International Journal of Innovative Research and Scientific Studies, 6(4) 2023, pages: 1015-1022

IJIRSS International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Investigating the effectiveness of TPACK and TGT in enhancing histogram learning achievement among eighth-grade students

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Abstract

This study aimed to explore the effects of employing the Technological Pedagogical Content Knowledge (TPACK) model integrated with the Teams Games Tournament (TGT) collaborative instructional approach in teaching the concept of histograms to eighth grade students. Additionally, the research sought to assess the students' satisfaction with this integrated method during the learning process. The participants in the study comprised 44 eighth-grade students from a public school in Thailand. Three primary instruments used in this study are the learning management plan, a learning achievement test and a satisfaction questionnaire. The findings of the study indicate that the integration of the TPACK model with TGT collaborative learning had a positive impact on the participants' comprehension and knowledge of histograms. The interactive and cooperative nature of TGT activities in addition to the integration of technological, pedagogical and content knowledge increased the learning outcomes of the students. Additionally, the participants expressed a high level of satisfaction with the integrated TPACK and TGT frameworks learning experiences. This suggests that the collaborative and technology-enhanced approach fostered a positive and engaging learning environment, facilitating a deeper understanding of the histogram concept. These findings contribute to the existing body of knowledge on innovative instructional methods and provide valuable insights for educators seeking to enhance students' learning experiences in mathematics and other related subjects.

Keywords: Histogram, Junior high school education, Learning achievement, Mathematics education, TGT, TPACK model.

DOI: 10.53894/ijirss.v6i4.2232

Funding: This research is supported by Mahasarakham University, Thailand (Grant number: 6607074).

History: Received: 6 February 2023/**Revised:** 4 September 2023/**Accepted:** 2 October 2023/**Published:** 16 October 2023

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Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

Competing Interests: The authors declare that they have no competing interests.

Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Institutional Review Board Statement: The Ethical Committee of the Mahasarakham University, Thailand has granted approval for this study (Ref. No. 408-434/2023).

Publisher: Innovative Research Publishing

1. Introduction

Students in the eighth grade are often known as junior high school students. They are transitioning from elementary school to high school while investigating their hobbies and possible career paths [1]. Mathematics is a fundamental subject for success in many other fields of study such as physics, engineering and economics. Students must have a solid grasp of mathematics to interact with these subjects and pursue relevant occupations in the future. Students can improve their capacity for abstract thought, logical reasoning and problem-solving by studying mathematics that is applicable to a variety of situations and tasks. Furthermore, given the importance of technology and data analysis in today's world, a strong foundation in mathematics is becoming crucial. Numerous STEM jobs (Science, Technology, Engineering and Mathematics) require solid math skills and expertise [2-4]. Therefore, mathematics learning achievement is an essential outcome of curricula worldwide.

Histograms are a valuable tool in mathematics education that assists students in learning and analyzing data. They visually represent mathematical concepts and connect math to real-world problems. Students can see patterns and trends in data and comprehend the statistical concept of frequency distribution by making histograms [5]. Additionally, creating histograms of relevant data allows students to see the practical applications of math concepts.

Some students may struggle with learning histograms. This topic is often taught in grade 8 and above in Thai education. Students without a strong foundation in mathematics may have difficulty understanding the concept [6]. Histograms involve abstract concepts such as frequency distribution which can be challenging for students to grasp. Additionally, creating histograms requires students to use mathematical reasoning and problem-solving skills to determine appropriate bin sizes and construct the graph. Students who struggle with these skills may have difficulty creating histograms [7]. Furthermore, histograms are visual representations of data and students who struggle with visual representation may have trouble understanding the distribution of data from a graph [8].

The teaching methodology in the context of Thai mathematics education has been criticized for its teacher-centered approach where the teacher is the main source of knowledge and control in the class, leaving students as passive learners [9, 10]. This method has a negative impact on student learning as it does not consider the diverse learning needs, styles and lack of student engagement and motivation. According to Thongphat [11], traditional teaching in the Thai context hinders the development of essential skills such as critical thinking and problem-solving which are crucial for success in the current world. This has been linked to poor educational outcomes at both the national and international levels.

The development of students' mathematical abilities and the creation of an engaging and purposeful learning environment are two requirements for an instructional strategy that could address issues in Thai mathematics education. In this situation, the TPACK model can be presented as an alternative solution to the problem. The TPACK (Technological Pedagogical Content Knowledge) model was introduced by Mishra and Koehler [12] as a framework for integrating technology, pedagogy and content knowledge in classrooms. It is a theoretical framework that can be used to design effective technology-enhanced instruction for histograms. The model's basic idea is that teachers need to have an in-depth understanding of both technological tools and the pedagogical and subject-matter knowledge necessary to use them effectively in the classroom [12-14]. The details of each component and how it could contribute to histogram teaching are described below.

Technological knowledge (TK) refers to the knowledge of how to use technology tools and resources effectively. A teacher can create captivating and important lessons for students by comprehending many pedagogical methods and techniques used for teaching histograms such as problem-based learning or inquiry-based learning [12]. For example, a teacher could use a problem-based learning approach in which students work in groups to analyze real-world data sets and create histograms to represent the data.

Pedagogical knowledge (PK) refers to the knowledge of how to teach and design instruction. A teacher can deliver precise and insightful training to students by having a thorough understanding of the concepts and principles of histograms such as how to read and interpret a histogram [13]. For example, a teacher could use a histogram to introduce the concepts of distribution and frequency and then explain how to read and interpret the histogram to understand the data.

Content knowledge (CK) refers to the knowledge of the subject matter that is being taught. A teacher can provide accurate and meaningful instruction to students by having a deep understanding of the concepts and principles of histograms such as how to read and interpret a histogram [14]. For example, a teacher could use a histogram to introduce the concepts of distribution and frequency and then explain how to read and interpret the histogram to understand the data.

Technological use in education needs to be integrated if it is to be effective because these three types of knowledge are interrelated. A teacher who possesses a deep understanding of the interplay between these three types of knowledge can design instruction that effectively integrates technology and enhances student learning [12, 15].

Moreover, problems in Thai mathematics education might be solved by allowing students to take control of their learning and collaborate in the process of learning. The Team Game Tournament (TGT) method is a type of collaborative learning strategy where students work in teams to compete against each other in a tournament of games [16]. These games can be educational activities or simulations such as board games, computer games, quizzes or interactive simulations that align with the learning objectives and content [17, 18]. The teams compete in a series of rounds and the team with the most points at the end of the tournament is declared the winner. The TGT method aims to enhance student motivation and engagement by providing a fun and interactive learning experience. It also allows students to work collaboratively and learn from each other while encouraging friendly competition. Additionally, it allows the teacher to assess the student's learning and understanding of the content in a formative way allowing the teacher to adjust the instruction accordingly [17, 19, 20].

In teaching histograms, TGT can be employed to enhance students' motivation and engagement, promote collaborative learning and active learning, provide formative assessment opportunities and make the learning experience more fun. The TGT method can make histogram learning more motivating and engaging for students by using a game-based approach. Moreover, the method promotes collaboration and teamwork as students work in teams to complete tasks and activities that foster a sense of community among the students and provide opportunities to actively learn from one another. The TGT can increase students' enjoyment and make learning about histograms more memorable.

Previous studies also indicate the benefits of TPACK [21-24] and TGT [25-27] on mathematics education. The TPACK model has been used to improve the quality of teaching in several math concepts (e.g, Geogebra).

Furthermore, the two techniques have properties that might be combined, which could be advantageous in mathematics classes where the topic of histograms is taught. The integration of the TPACK model and TGT method can create a technology-enhanced, game-based approach to teaching histograms and a theoretical framework for understanding how to effectively use technology in the classroom. This can be done by using technology tools such as interactive online histogram generators and visualization tools, supporting collaboration through online collaboration platforms and providing formative assessments through online quizzes.

The TPACK model and TGT collaborative techniques can be employed in mathematics classes and desirable outcomes can be expected. Previous studies still encourage using both methods to teach mathematics concepts. Moreover, there is no study using the integration of the two methods in teaching students in their early teens as grade 8 students.

Therefore, the contribution of the current study is the effectiveness of the TPACK model and TGT collaborative learning in improving students' mathematical knowledge of histograms. The result of the study would be beneficial for teachers who seek to design effective instructional strategies that integrate the TPACK model and TGT collaborative learning to enhance their students' learning experiences. Moreover, it could provide how the TPACK model would be applied with collaborative learning techniques and technology in mathematic instruction.

The current study was conducted considering the direction suggested by previous studies. The purpose of the study was 1) to investigate the effects of using the TPACK model and TGT as an integrated instructional method in teaching grade 8 students the concept of histograms and 2) to investigate students' satisfaction with the integrated TPACK and TGT during the process of histogram learning.

2. Methodology

2.1. Research Design

A one group pre- and post- tests design was used [28]. The findings of the study were determined by comparing the students' knowledge of histograms before and after deploying a learning management system based on the TPACK model and TGT.

2.2. Participants

The participants were 44 eighth grade students from a public Thai school. They were selected through cluster sampling from 13 groups of the 548 eighth grade students. Students have lower-intermediate math skills given to them by Thailand's mathematics education system. They received information about the study projects and consented to participate in data collection. The participants were treated with the ethical considerations of human subjects in mind.

2.3. Instruments

2.3.1. Learning Management Plan

The learning management plan was designed using the TPACK model and TGT learning activities. Therefore, aspects of technological, pedagogical and content knowledge were considered in the design of the learning activities. The details of each aspect are given below.

The learning management consists of 4 sub-lesson plans including dot plots, stem and leaf plots, histograms and medium of data. It took 8 class hours to complete. The TGT activities were employed for 5-8 hours to enhance the TPACK. The learning management was evaluated as very high. The details of the plan are given below.

In the technological knowledge aspect, technology-based tools such as Canva, Dot Plot Maker, YouTube, QR Codes and Live Worksheets were employed in the learning processes. Specifically, Dot Plot Maker has been employed as a free online tool to create dot plots also known as dot charts or scatterplots which are visual representations of data that use dots to display the frequency or distribution of a variable.

In this study, Dot Plot Maker was implemented as a tool to facilitate the teaching of histograms. Using Dot Plot Maker, students were afforded the opportunity to create visual representations of data in an alternative format. There are similarities between dot plots and histograms but they differ in terms of format with histograms using bars to represent data and dot plots using dots.

The implementation of Dot Plot Maker was used in various aspects of the teaching of histograms. Firstly, it was used to introduce the concept of data visualization providing students with hands-on experience in creating graphs. Additionally, it allowed for the comparison and contrast of histograms and dot plots enabling students to understand the differences between the two and their respective usefulness. Furthermore, Dot Plot Maker was used to develop the data analysis skills of students by allowing for the identification of the mode, median and range of a given data set. Lastly, custom data sets were created by students as a means of exploring different scenarios and creating their own histograms or dot plots.

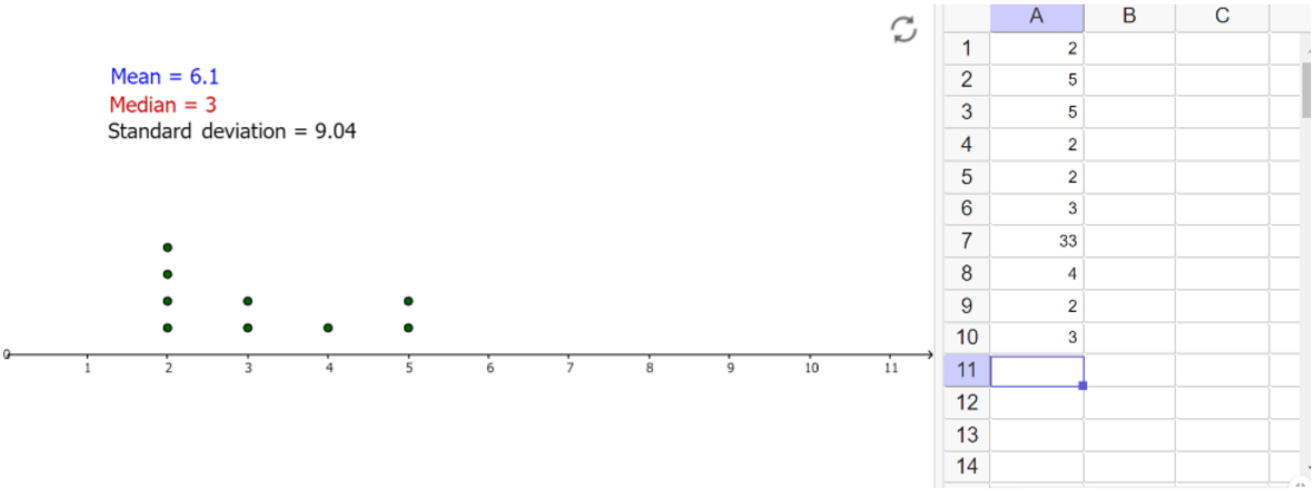

Figure 1.
Students check their answers on dot plots from the web dot plot maker.
Note: Bowman [29].

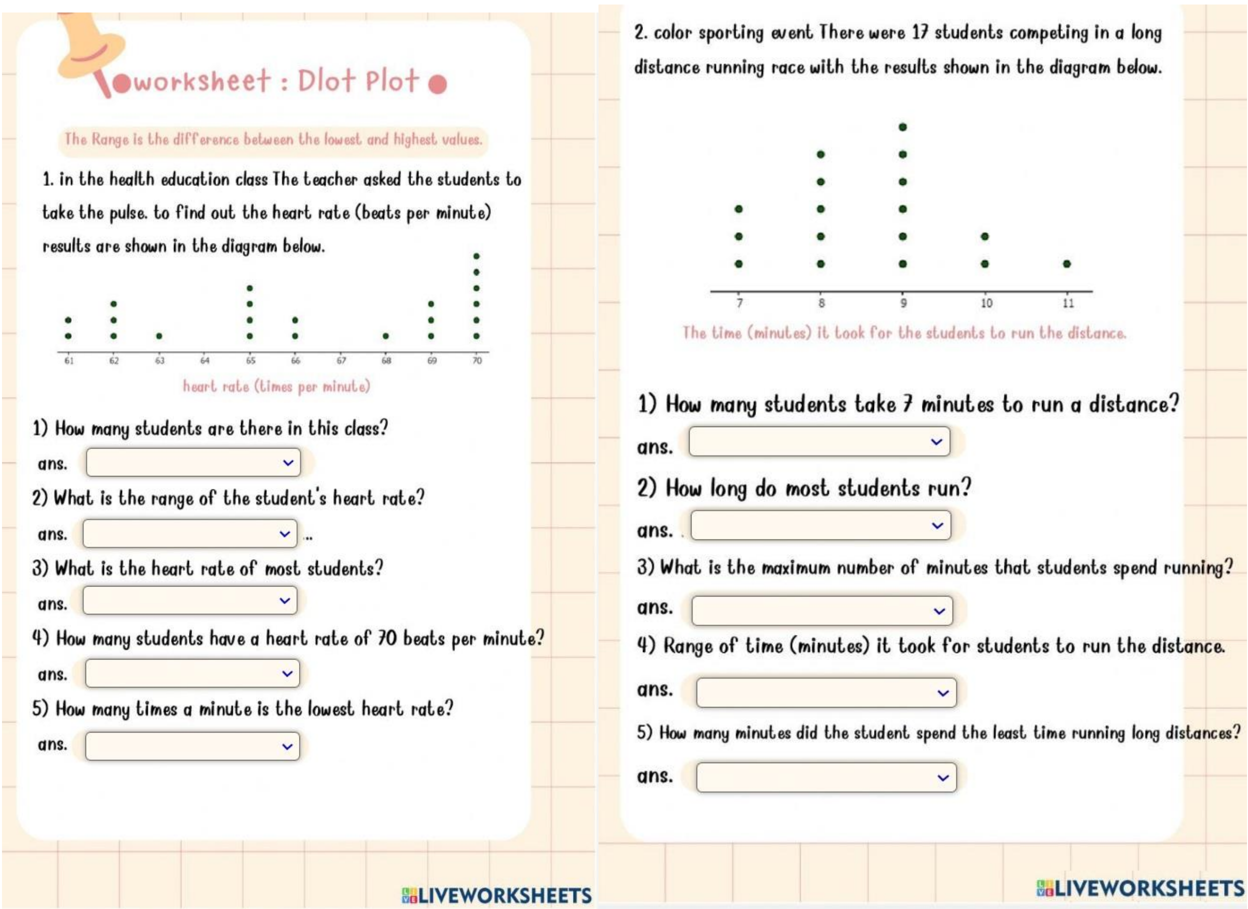

Figure 2.
Worksheets on Dot plots made from live worksheet.

Figures 1 and 2 depict the practical applications of the Dot Plot Maker and Live sheet tools in the context of teaching histograms. In Figure 1, the Dot Plot Maker is showcased as an effective aid in visualizing and analyzing data enabling students to construct and interpret histograms with ease. The user-friendly interface of the tool facilitates a deeper understanding of the histogram concept. On the other hand, Figure 2 highlights the utilization of a live sheet presenting real-time data collaboration and manipulation. Students can actively interact with the histogram data making changes and observations as they collaborate in order to provide a dynamic and engaging learning environment.

In the pedagogical knowledge aspect, Teams Games Tournaments (TGT) were employed to allow students to collaboratively learn the concept of histogram as it would allow them to work together to solve problems, make decisions, and share ideas. The details of class activities can be seen below.

Table 1.
Example TPACK model and TGT learning activities.

Stage	Activities	Detail
1	Team formation	The class was divided into teams of four or five students. Each team is formed considering learner diversity such as a mix of genders, abilities and personalities.
2	Explanation of the content	Teachers present a clear and comprehensive explanation of the concept of histograms, their purpose and their components and ensure that all students grasp it. In addition, the Dot Plot Maker was introduced.
3	Team study	Each team was assigned a specific task related to the concept of histograms. For example, one team may be responsible for identifying the mode while another team may be responsible for identifying the median.
4	Game	A game session was conducted. Each team member takes turns answering questions related to histograms. Students were encouraged to discuss and collaborate on the answers before responding.
5	Tournament	After the game, a tournament session was assigned. Teams compete against each other. The teacher assigned a set of questions related to histograms to each team and encouraged them to work together to answer the questions as accurately and quickly as possible.
6	Review and debrief	After the tournament, the class reviewed the questions and answers. Students were encouraged to reflect on what they have learned and how the Dot Plot Maker and the TGT strategy have helped them learn histograms more effectively. The teacher provided feedback and reinforced the importance of teamwork and collaboration.

Table 1 presents the activities for integrated TPACK and TGT learning. The learning process was divided into six stages. First, the class was organized into teams of four or five students taking into account learner diversity in terms of gender, abilities and personalities. After team formation, teachers thoroughly explained histograms to all students to ensure understanding and then introduced the Dot Plot Maker as a learning tool. Each team was assigned specific tasks related to histograms fostering a collaborative team study environment. During the game session, students took turns answering histogram-related questions, engaging in discussions and collaborative problem-solving. The competitive spirit was then introduced in the tournament stage where teams competed against each other collectively by answering a set of questions. Finally, after the tournament, the class reviewed the questions and answers encouraging students to reflect on their learning experiences about the Dot Plot Maker and the TGT strategy emphasizing the value of teamwork and collaboration in effectively mastering histograms.

The concept of histogram was specified in the core curriculum [30] to be taught at the grade 2 high school level of the Thai education system (equivalent to grade 8) in the area of subject matter knowledge. The content of the class includes dot plots, stem and leaf plots, histograms and the medium of data. It took 8 class hours to complete. The TGT activities were employed for 5-8 hours to enhance the TPACK. The learning management was evaluated as very high.

2.3.2. Learning Achievement Test

The test consists of two parts. The first section consists of 10 items with 4 multiple-choice questions having 10 marks. Item difficulty was 0.60-0.80 and item discrimination was 0.22-0.43. Test reliability was 0.84. The second part of the test was a demonstration test with two question items resulting in 10 marks. The item difficulty and discrimination were 0.53-0.70 and 0.63-0.71 respectively. Test reliability was 0.90.

2.3.3. Satisfaction Questionnaire

The questionnaire consists of 10 positive statements regarding students' learning experiences with the TPACK model and TGT collaborative learning. The content validity tested by the Index of Item Objective Congruence (IOC) of each item was 0.67-1.0.

2.4. Data Collection

The purpose of the study was to assess how well a learning management system worked. At the beginning of the semester, the participants conducted a pre-test to determine their level of knowledge. The learning management plan was implemented and integrated into the curriculum over the course of an 8-week period. After the intervention was finished, the participants took a post-test and filled out a questionnaire in the last lesson.

2.5. Data Analysis

The comparison of the student's learning achievement histogram was dependent on the sample t-test.

The overall satisfaction of the students with the investigation of TPACK and TGT was analyzed by mean and standard deviation (SD). The data was interpreted using the following criteria:

Mean		Degree of satisfaction.
4.50-5.00	=	Very high.
3.50-4.49	=	High.
2.50-3.49	=	Moderate.

1.50-2.49 = Low.
1.00-1.49 = Very low.

3. Result

1. The results of the study indicate that the participants' learning achievement in the histogram before the intervention was relatively low (Mean = 5.16, SD = 1.75) but after the intervention, it was relatively high (mean = 16.43, SD = 2.35). During the implementation of the learning management plan, their knowledge improved as their scores were over 90 % in each lesson plan (see Table 2).

Table 2.
Students' overall learning achievement

Statistic	Pre-test	On process performance					Posttest
		Lesson plan 1	Lesson plan 2	Lesson plan 3	Lesson plan 4	Total	
Full mark	**(20)**	**(15)**	**(20)**	**(10)**	**(12)**	**(57)**	**(20)**
Mean	5.16	14.59	19.05	10.00	11.39	55.02	16.43
SD	1.75	0.50	1.12	0.00	0.84	1.58	2.35
Percentage	25.80	97.27	95.23	100.00	94.89	96.53	82.16

2. The research findings indicated that the post-test score of the students after using the integration of the TPACK model and TGT was higher than that of the pre-test score at the 0.05 level of statistical significance (see Table 3).

Table 3.
The comparison between the participants' learning achievement before and after the treatment

Achievement	N	Mean	SD	Mean difference	SD difference	T	P
Pre-test	44	5.16	1.75	11.27	2.84	26.33*	0.000
Post-test	44	16.43	2.35				

Note: * $p < .05$.

3. According to the table, participants' favourable statements about learning in the TPACK model and TGT collaborative learning environment are representative of their satisfaction with the learning management system (mean = 3.93, SD = 0.70). The participants felt that the learning management system was effective in promoting collaborative, respectful and confident learning. In addition, they appreciated the clear instructions and guidance provided by the teacher which facilitated their understanding of the concept of histograms. Additionally, they reported that the learning management plan allowed them to work at their own pace and provided opportunities for self-reflection and self-assessment. Therefore, using the TPACK model and TGT collaborative learning might be seen as allowing the teaching environment for mathematics lessons (see Table 4).

Table 4.
The participants' satisfaction with the learning management

No.	Statements	Mean	SD	Interpretation
1	I had opportunities to learn collaboratively with others.	3.97	0.76	High
2	I respected my fellow group members' abilities.	4.00	0.82	High
3	I had opportunities to share my opinions.	3.94	0.81	High
4	I was more confident in my ability to express my thoughts.	3.91	0.87	High
5	I felt positive about the TPACK model of learning management.	3.85	0.82	High
6	I was more enthusiastic about learning maths.	3.91	0.67	High
7	I like studying and participating in activities with others.	3.94	0.89	High
8	I had the freedom to search for information from sources and use it to solve mathematical problems.	3.97	0.80	High
9	I could complete my goal of learning mathematics.	3.85	0.82	High
10	I could use the class knowledge in my daily life.	3.97	0.90	High
	Average	3.93	0.70	High

4. Discussion

4.1. The TPACK Model and Students' Learning Achievement

The results of our study indicate that the use of the TPACK model positively impacted participants' knowledge of histograms. This is in line with the findings of previous studies that have also reported the benefits of the TPACK model in mathematics education [21-24]. This suggests that the TPACK model is an effective approach for teaching histograms in mathematics education.

The TPACK model is a framework that emphasizes the integration of technology, pedagogy and content knowledge in teaching [12, 13]. Our study suggests that the use of technology in teaching histograms, in conjunction with appropriate pedagogy and content knowledge can have a positive impact on students' learning.

The TPACK model's beneficial effects on students' histogram knowledge may be explained by the fact that technology-enhanced instruction can promote active learning and participation [14]. For example, the use of interactive simulations and virtual manipulatives can enable students to manipulate histogram data and explore different concepts and patterns which can enhance their understanding of the subject. Additionally, the use of technology can also provide students with opportunities to collaborate and share their knowledge and ideas with their peers which can further promote their learning.

4.2. The TGT Collaborative Learning and Students' Learning Achievements

The current study employed TGT as a pedagogical approach within the framework of the TPACK model. The findings of the study indicate that TGT activities were effective in improving participants' learning achievement on the histogram.

According to Slavin [16], TGT emphasizes teamwork and collaboration in education. The results of the current study demonstrate that collaborative education can enhance students' learning of histograms by providing opportunities for students to work together, share their knowledge and ideas and engage in active learning. Furthermore, the use of TGT activities can also promote students' critical thinking, problem-solving skills and communication skills which are essential for mathematical understanding [17].

Teamwork may enhance the process of the TPACK model by helping students learn histograms through TGT activities. TGT activities can facilitate student-centered learning by enabling students to take an active role in their own learning rather than simply receiving information from the teacher. Additionally, TGT activities can also provide students with opportunities to collaborate and learn from one another.

Moreover, the results of the satisfaction questionnaire indicated that the participants were highly satisfied with their learning experiences during the intervention of the TPACK and TGT models in their learning of histograms. The high level of satisfaction expressed by the participants in this study highlights the importance of using instructional strategies that incorporate online technology and collaborative learning to enhance students' engagement, motivation and enjoyment of the learning process. The use of Dot Plot Maker allowed students to create visually appealing and interactive learning materials which provided a more engaging and stimulating learning environment.

5. Conclusion

The current study aimed to investigate the effects of using the TPACK model and TGT as an integrated instructional method in teaching eighth grade students the concept of histograms as well as students' satisfaction with this approach. The results of the study indicate that the use of the TPACK model integrated with TGT collaborative learning had a positive impact on participants' knowledge of histograms. Additionally, the participants were satisfied with the experiences in the learning management plan.

The study has implications for mathematics teaching as instructors could integrate the methods of TPACK and TGT into their teaching. Future researchers could explore the effectiveness of this approach in different grade levels and subjects as well as in different cultural and educational contexts. Additionally, future studies could investigate the long-term effects of this approach on student learning and satisfaction.

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