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The effects of the GPAS 5 steps and TPACK model on learning achievement and mathematical connection skills in sequences and series among grade 11 students

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Abstract

This quasi-experimental study aimed to investigate the effects of GPAS 5 Steps and TPACK-based instructional activities on Grade 11 students' learning achievement and mathematical connection skills in the topic of sequences and series. A total of control group 40 students and experimental group 40 students from a public secondary school in northeastern Thailand were assigned to either an experimental group receiving GPAS 5 Steps and TPACK-based instruction or a control group receiving traditional instruction. Research instruments included a learning achievement test, a mathematical connection ability test, and a satisfaction questionnaire. Data were analyzed using MANOVA, followed by univariate ANOVA. The results revealed that students taught through the GPAS 5 Steps and TPACK model significantly outperformed those in the traditional group in both learning achievement ($p = .01$) and mathematical connection skills ($p = .001$). Additionally, students in the experimental group reported a high level of satisfaction with the instructional approach, particularly in areas related to teacher preparedness, engagement, and opportunities for independent problem-solving. These findings highlight the comparative advantage of the GPAS 5 Steps and TPACK model in enhancing both cognitive and affective learning outcomes in mathematics education. The study contributes empirical evidence supporting the integration of technological, pedagogical, and content knowledge in secondary-level instruction.

Keywords: Learning Achievement, Mathematical connection Skills, TPACK.

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1. Introduction

The traditional method of mathematics teaching, in which the teacher acts as the sole source of knowledge and students are passive members of the class, may no longer meet the demands of modern education [1-3]. Teacher-centered approaches often overlook student engagement, critical thinking, and authentic applicability [4]. Consequently, learners may find it difficult to connect abstract mathematical concepts with practical situations, which causes limited understanding and low retention. The rigidity and lack of interaction in such methods also fail to accommodate diverse learning styles and technological advancements in education [5, 6].

With rapid developments in digital technology, the integration of technology into educational practice has become a pressing need [7-9]. Modern pedagogical models increasingly emphasize the use of technological tools both to enhance content delivery and to support collaborative learning and critical thinking. One of the promising frameworks is the Technological Pedagogical and Content Knowledge (TPACK), the model providing a structured approach for teachers to integrate technology in a balanced and effective manner [10, 11].

Additionally, the TPACK model could provide a potential benefit for mathematics education, where abstract concepts can be better understood through dynamic visualizations, simulations, and interactive tools [9]. For mathematics teachers, developing TPACK competencies results in the ability to design lessons that combine content knowledge with appropriate technological tools and effective pedagogical strategies [12, 13]. From the learner's perspective, the use of TPACK-based instruction formed conceptual understanding, improved problem-solving skills, and strengthened connections between mathematical ideas [14].

Although the TPACK model has gained wide recognition in educational research at the school level, its practical application in specific, more complex mathematical topics at the upper secondary level has not been extensively explored. Moreover, comparative studies between traditional methods and TPACK-based instruction remain scarce, especially in contexts where the development of mathematical connection skills is a key learning objective. In addition, limited attention has been given to how this instructional approach impacts both cognitive and affective domains, such as students' conceptual understanding and learning satisfaction. These gaps underscore the need for further investigation into the instructional potential of the TPACK framework in enhancing key mathematical competencies.

2. Literature Review

2.1. TPACK Framework: Theoretical Foundations

The Technological Pedagogical and Content Knowledge (TPACK) framework, introduced by Mishra and Koehler [10] provides a comprehensive model for integrating technology effectively into teaching. It emphasizes the interplay among three core components: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) [10, 11, 15]. Rather than treating these components in isolation, TPACK highlights the importance of their intersection in designing effective, contextually appropriate learning experiences [11]. Teachers operating within the TPACK framework are better equipped to select suitable technological tools, design pedagogically sound learning environments, and align instruction with subject matter [13, 16, 17]. The framework has gained traction in mathematics education as visualizations, simulations, and interactive digital tools can enhance conceptual understanding and engagement.

2.2. Application of TPACK in Mathematics Education

Research applying the TPACK model in mathematics has shown consistent benefits across cognitive domains. Chaidam and Poonputta [18] developed a TPACK-based lesson on weight and measurement using a problem-based learning (PBL) approach, achieving learning efficiency above the benchmark and statistically significant post-intervention gains among Grade 7 students. Similarly, integrated TPACK with Team Games Tournament (TGT) in teaching histograms to Grade 8 students, resulting in substantial learning improvements and high satisfaction levels. Therefore, the combination of digital tools, pedagogical strategies, and subject-specific content seems to enhance both learning achievement and engagement in mathematics.

Furthermore, Helsa et al. [19] demonstrated the potential of TPACK in improving computational thinking, with students achieving an average performance. The use of TPACK is also found to support skill development in problem-solving and logic, as well as align with 21st-century learning goals. Chaidam and Poonputta [18] earlier study (2022) further confirms TPACK's adaptability across topics and grade levels, reinforcing its efficacy in fostering a deeper understanding in mathematical contexts.

2.3. GPAS 5 Steps

The concept of acquiring fundamental and advanced cognitive abilities (GPAS) is based on Buddhist precepts, which outline three forms of wisdom: 1) wisdom resulting from reflection, 2) wisdom resulting from study, and 3) wisdom resulting from mental development [20] and this approach fosters student development by linking education to the societal context. Students can utilize their knowledge to address everyday challenges, which enhances their understanding, procedural skills, and attitudes/values [20-23]. This process structures student learning through stages of 1) gathering, 2) processing, 3) applying and constructing knowledge, 4) applying communication skills, and 5) self-regulation [20-24].

2.4. Mathematical Connection Skills and Instructional Models

Equally central to mathematics education is the development of mathematical connection skills the ability to link mathematical ideas internally, with other disciplines, and with real-life contexts. Development [24] examined the effectiveness of a multiliteration learning model for improving elementary students' connection abilities in geometry, finding significantly higher post-test scores in the experimental group. Abidin and Jupri [25] and Sari et al. [26] found that junior high school students in Surakarta demonstrated only moderate ability to connect mathematics to real-world experiences and struggled most with cross-disciplinary connections, suggesting persistent challenges in this domain. Similarly, Rafiepour and Faramarzpour [27] reported strong conceptual linking within mathematics and to other subjects, but only 42% of students could apply mathematics to daily life situations.

Domestically, a number of studies have addressed mathematical connection skills using various instructional strategies. Prapngoolueam and Education [28] and Temna [29] both incorporated GeoGebra into problem-based learning to enhance connection skills in geometry and vectors respectively, demonstrating statistically significant post-test gains. Phonyiem and Tunapan [30] integrated Creative-Based Learning (CBL) with TPACK in teaching circles to Grade 6 students, demonstrating learning progress and performance levels.

2.5. GPAS 5 Steps, TPACK and Mathematical Connection: Combined Perspectives

An increasing body of research supports the notion that TPACK-based instruction not only enhances general mathematics learning outcomes but also contributes to the development of specific skills, such as mathematical connections. Helsa et al. [19] demonstrated that integrating TPACK into a hybrid learning model improved students' computational thinking, a cognitive skill closely related to mathematical reasoning and conceptual linkage. Similarly, Vijayan et al. [31] found that students exposed to TPACK strategies performed significantly better in various domains of mathematical ability, including the capacity to link mathematical concepts, as measured by ANCOVA. Moreover, Rakes et al. [9] emphasized that effective TPACK-based mathematics instruction is associated with higher-order thinking, conceptual integration, and flexible problem-solving all of which are foundational to mathematical connection skills.

2.6. Gap in the Literature

Although existing literature supports the use of TPACK in mathematics instruction and highlights the importance of mathematical connection skills, studies that directly compare the effects of TPACK-based instruction with traditional methods, particularly in upper secondary education, remain scarce. Moreover, few investigations have explored the dual outcomes of cognitive development and affective responses, such as student satisfaction, within the same study. This gap is particularly evident in the topic of sequences and series, which require both procedural fluency and the ability to recognize underlying mathematical structures. The present study addresses these gaps by (1) comparing learning achievement and mathematical connection skills between students taught using the TPACK model and those receiving traditional instruction, and (2) examining students' satisfaction with TPACK-based learning activities.

3. Methodology

3.1. Participants

The participants in this study consisted of 80 Grade 11 students enrolled in a public secondary school in northeastern Thailand during the second semester of the 2024 academic year. The population comprised eight Grade 11 classrooms, totaling 320 students with mixed academic abilities. Two classrooms were selected as the sample using cluster random sampling, in which entire classrooms were randomly assigned as intact groups. One class was designated as the experimental group and received instruction based on the TPACK framework, while the other served as the control group and received traditional instruction. Each group consisted of 40 students. All participants were informed of the study's objectives, and participation was entirely voluntary. To protect their privacy, no identifying information was collected, and all data were treated with strict confidentiality in accordance with ethical research standards.

3.2. Instruments

3.2.1. GPAS 5 Steps and TPACK Learning Management Plan

The primary instructional tool employed in this study was a GPAS 5 Steps and TPACK-based learning activity package specifically designed to teach the mathematical topic of sequences and series while enhancing students' mathematical connection ability. The design of this learning package integrated the seven components of the TPACK framework: Content Knowledge (CK), Pedagogical Knowledge (PK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and the holistic Technological Pedagogical Content Knowledge (TPACK).

Content Knowledge (CK) in this study refers to the subject matter of sequences and series, including arithmetic and geometric progressions and their respective summations. Instructional activities emphasized conceptual understanding, procedural fluency, and the real-world applicability of these topics.

Pedagogical Knowledge (PK) was represented by the use of the GPAS 5 Steps instructional method, which structured student learning through stages of 1) gathering, 2) processing, 3) applying and constructing knowledge, 4) applying communication skills, and 5) self-regulation [20-24].

Technological knowledge (TK) involves the selection and application of three digital tools Mentimeter, Kahoot, and GeoGebra that are aligned with both content delivery and learning engagement.

For example, in teaching mathematical connection skills, students used GeoGebra to visually explore the behavior of arithmetic and geometric sequences, enabling them to recognize patterns and relationships between terms. This illustrates the integration of Technological Content Knowledge (TCK), where technology supported a deeper understanding of mathematical content. Similarly, Pedagogical Content Knowledge (PCK) was reflected in the teacher's ability to design tasks that guided students to connect the concept of arithmetic series to budgeting and installment plans real-life contexts familiar to students. Technological Pedagogical Knowledge (TPK) was demonstrated through the use of Mentimeter for live polling during the gathering phase, which elicited students' prior knowledge and misconceptions, and through the use of Kahoot quizzes to reinforce key concepts and promote immediate feedback. The quality of the instructional plans was evaluated by five experts. Overall, the plans were rated as highly appropriate (Mean = 4.54).

3.2.2. Conventional Plan

In addition to the TPACK-based instructional tool, a conventional instructional plan was developed and implemented for the control group. This plan adhered to the school's standard curriculum aligned with the Basic Education Core Curriculum [32] revised in 2017, and followed the typical deductive teaching method commonly practiced in Thai mathematics classrooms. The plan consisted of 12 one-hour lessons covering the topic of sequences and series, mirroring the content scope and instructional duration used in the TPACK group to ensure comparability. Each lesson was structured into four main phases: preparation, presentation of examples, concept summarization, and application. The instructional delivery was teacher-centered, focusing on the explanation of formulas, step-by-step demonstrations of problem-solving, and guided practice. Students' roles were primarily passive, involving listening, note-taking, and solving exercises individually. No technological tools or interactive platforms were employed. This conventional format provided a baseline against which the effects of the TPACK-based intervention could be assessed in terms of learning achievement, mathematical connection ability, and student engagement.

3.2.3. Learning Achievement Test

To measure students' academic performance in the topic of sequences and series, the researchers developed a multiple-choice learning achievement test consisting of 30 items. Each item had four answer choices, with only one correct answer. The test was constructed based on the content covered in both instructional conditions and was aligned with the learning objectives from the Grade 11 mathematics curriculum. The item distribution was as follows: 7 items focused on arithmetic sequences, 7 on geometric sequences, 9 on arithmetic series, and 7 on geometric series, for a total of 30 items. The items were developed to reflect varying levels of cognitive demand based on Bloom's taxonomy, particularly focusing on application, analysis, and evaluation. The test was evaluated to have content validity (IOC = 0.60-1.00). The trial phase of the test resulted in appropriate item difficulty (p = 0.45-0.77), item discrimination using Brennan's formula (B-index = 0.22-0.85), and reliability using the Lovett method [33] (r = 0.97).

3.2.4. Mathematical Connection Ability Test

To assess students' mathematical connection skills related to sequences and series, the researchers developed a written test consisting of five open-ended items. Each item was designed to evaluate students' ability to connect mathematical concepts within the topic, relate them to other areas of mathematics, and apply them to real-life contexts. The test content included tasks such as comparing arithmetic and geometric patterns, linking series to financial contexts like installment payments, and interpreting sequences through graphical representations. These items were constructed to align with the learning objectives of the Grade 11 mathematics curriculum and the specific indicators of mathematical connection ability. The test items were drawn from an initial pool of ten questions. The scoring rubric was developed and validated by three experts in mathematics education and included criteria such as accuracy of connection, depth of explanation, and appropriateness of application. The test was evaluated to have content validity (IOC = 0.60–1.00). The trial phase of the test resulted in appropriate item difficulty (p = 0.45–0.77), item discrimination (d = 0.22–0.85) using Whitney and Sabers method [34] and reliability using Cronbach coefficient [33] (α = 0.94).

3.2.5. Satisfaction Questionnaire

To assess students' affective responses to the TPACK-based instructional activities, a satisfaction questionnaire was developed by the researchers. The instrument consisted of 10 items constructed on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was designed to capture multiple dimensions of student satisfaction, including instructional clarity, engagement in activities, technological integration, perceived learning outcomes, opportunities for interaction, and overall learning experience. Example items included statements such as "The learning activities helped me understand the content better," and "The use of technology made the lessons more interesting." The questionnaire items were evaluated to have content validity (IOC = 0.60–1.00), item discrimination using item-total correlation (r_{xy} = 0.69–0.82), and reliability using Cronbach's alpha coefficient [33] (α = 0.93).

3.3. Research Design and Data Collection

This study employed a quasi-experimental research design using a posttest-only control group structure to examine the effects of GPAS 5 Steps and TPACK-based instructional activities on students' mathematical achievement and connection skills. The independent variable in this study was the instructional method, consisting of the GPAS 5 Steps and TPACK model-based instruction for the experimental group and the traditional approach for the control group. The dependent variables included students' post-instructional learning achievement and their mathematical connection skills in the topic of sequences and series. Additionally, student satisfaction was assessed as a complementary affective outcome within the experimental group.

The data collection process was conducted over a period of six weeks during the second semester of the 2024 academic year. Prior to the intervention, both the experimental and control groups were oriented to the study procedures, and informed consent was obtained from all participants. The instructional intervention spanned 12 class sessions for each group. The experimental group was taught using the GPAS 5 Steps and TPACK-based learning activity package, while the control group received conventional instruction. Upon completion of the instructional period, both groups were administered the same learning achievement test and the mathematical connection ability test to assess the effects of the respective teaching methods. Additionally, the students in the experimental group were asked to complete the satisfaction questionnaire to evaluate their perceptions of the GPAS 5 Steps and TPACK-based learning experience. All data were collected in a classroom setting under the supervision of the researchers to ensure standardized administration procedures.

Table 1.
Data collection.

Group	n	Treatment	Post-test
Experimental group	40	GPAS 5 Steps and TPACK model	1. Learning Achievement Test 2. Mathematical Connection Ability Test 3. Satisfaction questionnaire
Control group	40	traditional approach	1. Learning Achievement Test 2. Mathematical Connection Ability Test

3.4. Data Analysis

Data were analyzed using descriptive and inferential statistics. For the achievement and mathematical connection ability tests, mean scores, standard deviations, and independent samples t-tests were employed to compare the performance between the experimental and control groups. A significance level of .05 was used to determine whether differences between group means were statistically significant.

Interpretation of questionnaire data followed a standard criterion: 4.49–5.00 was considered “very high satisfaction,” 3.50–4.49 as “high,” 2.50–3.49 as “moderate,” 1.50–2.49 as “low,” and 1.00–1.49 as “very low.”

4. Results

Table 2.
Normality of data distribution.

Variables	Test Normality			
	$\bar{X}$	SD	Skewness	Kurtosis
Learning achievement test				
Experimental group	18.22	4.81	-0.016	-0.961
Control group	15.53	4.31	0.762	-0.075
Mathematical Connection Ability Test				
Experimental group	9.63	1.44	-0.478	-1.366
Control group	7.23	4.17	-0.380	-1.389

Prior to conducting inferential statistical analyses, the normality of data distribution was examined for both the learning achievement test and the mathematical connection ability test. As shown in Table 2 the skewness and kurtosis values for all variables fell within acceptable ranges, indicating approximate normality. For the learning achievement test, the experimental group had a skewness of -0.016 and kurtosis of -0.961, while the control group showed a skewness of 0.762 and kurtosis of -0.075. Similarly, the mathematical connection ability test results demonstrated skewness values of -0.478 and -0.380 and kurtosis values of -1.366 and -1.389 for the experimental and control groups, respectively. According to skewness values between -2 and +2 and kurtosis values between -7 and +7 suggest that the assumption of normality is met [35]. Therefore, the data were considered sufficiently normal for the application of parametric tests, such as the independent samples t-test, in subsequent analyses.

Table 3.
The results of testing the assumptions for comparing learning achievement and mathematical connection skills on the topic of sequences and series between experimental and control groups.

Box’ M Test	F	df1	df2	p
39.83	12.91	3	1095120.000	0.000

As shown in Table 3, the results of Box’s M test indicated a violation of the assumption of homogeneity of covariance matrices, with a statistically significant result ($p < .001$). However, because the group sizes were balanced, it was deemed appropriate to proceed with the MANOVA analysis using Pillai’s Trace as the test statistic, which is robust under such violations and was found to be statistically significant [36]. The analysis further confirmed that the variances of learning achievement and mathematical connection skills met the necessary preliminary assumptions, allowing for the application of one-way multivariate analysis of variance (MANOVA), as presented below.

Table 4.
The results of the one-way multivariate analysis of variance (MANOVA) on learning achievement and mathematical connection skills between experimental and control groups.

Statistic Test	Value	F	Hypothesis df	Error df	p
Pillai's Trace	0.16	7.46	2.00	77.00	0.001

As shown in Table 4, results of the one-way multivariate analysis of variance (MANOVA) examining learning achievement and mathematical connection skills on the topic of sequences and series among Grade 11 students revealed a statistically significant difference between the group taught using the TPACK model and the group taught using traditional instructional methods. The Pillai's Trace value was .16, with an associated F value of 7.46 and a significance level of $p < .05$. These findings indicate that the two groups differed significantly in terms of their combined scores on learning achievement and mathematical connection skills. Given the sufficient sample size in this study, the statistical power was adequate to detect significant effects. As a result, follow-up univariate analyses of variance (ANOVA) were conducted as shown in Table 5.

Table 5.
The results of the one-way multivariate analysis of variance (MANOVA) on learning achievement and mathematical connection skills between experimental and control groups.

		SS	df	MS	F	p
Group	Learning achievement test	145.80	1	145.80	6.99	.01
	Mathematical Connection Ability Test	115.20	1	115.20	11.85	.001
Error	Learning achievement test	1626.95	78	20.86		
	Mathematical Connection Ability Test	758.35	78	9.72		
Total	Learning achievement test	24554.00	80			
	Mathematical Connection Ability Test	6552.00	80			

As shown in Table 5, the results of the one-way analysis of variance (ANOVA) indicated that Grade 11 students who participated in the GPAS 5 Steps and TPACK-based learning activities outperformed those in the traditional instruction group in both learning achievement and mathematical connection skills related to sequences and series. Specifically, the p-value for learning achievement was .01, and for mathematical connection skills, it was .001 both statistically significant at the .05 level. These results suggest that the GPAS 5 Steps and TPACK model significantly enhanced students' understanding of mathematical content as well as their ability to connect mathematical concepts. Therefore, it can be concluded that the TPACK-based instructional approach was more effective than traditional methods in improving both the academic performance and mathematical connection ability of Grade 11 students.

Table 6.
Students' Satisfaction with the TPACK-Based Learning Activities.

No.	Items	$\bar{x}$	SD	Level of satisfaction
1	The teacher was well-prepared for instruction, as evidenced by the availability and readiness of teaching materials and equipment.	4.80	0.40	Very high
2	Students actively participated in classroom activities.	4.40	0.70	High
3	Students had opportunities to practice using technology during the lessons.	4.30	0.87	High
4	The learning activities were engaging and interesting.	4.55	0.67	Very high
5	The teacher provided students with opportunities to ask questions.	4.40	0.92	High
6	The activities assigned by the teacher helped students better understand the lesson content.	4.50	0.63	Very high
7	The learning activities encouraged students to perform mathematical calculations independently.	4.65	0.57	Very high
8	Students demonstrated a good understanding of the topic of sequences and series.	4.45	0.74	High
9	The integration of technology enhanced students' mathematical connection skills.	4.50	0.77	Very high
10	Students were informed of the assessment criteria in advance.	4.13	1.19	High
Average		4.47	1.46	High

As shown in Table 6, Grade 11 students reported a high level of satisfaction with the GPAS 5 Steps and TPACK-based learning activities on the topic of sequences and series. The overall satisfaction mean score was interpreted as high ($\bar{x}$ = 4.47, S.D. = 1.46). When examining individual items, five were rated at the highest level of satisfaction, while the remaining five were rated at a high level. Considering the content of the questionnaire items, it can be inferred that the GPAS 5 Steps and TPACK framework effectively supported instructional design from the teacher's perspective. Items receiving the highest ratings included teacher preparedness, the opportunity for students to perform mathematical calculations independently, and the overall engaging nature of the learning activities. These findings suggest that GPAS 5 Steps and TPACK-based instruction promotes both structured teacher planning and learner-centered experiences, resulting in increased student engagement and satisfaction.

5. Discussion

The findings of this study revealed that Grade 11 students who received instruction through the GPAS 5 Steps and TPACK-based learning activities demonstrated significantly higher levels of learning achievement and mathematical connection skills on the topic of sequences and series compared to those taught using traditional instructional methods. This result underscores the instructional effectiveness of integrating technology, pedagogy, and content within a coherent framework, consistent with the principles of the TPACK model [10] and Pedagogical Knowledge by GPAS 5 Steps [21, 24].

These findings are supported by Chaidam and Poonputta [18] who found that TPACK-based instruction significantly enhanced students' achievement in mathematics through the use of problem-based learning. Similarly reported that integrating TPACK with TGT strategies improved students' understanding of histograms and resulted in high satisfaction levels. The present study aligns with these outcomes and extends them to the context of sequences and series, a foundational topic that requires both procedural fluency and conceptual insight Tanyarattanasrisakul et al. [22] who found that mathematical connection skills after learning management by GPAS 5 steps were higher than those before, at a .05 statistical significance [37]. Who found that the posttest was higher than the pretest by GPAS 5 Steps at the statical significance .05.

Moreover, the significant improvement in mathematical connection ability observed in this study confirms the importance of instructional models that emphasize interrelated concepts and real-world applications. This finding is consistent with Abidin and Jupri [25] who reported that multiliteration models improved elementary students' ability to link mathematical ideas in geometry, and with Rafiepour and Faramarzpour [27] who noted that students often struggle to connect mathematics to everyday contexts when taught through conventional means. The TPACK model, by integrating dynamic visualization tools like GeoGebra and interactive platforms like Mentimeter and Kahoot, likely facilitated more meaningful connections across mathematical concepts, other disciplines, and real-life situations.

Students' high satisfaction with the TPACK-based learning experience further reinforces the model's value. The highest-rated items in the satisfaction questionnaire pointed to the teacher's preparedness, the engaging nature of the activities, and opportunities for students to think independently key indicators of a well-designed, learner-centered environment. These findings align with those of Muangtam and Poonputta [38] who found the overall satisfaction of the students with the integrated learning TPACK Model was at a high level, Helsa et al. [19] who demonstrated that TPACK-based instruction enhances 21st-century skills, and with whom found similar results on the affective aspects of learning regarding TPACK in mathematics education. Tanyarattanasrisakul et al. [22] found that learning management by GPAS 5 steps is an innovative thinking skill, and it was at a very good level. Suradom and Vibulrangson [37] who found similar results among the students, had the satisfaction of learning management through GPAS 5 Steps at a high level.

6. Conclusion

This study examined the effects of GPAS 5 Steps and TPACK-based learning activities on Grade 11 students' learning achievement and mathematical connection skills in the topic of sequences and series. A quasi-experimental design was used to compare outcomes between a group receiving GPAS 5 Steps and TPACK-based instruction and a group taught using traditional methods. The results indicated that students in the GPAS 5 Steps and TPACK group outperformed their peers in both academic achievement and mathematical connection ability. Additionally, the students expressed high levels of satisfaction with the GPAS 5 Steps and TPACK-based learning experience, particularly in areas related to teacher preparedness, engagement, and opportunities for independent thinking.

7. Suggestion

The study contributes to the growing body of research supporting the effectiveness of the GPAS 5 Steps and TPACK framework, particularly in its comparative advantage over conventional instruction. It demonstrates how GPAS 5 Steps and TPACK enhance learning outcomes and students' affective engagement in learning. The findings suggest that technology-integrated pedagogical design can yield more comprehensive educational benefits. However, the study was limited by its exclusive reliance on quantitative methods and short-term measurements. Future research should incorporate qualitative data to capture deeper insights into student learning processes and explore the long-term effects of GPAS 5 Steps and TPACK-based instruction.

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