract concepts. These people are creative and theoretical in searching for the solution to the problems. Some of them are very unusual in thinking or unconventional. But, it is noted that any person of any thinking preference can be ingenious in their way, not only the conceptual thinkers (Torino, 2018).

The four thinking styles are coupled with the three characteristics such as expressiveness, assertiveness, and flexibility (Emergenetics® International, 2019). These are based on what other people perceived the four types of thinkers. Expressiveness shows the person's level of participation in social context either introvert or extrovert personality. On the other hand, assertiveness tells how passive or aggressive a person can be in expressing thoughts, feelings, and beliefs, while flexibility refers to a person's opinion and ability to deal with others' needs, decisions, and suggestions. It measures the openness to cater to the actions of others and thoughts to build a harmonious relationship that makes all members comfortable in working. The Emergenetics® profiling tool produces a profile that enables teachers to better understand how students think and behave in a classroom (Mitchell, 2016). The present study uses the four thinking attributes only in profiling which provides a means by which mathematics teachers can affect positive results on student individual success in the classroom group activity.

This study strongly believed in Social Learning Theory, developed by Albert Bandura (1977), postulates that learning takes place from human interaction through imitating, observing, and modeling. The theory acts as a link between cognitive and behaviorist learning theories since it brings about concentration, motivation, and memory. Through group activities, students learn more by interacting with each other and collaborating. Moreover, Emergenetics® is an instrument to help create a grouping environment that promotes collaboration, commitment, and communication among members (Browning, 2006). This is the reason why the grouping mechanism is proposed to boost the mathematical critical thinking and problem-solving skills of the students through collaboration with diversity.

In this study, the researchers make profiling of the students to identify their dominant thinking preference and group them diversely with a complete set of four thinking attributes based on Emergenetics® theory. Hence, there is a call for an investigation inspecting the

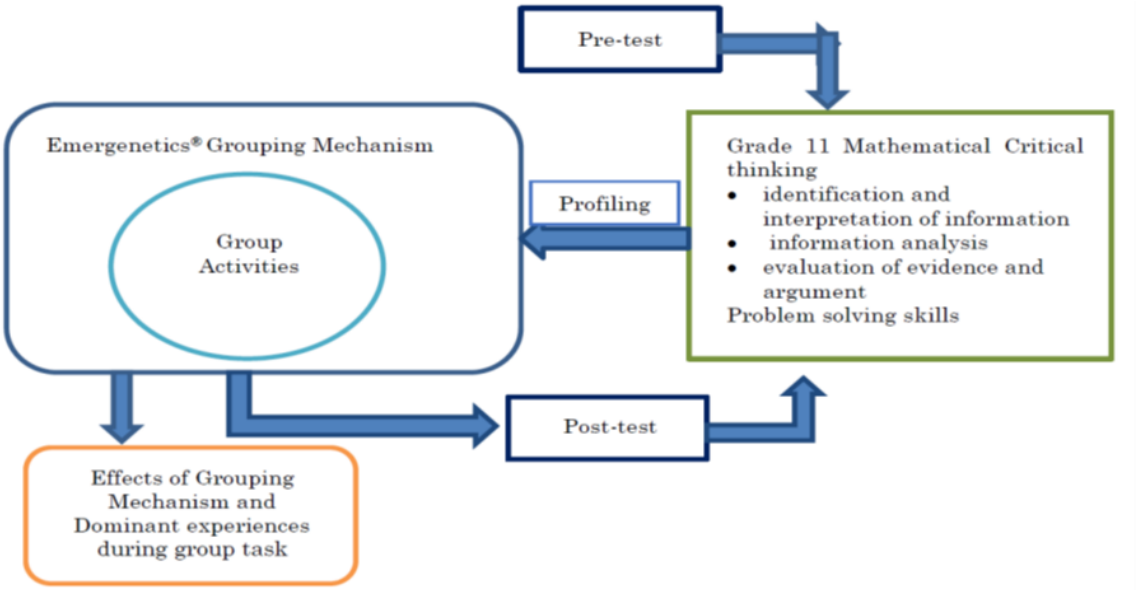

Figure 2. Conceptual Paradigm

consequence of group formation on the nature of small-group cooperation that happens in classroom activities (Murphy et al., 2017). In terms of the number of members per group, 6 - 8 members per group are formed. Most experts agreed that the number of members in a group is at least three with small groups arbitrarily ranging from 3 to 15 (Tubbs, 2012). However, Lencioni (2007) suggests the number of members per group ranges between 3 and 12. So, there is a call for studying the consequence of small group composition on the nature of group tasks (Wichmann et al., 2016).

The said intervention was pilot tested in two sections of Science, Technology, Engineering, and Mathematics (STEM) Grade 11 students. Profiling was done for two weeks based on their preferred thinking attributes and group formation was implemented. Two group activities were given to these sections to see if the intervention will produce better outcomes in terms of mathematical critical thinking and problem-solving skills for two weeks. Their outputs were analyzed based on the rubric presented ahead of the activity and it shows better results compare to the previous activities wherein they grouped by counting or learning style.

Figure 2 shows the conceptual paradigm of the study which tells the flow of the study. It presents the concepts of the study to understand the process involved in this study.

Figure 2 shows the pre-test of students' mathematical critical thinking and problem-solving skills was administered before the implementation of the intervention during group activities. After two months, the post-test was administered to measure again the dependent variables. A significant difference was used to determine if the intervention is effective. Moreover, the interview was considered to elicit the effect of the Emergenetics® grouping mechanism and dominant experiences to support the quantitative findings.

This study aimed to enhance students' mathematical critical thinking and problem-solving skills by forming a complete set of different dominant thinking attributes using Emergenetics® as a grouping mechanism. Specifically, the following questions were addressed:1. What is the level of mathematical critical thinking of the respondents before and after the group learning task in terms of a. identification and interpretation of information, b. information analysis; and c. evaluation of evidence and argument? 2. What is the level of mathematical problem-solving skills of the respondents before and after group learning tasks? 3. How does grouping composition help the students to deal with group tasks? 4. What will be the dominant experiences of students during the group learning tasks when they are grouped according to Emergenetics® theory?

METHODOLOGY

Research Design

The study utilized practical action design focusing on how to boost the critical thinking and problem-solving skills of Grade 11 students in Mathematics through diverse grouping mechanism. Fraenkel & Wallen (2010) described practical action research as a method of addressing a particular problem within the context of the classroom setting, school arena, or community. It is a typical method of research in addressing classroom-based problems utilizing the available materials, resources, and people involved in the teaching-learning process. This method helped teachers to enhance critical thinking and problem-solving skills of students in group tasks by forming a complete set of four thinking attributes. This may improve the teacher's practices in forming a group to maximize the potentials of the students to work diversely by sharing different knowledge, expertise, and skills.

Research Participants

The participants of this study were the Grade 11 students enrolled in San Pedro Relocation Center National High School - Main Campus for the school year 2019 - 2020. A small group of 6 to 8 students with a complete set of thinking attributes was intentionally formed for an identified group learning task in their Grade 11 Statistics and Probability (StatProb) subject which is offered in the second semester. Three sections with the lowest mean per section (MPS) underwent the intervention as shown by the result of the third grading examination and the diagnostic test in the fourth grading period.

The study used a purposive sampling technique in the selection of subjects of study as the group members which is based on the dominant thinking attributes of each student as evidenced by the result of their profiling using 4T's instrument. Zulueta and Costales (2003) said that in purposive sampling, the researcher chose the samples based on his/her subjective acumen. Those people who satisfied the criteria in choosing participants of the study are purposely included as samples. Students are grouped forming a complete set of dominant thinking attributes for every group based on the principles of group diversity which states that it promotes benefits and opportunities for group effectiveness and will cause to a better information abundance within the group through various knowledge, expertise, skills, and cognition that will be transformed into bright decisions, more productive plans, and more innovative solutions (Harrison & Klein, 2007; Van Knippenberg & Schippers, 2007).

Research Instruments

The following instruments were utilized in this study.

4T's. This stands for four thinking styles which are designed based on the theory of Emergenetics® to measure the four thinking styles: analytical, structural, social, and conceptual adopted from the work of Torino (2018). Permission from Torino was secured first before the use of the said instrument to establish ethical consideration. The instrument comprising 17 items was used to identify the dominant thinking attributes of the students using a five-point Likert scale covering from Strongly Disagree to Strongly Agree (1 to 5). It was developed and validated from Torino's work for profiling thinking styles, where exploratory and confirmatory factor analyses were employed for its development. The instrument was reliable at .798 using Cronbach's alpha. The researchers did not make any modifications to this instrument. This is a self-evaluation questionnaire to be answered by the students before grouping composition.

Group learning task. This instrument was developed to demonstrate the critical thinking and problem-solving skills of the Grade 11 students. It was assessed by two teachers in terms of objectives, clarity, content, design characteristics, and evaluation. This was given in every group activity together with a rubric to be performed for fifty minutes.

Group learning rubric. This was the scoring guide that was utilized to assess the level of mathematical critical thinking and problem-solving skills of the Grade 11 students. A single rubric was designed for the group learning task performance. Glass (2005) claimed that rubrics are commonly used in the classroom nowadays and presented before the start of the task as a guide for the students in what aspect they are going to assess.

Test material. This instrument was used to assess the mathematical critical thinking and problem-solving skills of the students. The fifty-item test was constructed aligned with learning competencies in the curriculum guide of Statistics and Probability subject. There are thirty-eight items for critical thinking and twelve items for problem-solving skills. Three experts in the area of mathematics education validated the first draft for content and face validity. They rated it with a mean of 2.93 which means suitable for the study. However, necessary revisions were made based on the suggestions of validators. After validation, this was administered in 33 Grade 11 students from private senior high school to compute reliability using Cronbach's alpha. The alpha value was .901.

Interview guide questions. This was the last instrument to elicit qualitative data to support the quantitative findings with four items. This was used for the conduct of semi-structured interviews to deepen the data based on the students' perspective on how their group helps them to promote their critical thinking and problem-solving skills. It has 4 items validated by there experts and pilot tested in 20 students not included in the participants to establish its validity.

Data Gathering Procedure and Data Analysis

Figure 3 shows the step-by-step procedure for the study. The figure shows the procedure done in the study. Permission from Emergenetics® International was secured for the use of their registered name and concept through email. Also, permission from Dr. Torino for the use of her developed profiling questionnaire was secured. Similarly, a permit from the school head was secured through a formal letter noted by the Mathematics headteacher. The orientation of teachers and students was conducted right after the permission was granted. Moreover, parental consent and assent form were secured before the administration of 4T's instrument. The purpose of administering the instrument was to determine the dominant thinking attribute of the student which served as a basis for the formation of the group. Eventually, a pre-test was administered to assess the prior students' critical thinking and problem-solving skills.

After getting the result of 4T's instrument, codes were assigned to identify the dominant thinking attribute of each student. Formation of groups with a complete set of thinking attributes was made before group activity. Four sets of group activities were given to the students at regular intervals. The direction and rubric used had been discussed first before the beginning of the group task. Materials were distributed and after 40 minutes, each group presented their output while their teacher was scoring their work. Fifty percent of their scores were given by the teacher while the remaining half was given by other mathematics teachers. After three months, a post-test was administered to measure their critical thinking and problem-solving in Mathematics. The result was compared with the pre-test result to determine the significant difference that exists if any using the t-test for correlated samples. Moreover, interviews for the 50 students were conducted with the help of student teachers to elicit qualitative data to support the quantitative findings. Thematic analysis was used on the transcript to build reliable and meaningful data.

Ethical Considerations

Since the data were collected among human participants, it is a must to establish ethical considerations, particularly when dealing with minors. Ethical practices are expert standards required for all researchers, especially when dealing with humans. These ethical considerations consist of informed consent and accent, confidentiality and security, crisis management, and emergency contact (Layne & Hohenshil, 2005; Shaw & Shaw, 2006; Vaccaro & Lambie, 2007). Informed consent, confidentiality, and security of the participants' information and the mechanism of sharing the result of the study were strictly considered. Acknowledgment of the registered name of Emergenetics® was always indicated in any part of the research paper. Since some Grade 11 students are minors with age ranging from 16 to 19 years old, consent and assent from parent/guardian were solicited. The form was distributed to the Mathematics teacher; written there are the objectives, process, and possible benefits of the students if they

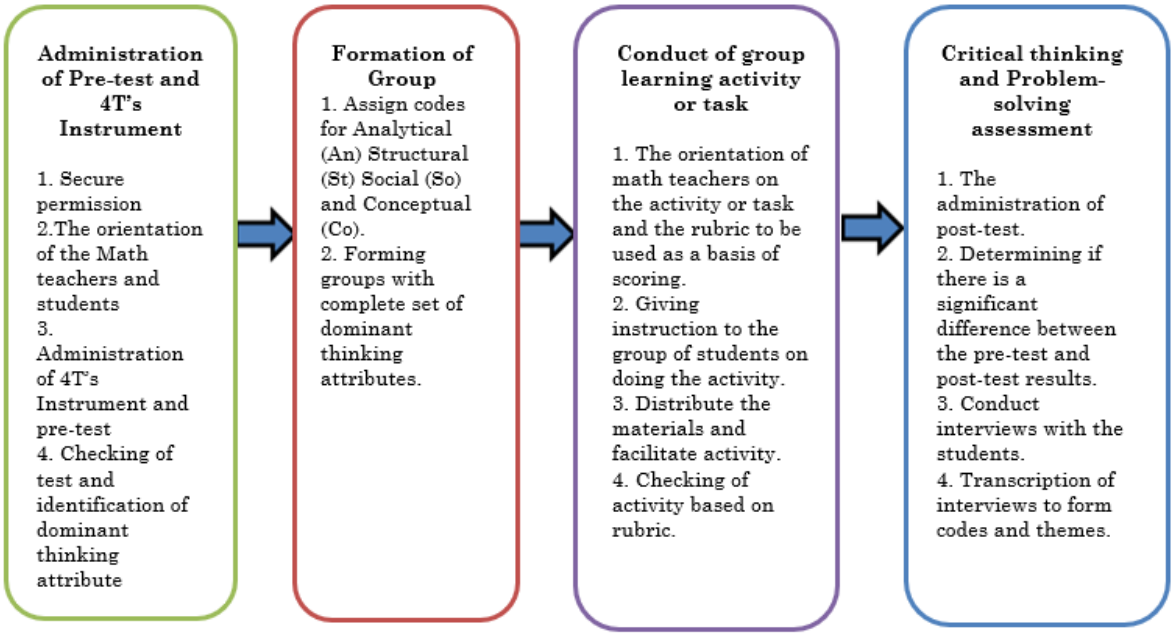

Figure 3. Flow Chart of Data Gathering Procedure in Four Stages

Table 1. One-Sample Kolmogorov-Smirnov Test for Normality of Data from Pre-test and Post-test Results

Statistics		Pre-test			Post-test		
		A	D	HUMSS A	A	D	HUMSS A
N		50	50	50	50	50	50
Normal Parameters[a,b]	Mean	8.33	4.92	11.20	28.34	31.54	32.92
	Std. Deviation	3.42	3.27	5.94	4.26	2.02	2.15
Most Extreme Differences	Absolute	.176	.108	.115	.186	.189	.201
	Positive	.105	.108	.115	.189	.172	.168
	Negative	-.176	-.072	-.069	-.182	-.089	-.091
Test Statistic		.176	.108	.115	.089	.117	.124
Asymp. Sig. (2-tailed)		.100[c]	.200[c]	.099[c]	.200	.086	.052

participated in this study. The participants may withdraw anytime they want and not receive any favor in exchange for their participation

Also, data confidentiality was assured. The participants were informed that the data gathered from this study has stored securely on the researchers' personal computer and school office for three years. However, softcopy of the summary of the findings was made available to the participants upon their request. Furthermore, the researchers are committed to sharing the findings of this study to senior high school faculty through a forum to discuss the significance of this study to mathematics education.

RESULTS AND DISCUSSIONS

The data collected through the test material were treated statistically to test the hypothesis of the study, while the data from the interview were treated thematically. Below is the test of normality for quantitative data. **Table 1** shows the normality of the results of the pre-test and post-test from three sections using the Kolmogorov-Smirnov Test. The data reveals the normal distribution of scores since the p-values are more than a 5% significance level which manifests the appropriateness of the parametric test for significant difference among the means. Moreover, HUMSS A got the highest mean (x=11.46) and standard deviation (s = 5.943) in the pre-test compared with the two sections.

Table 2. Level of Critical thinking and Problem Solving Skills Before and After the Intervention

Variables	Pre-test		Post-test	
	mean	s	mean	s
Identification & interpretation of information	9.19	4.12	31.85	3.01
Information analysis	7.95	3.82	31.64	2.01
Evaluation of evidences & argument	10.70	6.87	31.54	3.43
Problem-solving	5.58	4.87	28.54	4.42

It can be gleaned in **Table 2** that the mean of critical thinking and problem-solving skills of the participants were low before the implementation of group activity. This is a good manifestation from the start of an intervention that twin goals of mathematics curriculum need to be enhanced. However, their abilities increase after the implementation of the treatment. This is a good indicator of enhancing the mathematical critical thinking and problem-solving skills of the students. The mean scores increase after the implementation of the intervention.

As depicted in **Table 3** the significant difference in the means of pre-test and post-test scores at a 5% significance level with a t-computed value of -48.020 (p-value=.000). It means post-test scores are highly different from the pre-test that signifies an increment in the performance of the students in the examination. It implies that the grouping mechanism through Emergenetics® grouping helps the

Table 3. t-test for Correlated Samples for Significant Difference

Scores	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-test Post-test	7.99 30.94	5.14 3.52	1.434	-71.742	-65.978	-48.020	49	.000

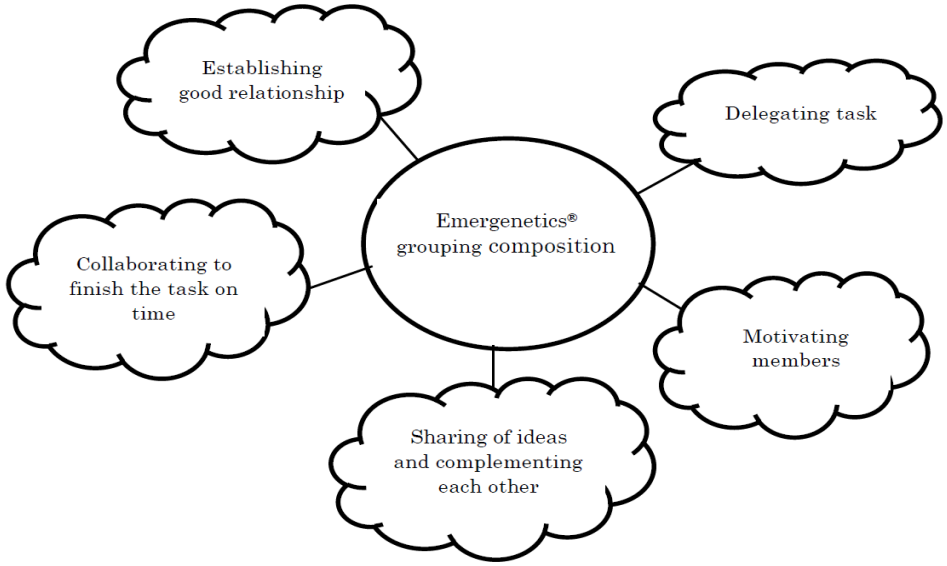

Figure 4. Effects of Emergenetics® Grouping Composition

students to perform well in academics. It manifests that the grouping mechanism in the formation of the group is empirically valid.

Figure 4 shows the themes that arrived from the axial coding of the responses of the students from the interview. Using the Emergenetics® grouping mechanism, each member of the group has the assigned task to perform and to collaborate which made the task easy and finished on time. The delegation of work was a good strategy in dealing with the task where different thinking attributes were utilized upon the completion of the task.

Each member was motivated to do his/her part because everyone was busy on their assigned task and expecting to contribute toward the attainment of their goals. Hence, sharing ideas through brainstorming enhances their ability to deal with the problems arises while doing the task, elicit more suggestions and allow them to reflect their work. If one member cannot perform the assigned task, another member will help to complement each other. Due to this, unity among the group members was established which manifest good relationship among them. This was supported by the words of the participants below.

> "It helps us because when I don't know the answer someone in my group fills it up. Because sometimes when you do not know what to do you can ask your groupmates. They give you suggestions." - Participant 2

> "Everyone has a task to do so, group activity becomes faster. Our work is distributed depending on what you can do. The others cheered us on while computing the others." - Participant 12

As seen in **Table 4** the dominant experiences of the students during the group task. They enjoyed doing the group activity because of brainstorming where different perspectives on how to deal with the task were elicited. They showed a willingness to listen to each member's suggestions and queries. Sometimes different arguments aroused academic noise but controllable within the group. They also experienced conflicts but resolved it through considering each idea and suggestion, allowing each member to talk and listen to each other. If one of the group members did not understand the solution to the given problem, other members would help him or her. They made group discussions, clarifications, and suggestions to produce better output. If they did not understand how to attack the problem, they would boost their self-confidence by keeping the knowledge that they can accomplish the task given by the teacher as one team working together. The brainstorming allowed the members to form different arguments that served as manifestations of their collaboration. They developed good relationships among members by combining their different thinking abilities towards the attainment of their goal - to do the given task correctly. However, they felt stress because of the limited time imposed. Also, some problems were hard-to-solve which required a lot of recalls in the previous lessons. Even so, they did not surrender. They exhausted all means to answer the problems.

Table 4. Participants' Dominant Experiences During Group Learning Task

Themes	Core ideas
happy	sharing ideas helping peers moral support noisy in doing the task
stress	time pressure hard-to-solve problems
collaborating	delegation of work become responsible and active complementing each other

Collaboration among the members was seen in their group work because each member has an assigned task to do. In addition, if one of the members failed to do his/her task, they would help him/her to complete the task assigned. They believed that the more heads are thinking, the better outcome will come specifically if they combined their different abilities. There were times that the members worked independently to compare and verify the correctness of each work. This implies that their group composition helps them a lot because of their differences in thinking and behaving during group tasks. This is supported by the responses of the participants below.

> "Sometimes messy, noisy because of arguing because of the right answer, but happy when we do it right. We all have our part to solve." - Participant 31

> "My ability to solve math problems increased because every time my teammates and I worked together, I understood the lesson better. I became more and more clear about things I could barely understand." - Participant 46

CONCLUSIONS AND RECOMMENDATIONS

The use of Emergenetics® profiling is an effective grouping mechanism when facilitating group activity that enhances mathematical critical thinking and problem-solving skills. Students, despite their weaknesses in understanding mathematical concepts, felt confident in facing mathematical problems when they worked together sharing different abilities and thinking preferences. Moreover, the use of the developed profiling mechanism from business sectors in the groupings of the students for the performance task or activities for math subjects can create an intervention on how to combine students with different thinking preferences and attributes to foster harmony among them. Since generally, the developed profiling system has been found to positively enhance critical thinking and problem-solving skills, it can be disseminated to other teachers concerned for utilization, integration, and further evaluation.

Before the start of the intervention, participants' critical thinking and problem-solving skills were low. After three months of implementation, these two skills increased due to the effect of grouping mechanisms on group tasks. The grouping composition helped each member of the group to become interdependent to each other through collaboration. Different experiences during group activity helped them to build rapport among them. Moreover, the concept of Emergenetics® is a grouping mechanism that helped the participants to enhance their critical thinking and problem-solving in mathematics.

Participation of each member to Emergenetics® groups can be adopted by other teachers to ensure their effective performance in math group tasks. Rest assured that the four thinking preferences are present in every group to complement each other and maximize the utilization of their potentials. Combining students with different thinking abilities makes the group more innovative and creative in dealing with the problem. Needless to say, homogenous groups contribute to perform well together on particular objectives while heterogeneous groups contribute to be more effective at formulating ingenious solutions (Bekele, 2006). Grouping the students heterogeneously means combining different abilities as one despite their different thinking preferences. Heterogeneous ability grouping is more fruitful than homogeneous ability grouping for learners with advanced understanding, while on average, with poor ability learners who have difficulty in learning (Murphy et al., 2017). Heterogeneous groups are still more beneficial than homogeneous groups implying heterogeneous groups are the better option in group composition (Wichmann et al., 2016). Moreover, heterogeneous groups of students with a diversity of thinking preferences can acquire learning from sharing ideas and happy with the learning experiences and the results of their work (Sundquist, 2019).

In addition, considering the individuality of the dominant math thinking attribute of the students, it is suggested to have a study on corresponding math pedagogy and instruction that can be facilitated to address critical thinking and problem-solving skills through group activities for students with diverse math attributes in a classroom setting. This makes the teachers mindful of the individuality of his/her students considering thinking preferences which enable the teachers to better understand how these students are thinking and working for. It is suggested to have a small group task for the students to facilitate learning in groups. Small-group tasks give a better avenue for students to identify and settle knowledge deficiency and cognitive struggle (Wichmann et al., 2016).

This study is limited to three sections of Grade 11 in the San Pedro Relocation Center National High School-Main Campus. It is better if Emergenetics® as a grouping mechanism was used in a big population to verify the findings of this study. Generally, it is better if this grouping mechanism is used in different subjects to gather more empirical data. However, due to the restriction of time imposed and scope of action research, selected students were utilized which served as the participants. The use of Emergenetics® as a grouping mechanism can be pioneered in the city of San Pedro on a larger scale for cross-validation. Hence, this study helps the teachers gain a better understanding of how group composition is formulated to make the students more productive in doing tasks collaboratively.

This study challenges the future researchers to develop a more general profiling system based on Emergenetics® theory that needs to include the behavior attributes which is not much considered in this study. Aside from the thinking attributes, behavioral attributes on the Emergenetics® profiling system would be more comprehensive if both traits can be accredited. This calls for a more analytical and sophisticated profiling system that caters both cognitive and affective aspects of the learning process. Moreover, it is highly suggested to conduct a similar study in different settings to verify the findings of this study.

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