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Deriving the Angles of a Convex Polygon through Realistic Mathematics Education Approach

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Abstract

Realistic Mathematics Education (RME) is a learning strategy that allows students to engage with real-world contexts. This study aimed to evaluate the performance of Grade 7 students in deriving the relationship between the exterior and interior angles of a convex polygon, identified as the least mastered competency, using the RME approach. A quantitative, quasi-experimental one-group pre-test and post-test design was employed, with 41 Grade 7 students from a National High School in Biliran, Philippines serving as the respondents. Data were analyzed using mean, standard deviation, and Wilcoxon signed-rank test. The pre-test results classified students' performance as "Did Not Meet Expectations," while post-test results improved to "Fairly Satisfactory." The Wilcoxon signed-rank test revealed a significant difference between pre-test and post-test scores, demonstrating the effectiveness of the RME approach in enhancing students' understanding of the targeted competency. It is recommended that future studies explore broader settings, different competencies, and longer implementation durations for the RME approach.

Keywords: realistic mathematics education approach, convex polygon, real-world context, mathematics performance

Introduction

Background of the Study

Geometry is the basis for many advanced mathematical concepts and theories. A strong basis for additional mathematical study is laid by comprehending the relationship of external and internal angles of a convex polygon. This helps learners to clearly understand its concept and is a necessary skill for future geometry topics.

In geometry, it is recommended that schools create a more contextual environment that is rich in information about how to solve real-life problems (Laurens et al., 2018). When children can relate their mathematical understanding to practical situations, they become more engaged and understand why and how specific calculations are used to solve problems (Listiawati et al., 2023). Therefore, teachers may utilize it to expose their students to more engaging and collaborative learning experiences with the incorporation of real-world scenarios (Dinglasan, Caraan & Ching, 2023).

To implement engaging learning in lower-grade classes, teachers must be creative and innovative. They are required to deliver mathematical material that is interesting, fun, and relates to contextual problems according to the slow

learner ecosystem (Hafidah & Rukli, 2022). In line with this, the utilization of Realistic Mathematics Education (RME) approach emphasizes mathematics as a human activity, expressing process over results, and involves authentic problems and problem-solving that can be interpreted realistically according to the context (Nurmasari et al., 2024). Furthermore, Putranto & Marsigit (2018) revealed the effectiveness of this method and approach to improve other cognitive or affective aspects of slow learners.

Laurens et al. (2018) asserted that mathematics teachers need to apply the Realistic Mathematics Education Approach in the classroom to make abstract mathematical concepts more understandable. The teachers must develop more appropriate learning media, strategies, or models that are more suitable for learning materials or with the contexts that their students are dealing with. Moreover, RME represents an encompassing pedagogical approach that fosters mathematical learning for individuals across a broad spectrum of abilities, emphasizing its relevance for all rather than solely providing it to those considered slow learners (Listiawati et al., 2023).

Applying the RME through the use of concrete instructional materials or models in solving problems involving real-life situations. It positively affects students' making the connection between mathematics and real life and enables them to start using mathematical knowledge in many different areas of real life (Üredi & Doganay, 2023). Learning materials based on a realistic mathematics education approach are important things to consider to maximize student mathematics learning achievement. Thus, it is expected that mathematics teachers seek mathematical learning using learning materials based on a realistic mathematics education approach (Ulandari, Amry & Saragihhows, 2019)

Mathematical learning becomes more meaningful and students' approaches to solving geometric problems become more diverse when they are exposed to realistic mathematics education (Nirawati et al., 2021). Numerous research studies have demonstrated the efficacy of the Realistic Mathematics approach as a teaching and learning intervention. The present study centers on the Realistic Mathematics Education as an approach in enhancing the student's performance in deriving the relationship of the exterior and interior angles of a convex polygon. Thus, Prior studies have found that students who studied with RME performed better than those who learned through conventional methods (Laurens et al., 2018).

One of the least learned concept of the seventh graders at the identified National High School is deriving the relationship between the exterior and interior angles of a convex polygon. For the previously described rationale as well as to address the identified least learned competencies in mathematics, the researchers intend to use the Realistic mathematics education approach.

Objectives of the Study

The study investigated the use of the Realistic Mathematics Education (RME) approach in enhancing the class performance of Grade 7 students in deriving the relationship between the exterior and interior angles of a convex polygon. Specifically, it aimed to achieve three objectives. First, it sought to determine the pre-test score of the respondents in deriving the relationship between the exterior and interior angles of a convex polygon. Second, it aimed to determine the post-test score of the respondents for the same concept. Lastly, the study sought to determine the significant difference between the pre-test and post-test scores of the respondents in deriving the relationship between the exterior and interior angles of a convex polygon.

Theoretical Framework

Realistic Mathematics Education (RME) is a theory of mathematics education, developed in the Netherlands by H. Freudenthal in 1971. One aspect of realistic mathematics education (RME) is learning that starts with this real-world scenario. According to Van den Heuvel-Panhuizen & Drijvers (2014), RME is a special theory of mathematics instruction. This approach's peculiarity is that it gives rich and "realistic" situations and a prominent position in learning activities. Teaching and learning RME have five main criteria, namely, students' experience in daily life; changing reality to a model and changing the model through a mathematical vertical process before turning it into a formal system; use of students' active style; use of discussions and question and answer methods to cultivate the mathematics skills of students and formation of a connection between concepts and topics until learning becomes holistic and complete (Yuanita, Zulnaidi, & Zakaria, 2018).

This study was supported by John Dewey's (1938) theories about education and social reform. These ground-breaking theories on education centered on the notion of experiential learning, which shares that all knowledge should be rooted in real, practical experience and that students could only genuinely engage in meaningful research and learning when they experimented or dealt with the material directly. John Dewey's view on pedagogy was that it should be a holistic approach to teaching and learning. He believed in using experiential learning as part of the educational process, whereby students are encouraged to combine their theoretical knowledge with practical experience.

Dewey's philosophy of "Learning by Doing" offers a robust framework for fostering deep, meaningful learning experiences. His ideas underscore the importance of active engagement, problem-solving, and social interaction in the learning process. Dewey also focused on providing meaningful experiences that contribute to a student's growth as a learner. He believed that this type of pedagogy could help shape a well-rounded student who can think critically and take tangible skills into the world

About one's build representation and incorporating new ideas, Constructivism Learning Theory is a concept that supports this area. Constructivism is a learning theory that emphasizes the active role of learners in building their understanding. Rather than passively receiving information, learners reflect on their experiences, create mental representations, and incorporate new knowledge into their schemas. This promotes deeper learning and understanding. According to Ayaz & Hanifi (2015), the constructivist learning approach makes a more significant contribution to learners' academic achievement than traditional learning methods.

Sarbah (2020) asserted that Constructivist learning approaches such as inquiry-based learning which also allows students to explore a subject can be adopted in the classroom. Therefore, constructivism is a wide theoretical framework that proposes that rather than passively absorbing knowledge, students actively construct their view of the world through interactions with their surroundings. It places a strong emphasis on the value of social interaction, experience learning, and the synthesis of new and prior information.

Conceptual Framework

This framework summarizes the major concepts and the underlying basis of the investigation. The initial phase of the study is administering a pre-test, followed by the intervention using Realistic Mathematics Education approach. After the intervention, a post-test is conducted to assess changes in students' scores and determine if there is a statistically significant difference between the pre-test and post-test results. These results are analyzed to evaluate whether the performance of Grade 7 students on the topic 'Deriving the relationship between the exterior and interior angles of a convex polygon' improves through the application of the RME approach.

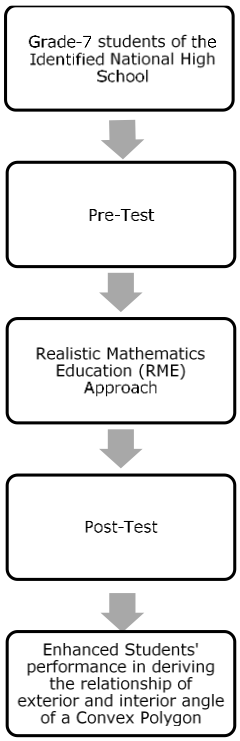

Figure 1. The Conceptual Framework of the Study

Literature Review

Many studies show that the RME approach can effectively improve students' mathematical abilities, Mutaqin et al. (2021) suggested that teachers who implement the RME approach focus on concrete media and further increase the ability to stimulate students to ask questions so that students are more active in learning activities.

To overcome obstacles for trainee teachers in teaching practical mathematics, the study of Wahyudi et al. (2017) proposed the following solutions: (1) reinforcing the mastery of teaching knowledge and mathematical concepts, (2) strengthening the relationship between teaching knowledge with practical problems. (3) fortifying the ability to identify and use visual/communication tools in math teaching, (4) reinforcing a variety of teaching methods, (5) consolidating standardized ability to have teaching lesson plans, and (6) strengthening the ability to simulate (Uyen, Tong, Loc & Thanh, 2021; Wahyudi et al., 2017).

The existence of real-life fields of study that require geometry has made the authorities of education systems consider geometry with the highest priority in school curricula right from the primary level. In line with this, the study of Deniz and Kabael (2017) examined the idea of the process of students re-forming the concept of angle coefficients through the development of right triangle models is demonstrated by the student's angle coefficient when the teaching process is created with the theory of RME. According to Afthina et al. (2017), the impact of the application of TPS learning model using the RME approach affects the increase of students' activeness in the learning activity and students' comprehension of geometry learning. It also increases awareness of students that mathematics application is used as well as beneficial in daily life aspects. Despite external factors such as the learning model and learning approach, it is important as well to consider internal factors, for example, the mathematical-logical intelligence of students.

The study of the properties of polygons, particularly the relationship between their interior angles, has been a topic of ongoing interest in the field of geometry. Meanwhile, researchers have continued to explore the inductive approach to deriving this fundamental relationship, with a focus on grounding the analysis in a realistic mathematics perspective. Educators want precise information that can be considered when implementing RME. In other words, a systematic study is required to comprehend the relationship between mathematical talents and the moderator's role in RME application (Juandi, D., Tamura, M. & Kusumah, Y., 2022)

Students in grade 4 had their mathematical ability evaluated by the Trends in International Mathematics and Science Study (TIMSS). Students' average score in 2015 was 397, which is much lower than the global average of 505 points (Nurmasari et al., 2024). Additionally, Reinke and Casto (2022) showed the correlation between using curricula that intentionally incorporate contexts as conceptual supports and developing more nuanced understandings of how contexts can foster deep mathematical understanding in students.

The role of students in RME is that they work individually or in a team, which means that students are free to make discoveries at their level, to build knowledge from their own experience. Nirawati et al. (2021) revealed that the student's ways of thinking have various visual interpretations and symbols, ways of explaining, approaches or strategies in problem-solving, and ways of concluding. Higher ability scores from students are achievable the more diversified ways of thinking they raise.

According to Hasibuan, Saragih & Amry (2019), one important factor that can improve mathematical skills is to conduct quality learning by making the right learning materials. The use of learning materials provides good benefits in learning. The purpose of developing learning materials is to improve and produce new products. It is a teaching method that uses students' everyday experiences as a starting point for their learning (Dinglasan, Caraan, & Ching, 2023). It proves sufficient understanding of math, including how to apply it in real-life scenarios. Furthermore, the RME approach incorporates three fundamental heuristic principles: guided reinvention, self-developed or emergent models, and didactical phenomenology (Bray & Tangney, 2016).

Üredi & Doğanay (2023) revealed that Realistic Mathematics Education reinforced with educational games improved secondary school sixth-grade students' skills in associating mathematics with real life. Accordingly, mathematics lessons could be lectured with problem situations selected from real life, educational games related to the subject taught in mathematics lessons could be included, and activities could be organized by the principles of Realistic Mathematics Education.

One approach to learning mathematics (including geometry) that emphasizes the use of contextual problems as a starting point for learning is Realistic Mathematics Education (RME). This RME came from the Dutch kingdom (Institut Freudenthal Universiti Utrecht), which was later adapted by Indonesia into Indonesian Realistic Mathematics Education (PMRI), which was adapted to conditions, nature, social systems, and culture (Ahmad, 2022).

Jannah, Aditya & Khoiriyah (2023) conducted a research focus on integrating Realistic Mathematics Education (RME), Problem-Based Learning (PBL), and Teams Games Tournaments (TGT) in Indonesia revealed that teachers can

consider choosing and implementing learning models that will be used in learning, teachers can use various learning models according to the material to be taught to create effective and efficient teaching and learning atmosphere. Besides that, it can also be used as reference material to add insight, knowledge, and skills for further research.

The reviewed related studies revealed that Realistic Mathematics Education is an effective and efficient approach where students can experience real-life context and application. Furthermore, research on the Realistic Mathematics Education approach is not widely known in the Philippines and has not been specifically incorporated into the curriculum. This study aimed to fill this gap by using the Realistic Mathematics Education approach to enhance the performance of the grade 7 students specifically in deriving the relationship of exterior and interior angle of a convex polygon.

Methodology

Research Design

This study utilized a quantitative research design, particularly the quasi-experimental one-group pretest-posttest design. According to Cook and Campbell (1979), a quasi-experiment is a research design that lacks the random assignment of subjects to experimental conditions. Although it often uses comparison groups, the groups may differ at the outset of the study, making it necessary to employ additional techniques to account for these preexisting differences. This allows the researchers to determine the performance of each student in deriving the relationship of the exterior and interior angle of a convex polygon through a pretest as well as determining if the student's performance in solving this specific topic enhanced after the implementation of the intervention.

Research Respondents

The respondents of this study were 41 Grade 7 students officially enrolled at a National High School in Naval, Biliran, Philippines, during the 2023-2024 school year. Only regular seventh-grade students were selected as respondents, as they were currently enrolled in Mathematics 7 classes.

Research Instrument

The data-gathering tool used in the study was a researcher-made 10-item test that has undergone validation and pilot testing. The validity of the research instrument was verified by four experts with an I-CVI equal to 1.0, which is interpreted as highly relevant. The researcher-made test was also pilot-tested in another National High School, and an item analysis was subsequently conducted. The discriminant and difficulty index of the test are interpreted as very good items and retain, respectively. Thus, the pilot study results indicated that the developed items are solid and strong for the actual study. The researchers used a lesson plan to apply the Realistic Mathematics Education Approach. Additionally, for the RME Approach as an intervention, the researchers used a model and other materials wherein the students could apply a realistic convex polygon that allowed them to understand the relationship between its exterior and interior angle.

Data Fathering Procedure

This study adhered to the standard protocol for conducting research. The researchers obtained an approval letter from the School Principal, as well as informed consent and assent from the adviser, respondents, and their parents, ensuring ethical compliance throughout the study. During the test, the researchers oriented the respondents about the objectives of the study. The researchers conducted a three-day intervention. On the first day, after clarifying the objectives, the researchers administered a pre-test to measure the students' prior knowledge of deriving the relationship between the exterior and interior angles of a convex polygon. After the pre-test, the researchers implemented a group motivational activity exploring the topic through the Realistic Mathematics Education (RME) approach. During the activity, the students were tasked with measuring the different angles of a convex polygon using tools such as a model, protractor, pencil, bond paper, and small sticks. After completing the activity, the students shared their thoughts on what they had learned and observed about convex polygons. On the second day, the researchers continued the activity and conducted a short discussion using the Realistic Mathematics Education approach, guided by a lesson plan. On the final day, the researchers conducted a brief review and evaluation, followed by a post-test parallel to the pre-test. To ensure the integrity of the results, the researchers collected the completed test instruments from the respondents immediately after they finished. The data was then checked, tabulated, and prepared for analysis and interpretation.

Data Analysis

All gathered data were analyzed using various statistical measurements to address the research questions and test the hypothesis of the study. The trial version of IBM SPSS version 20 served as the primary tool for conducting the statistical analyses. Specifically, the following statistical tools were employed: Frequency Count and Percentage were used to determine the frequency and percent distribution of the respondents' performance. This method allowed for the identification and representation of patterns within the data set. Mean and Standard Deviation were utilized to describe the central tendency and variability of the data. The mean provided the average score of the data values, while the standard deviation measured the extent to which individual scores deviated from the mean. These measures were particularly important for assessing the students' performance before and after the intervention. The researchers also tallied and categorized the students' performance using the grading scale outlined in DepEd Order No. 8, s. 2015. Scores of 90-100% were classified as "Outstanding" (9-10), 85-89% as "Very Satisfactory" (8), 80-84% as "Satisfactory" (7), 75-79% as "Fairly Satisfactory" (6), and below 75% as "Did Not Meet Expectations" Lastly, the Wilcoxon Signed-Rank Test, a nonparametric alternative to the dependent t-test, was applied to determine whether there was a significant difference between the pre-test and post-test scores. This test was particularly suitable for the study due to its ability to analyze paired or related samples without assuming a normal distribution.

Results and Discussions

Performance of the Respondents in Deriving the Relationship of an Exterior and Interior Angle of a Convex Polygon

Table 1
Pre-Test Results of the Respondents

Grading Scale (%)	Equivalent Score	Frequency	Percentage (%)	Interpretation
90-100	9-10	0	0	Outstanding
85-89	8	0	0	Very Satisfactory
80-84	7	3	7.32	Satisfactory
75-79	6	6	14.63	Fairly Satisfactory
Below 75	1-5	32	78.05	Did Not Meet Expectations

M = 3.98, SD = 1.59, Did Not Meet Expectation

Table 1 revealed that out of forty-one (41) students, none received a score of 8–10, meaning that none were considered outstanding or very satisfactory. Three (3) students, or 7.32% of the total, were found to be satisfactory, six (6) students, or 14.63% of the total, were found to be fairly satisfactory, and 32 (thirty-two) students, or 78.05% of the total, did not meet the expectations. Generally, the performance of the students based on their pre-tests scores was classified as Did Not Meet Expectation (M=3.98, SD=1.59). The result is supported by the study of Imam (2016) that the country's mathematics performance is still considered poor, and affirm that the initial result of current efforts of the government by adopting K-12 curriculum did not do much to change the status quo.

Table 2
Post-Test Results of the Respondents

Grading Scale (%)	Equivalent Score	Frequency	Percentage (%)	Interpretation
90-100	9-10	6	14.6	Outstanding
85-89	8	5	12.2	Very Satisfactory
80-84	7	5	12.2	Satisfactory
75-79	6	13	31.7	Fairly Satisfactory
Below 75	1-5	12	29.3	Did Not Meet Expectations

M = 6.41, SD = 1.78, Fairly Satisfactory

Table 2 showed that after the intervention, six (6) students or 14.6% of the forty-one (41) students were classified as outstanding, five (5) students or 12.2% of the students were considered very satisfactory, five (5) students or 12% of the students were considered satisfactory, thirteen (13) students or 31.7% of the students were fairly satisfactory, and twelve (12) students or 29.3% of the students did not meet the expectations. In general, the post-test results of the respondents were categorized as Fairly Satisfactory (M=6.41, SD=1.78). Therefore, the statistics demonstrated that the student's scores improved after the application of the Realistic Mathematics Education approach. Yuanita, Zulnaidi, & Zakaria (2018) claim that the use of RME can increase mathematical belief, representation and problem solving skills. This approach successfully trains students to formulate their own ideas from real-life situations or experiences. Thus, Outstanding improvement is reflected in the post-test performance of the students after the exposure to the RME approach (Dinglasan, Caraan & Ching, 2023).

Difference Between the Pre-Test and Post-Test Scores of the Respondents in Deriving the Relationship of an Exterior and Interior Angle of a Convex Polygon

To determine the significant difference between the pre-test and post-test scores, the Kolmogorov-Smirnov and Shapiro-Wilk tests were employed as a preliminary analysis to see whether the data was normally distributed.

Table 3
Test of Normality

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Test	.194	41	.000	.930	41	.014
Post-Test	.201	41	.000	.943	41	.040

Based on the Kolmogorov-Smirnov and Shapiro-Wilk test for normality, the data does not approximate a normal distribution, with a p-value less than .05 alpha level for each variable. The pre-test p-value is equal to .000 in Kolmogorov-Smirnov test while .014 in Shapiro-Wilk test and the post-test p-value is equal to .000 in Kolmogorov-Smirnov test and .040 in Shapiro-Wilk test. These results suggest a significant deviation from normality in the distribution of variables. Therefore, a dependent t-test, a parametric test, cannot be used for this analysis of difference. Hence, the Wilcoxon signed-rank test, a nonparametric test equivalent to a dependent t-test, was used. As the Wilcoxon signed-rank test does not assume normality in the data, it can be used when this assumption has been violated and the use of the dependent t-test is inappropriate.

Table 4
Results for Wilcoxon Signed-Rank Test showing Negative and Positive Ranks

		N	Mean Rank	Sum of Ranks
Post-test - Pre-test	Negative Ranks	3	4.00	12.00
	Positive Ranks	34	20.32	691.00
	Ties	4		
	Total	41		

Results for the Wilcoxon signed rank test showing negative and positive ranks are shown in table 4. Table 4 showed three (3) negative rank differences with a mean rank of 4, thirty-four (34) positive rank differences with a mean rank of 20.32, and four (4) tied scores. The findings indicate that, of the forty-one (41) students, three (3) had a lower score after the intervention, thirty-four (34) had a higher score, and four (4) had the same results as the pre-test. Note that the sum of the ranks is also reported. Soraya et al. (2018) revealed that RME can improve the ability of creative thinking, able to increase activity, creativity and communication skills to answer, able to integrate daily problems, student-centered, and the students have freedom in construing knowledge and understanding which are owned.

Table 5
Results for Wilcoxon Signed-Rank Test showing Significant Differences between Ranks

	Post-test - Pre-test	Decision
Z	5.166	The Null Hypothesis was Rejected
Asymp. Sig. (2-tailed)	.000	
Exact Sig. (2-tailed)	.000	
Exact Sig. (1-tailed)	.000	
Point Probability	.000	

Results reported in Table 5 show that the rank differences between the pretest and posttest scores were statistically significant ($z = 5.166$, $p = .000$) Based on the results, the z statistic is 5.166 and the corresponding p-value (Sig. 2-tailed) was .000. Therefore, the null hypothesis (There is no significant difference between the pre-test and post-test scores of the Grade 7 students in deriving the relationship between the exterior and interior angle of a convex polygon) was rejected. This is a strong evidence ($z = 5.166$, $p = .000$) that after the utilization of the Realistic Mathematics Education approach, there was a significant difference between the scores of students' pretest and posttest. It has been demonstrated that the realistic mathematics approach enhances student learning results, and it is advised that it be developed further over time to keep students engaged and motivated in mathematics instruction in particular (Qomario, Tohir, & Mashari, 2020).

Conclusion

The study's findings led to the conclusion that the use of the Realistic Mathematics Education (RME) approach significantly enhanced students' learning outcomes. Specifically, students demonstrated substantial improvement in their post-test scores compared to their pre-test scores, highlighting the positive impact of this teaching strategy on their performance. The statistical analysis supported this observation, with a p-value below the .05 alpha level, confirming a significant difference between the pre-test and post-test scores. This indicates that the RME approach effectively facilitated students' understanding of mathematical concepts, particularly the relationship between the exterior and interior angles of a convex polygon. By incorporating models, real-world contexts, and practical applications, the RME approach proved to be a valuable intervention in fostering deeper engagement and comprehension of the subject matter, making it an effective pedagogical tool in mathematics education.

Recommendation

Building on the results and discussion, several recommendations were formulated to enhance mathematics education. First, mathematics teachers are encouraged to identify and address the least learned topics in the subject. By doing so, they can assist students in appreciating and understanding mathematics in a more relatable and meaningful manner. Teachers should adopt strategies that enable students to comprehend complex topics, such as the relationship between the exterior and interior angles of a convex polygon, through realistic and practical experiences. Providing models and materials that simulate real-world contexts can help students grasp these concepts more effectively. Second, school administrators play a crucial role in supporting the implementation of the Realistic Mathematics Education (RME) approach. They are urged to provide resources and professional development opportunities, such as workshops and specialized teaching materials, to empower educators in utilizing this method effectively. Lastly, future research is recommended to expand the scope of the study. This includes exploring the application of the RME approach across a wider locale, incorporating different mathematical competencies, and allowing for a longer duration of implementation to assess its sustained impact. Collectively, these actions aim to create a more engaging and effective mathematics education experience for students.

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