

Clicking Into Algebra: Exploring Lego[®] Manipulatives' Impact on At-Risk Grade 8 Learners' Algebraic Reasoning Skills

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ABSTRACT

This action research investigates the effectiveness of LEGO[®] manipulatives in improving the algebraic reasoning skills of at-risk grade 8 learners. The study aims to determine if incorporating hands-on activities with Lego bricks leads to statistically significant gains in students' understanding and applying algebraic concepts. A purposive sample of 8 grade 8 students identified as at-risk in mathematics participated in the study. Selection criteria included past academic performance, teacher observations of learning difficulties, and documented learning challenges. This research employed an action research design with iterative cycles of implementation, observation, reflection, and refinement. The intervention involves integrating LEGO[®] manipulatives into lessons targeting key algebraic concepts. These activities will promote a deeper understanding of mathematical relationships and problem-solving skills. Pretest and post-test were administered, assessing algebraic reasoning skills to measure quantitative changes. Additionally, qualitative data will be gathered through classroom observations, student interviews, and teacher reflections. This data triangulation will provide a holistic understanding of the interventions' impact. According to the results, the post-test scores of students who participated in the Lego manipulatives intervention improved statistically significantly compared to their pretest levels. Qualitative data from observations, interviews, and reflections reveal increased student engagement, improved conceptual understanding, and enhanced problem-solving skills when utilizing LEGO[®] manipulatives. This action research can potentially demonstrate the effectiveness of LEGO[®] manipulatives in fostering algebraic reasoning skills among at-risk students. Developing more engaging and successful methods for teaching algebra to at-risk students may result in positive outcomes, which will also provide essential insights into mathematics education and inspire instructional approaches that accommodate a variety of learning styles. However, limitations inherent to action research, such as the small sample size and potential for research bias, necessitate further investigation in larger-scale studies.

Keywords: Action research, algebraic reasoning, at-risk students, LEGO[®] manipulatives.

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1. INTRODUCTION

The crisis of mathematics learning within the Philippine education system is a pressing concern, as Filipino students consistently demonstrate mediocre performance compared to their global counterparts (Bernardo *et al.*, 2022). Reports indicate that students in the Philippines

lag by an average of five to six years in mathematical competencies.

The Department of Education's (2019) findings reveal significant disparities in performance between public and private school students, with average scores of 343 and 395, respectively. This situation is further highlighted by the Philippines' PISA score from 2022, which showed no



significant improvement from previous years. In response to these challenges, innovative teaching strategies, mainly using manipulatives, have been explored to enhance student engagement and understanding of mathematics (Bernardo *et al.*, 2022).

Despite various interventions to improve math instruction, many students struggle with abstract concepts such as algebra, particularly those in high school. The inherent difficulties associated with algebra often lead to disengagement and negative attitudes towards mathematics (Aguilar, 2021).

This action research investigates explicitly the use of LEGO® bricks as manipulatives to enhance engagement and understanding in arithmetic among at-risk grade 8 students at St. Rita's College of Balingasag. Previous studies indicate that LEGO® improves problem-solving and mathematical fluency (Kazez Güneş & Genç, 2021). Furthermore, there is a notable lack of research focused on applying LEGO® bricks to enhance math skills among at-risk junior high school students.

Addressing this gap is significant because LEGO® bricks have the potential to serve as practical educational manipulatives that transform traditional learning methods into engaging hands-on experiences. By leveraging the constructivist framework, this research explores how active engagement with manipulatives like LEGO® can facilitate a more profound understanding and retention of mathematical concepts among students who typically struggle with conventional instruction.

Addressing the identified problem is crucial for several reasons. First, enhancing performance among at-risk students can improve academic outcomes and increase confidence in their mathematical abilities. Good results also surfaced as a reason for liking mathematics (Mazana *et al.*, 2018).

Second, adding manipulatives like LEGO® to the curriculum would encourage students to view mathematics more positively, lessening their fear and resistance to the subject. It was found that questions with abstract concepts are easier to understand through concrete manipulatives (Kazez Güneş & Genç, 2021).

The potential contribution of this research extends beyond individual classrooms; insights gained could inform broader educational practices aimed at improving math education across diverse learning environments. Various studies have demonstrated that physical objects ranging from blocks to geometric shapes can significantly enhance students' ability to grasp complex mathematical ideas (Mainali, 2021).

For instance, studies show that by enabling students to interact with and perceive mathematical concepts physically, manipulatives help close the gap between abstract ideas and concrete comprehension (Larbi & Mavis, 2016).

In particular, LEGO® bricks have emerged as versatile tools for teaching various math concepts. They facilitate hands-on exploration and encourage thinking while catering to different learning styles. Studies have shown that using LEGO® in educational settings can improve students' number awareness, logic, and overall comprehension (Kazez Güneş & Genç, 2021).

Furthermore, spatial numerical association theory states that constructing activities like building with LEGO® can enhance mathematical skills by improving visuospatial memory, a crucial cognitive process in learning mathematics (McDougal *et al.*, 2023). These findings suggest that engaging with LEGO® supports the development of foundational math skills and fosters collaboration and problem-solving abilities essential for academic success.

This study aims to investigate the influence of the activity, the perceived difficulties, and the increase in arithmetic ability of grade 8 students. Specifically, it aims to assess improvements in math performance through pretest and posttest evaluation while analyzing qualitative data from in-depth interviews. By addressing these objectives, this research provides valuable insights into effective teaching strategies to help at-risk students build a solid foundation in algebra and realize their full mathematical potential.

1.1. Statement of the Problem

Many students, especially those in high school, find abstract topics like algebra difficult to understand, even with a variety of interventions aimed at improving math instruction. Algebra's intrinsic challenges frequently cause disinterest and unfavorable opinions toward mathematics (Aguilar, 2021).

1. What is the level of the participants' achievement in Algebra?
2. Do the participants' pretest and posttest results for their algebraic proficiency alter significantly?
3. What are the participants' perceptions of their experiences utilizing LEGO® bricks as manipulatives in factoring polynomials?

2. METHODOLOGY

2.1. Research Design

This study's research design is action research. Action research is a research approach that seeks to investigate and resolve a problem simultaneously. It has benefited the professional growth of in-service teachers. As a result, a number of scholars suggest using it in pre-service training (Morales, 2016).

Additionally, the researcher wanted to explore the potential of LEGO® bricks for improving math performance in a directly relevant, adaptable way and contributing to positive change within the school community. The study's results support the practical application of LEGO® in math education and highlight its potential to impact students' mathematical understanding and skills positively; it looks into how using LEGO® manipulatives affects students' ability to solve problems and offers empirical proof of how action-based manipulatives affect mathematical capabilities (Kazez Güneş & Genç, 2021).

This action research examined how students can utilize manipulatives to enhance their math skills using a mix of quantitative and qualitative approaches. The small group of respondents' prior knowledge was evaluated using a pretest, and after the intervention, a posttest was administered. During in-person classes, the same group received

instruction using LEGO® bricks. The intervention denotes the teaching approach used.

2.2. Research Setting

This study was conducted at the Filipino Catholic coeducational St. Rita's College of Balingasag, located in the Brgy. 3 Martires, Balingasag, Misamis Oriental. It was established by Father Gregorio Parache in 1957. The academic institution has now built steps toward the aspirations and aims of Filipino youth, going far beyond the intention of its founder.

The researcher chose to perform the study in this area to determine the improvement of a few students who need help learning algebra. Based on the observation of teachers in the school, there were a few students who lagged behind their peers in learning abstract concepts. So, this intervention, which was conducted in this area, hopes to help these few students improve their interest and performance in this subject.

2.3. Participants of the Study

This action research looks into the impact of using LEGO® bricks on the math performance of Grade 8 students at St. Rita's College of Balingasag during the 2023-2024 academic year. Following ethical rules and gaining informed consent from children and their parents/-guardians, a purposive sample of 8 students was chosen based on numerous characteristics suggesting the need for individualized mathematics teaching.

These criteria included academic performance, instructor observations, and learning challenges. The final selection ensured that the sample was diverse to reflect the various learning styles and needs of children who may require further support. For almost 1 month, these students participated in the LEGO® brick-based intervention. All data will be collected and processed anonymously to protect participant confidentiality throughout the research process.

2.4. Research Instruments

This study used two distinct research instruments—a comprehensive interview guide and an achievement test—to answer the given research topic. The researcher developed both to address the study's questions.

1. The achievement tests consist of 20 multiple-choice questions covering the most important learning skills, including factoring polynomials (Philippine Department of Education, 2016).
2. There are five open-ended or subjective items in the interview guide questions. These inquiries will give insight into the effects and the perceived difficulties that students have with the long-term incorporation of Lego bricks activities within the arithmetic curriculum.

2.5. Data Gathering/Experimentation Process

Obtaining informed consent from the school administration and participating students, researchers accessed the complete math dataset of Grade 8 students at St. Rita's College of Balingasag. Recognizing the limitations

TABLE I: THE ALGEBRAIC PROFICIENCY OF STUDENTS PRIOR TO LEARNING USING LEGO® BRICKS

Number	Students	Pretest
1	A	7
2	B	5
3	C	5
4	D	4
5	E	3
6	F	3
7	G	2
8	H	2

of relying solely on grades, they employed a multifaceted approach to identify students who might benefit from additional math support. This included considering factors beyond scores below 80, such as standardized test results, teacher observations, and student self-reports. Utilizing purposive sampling, they selected a group of students exhibiting math difficulties for the study.

Before the intervention, a validated 20-item multiple-choice test covering key algebra topics assessed their understanding. The researchers used the same lesson plan for one-quarter of the intervention, focusing on the key concepts of algebraic expressions. The intervention will be once a week for a quarter, with a time allotment of one hour for each meeting.

The class discussion has an estimated time of 30 minutes, and after that, the activity will take place. The activity title is "Factoring polynomials with LEGO® Bricks" with a time allotment of 30 minutes. The student will be proficient in factoring polynomial expressions by the end of this activity.

The materials for this activity are LEGO® bricks in various colors and sizes, bond paper, markers, and worksheets with pre-written descriptions of algebraic expressions. In 5 minutes, there will be an introduction to the activity, a brief review of the concept of algebraic expressions, focusing on variables, coefficients, and operations, and an explanation of the activity will vary.

Second will be a building activity; in 15 minutes, the students will be divided into two pairs, provided with LEGO® bricks, challenged to build a model of the given algebraic expression, encouraged to be creative and use different colors and sizes to represent different parts of the expression and guidance when needed. After sharing and discussion in 10 minutes, each group will be asked to present their LEGO® model, explain the algebraic expression it represents, and facilitate a class discussion to summarize the key learning points and address any misconceptions.

Lastly, there is the assessment, such as observing students' participation and understanding during the building and sharing activities and collecting the students' LEGO® models and worksheets with their written expressions to assess their accuracy and understanding.

At the end of the quarter, the same pre-test served as a post-test to measure students' progress. Additionally, interviews exploring students' experiences, perceptions, and learning preferences provided valuable qualitative data. A quantitative analysis of pretest and posttest scores will

TABLE II: ONE-SAMPLE T-TEST

Test value = -0.20473			
95% confidence interval of the difference: 2.431285,5.318715			
	P-value	Df	Mean of x
Pretest	0.8436	7	3.875

be performed to evaluate overall learning gains. Qualitative analysis of observational notes, LEGO® models, and student expressions will explore deeper understanding, misconceptions, and the impact of the LEGO® activity on learning.

This comprehensive data-gathering procedure, conducted in collaboration with school stakeholders, aims to inform future math instruction and support strategies and contribute to a more inclusive and engaging learning environment that can foster a love for math in all students.

3. RESULTS AND DISCUSSIONS

3.1. Summary

The researcher wanted to know how well the participants performed in the algebra, how much the pretest and posttest differed, and how the students felt about using LEGO® bricks as manipulatives to factor polynomials. Using a mixed methods action research methodology, the researcher conducted in-depth interviews, pretests, and posttest assessments with at-risk grade 8 students at St. Rita’s College of Balingasag during the 2023–2024 academic year. Eight students participated in the study, and tests were used to gather data. Before the students received the intervention, the pretest was completed, and the goal was to determine the participant’s pre-intervention skill level. The pretest results demonstrated their inadequate factoring skills.

Following the pretest, the researcher began the intervention, which involved factoring polynomial expressions using LEGO®. The students were eager to factor in the polynomials and enjoyed learning during the intervention. To determine the student’s progress in factoring perfect square polynomials, the researcher gave them a post-test following the intervention. The post-test results indicate that the pupils’ factoring abilities greatly improved.

3.2. Findings

3.2.1. Algebra Proficiency of the Students Prior to the Intervention

The student completed a 20-item multiple-choice pretest on April 12, 2024, before receiving treatment. Eight pupils took the pretest. Table I below shows the algebraic proficiency of the students on the pretest.

No student scored 10 out of 20 on the evaluation, as shown in Table I. The highest score was seven, and the lowest score was 2.

Table II shows that the one-sample t-test showed that the pretest mean was 3.875 and the test value was -0.20473. A poor level of student achievement before any intervention is indicated by the pretest mean score of 3.875 out of 20. These findings demonstrate the necessity of focused

teaching methods to close knowledge gaps and enhance understanding.

3.2.2. Students’ Achievement in Algebra after the Intervention

After the intervention, the posttest was administered to the pupils on May 6, 2024. Although not exactly the same, it contains a collection of pre-test-related problems. Eight students took the posttest, which was designed to determine whether or not students’ algebraic performance had improved following the intervention. Table III below shows the results of the posttest.

As shown in Table III, the post-test had a maximum score of six and a minimum score of 10. Seven students received passing grades, while one received the maximum possible score.

Based on Table IV, one sample t-test revealed that the mean of the post-test was 13.125. The increase in the mean score to 13.125 indicates a significant improvement in student achievement. This suggests that the intervention conducted on grade 8 students effectively enhanced understanding and performance in the subject matter.

3.2.3. The Outcome of One Experimental Group Pretest and Posttest

As presented in Table V, the data shows the improvement of students’ scores before and after the intervention. The highest score from the pretest, 7, becomes 16 in the posttest, and the lowest score, 2, becomes 10 in the posttest. The box plot in Fig. 1 below further illustrates how the pretest and posttest scores improved.

The paired sample t-test results between the pretest and posttest are shown in Table VI. The mean is 9.25 and the standard deviation is 0.07. This suggests that the scores on the pretest and posttest have significantly improved. In addition, the p-value was 2.738e-09, the t-value was 37, the df was 7, and the p-value was less than 0.05, which is at the threshold of statistical significance.

TABLE III: THE ALGEBRAIC PERFORMANCE OF STUDENTS FOLLOWING THE INTERVENTION

Number	Students	Posttest
1	A	16
2	B	15
3	C	14
4	D	13
5	E	13
6	F	12
7	G	12
8	H	10

TABLE IV: ONE SAMPLE T-TEST

Test value = 0.18755			
95% confidence interval of the difference: 11.54902, 14.70098			
	P-value	df	Mean of x
Posttest	0.8565	7	13.125

TABLE V: PRETEST AND POSTTEST

Number	Students	Pretest	Posttest
1	A	7	16
2	B	5	15
3	C	5	14
4	D	4	13
5	E	3	13
6	F	3	12
7	G	2	12
8	H	2	10

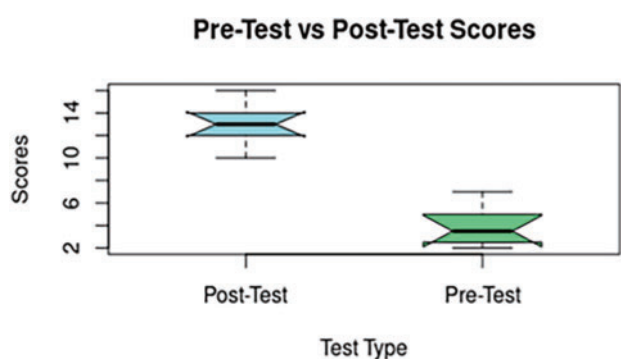


Fig. 1. The box plot of grade 8 at-risk students' pretest and posttest results.

3.2.4. Hypothesis Testing

The researcher interpreted significant value based on the statistical computation utilizing R. The study's p-value was less than 0.05 at 2.738e-09. Thus, the null hypothesis (H_0) states that there is no significant difference between the scores of the students before and after the intervention was rejected. In contrast, the alternative hypothesis (H_a) states that a significant difference between the scores of students before and after the intervention was accepted.

3.2.5. Thematic Analysis

For the qualitative research question, the data were gathered through interviews to learn the respondents' experiences during the intervention. The information about the participants is displayed in Table VII below.

The study involved eight male participants; all are grade 8 students. These participants were specifically selected for their involvement in a study group, facilitating an in-depth exploration of their experiences during the intervention. The themes and core ideas are presented in Tables VIII–X below.

3.2.6. Enhanced Problem-Solving Skills

Most of the participants in the in-depth interview said that the intervention activity helped them to enhance their problem-solving skills.

Three of the participants in in-depth interview expressed:

"Before I can't easily factor polynomials because I find it hard but with Lego I find it easier to factor."

"Dili ko komportable magfactor sauna kay boring og lisod perme na sa akong hunahuna kumpara karun na mas ganahan nako magtry og factor (Before I am not comfortable because in my mind it is boring and difficult however using Lego makes me try to learn)."

"Aglisod kog factor sauna pero pagtry nako sa lego mas feel nako na dali ra magfactor pero hasul lang mag sigi og tanggal (Before, I find it difficult to factor, but using Lego made it easier to factor however it is too hassle to assemble)."

3.2.7. Improved Conceptual Understanding

The participants almost share the same answer on how LEGO® bricks as manipulatives improve their conceptual understanding. Most of their answers revealed that they understand clearly the factoring after the intervention.

Four of the participants from the in-depth interview expressed:

"Yes factoring make more sense to me because I can easily visualize it".

"Mas dali ivisualize kay Makita ra sa paggamit og lego ang factor sa polynomial (It's easier to visualize because the factor of the polynomial can be seen after using it)".

"Aglisod kog factor sauna pero pagtry nako sa paggamit og Lego mas makatabang sya para mas masabtan ang mga coefficients, og constants nga naa sa polynomial (Before I find it difficult to factor but using Lego helps me to understand the coefficients and constants of the polynomial)."

3.2.8. Increased Student Engagement

Five students stated that utilizing bricks as the manipulative in factoring increased their engagement. Their answers had the same idea that Lego bricks help them to increase their engagement in solving problems involving factoring.

Five of the participants expressed:

TABLE VI: PRETEST AND POSTTEST PAIRED SAMPLE T-TEST

p-value	Mean of x	t	df	SD
2.738e-09	9.25	37	7	0.707

TABLE VII: PARTICIPANTS' INFORMATION

Students	Gender	Level	Study group
A	Male	Grade- 8	In-depth Interview
B	Male	Grade-8	In-depth Interview
C	Male	Grade-8	In-depth Interview
D	Male	Grade-8	In-depth Interview
E	Male	Grade-8	In-depth Interview
F	Male	Grade-8	In-depth Interview
G	Male	Grade-8	In-depth Interview
H	Male	Grade-8	In-depth Interview

TABLE VIII: THEME AND CORE IDEAS ON UTILIZING LEGO® BRICKS AS MANIPULATIVE IN FACTORING POLYNOMIALS ENHANCED PROBLEM-SOLVING SKILLS AMONG AT-RISK GRADE 8 STUDENTS IN ST. RITA'S COLLEGE OF BALINGASAG

Major theme	Core ideas
Enhanced problem-solving skills	- Before I can't easily factor polynomials because I find it hard but with Lego I find it easier to factor. - Dili ko komportable magfactor sauna kay boring og lisod ang perme sa akong hunahuna, kumpara karun na mas ganahan nako magtry og factor (Before I am not comfortable because in my mind it is boring and difficult however using Lego makes me try to learn). - Aglisod kog factor sauna pero pagtry nako sa lego mas feel nako na dali ra mag factor pero hasul lang magsige og tanngal (Before, I find it difficult to factor, but using Lego made it easier to factor however it too hassle to assemble).

TABLE IX: THEME AND CORE IDEAS ON HOW UTILIZING LEGO® BRICKS AS MANIPULATIVE IN FACTORING POLYNOMIALS IMPROVES CONCEPTUAL UNDERSTANDING AMONG AT-RISK GRADE 8 STUDENTS IN ST. RITA'S COLLEGE OF BALINGASAG

Major theme	Core ideas
Improved conceptual understanding	- Yes factoring make more sense to me because I can easily visualize it. - Mas dali ivilualize kay makita ra sa pag gamit og lego ang factor (It's easier to visualize because factor can be seen after using it). - Aglisod kog factor sauna pero pagtry nako sa lego mas makatabang sya para masabtan ang mga coefficients, og constants nga naa sa polynomial (Before I find it difficult to factor but using Lego helps me to understand the coefficients and constants in polynomial).

TABLE X: MAJOR THEME AND CORE IDEAS ON HOW UTILIZING LEGO® BRICKS AS MANIPULATIVES IN FACTORING POLYNOMIALS INCREASES STUDENT ENGAGEMENT AMONG GRADE 8 STUDENTS IN ST. RITA'S COLLEGE OF BALINGASAG

Major theme	Core ideas
Increased student engagement	- Yes it is more engaging and enjoyable in using Lego in factoring polynomials because it is colorful and make me express my creativity. - Mas enjoy ang paggamit og lego sa pagfactor og polynomials kay mura rakag nagdula sa pagsolve (It is more enjoyable and engaging in using lego in factoring polynomials because it feels like you are just playing). - During the activity using Lego while solving feels like playing and enjoying with peers.

"Yes it is more engaging and enjoyable in using Lego in factoring polynomials because it is colorful and make me express my creativity."

"Mas enjoy ang paggamit ug Lego sa pagfactor og polynomial kay mura rakag nagdula sa pagsolve (It is more enjoyable and engaging in using Lego in factoring polynomials because it feels like playing)."

"During the activity using Lego while solving feels like playing and enjoying with peers."

4. CONCLUSION AND RECOMMENDATIONS

The study's findings showed that students who took part in the LEGO® manipulative intervention had statistically higher post-test scores than those who did not. Qualitative data collected from observations, interviews, and reflections revealed several key themes associated with this intervention. Participants reported increased student engagement, as the hands-on nature of LEGO® bricks made learning more enjoyable and interactive. Additionally, students experienced improved conceptual

understanding, particularly in visualizing and grasping complex mathematical concepts. Furthermore, using LEGO® manipulatives enhanced problem-solving skills, enabling students to approach challenges with greater confidence and creativity. These findings underscore the effectiveness of incorporating LEGO® bricks into educational practices to foster a more engaging and productive learning environment. According to the study of Gen Z, students' problem-solving abilities and mathematical fluency improved (Kazez Güneş & Genç, 2021).

The study's conclusion led to the following suggestions being made.

1. The researcher recommends conducting further studies to explore the specific mechanisms by which LEGO® improves factoring skills.
2. Investigate the effectiveness of LEGO® for factoring at different age groups, learning levels, and larger sample sizes.

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