International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 5, October 2025, pp. 4029~4039
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i5.33969

Boosting algebra mastery through activity-based learning in an indigenous peoples education secondary school

Rolly Najial Apdo[1], Rachel Basañez Apdo[2]
[1]Department of Secondary Education, Caraga State University, Butuan City, Philippines
[2]Department of Mathematics, Caraga State University, Butuan City, Philippines

Article Info

Article history:

Received Dec 9, 2024
Revised May 9, 2025
Accepted Jun 30, 2025

Keywords:

Activity-based learning
Algebra
Conceptual understanding
Least-learned competencies
Procedural skills

ABSTRACT

Algebra is a fundamental area of mathematics, yet many students, particularly indigenous learners, struggle with its concepts and procedures. This study examines the impact of activity-based learning on the conceptual understanding and procedural skills of junior high school students in an indigenous peoples education (IPEd) school. Using a mixed-methods approach, 105 indigenous students from grades 7 to 9 at Daan Taligaman Integrated Secondary School (DTISS), Philippines, participated. Pre-test and post-test scores were analyzed using a paired-samples t-test, while thematic analysis explored students' learning experiences. The results revealed significant improvements in both conceptual understanding and procedural skills, with grade 7 scores increasing from 41.08% to 80.38% (conceptual) and 34.83% to 74.13% (procedural). A similar trend was apparent for the grades 8 and 9 students. Key themes identified were engagement and enjoyment, increased confidence, and improved understanding. The study highlights the effectiveness of interactive, culturally responsive learning strategies in enhancing algebra mastery among indigenous students and calls for their integration into mathematics education.

Corresponding Author:

Rolly Najial Apdo
Department of Secondary Education, Caraga State University
Butuan City, Philippines
Email: rnapdo@carsu.edu.ph

1. INTRODUCTION

In almost every country, Mathematics is considered as one of the important subjects in a students' curriculum [1]. It helps students with critical thinking, problem solving, and logic [2]–[5]. These logical thought processes can expand into more advanced concepts in various fields including science, technology, engineering, and economics [6], [7]. It is a universal subject with real life applications in many areas of human life [8]. So too, it is a very essential aspect dealing with issues of day-to-day life such as finances and decision making [9]–[11].

Algebra is one of the building blocks of mathematics so to speak, any one not understanding this is bound to struggle with the more complex logic and ideas associated with it [12]. This is not the reality for many as students find this branch in mathematics to be tough and often times have to struggle with getting the overall understanding of the topic as well as the techniques associated with problem solving [13], [14]. These obstacles however do not come free as they have great consequences as in the end having a dominant understanding in Algebra is very important if one has aims of completing secondary school and aiming for higher studies [15]. Educational practitioners and researchers have administered and researched various themes and methodologies so to speak in order to help the students overcome these barriers one such theme is activity-based learning [16].

It is quite evident that if students are encouraged to take part in learning engaged and practical activities which help them for the future, this would help them learn a lot as well as keep them engaged.

A few of these would include manipulatives, games, and physical activities within the classroom. There are many branches and tasks that focus on movements along with physical activities. For example, many teachers state such tasks can increase participation and improve knowledge retention [17]. Where it was found that when physical activity was combined with math, the students performed a lot better than those who did the opposite [18]. Game-based learning reinvents the forms of education by utilizing games and game-like features to motivate and engage students. As it turned out, students prefer and are more active in game-based learning [19]. Games have a positive effect on the various emotions of the students and it similarly has a positive influence on students' levels of motivation, engagement, attitude, enjoyment, and state of flow [20]. Mathematical manipulatives are tools designed for students to explore and grasp the idea of mathematics through the senses [21]. However, there is no doubt that students understand and work mathematically, even so, with the help of manipulatives [22]. It has come out manipulatives that when used makes students understand and develops higher order thinking skills [23]. Some types of manipulatives include the use of algebra tiles, number lines, and number chips with respect to addition and subtraction [24]–[26].

In the Philippines, the mission of the Department of Education (DepEd) states that every student should be afforded the right to possess a quality, equitable, culturally relevant and complete basic education [27]. Given DepEd's understanding of its mandate to provide insight and guidance in promoting and ensuring the quality of basic education throughout the Philippines' region, it continues to engage in various assessments aimed at addressing the challenge of improving and progressing towards the internationalization of the basic educational quality. One of these assessments is the Programme for International Student Assessment (PISA), where it examines the proficiency of students in the three domains–reading, mathematics, and science literacy. As indicated by the results of PISA, the Philippines has not been able to excel the mathematics domain. In the 2022 assessment, it achieved an average of 355 points which was considerably less than the 472 points that the Organization for Economic Co-operation and Development (OECD) members obtained. At best, only 16% of the students who were 15 years old could obtain level 2, which has been designated as the minimum level required for understanding and finding simple mathematical content. For comparison purposes, the average for the OECD area is 69%. In addition, no Filipino students reached the highest levels of proficiency (level 5 or 6) which require advanced problem solving and modeling mathematics [28]. This suggests a significant gap to enable learners to develop high-order mathematical competencies.

Daan Taligaman Integrated Secondary School (DTISS) is a remote indigenous peoples education (IPEd) secondary school in Butuan City, Philippines, established to serve *Manobo* indigenous students by providing culturally relevant and accessible education. The school is committed to fostering quality education that integrates indigenous knowledge systems while addressing the unique learning needs of its students. One of the significant challenges in IPEd schools is ensuring that mathematical concepts, such as algebra, are taught in a manner that aligns with students' cultural backgrounds and learning styles. Recognizing these challenges, the DepEd and indigenous peoples (IP) leaders formulated the National Indigenous Peoples Education Policy Framework (DepEd Order 62, s. 2011). This policy adopts a rights-based approach to education, emphasizing the need for an inclusive curriculum grounded in the social and cultural context of IP learners. Despite these efforts, data from previous summative assessments at DTISS indicate that 76% of students continue to struggle with mathematics, particularly algebra, as reflected in their least-learned competencies. Algebraic concepts and procedures have been identified as the most challenging areas for students, impeding their ability to progress in the subject. Since the K to 12 curriculum follows a spiral progression approach, mastering foundational algebraic concepts at lower grade levels is crucial, as these concepts become more complex in higher grades [29]. However, there is limited research on the effectiveness of alternative teaching strategies, such as activity-based learning, in addressing these persistent difficulties among indigenous students in IPEd schools. This gap highlights the need for an investigation into how interactive, culturally responsive, and engaging learning methods can enhance algebra mastery in this unique educational setting.

This research focused on the activity-based learning of junior high school students in algebra in terms of the concepts and procedures. Conceptual understanding refers to the ability to understand mathematical ideas, the way they are related, and the way they work together. It is one thing to be able to carry out a certain mathematical operation, but it is another thing, entirely, to comprehend the rationale behind the steps taken. On the other hand, procedural understanding in mathematics means carrying out the mathematical algorithms and procedures accurately. This entails knowing how to go through all the necessary steps and rules to be able to make the appropriate calculations and derive the required answers [30].

To address students' difficulties in algebra, this research introduced engaging and interactive class activities, such as DaMath and Maze Math exercises. DaMath, derived from the traditional Filipino board game Dama, was adapted to reinforce algebraic operations by incorporating mathematical expressions on game pieces and assigning different mathematical rules to each grid [31]. Meanwhile, Maze Math exercises combined problem-solving with physical movement, allowing students to actively engage in solving math problems that progressively increased in complexity. Indigenous learners generally enjoy interactive, hands-on activities like Dama and Maze Math, as these align well with their traditional ways of learning, which often involve storytelling, play, movement, and social interaction. These activities were specifically designed to target students' least-learned competencies in algebra, including grade 7: laws of exponents; grade 8: solving systems of linear equations in two variables; and grade 9: laws of radicals. The study aimed to examine the impact of activity-based learning on students' conceptual understanding and procedural skills in these topics. Specifically, it sought to determine whether significant improvement occurred in students' conceptual understanding and procedural skills after implementing activity-based learning and the emerging themes in students' responses regarding their experiences with the activities.

2. METHOD

2.1. Research design

The research design used in this study was mixed-methods research. Mixed methods research is a methodological approach wherein a researcher can utilize both qualitative and quantitative methodologies, data collection tools, and data analysis. It seeks to integrate both to enhance the explanation of the objective addressed [32]. It employs quasi-experimental quantitative research [33]. This quasi-experimental research employed a pre-test post-test design that compares two measures of the dependent variable (student performance) taken on the same group or individual, one before and the other one after the activities, to evaluate the impact the activities had on the group. Participants are tested before the activities (pre-test) to establish a baseline and again after the activities (post-test) to measure the changes [34]. Qualitatively, it used thematic analysis of student responses to learn more about how they experienced and perceived the activities, which helps to clarify its impacts. Thematic analysis is the process of identifying patterns or themes within qualitative data [35]. A thorough assessment of the activities' efficacy is provided by this blend of quantitative and qualitative methods. Because of its various advantages, this research paradigm is often employed in educational research, it offers the best knowledge of a research problem.

2.2. Sampling technique and participants

This study utilizes a stratified random sampling technique, which involves dividing the population into smaller subgroups known as strata. For this study, the strata comprise the three grade levels of DTISS–grades 7, 8, and 9. The sample sizes for each grade level will be allocated proportionally based on the number of students. Within each stratum, a simple random sampling technique will then be employed to select the respondents.

In this particular study, the research proponent utilized the Cochran formula for finite population [36], which is $n' = n/(1 + (z^2 \cdot p(1-p)/(e^2 \cdot N))$, where n' is the sample size, n is the sample size for unlimited population denoted by $n = (z^2 \times p(1-p))/e^2$, z is the z-score corresponding to the chosen level of confidence; p is the expected prevalence or proportion of the outcome in the population; and e is the desired margin of error. Now, N=144. Setting a confidence level of 95%, corresponding to a z-score of 1.96, with expected prevalence p=0.5, and a desired margin of error e=0.05 yield the sample size which is 105 students. The breakdown per grade level can be seen in Table 1.

Table 1. Sample size per grade level

Grade	No. of students	Proportion (%)	No. of participants
7	50	34.72	36
8	46	31.94	34
9	48	33.33	35
Total	144		105

2.3. Instrument and data collection

A questionnaire was used as a pre-test and post-test. This questionnaire was a 48-point test that assessed the students' conceptual understanding and procedural skills in the laws of exponents, solving systems of linear equations in two variables, and laws of radicals. There were twelve items (2 points each) in conceptual understanding across the grade levels and procedural skills; there were six items (24 points) in grades 7 and 9, while four items (24 points) in grade 8. The researcher personally developed the questionnaire using a table of specifications following the DepEd's learning competencies in the abovementioned topics. Prior to data collection, the questionnaire was validated for validity and reliability to confirm that it met the requirement [37]. The instrument underwent content validation by three experts in mathematics education to ensure that the items accurately reflected the intended learning competencies.

The validators examined the questionnaire for clarity, relevance, and appropriateness of the items for the targeted grade levels. Feedback from the validators was used to refine the instrument before its administration. To establish reliability, a pilot test was conducted among a group of 30 students who were not part of the actual study but had similar characteristics to the participants. The reliability of the instrument was measured using Cronbach's alpha, yielding a coefficient of 0.82, indicating good internal consistency [38]. To control confounding variables, the researcher implemented a consistent testing environment by administering the pre-test and post-test under similar conditions, including the same time allotment, same classroom settings, same instructions, activities were conducted uniformly and same set of activities. That is, the researcher administered the pre-test for 1 hour to the students. Note that the pre-test means the assessment before the activities. The results of the pre-test were then assessed. The activities were given every Friday of the week for one hour. The activities run for one month. During the activities, the researcher gave variety of activities to the students such as DaMath and Maze. The researcher again administered a post-test. The scores of the students were consolidated for data analysis. Finally, the students were asked on their experiences and perceptions of the activities they encountered.

The activities were DaMath on laws of exponents and radicals and Maze on laws of exponents, system of linear equations in two variables, and laws of radicals. Figure 1 shows the DaMath on Laws of exponents where students can play and either simplify, multiply, or divide expressions on the chips. Figure 2 shows the Maze on solving systems of linear equations in two variables and laws of radicals where the students solve system of equations or simplify radical expressions until they reached the finish line.

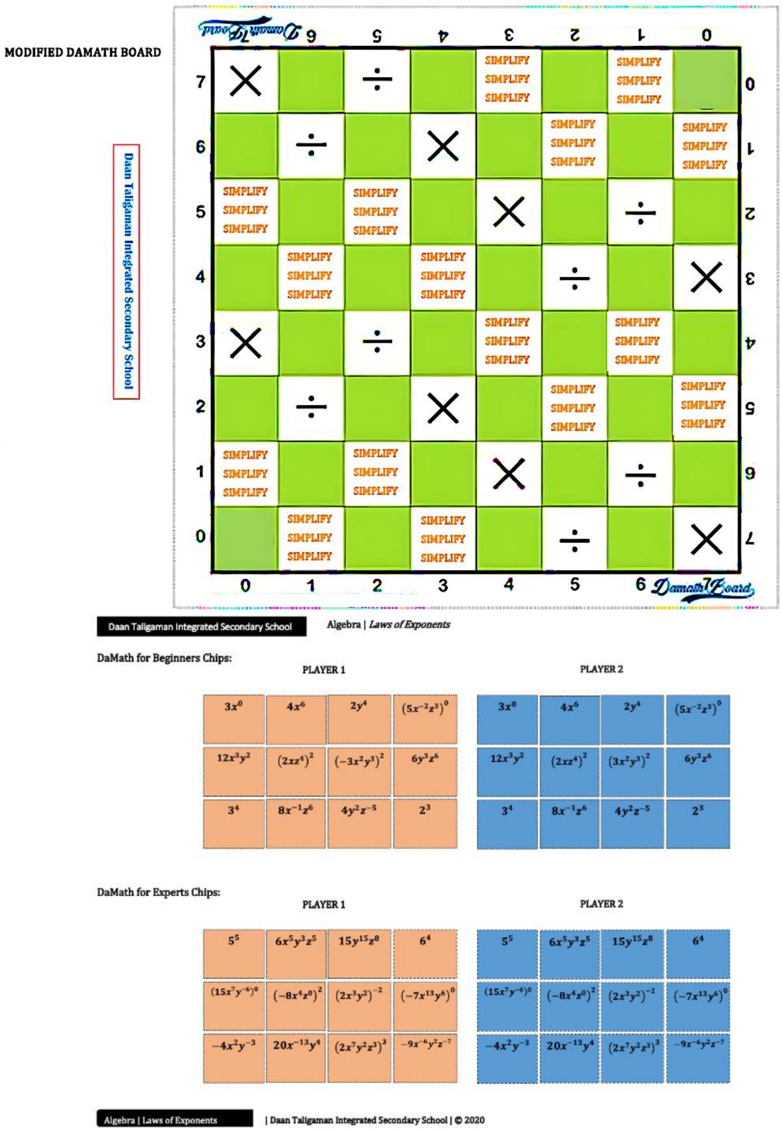

Figure 1. Modified DaMath on laws of exponents

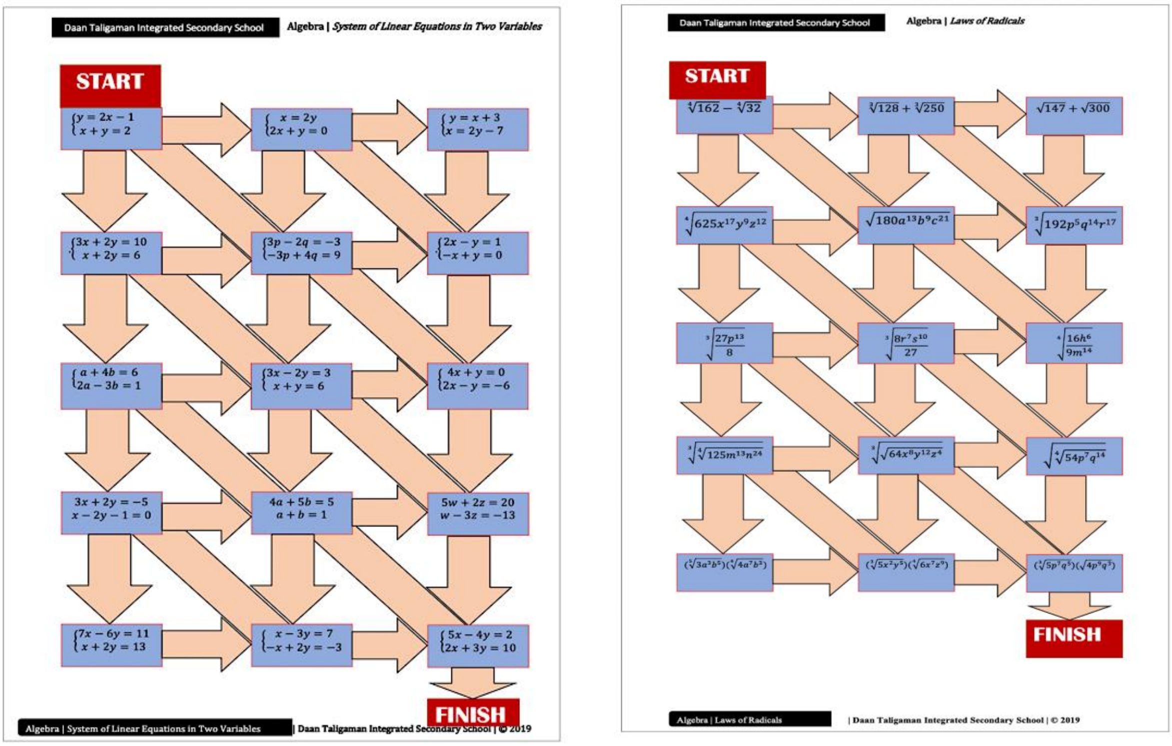

Figure 2. Maze on solving systems of linear equations in two variables and laws of radicals

2.4. Analysis

The scores and the mean percentage score (MPS) before and after the activities were computed. On the other hand, under inferential analysis, the paired sample t-test was used. Since the paired-samples t-test is a parametric test, the assumptions were checked to ensure the validity of its results and once the assumptions are met, then the test can be used [39]. The paired samples t-test is used to measure if there is a significant difference between the students' conceptual understanding and procedural skills before and after the activity-based teaching. Prior in using the null hypothesis (H_0) is: there is no significant difference between the students' conceptual understanding and procedural skills before and after the activity-based learning.

The level of significance used in the study is 0.01. If the p-value is less than 0.01, then the H_0 will be rejected. Otherwise, the null hypothesis will not be rejected. The rejection of the H_0 means that there is a significant difference between the students' conceptual understanding and procedural skills before and after the activity-based learning. Meaning, there will be a significant improvement after the activities.

The responses of the students on their experiences and perception on the activities were analyzed using thematic analysis. This involves several steps from familiarization with the data, generating initial codes, searching and reviewing themes, and defining and naming themes. The themes after the thematic analysis would support the study highlighting on the role that activity-based learning had on their learning of algebra.

3. RESULTS AND DISCUSSION

The focus of this study is to investigate how DaMath and Maze activities enhance students' understanding of algebraic concepts and their ability to apply procedural skills effectively. Specifically, it examines how these interactive activities contribute to improving students' conceptual understanding and mastery of algebra. The study aims to determine whether engaging, hands-on learning experiences can address difficulties commonly faced by junior high school students in learning algebra.

3.1. Before activity-based learning

Table 2 presents the MPS and standard deviation of the students' scores in conceptual understanding and procedural skills prior to the activities. The mean score reflects the students' average performance, while the MPS indicates the corresponding percentage of this mean score. The standard deviation illustrates the spread or variability of the scores, providing insight into the consistency of students' performance.

It can be seen in Table 2 that grade 7 students got low scores in the pre-test, both in conceptual understanding and procedural skills. The mean scores, 9.86 for conceptual and 8.36 for procedural with corresponding MPS of 41.08 and 34.83, respectively suggest that their scores are below half of the total score. The grade 8 students' conceptual mean score is 11.87, and the procedural mean score is 10.40 with corresponding MPS of 39.46 and 43.33, respectively. These suggest that their scores are also below half of the total score. The grade 9 students performed better in the conceptual where the mean score is 13.69 with MPS of 57.04 but low in procedural with the mean score of 8.54 with MPS of 35.58. The standard deviations of the scores in grades 7 and 8 in conceptual are higher than in the procedural. This result means that the scores in conceptual are more dispersed compared to the scores in the procedural. However, the dispersion of the grade 9 scores in conceptual and procedural are almost the same. These results align with previous studies emphasizing the challenges students face in mastering algebraic concepts through traditional teaching methods. For instance, a study by Ying *et al.* [13] identified that students predominantly struggled with text difficulties and unfamiliar contexts when solving algebraic word problems and faced visual-spatial awareness issues in diagrammatic problem-solving. Additionally, Rafiepour *et at.* [40] highlighted that student often encounter challenges in simplifying algebraic expressions due to misunderstandings of symbols and letters, suggesting that traditional teaching methods may not effectively address these issues.

The exceptionally low pre-test scores across all grade levels indicate significant weaknesses in both conceptual understanding and procedural skills in algebra. This suggests that students struggle not only with grasping algebraic concepts but also with applying the necessary procedures to solve problems effectively. These findings highlight the urgent need for targeted instructional strategies to bridge these learning gaps and enhance students' algebra proficiency.

Table 2. Descriptive statistics in conceptual understanding and procedural skills scores before activity-based learning

Grade level	Skills	Mean	MPS	Standard deviation
Grade 7	Conceptual	9.86	41.08	3.63
	Procedural	8.36	34.83	1.78
Grade 8	Conceptual	11.87	49.46	3.42
	Procedural	10.40	43.33	1.64
Grade 9	Conceptual	13.69	57.04	2.29
	Procedural	8.54	35.58	2.30

3.2. After activity-based learning

Table 3 presents the improvement in mean scores from the pre-test to the post-test, showing a consistent increase in both conceptual understanding and procedural skills across all grade levels. The significant gains in students' scores suggest that activity-based teaching has a positive impact on their algebra proficiency. These findings highlight the effectiveness of hands-on and interactive learning strategies in enhancing students' mathematical performance.

Table 3. Descriptive statistics in conceptual understanding and procedural skills scores after activity-based learning

Grade level	Skills	Mean	MPS	Standard deviation
Grade 7	Conceptual	19.29	80.38	2.55
	Procedural	17.79	74.13	1.67
Grade 8	Conceptual	19.07	79.46	2.49
	Procedural	18.40	76.67	1.64
Grade 9	Conceptual	21.23	88.46	2.09
	Procedural	19.08	79.50	2.72

The MPS of grade 7 in conceptual understanding increases from 41.08 to 80.38, while procedural skills MPS increases from 34.83 to 74.13 after the activities. These suggest that improvements happen after the activities are applied. Similar observations can be made for grade 8 students. The conceptual understanding MPS increases from 49.46 to 79.46, while procedural skills MPS increases from 43.33 to 76.67 after the activities. The grade 9 students performed excellently in the conceptual with a mean score of 21.23 with MPS of 88.46. The students' procedural mean score also improves, rising from 8.54 to 19.08 with MPS of 79.50. The standard deviations of grades 7 and 8 scores after activity- based teaching in conceptual are higher than in the procedural, which means that the scores in conceptual are more dispersed compared to the scores in the procedural. However, the procedural scores in grade 9 are more dispersed than in conceptual scores. These findings align with existing literature emphasizing the efficacy of activity-based learning in mathematics education. A study by Anwar [41] highlighted that learner tend to be more interested in activity-based teaching compared to traditional lecture methods, which can lead to increased mathematics achievement. Furthermore, game-based learning experiences positively influence primary students' attitudes toward mathematics, thereby improving their engagement and understanding [42].

The significant improvement observed across all grade levels in the post-test indicates that participants achieved substantial progress in both conceptual understanding and procedural skills in algebra. This suggests that activity-based learning effectively enhances students' ability to grasp and apply algebraic concepts. As previously highlighted, hands-on learning activities not only improve academic performance but also foster greater student interest and engagement in learning abstract mathematical concepts like algebra.

3.3. The effect of DaMath and maze activities in the conceptual understanding and procedural skills

Table 4 highlights a clear improvement in students' scores, showing positive mean differences between their post-test and pre-test results in both conceptual understanding and procedural skills. On average, students scored 7 to 11 points higher after engaging in activity-based learning, reflecting significant progress. This suggests that interactive and hands-on learning methods truly help students grasp algebraic concepts more effectively and apply them with greater confidence.

The p-values are all 0.00, which are less than the significance level 0.01. This result indicates that there is a significant difference between the students' conceptual understanding before and after the activity-based learning. Similarly, there is a significant difference between the students' procedural skills before and after the activity-based learning. Hence, activity-based learning is effective in helping students improve their academic performance in algebra. These results further support the findings of Shloul [43], which revealed that project-based learning enhances critical thinking and mathematical engagement, leading to higher performance in algebra. Similarly, Hiltrimartin *et al.* [44] confirmed that engaging students in structured activity-based learning approaches significantly improves mathematical abilities

Hence, activity-based learning is a powerful way to help students build their algebra skills with confidence. By making learning more interactive and hands-on, it allows students to truly understand mathematical concepts rather than just memorize procedures. This approach not only strengthens their problem-solving abilities but also makes algebra more engaging and enjoyable, leading to better academic performance.

Table 4. Descriptive statistics in conceptual understanding and procedural skills scores after activity-based learning

Grade level	Skills	Mean	SD	t	Sig
Grade 7	Conceptual	9.43	2.53	13.93	0.00*
	Procedural	9.43	1.34	26.28	0.00*
Grade 8	Conceptual	7.20	2.11	13.21	0.00*
	Procedural	8.00	1.65	18.81	0.00*
Grade 9	Conceptual	7.54	1.85	14.66	0.00*
	Procedural	10.54	2.03	18.76	0.00*

*Significant at 0.01 level of significance

3.4. Thematic analysis of students' experiences with DaMath and Maze activities

There are three emerging themes in students' responses when asked about their experiences with DaMath and Maze activities. These themes are engagement and enjoyment, increased confidence, and improved understanding. The first theme is engagement and enjoyment. Most of the students expressed that the activities allowed them to enjoy and feel engaged with the topics. For example, one student said verbatim, with the corresponding translation in English:

> "*Malingaw ko kay dula man siya ug kami mismo makabalo kung sakto ba mi or dili.*"
> "*I enjoy the activity, and I can tell if I'm correct or not because it is hands-on.*" (Translation)

The second theme is the increase in confidence of the students. Some of the students expressed that they became more confident in learning by having activities in class. One student said that:

> "*Dili ko maulaw mamali ug mas confident ko, ah, ang importante makabalo ko sa topic kay dula man siya.*"
> "*I am not ashamed of making mistakes. I become more confident. The important thing is that I learned.*" (Translation)

The final theme is the improved understanding of the students. Most of the students have expressed that they understand the concepts well and know how to apply the procedures in solving problems because of the activities. These activities allow them to interact with the material, resulting in an improved understanding of the lesson. One student said that:

> "*Mas nakasabot ko sa lesson, sa concepts sa topic ug sa pagsolve karon nga nay dula. Dali ra siya masabtan.*"
> "*The activities helped me understand the lesson well and how to apply them.*" (Translation)

The results are supported with some studies that activity-based learning significantly improves the academic performance of students in mathematics [16]. The activities helped students to be more involved with the topics, resulting in an increase in students' understanding [19]. Not only do their scores improve, but so do their attitudes and interests for math-related topics [20].

The results of this study are consistent with the literature that activity-based learning boosts up students' performance in mathematics. The increased involvement does not only improve their scores but also ultimately creates a positive perception towards practicing mathematics that makes it more interesting and less fearful. The findings, in this case, underscore the role of activity-based learning strategies in the development of both the cognitive and emotional aspects of the students.

4. CONCLUSION

This study investigated the effect of activity-based learning on the conceptual understanding and procedural skills of junior high school students in an indigenous learning environment. The results showed a significant impact of activity-based learning on understanding algebraic concepts and applying procedures, particularly in the least-learned topics among indigenous learners. The improvement was evident in the marked difference between pre-test and post-test scores, demonstrating that interactive, hands-on activities such as DaMath and Maze Math are effective in making abstract algebraic concepts more accessible to indigenous students. In indigenous learning contexts, where traditional teaching methods may not always align with students' cultural backgrounds and learning styles, activity-based learning proved to be an effective strategy. By shifting from lecture-based instruction to student-centered, interactive learning, students were more engaged, and their difficulties in algebra were reduced. Moreover, this approach not only improved algebra mastery but also fostered confidence, motivation, and a more positive attitude toward mathematics, which is crucial in indigenous education settings where learning disparities often exist due to socio-cultural factors.

From the findings of this study, educational institutions serving indigenous students might consider implementing culturally responsive activity-based learning strategies within the curriculum to enhance both conceptual understanding and procedural skills. Teachers should be trained and retrained in these approaches to bridge the gap between mathematical learning and indigenous students' ways of understanding. Furthermore, regular assessments and feedback mechanisms should be incorporated to monitor student progress effectively. Strengthening community involvement—by engaging parents, elders, and local leaders—can further enrich this approach, ensuring that learning remains rooted in indigenous culture while promoting academic success. Future research should explore the long-term effects of activity-based learning in indigenous education through longitudinal studies, comparing it with other teaching methodologies. Expanding this approach to other STEM disciplines and developing teacher training programs tailored to indigenous learners would provide broader insights into the advantages of this method. These efforts will contribute to a more inclusive and culturally sensitive education system, where indigenous students can thrive and develop stronger mathematical competencies through meaningful, engaging, and contextually relevant learning experiences.

ACKNOWLEDGMENTS

We extend our heartfelt gratitude to the administrators, students, and parents of Daan Taligaman Integrated Secondary School (DTISS) for their invaluable support and participation, which made this study possible. Your cooperation and commitment to education have been instrumental in the success of this research.

FUNDING INFORMATION

This study was conducted without any external funding or financial support.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Rolly Najial Apdo	✓					✓	✓	✓		✓	✓			
Rachel Basañez Apdo	✓	✓	✓	✓	✓			✓	✓			✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [RNA], upon reasonable request.

REFERENCES

[1] M. V. Siagian, S. Saragih, and B. Sinaga, "Development of Learning Materials Oriented on Problem-Based Learning Model to Improve Students' Mathematical Problem Solving Ability and Metacognition Ability," *International Electronic Journal of Mathematics Education*, vol. 14, no. 2, pp. 331–340, 2019, doi: 10.29333/iejme/5717.

[2] H. Basri, P. Purwanto, A. R. As'ari, and S. Sisworo, "Investigating critical thinking skill of junior high school in solving mathematical problem," *International Journal of Instruction*, vol. 12, no. 3, pp. 745–758, Jul. 2019, doi: 10.29333/iji.2019.12345a.

[3] L. Ulandari, Z. Amry, and S. Saragih, "Development of learning materials based on realistic mathematics education approach to improve students' mathematical problem solving ability and self-efficacy," *International Electronic Journal of Mathematics Education*, vol. 14, no. 2, pp. 375–383, Feb. 2019, doi: 10.29333/iejme/5721.

[4] M. Khalid, S. Saad, S. R. A. Hamid, M. R. Abdullah, H. Ibrahim, and M. Shahrill, "Enhancing creativity and problem solving skills through creative problem solving in teaching mathematics," *Creativity Studies*, vol. 13, no. 2, pp. 270–291, May 2020, doi: 10.3846/cs.2020.11027.

[5] C. Cresswell and C. P. Speelman, "Does mathematics training lead to better logical thinking and reasoning? a cross-sectional assessment from students to professors," *PLoS ONE*, vol. 15, no. 7 July, p. e0236153, Jul. 2020, doi: 10.1371/journal.pone.0236153.

[6] K. Maass, V. Geiger, M. R. Ariza, and M. Goos, "The role of mathematics in interdisciplinary stem education," *ZDM - Mathematics Education*, vol. 51, no. 6, pp. 869–884, 2019, doi: 10.1007/s11858-019-01100-5.

[7] N. H. Kang, "A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea," *Asia-Pacific Science Education*, vol. 5, no. 1, pp. 1–22, 2019, doi: 10.1186/s41029-019-0034-y.

[8] Y. M. A. Algani, "Role, need and benefits of mathematics in the development of society," *Journal for the Mathematics Education and Teaching Practices*, vol. 3, no. 1, pp. 23–29, 2022.

[9] N. P. Jewell, J. A. Lewnard, and B. L. Jewell, "Predictive mathematical models of the COVID-19 pandemic: underlying principles and value of projections," *JAMA - Journal of the American Medical Association*, vol. 323, no. 19, pp. 1893–1894, 2020, doi: 10.1001/jama.2020.6585.

[10] B. Jahn *et al.*, "On the role of data, statistics and decisions in a pandemic," *AStA Advances in Statistical Analysis*, vol. 106, no. 3, pp. 349–382, 2022, doi: 10.1007/s10182-022-00439-7.

[11] J. Hong, P. (Vonu) Thakuriah, P. Mason, and C. Lido, "The role of numeracy and financial literacy skills in the relationship between information and communication technology use and travel behaviour," *Travel Behaviour and Society*, vol. 21, pp. 257–264, 2020, doi: 10.1016/j.tbs.2020.07.007.

[12] W. Osei and M. K. Kubi, "Algebra teaching knowledge of professional and non-professional basic school mathematics teachers," *International Journal of Scientific and Research Publications (IJSRP)*, vol. 12, no. 1, pp. 41–48, 2022, doi: 10.29322/ijsrp.12.01.2022.p12107.

[13] C. L. Ying, S. Osman, D. Kurniati, E. S. Masykuri, J. A. Kumar, and C. Hanri, "Difficulties that students face when learning algebraic problem-solving," *Universal Journal of Educational Research*, vol. 8, no. 11, pp. 5405–5413, 2020, doi: 10.13189/ujer.2020.081143.

[14] T. I. Pramesti and H. Retnawati, "Difficulties in learning algebra: an analysis of students' errors," *Journal of Physics: Conference Series*, vol. 1320, no. 1, p. 012061, 2019, doi: 10.1088/1742-6596/1320/1/012061.

[15] A. Y. Asfaw, K. M. Weldeyesus, and M. A. Ayele, "The effect of assessment for learning on prospective teachers' learning of algebra through a professional development program," *International Electronic Journal of Mathematics Education*, vol. 17, no. 4, p. em0718, 2022, doi: 10.29333/iejme/12587.

[16] R. Noreen and A. M. K. Rana, "Activity-based teaching versus traditional method of teaching in mathematics at elementary level," *Bulletin of Education and Research*, vol. 41, no. 2, pp. 145–159, 2019.

[17] F. Egger, V. Benzing, A. Conzelmann, and M. Schmidt, "Boost your brain, while having a break! The effects of long-term cognitively engaging physical activity breaks on children's executive functions and academic achievement," *PLoS ONE*, vol. 14, no. 3, p. e0212482, 2019, doi: 10.1371/journal.pone.0212482.
[18] S. Sneck *et al.*, "Effects of school-based physical activity on mathematics performance in children: a systematic review," *International Journal of Behavioral Nutrition and Physical Activity*, vol. 16, no. 1, pp. 1–15, 2019, doi: 10.1186/s12966-019-0866-6.
[19] M. Hartt, H. Hosseini, and M. Mostafapour, "Game on: exploring the effectiveness of game-based learning," *Planning Practice and Research*, vol. 35, no. 5, pp. 589–604, 2020, doi: 10.1080/02697459.2020.1778859.
[20] P. Vankúš, "Influence of game-based learning in mathematics education on students' affective domain: a systematic review," *Mathematics*, vol. 9, no. 9, p. 986, 2021, doi: 10.3390/math9090986.
[21] M. G. Bartolini and F. Martignone, "Manipulatives in mathematics education," in *Encyclopedia of Mathematics Education*, S. Lerman, Ed., Cham: Springer International Publishing, 2020, pp. 487–494, doi: 10.1007/978-3-030-15789-0_93.
[22] E. B.- Abarquez, "The use of manipulative in teaching elementary mathematics," *International Journal of Linguistics, Literature and Translation*, vol. 3, no. 11, pp. 18–32, Nov. 2020, doi: 10.32996/ijllt.2020.3.11.3.
[23] I. Hidayah, I. Isnarto, M. Masrukan, M. Asikin, and M. Margunani, "Quality management of mathematics manipulative products to support students' higher order thinking skills," *International Journal of Instruction*, vol. 14, no. 1, pp. 537–554, Jan. 2021, doi: 10.29333/iji.2021.14132a.
[24] B. Ç. Ergene and Ç. Haser, "Students' algebra achievement, algebraic thinking and views in the case of using algebra tiles in groups," *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, vol. 15, no. 2, pp. 254–281, Dec. 2021, doi: 10.17522/balikesirnef.1019292.
[25] C. A. Barbieri, J. Rodrigues, N. Dyson, and N. C. Jordan, "Improving fraction understanding in sixth graders with mathematics difficulties: effects of a number line approach combined with cognitive learning strategies," *Journal of Educational Psychology*, vol. 112, no. 3, pp. 628–648, Apr. 2020, doi: 10.1037/edu0000384.
[26] M. Khalid and Z. Embong, "Emphasizing concrete representation to enhance students' conceptual understanding of operations on integers," *Turkish Journal of Computer and Mathematics Education*, vol. 11, no. 3, pp. 762–773, Nov. 2020, doi: 10.16949/turkbilmat.775605.
[27] Department of Education, "Vision, mission, core values, and mandate," Republic of the Philippines. Accessed: Mar. 02, 2024. [Online]. Available: https://www.deped.gov.ph/about-deped/vision-mission-core-values-and-mandate/
[28] PISA, *PISA 2022 results (Volume I)*. Paris: OECD, 2023, doi: 10.1787/53f23881-en.
[29] Department of Education, "K to 12 basic education curriculum." Accessed: Mar. 02, 2025. [Online]. Available: https://www.deped.gov.ph/k-to-12/about/k-to-12-basic-education-curriculum/
[30] B. Rittle-Johnson and R. S. Siegler, "The relation between conceptual and procedural knowledge in learning mathematics: a review," in *the Development of Mathematical Skills*, C. Donlan, Ed., London: Psychology Press, 2021, pp. 75–110, doi: 10.4324/9781315784755-6.
[31] M. Cabatuan, "Dismath: discrete math gamified educational tool in logic with minimax algorithm and pruning," in *2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, IEEE, Nov. 2019, pp. 1–6, doi: 10.1109/HNICEM48295.2019.9072894.
[32] S. Dawadi, S. Shrestha, and R. A. Giri, "Mixed-methods research: a discussion on its types, challenges, and criticisms," *Journal of Practical Studies in Education*, vol. 2, no. 2, pp. 25–36, 2021, doi: 10.46809/jpse.v2i2.20.
[33] M. Gopalan, K. Rosinger, and J. bin Ahn, "Use of quasi-experimental research designs in education research: growth, promise, and challenges," *Review of Research in Education*, vol. 44, no. 1, pp. 218–243, 2020, doi: 10.3102/0091732X20903302.
[34] S. J. Stratton, "Quasi-experimental design (pre-test and post-test studies) in prehospital and disaster research," *Prehospital and Disaster Medicine*, vol. 34, no. 6, pp. 573–574, 2019, doi: 10.1017/S1049023X19005053.
[35] K. L. Peel, "Beginner's guide to applied educational research using thematic analysis," *Practical Assessment, Research and Evaluation*, vol. 25, no. 1, pp. 1–16, 2020, doi: 10.7275/ryr5-k983.
[36] S. H. Golafshani, A. Kebriaei, G. Hoseindoost, M. Arani, and A. Ansaritabar, "Investigating the effective factors on tendency toward virtual education among the students of payame noor university in Kashan and Aran-Va-Bidgol county in 2017," *International Archives of Health Sciences*, vol. 7, no. 2, pp. 64–67, 2020, doi: 10.4103/iahs.iahs_60_18.
[37] L. Sürücü and A. Maslakçi, "Validity and reliability in quantitative research," *Business & Management Studies: An International Journal*, vol. 8, no. 3, pp. 2694–2726, 2020, doi: 10.15295/bmij.v8i3.1540.
[38] A. N. Hidayah, K. Kertono, and S. Suciati, "Math learning outcomes with cooperative learning model (STAD) reviewed from students' self efficacy," *AlphaMath: Journal of Mathematics Education*, vol. 9, no. 2, p. 169, 2023, doi: 10.30595/alphamath.v9i2.18955.
[39] S. Afifah, A. Mudzakir, and A. B. D. Nandiyanto, "How to calculate paired sample t-test using SPSS software: From step-by-step processing for users to the practical examples in the analysis of the effect of application anti-fire bamboo teaching materials on student learning outcomes," *Indonesian Journal of Teaching in Science*, vol. 2, no. 1, pp. 81–92, Mar. 2022, doi: 10.17509/ijotis.v2i1.45895.
[40] A. Rafiepour, N. Faramarzpour, and M. R. Fadaee, "Introducing a teaching technique for reducing students' mistakes in simplifying algebraic expressions," *Mathematics Teaching-Research Journal*, vol. 15, no. 5, pp. 193–208, 2023.
[41] F. Anwar, "Activity-based teaching, student motivation and academic achievement," *Journal of Education and Educational Development*, vol. 6, no. 1, pp. 154–170, May 2019, doi: 10.22555/joeed.v6i1.1782.
[42] E. Debrenti, "Game-based learning experiences in primary mathematics education," *Frontiers in Education*, vol. 9, p. 1331312, Mar. 2024, doi: 10.3389/feduc.2024.1331312.
[43] T. Al Shloul *et al.*, "Role of activity-based learning and ChatGPT on students' performance in education," *Computers and Education: Artificial Intelligence*, vol. 6, p. 100219, Jun. 2024, doi: 10.1016/j.caeai.2024.100219.
[44] C. Hiltrimartin, Y. Hartono, and I. Indaryanti, "Development of student activities in algebra based on problem solving in middle school," in *Proceedings of the 2nd National Conference on Mathematics Education 2021 (NaCoME 2021)*, pp. 47–55, 2022, doi: 10.2991/assehr.k.220403.008.

BIOGRAPHIES OF AUTHORS

Rolly Najial Apdo is an instructor at the Department of Secondary Education, Caraga State University, Philippines. He pursued Ph.D. in Mathematics at Caraga State University, Philippines. His research focuses on mathematical modeling and mathematics education. He can be contacted at email: rnapdo@carsu.edu.ph.

Rachel Basañez Apdo is an instructor at the Department of Mathematics, Caraga State University, Philippines. She pursued Master of Science in Mathematics at Caraga State University, Philippines. Her research focuses on mathematical modeling and mathematics education. She can be contacted at email: rbapdo@carsu.edu.ph.