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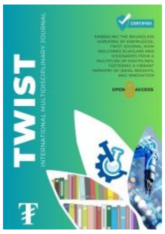

Integration of Van Hiele's Phase-Based Learning for Student's Critical and Creative Thinking Skills Improvement in Algebra

Maidy F. Redublo
Department of Education, Leonarda D. Vera Cruz National High School,
Unisan, Quezon, 4305, Philippines

Rose R. Andrade*
Faculty of College of Teacher Education-Graduate Studies and Applied Research,
Laguna State Polytechnic University-San Pablo City Campus, San Pablo City, Laguna, 4000, Philippines
[**Corresponding author*]

Abstract
Cultivating 21st-century skills is imperative in this rapidly changing environment. To keep pace with these impending shifts, incessant and heightened revision in the educational system must be done to meet future challenges. Thus, the main goal of the study was to determine the effectiveness of Van Hiele's phase-based learning in improving the critical and creative thinking skills of Grade 9 students. This study utilized a quasi-experimental research design using two groups which consisted of a total of 84 respondents. The control group learned through traditional instruction, while Van Hiele's phase-based learning was used to teach those from the experimental group. A significant change was found in the results of the critical thinking skills of the students as to analysis, judgment, and decision-making and creative thinking skills as to fluency, flexibility, and elaboration. Hence, integrating Van Hiele's phase-based learning into mathematics instruction efficiently improves the student's critical and creative thinking skills. However, no significant change was found in the critical thinking skills as to reasoning and creative thinking skills as to originality. The present study recommends to future researchers that they conduct similar studies using different grade levels in other branches of mathematics.

Keywords
Van Hiele's Phase-based learning, Critical thinking, Creative thinking

INTRODUCTION

The global economy calls for educational reform to meet its growing needs. Thus, the Philippines adopted the kindergarten through grade 12 basic education program. Under the K-12 program is the Mathematics Curriculum, which encompasses skills that 21st-century students should possess (Balagtas et al., 2019). Among these skills are the Higher-Order Thinking Skills (HOTS), which primarily made up of extensive critical and creative thinking processes that allow a person to solve complicated problems. They assist students in critically evaluating information before drawing initial conclusions and generalizations. Hence, it is imperative to incorporate these types of thinking skills into the curriculum to encourage students to think critically and creatively while also helping them justify their solutions when solving complex mathematical problems (Abdul et al., 2022).

Critical thinking is usually used when someone is carefully making decisions, planning strategically, applying processes scientifically and solving problems in daily living (Mohammed, 2021). On the other hand, creative thinking is a skill that is rational and divergent to develop new ideas inspired by unique and challenging problems (As'ari et al., 2020). According to Youssif et al. (2021), a significant positive correlation lies between student's creative writing and critical thinking skills, which means that students who are good at creative writing are more likely to possess a high level of critical thinking skills.

As to Bora (2020), critical thinking and creativity may be thought of as two peas in a pod because great reasoning requires the ability to create scholarly items, which is linked to creativity. In addition, these two skills cannot be replaced by artificial intelligence (AI) but can expand it to new frontiers and promote its development (Markauskaite et al., 2022). AI carries both promising and harmful effects on education, for instance, the threats to the critical and creative thinking skills of the students (Humble et al., 2019; Propenici & Kerr, 2017; Wogu et al., 2018). With this, students must have a strong foundation in these domains. Thus, several researchers have investigated how these two skills can be fostered by applying the Van Hiele model in the classroom instruction (Siew & Chong, 2014; Musdi et al., 2020).

To illustrate the changes of the thinking process in Van Hiele's phase-based learning, "information, guided orientation, explication, free orientation, and integration" were employed (Al-ebous, 2016; Armah et al., 2019; Luneta & Mbusi, 2021; Pujawan et al., 2020; Roldan-Zafra et al., 2022). Information is where the teaching of the topic starts, which helps the students discover specific structures, make a review of what they have already learned, and make them feel motivated to learn. Guided orientation is the presentation of tasks to help students realize and communicate their new comprehension of the geometric concepts taught in the first phase. Explication is where the engagement happens, when students verbalize their knowledge of the geometric principles that they have witnessed and share ideas with their peers or classmates. Free orientation is where the students finish their task in various ways and obtain experience from it. Integration is the part where students summarize what they have learned and draw some new conclusions (Al-ebous, 2016). This pedagogical lens can be used to guide teachers in developing relevant activities for a specific lesson (Adeniji & Baker, 2022). These phases of learning were embodied in the lesson plan or study to foster the critical and creative thinking skills of the students.

It is alarming that for the past years Filipino students performed a below average performance in Mathematics in international assessment (Program for International Student Assessment [PISA], 2018). Consequently, the Philippines is placed at the second bottom rank among 79 participating countries. This shows that enhancing students 21^{st} century skills, for instance, the problem-solving, critical and creative thinking skills is gravely important.

Moreover, one national high school in Quezon, Philippines did not meet the goal of the Department of Education (DepEd) for the last three years as shown in the mean percentage score (MPS) in mathematics, which is to attain 75%, putting it to ranked 8^{th} or lowest among all the subjects in junior high school. In addition, the MPS of mathematics was at its lowest almost every first quarter which indicates that the students have no mastery of the competencies on algebra topics. Consequently, the identified least learned competency in the first quarter of Grade 9 was solving quadratic equations.

According to Siew and Chong (2014), Van Hiele's phase-based learning demonstrates positive change in the critical and creative thinking in the different areas of mathematics. The same findings were yielded by Musdi et al. (2020). Furthermore, several studies concluded that Van Hiele's model was very effective in learning geometry (Abdullah et al., 2013; Alex & Mammen, 2016; Ansah et al., 2021; Machisi & Feza, 2021) and suggested to confirm its efficiency in other areas of mathematics (Adeniji & Baker, 2022; Colignatus, 2015; Sadiki, 2016). Thus, the researcher utilized Van Hiele's phase-based learning to foster students' critical and creative thinking skills in algebra.

RESEARCH PROBLEMS

Specifically, this study intended to answer the given questions:

1. Does significant change exist between both groups' initial and final score as to their critical thinking skills?
2. Does significant change exist between both groups' initial and final score as to their creative thinking skills?
3. Does significant change exist between the students' initial score in both groups as to their critical and creative thinking skills?
4. Does significant change exist between the students' final score in both groups as to their critical and creative thinking skills?

MATERIALS AND METHODS

Quasi-experimental research design was used in which some respondents were acquainted with Van Hiele's phase-based instruction and others were not at random (Gopalan et al., 2020). The control group represents what would have been the outcomes if Van Hiele's phase-based learning was not integrated into the algebraic instruction. Thus, the integration of Van Hiele's phase-based learning into the teaching and learning process can be argued to have produced any change in outcomes of the experimental group (White & Sabarwal, 2014).

Respondents were selected using stratified random sampling technique from four sections of Grade 9, consisting of twenty-one (21) students from each section: seven (7) high-achieving, seven (7) average-achieving and seven (7) low-achieving students. There were forty-two (42) respondents in the control group and another forty-two (42) in the experimental group, for a total of 84 student-respondents. A population is divided into groups using stratified sampling, which then includes a portion of each group's members (Zach, 2021).

The initial and final examinations were utilized to gauge the critical and creative thinking skills of the students, with a content validation index of 0.98. These were carefully drafted to ensure that the domains of critical and creative thinking skills were measured. It consists of two parts; the first part includes twenty (20) multiple-choice questions for critical thinking: five (5) for analysis, five (5) for reasoning, five (5) for judgment, and another five (5) questions for decision-making. These questions were aligned with the Multi-Dimensional Assessment along with its rubric proposed by the DepEd-Division of Quezon (DM No. 610 s. 2022), while the second part contains five (5) questions under creative thinking as to "fluency, flexibility, originality, and elaboration" along with the rubrics formulated, which were adopted and revised from different research studies (Blyman et al., 2020; Munahefi et al., 2021).

Table 1 exhibits the outcome of the test reliability for the critical thinking questionnaire using the Kuder-Richardson method. In this case, initial and final scores were reported separately, and each score was associated with a Kuder-Richardson coefficient (KR coefficient).

Table 1 Test Reliability Results for Critical Thinking (Pradana et al., 2023)

	KR Coefficient	Interpretation
Initial Test	0.87	Very high reliability
Final Test	0.88	Very high reliability

Legend: 0-0.20 Very low reliability, 0.21-0.40 Low reliability, 0.41-0.60 Intermediate reliability, 0.61-0.80 High reliability, and 0.81-1.00 Very high reliability

For the initial test, the KR coefficient was 0.87, which indicates very high reliability. For the final test, the KR coefficient was 0.88, which was slightly higher than the initial and also indicates very high reliability. Thus, both coefficients indicated a higher level of internal consistency reliability and was typically preferable (Ntumi et al., 2023).

Table 2 conveys the outcome of the inter-rater test reliability of the research instruments for the creative thinking questionnaire using the correlation coefficient. In this case, the initial and final test scores were reported separately, and each score given by the raters was associated with a correlation coefficient.

Table 2 Test Reliability Results for Creative Thinking (Napitupulu et al., 2018)

	Correlation Coefficient	Interpretation
Initial Test Rating	0.916	Very strong correlation
Final Test Rating	0.922	Very strong correlation

Legend: 0-0.199 Very weak correlation, 0.20-0.399 Weak correlation, 0.40-0.599 Medium correlation, 0.60-0.799 Strong correlation, and 0.80-1.000 Very strong correlation

The initial test rating correlation value was 0.916, indicating a very strong relationship. Moreover, the final test rating correlation value was 0.922. Thus, both coefficients imply a very strong correlation, which makes the rubric used in scoring the responses in the creative thinking questionnaire reliable (Schober et al., 2018).

The researcher sought first for the approval of the paper, evaluated instruments, a rubric, and a lesson plan, and secured permissions to conduct the present study.

The classroom instruction started with the information phase, wherein students were given an answer sheet with several questions that caters their critical thinking skills and eventually led them to acquire new information while incorporating prior knowledge or understanding about quadratic equations. During this phase, students were able to define mathematical terms, analyze situations, and reflect on their own ideas. After the students had time to reflect and the teacher had given them feedback while ensuring that they were able to do the task on the first phase, they were ready to move on to the next phase.

After the information phase, students moved to the guided orientation phase. During this phase, students were able to do the assigned task in connection with the acquired information from the previous phase, but with the guidance of their teacher. This was where the students applied what had been introduced in the previous phase. They were also guided by several questions that helped them understand the step-by-step procedure of solving and illustrating quadratic equations, which led them to the correct answers and a clear understanding of the quadratic equations. Students were also able to reflect on their own thinking, which helped them have a clear understanding of solving and illustrating quadratic equations.

In the third phase, the students encountered the explication phase, wherein they were going to do a task with a minimal guide from their teacher. During this phase, students were able to apply what they had learned from the previous phases. This was where they encountered and learned different methods of solving quadratic equations. They were able to engage with their teacher as well as with their classmates by finishing the assigned task about solving quadratic equations using any of the taught techniques, exchanging ideas with their classmates and teacher, and sharing their answers with the whole class through the think-pair-share activity. In this phase, students were also able to explain their answers comprehensively and flexibly, getting all the possible correct answers.

The fourth phase, or the free orientation phase, provided an opportunity for the students to collaborate with each other by dealing with non-routine problems involving quadratic equations. During this phase, students were able to apply what they had learned from the previous phases by solving real-life problems involving quadratic equations. They were also able to explore, discover, create new methods or techniques of solving quadratic equation, and appreciate the significance of quadratic equations in real-world situations.

The last phase was the integration phase. During this phase, the students were able to summarize what they had learned from the previous phases and draw a new conclusion about quadratic equations by answering several questions. This phase helped students reflect on and justify their own learning. The final tests for critical thinking and creative thinking were given on the last two days of implementation. To analyze the data, frequency, percentage, mean and standard deviation were applied to know the initial and final scores of the students. To check if the data are normally distributed, Kolmogorov-Smirnov Test was used. Furthermore, dependent t-test was utilized to calculate whether a significant change existed between their critical and creative thinkings' initial and final scores. Lastly, independent t-test was used to find out whether a significant change existed in the initial and final scores of the respondents in the control and experimental groups as to their critical and creative thinking skills.

RESULTS AND DISCUSSION

Table 3 demonstrates a p-value of 0.000 in both groups for all domains of critical thinking skill which pose a significant change between the initial and final scores of the students. This implies that the use of the daily lesson plan (DLP) or the traditional approach in classroom instruction was also good at strengthening the critical thinking skills of the students. Masek and Yamin (2012) affirmed that the lecture method or conventional approach enhances the student's critical thinking ability as compared to problem-based learning. However, it is still scanty to achieve the expert level in critical thinking skills as to analysis, reasoning, judgment, and decision-making, as shown by the final mean scores. Supported by Hitchcock (2017) that there is only a slight improvement in the student's critical thinking skills in the traditional critical thinking courses.

Moreover, it is evident that there is a high increase in the mean percentage score of the students in the experimental group in terms of their critical thinking skills as to analysis, reasoning, judgment, and decision-making, which means that after the implementation of Van Hiele's phase-based learning, the student's critical thinking skills were improved. Van Hiele's phase-based learning aid students boost their critical thinking skills through the given questions in the information, guided orientation, and integration phases, which require them to think deeply, analyze, and reason out what eventually leads to a conclusion. Moreover, different tasks under the aforementioned phases also allowed students to make judgments and decisions on illustrating and solving quadratic equations, specifically on the step-by-step procedure of each method. Thus, Van Hiele's phase-based learning is effective in improving the critical thinking skills of the students. This is in line with Musdi et al. (2020), who found out that the learning tools (lesson plans and worksheets) produced based on Van Hiele's phase-based learning are effective in increasing the critical thinking skills of the students.

Table 3 Initial and Final Score Difference in the Control and Experimental Group

Critical Thinking	Initial		Final		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Control Group							
Analysis	6.71	2.29	10.19	2.10	-7.935	41	.000
Reasoning	8.21	1.57	11.31	2.21	-9.584	41	.000
Judgment	7.57	1.78	10.88	2.36	-9.500	41	.000
Decision-Making	6.45	2.09	10.10	2.13	-12.040	41	.000
Experimental Group							
Analysis	5.88	2.36	11.90	2.42	-14.913	41	.000
Reasoning	7.90	2.29	12.00	2.39	-9.389	41	.000
Judgment	8.93	1.99	12.74	1.77	-11.002	41	.000
Decision-Making	5.71	2.27	11.43	2.53	-13.587	41	.000

Table 4 conveys a significant change between the initial and final scores of the students in the control and experimental group on their creative thinking skills with p-values of 0.000 in all domains. This implies that in the control group, the utilization of a daily lesson plan (DLP) or traditional instruction was also good at enhancing the creative thinking skills of the students. Arga et al. (2020) mentioned that traditional instruction can be used to develop students' creative thinking abilities. However, it was still rare for the students to achieve the mastery or even expert level in any of the domains of creative thinking skills.

Furthermore, in the experimental group, it is evident that there is a high increase in the MPS of the students as to their creative thinking skills. It only demonstrates that the application of Van Hiele's phase-based through the different tasks under the explication and free orientation phases aids student achieve an increased level in their creative thinking skills. In the explication phase, students were able to explain in detail the solution to a certain algebraic equation, which enabled them to elaborate their answers. Moreover, during the free orientation phase, students were allowed to use their own techniques or ways of solving a real-life problem involving a quadratic equation, which aided them to determine all possible correct answers. This affirms the findings of Rahayuningsih et al. (2021) that the open-ended approach assists the students' development of creative thinking abilities particularly cognitive fluency and flexibility. Thus, the use of Van Hiele's phase-based learning was efficient in fostering the creative thinking skills of the students. These findings are consistent with Siew and Chong (2014), who stated that tangram activities combined with Van Hiele's five phases of learning will encourage the students to think creatively.

Table 4 Initial and Final Score Difference in the Control and Experimental Groups

Creative Thinking	Initial		Final		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Control Group							
Fluency	3.10	2.39	6.79	3.61	-13.485	41	.000
Flexibility	4.64	3.02	8.67	3.28	-18.789	41	.000
Originality	3.52	2.67	7.55	3.71	-14.590	41	.000
Elaboration	3.67	2.72	7.74	3.69	-14.662	41	.000
Experimental Group							
Fluency	3.17	2.77	9.38	3.45	-24.468	41	.000
Flexibility	4.43	3.25	10.67	3.43	-25.936	41	.000
Originality	3.05	2.57	8.81	3.56	-16.436	41	.000
Elaboration	3.05	2.50	9.33	3.38	-22.485	41	.000

The findings conveyed in table 5 shows that the two groups' mean initial results in terms of critical and creative thinking skills were nearly identical. This implies that the present study's respondents are equally distributed. The Department of Education (DepEd) encourages heterogeneous parting of classes rather than homogeneous ones, wherein the number of academically proficient students varies by section (de Guzman & Balmeo, 2018).

Table 5 Initial Score Difference Between the Control and Experimental Groups

	Control		Experimental		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Critical Thinking Skills							
Analysis	6.71	2.29	5.88	2.36	1.643	82	.104
Reasoning	8.21	1.57	7.90	2.29	.722	82	.472
Judgment	7.57	1.78	8.93	1.99	-3.290	82	.001
Decision-Making	6.45	2.09	5.71	2.27	1.553	82	.124
Creative Thinking Skills							
Fluency	3.10	2.39	3.17	2.77	-.127	82	.900
Flexibility	4.64	3.02	4.43	3.25	.313	82	.755
Originality	3.52	2.67	3.05	2.57	.833	82	.407
Elaboration	3.67	2.72	3.05	2.50	1.086	82	.281

However, significant change existed in the initial scores of the two groups as to judgment which has a p-value of 0.001. It is evident that in the initial score of the two groups, students from the experimental group dominated the scores. They were observed to be active participants in the different extracurricular activities at the school. Thus, even though the respondents were evenly distributed, students in the experimental group who happened to be part of the school's newspaper, academic excellence awardees, and chess players, were the ones who dominated the scores as to judgment. Jankovic and Novak (2019) claimed that chess is an effective educational tool due to its advantageous characteristics, one of which is critical thinking, which involves the capacity to appraise strengths and weaknesses, develop value judgments, and make decisions. Thus, students who play chess possess these critical thinking factors.

Table 6 Final Score Difference Between the Control and Experimental Groups

	Control		Experimental		t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Critical Thinking Skills							
Analysis	10.19	2.10	11.90	2.42	-3.471	82	.001
Reasoning	11.31	2.21	12.00	2.39	-1.374	82	.173
Judgment	10.88	2.36	12.74	1.77	-4.081	82	.000
Decision-Making	10.10	2.13	11.43	2.53	-2.614	82	.011
Creative Thinking Skills							
Fluency	6.79	3.61	9.38	3.45	-3.367	82	.001
Flexibility	8.67	3.28	10.67	3.43	-2.732	82	.008
Originality	7.55	3.71	8.81	3.56	-1.590	82	.116
Elaboration	7.74	3.69	9.33	3.38	-2.067	82	.042

It could be drawn from table 6 that in the experimental group, the mean final score of the students for all the domains of critical thinking skills is way higher than the mean final score of the control group. The mean final score of the students in the experimental group ranges from master to expert level, while in the control group, student's mean score is only at the master level. This signifies that incorporating Van Hiele's phase-based learning into mathematics instruction is far more effective than traditional instruction in fostering the critical thinking skills of the students as to analysis, judgment, and decision-making with p-values less than 0.05. Three of Van Hiele's five phases of learning, "information, guided orientation, and integration" with the use of Socratic questions and tasks exceptionally help the students cultivate their critical thinking skills which allow them to think, analyze, reason out, make a judgment, and make a decision on illustrating and solving quadratic equations. Supported by Alsaleh (2020) and Sahamid (2016), who both claimed that the Socratic questioning technique is one of the strategies that enhances the critical thinking skills of the students. Moreover, Van Hiele's phase-based learning allowed students to think outside the box, which led them to draw conclusions rather than just answering questions that did not require them to think deeply. It also allowed students to reflect on their performance in each phase, which enabled them to assess their learning, which was not present in traditional instruction.

On the other hand, the table also shows that there is no significant change between the final scores of the control and experimental groups in terms of critical thinking skills as to reasoning. This means that the final scores of the two groups do not significantly differ from one another as to reasoning. According to Ayal et al. (2016), one of the major problems in mathematics education is the absence of mathematical reasoning skills among the junior high. They further asserted that most teachers pay less attention to students' ability to reason out. This causes students to think in mechanistic and less honed reasoning ways, making it difficult for them to solve new problems. This is in consonant with Sofiyati's (2022) that students with low levels of critical thinking, lack reasoning skills and the ability to deal with real-world circumstances. As a result, they are unable to assure the validity of their responses because they fail to check and verify their solutions.

The table also reveals that a significant change existed between the final scores of the two groups in terms of creative thinking skills as to fluency, flexibility, and elaboration.

It could be derived from Table 6 that in the experimental group, the mean final score of the students for all the domains of the creative thinking skills is way higher than the mean final score of the control group. The mean final score of the students in the experimental group ranges from quite master to master level, while in the control group, student's mean score is only at the quite master level. The efficacy of Van Hiele's phase-based learning in fostering the creative thinking skills of the students was evident in each phase of instruction, specifically in the explication and free orientation phases. These phases of learning aid students foster their creative thinking skills through the different tasks, which enable them to elaborate on their answers by explaining the solution or process in detail and using their own techniques or ways of solving a quadratic equation. Furthermore, Van Hiele's phase-based learning allowed students to explore the real-life applications and apply through any medium to solve different worded problems applying quadratic equations, which was not given emphasis in the traditional instruction since it just enabled students to provide answers to the given tasks.

On the other hand, it could be obtained from the table that no significant change existed between the final scores of the two groups in terms of creative thinking as to originality. According to Siew and Chong (2016), numerous factors could be responsible for the decline in creativity as to originality. It could be attributed that pupils learned to construct some figures during group exercises, which acted as a springboard for their creativity. Murtianto et al. (2019) confirmed that students are prone to errors in solving a problem and deficient in thinking, investigating, or looking for something "new" since they lack the capability and novelty to either solve or suggest a problem. As a result, there is a need to break free from these common thought patterns and seek out more novel solutions (Bishara, 2016).

Furthermore, it is likely true that student's low mathematical reasoning ability results in low creative thinking ability as to originality. This supports Firdausy et al.'s (2021) results that pupils in the low reasoning categories are only capable to answer questions and unable to fulfill any parts of creative thinking.

FINDINGS AND CONCLUSIONS

It was found out that the use of traditional instruction and Van-Hiele's phase-based learning were both efficient in improving the student's critical and creative thinking skills. However, no significant change was found in the critical thinking skills as to reasoning and creative thinking skills as to originality after the exposure to Van Hiele's phase-based learning. Moreover, the mean final scores of the control and experimental groups revealed that the utilization of Van Hiele's phase-based learning creates a higher improvement in the critical thinking skills of the students in terms of analysis, judgment, and decision-making and creative thinking skills as to fluency, flexibility, and elaboration compared to the traditional instruction. Thus, Van Hiele's phase-based learning is more efficient in improving the critical and creative thinking skills of the students.

RECOMMENDATIONS

Based on the above conclusions, mathematics teachers may integrate Van Hiele's phase-based learning into their lesson plans to develop 21st century skills, specifically their critical and creative thinking skills. To further enhance the process of integrating Van Hiele's phase-based learning into the mathematics instruction, a well-organized lesson plan suited to the respective time frame should be carefully dealt with. Moreover, to confirm the results of the study, future researchers may conduct similar investigations using different grade levels in other branches of mathematics.

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DECLARATION OF CONFLICT

The authors declare that no conflict can be derived from this study.

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