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CLASSROOM MANAGEMENT ENHANCEMENT USING GEOGEBRA IN TEACHING INTERNATIONAL POST-GRADUATE STUDENTS

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ABSTRACT

This study aims to explore the role of GeoGebra, an interactive mathematics software, in enhancing multi-national classroom management, specifically in the context of learning mutually exclusive and non-mutually exclusive events. The key research question is how using GeoGebra in probability lessons helps teachers manage a classroom involving international students. This qualitative case study was conducted with a group of 16 students from Malaysia, China, and Japan in the Master of Mathematics Education with Technology programme at a university in Malaysia. During the study, the researchers monitored the participants' learning process as they engaged in collaborative problem-solving sessions using GeoGebra. A specific focus is placed on verbal and non-verbal communication, collaborative engagement, and managing disruptive behaviours. In addition, students' engagement with GeoGebra is recorded by an activity log, which documents the specific tools and features used throughout the problem-solving process. The findings of this study reveal that using Geo-Gebra in the teaching and learning of probability enhances the management of classroom communication, distracted students, class time, and language barriers while promoting students' engagement with the topic, fostering classroom collaboration, and improving understanding and problem-solving abilities. This study provides insights into creating a more interactive and collaborative learning environment and offers valuable guidance for educators seeking to integrate GeoGebra into the teaching and learning of probability.

Keywords: **Classroom Management, Problem-Solving Ability, GeoGebra, Communication Skills, Probability Concept, Technology in Education**

INTRODUCTION

In today's educational landscape, technology has become integral in teaching and learning, significantly aiding classroom management (Angwaomaodoko, 2023; Emmer & Sabornie, 2015). Mathematical apps, in particular, serve as powerful tools that enhance student engagement and assist teachers in dealing with common challenges such as communication barriers, student distractions, time management, and diverse learning needs. One notable example is GeoGebra, an app widely used as an educational tool for teaching mathematics in schools (Batiibwe, 2024; Chalaune & Subedi, 2020). This dynamic application provides features that facilitate the swift, precise visualisation and manipulation of abstract geometric shapes, thus enhancing students' understanding of mathematical concepts (Yohannes & Chen, 2023). Research has shown that students' skills and reactions improve when geometry is taught using GeoGebra (Ridha et al., 2020), and it significantly enhances comprehension compared to traditional learning methods (Jelatu, 2018). Additionally, students demonstrate excellent knowledge retention when learning with GeoGebra (Condori et al., 2020), as it fosters a positive mindset and improves problem-solving abilities.

GeoGebra is an effective tool for enhancing learning in diverse classroom environments, catering to numerous student needs and abilities. Albaladejo and Lopez (2023) studied mathematical attitudes transformation when introducing GeoGebra in the secondary classroom and found that GeoGebra transformed three key mathematical attitudes in students: perseverance, precision, and autonomy. Using GeoGebra would foster new behaviours, such as more persistent problem-solving, a greater focus on accuracy, and increased collaboration among peers. Students became more independent, relying on each other to solve non-routine tasks rather than depending on the teacher. GeoGebra as a pedagogical tool was also found to work effectively in disadvantaged and under-resourced rural schools where geometry is hardly taught (Manganyana et al., 2020). Research on using GeoGebra to teach gifted students also found the positive impacts of integrating effective and well-designed prompts into computer-based tools (Azimi et al., 2023).

Despite these advantages, there is a noticeable lack of research focusing on how GeoGebra contributes to effective classroom management. While the impact of GeoGebra on student learning outcomes is well-documented, further exploration is needed to understand how this technology can enhance classroom dynamics and support teachers in maintaining an organised and productive learning environment. As continuous advancements in technology necessitate regular modifications in education, educators must innovate and creatively integrate tools like GeoGebra into their teaching practices to fulfil the diverse needs of learners. This gap highlights the need for further exploration into how such technology can enhance students' understanding of key probability concepts and how it can be leveraged to provide a better learning environment, especially in a multi-national classroom.

This study aims to explore the use of GeoGebra in teaching probability, focusing on its impact on multi-national classroom management. This study is important as it highlights the transformative impact of GeoGebra in improving mathematics education. Addressing critical challenges like student engagement, inclusivity, and classroom efficiency would provide valuable insights into how digital tools can enhance teaching practices and enrich learning experiences. It also emphasises adopting innovative strategies that cater to diverse learning needs while fostering essential 21st-century skills.

PROBLEM STATEMENT

The effective integration of technology and the development of fundamental skills are vital in modern mathematics education to ensure students have a deeper understanding and practical application of probability concepts (Chance et al., 2007; Van den Heuvel-Panhuizen & Drijvers, 2020; Wang et al., 2023). Although tools such as GeoGebra are used more frequently, there is still a lack of understanding about how the collaborative use of GeoGebra affects students' learning experience and ability to solve problems related to mutually exclusive and non-mutually exclusive events in probability theory. Senthamarai (2018) states that traditional teaching techniques frequently fail to handle

dynamic and interactive probability concepts. In addition, students often face difficulties applying theoretical knowledge in problem-solving, especially when they face complicated probability problems involving mutually exclusive and non-mutually exclusive events. Bringing technology like GeoGebra into mathematics classrooms provides an attractive possibility to improve learning experiences (Aizikovitsh-Udi & Radakovic, 2012; Borovik, 2012; Sarifah et al., 2022). Conversely, the actual effect of students' problem-solving skills in probability theory when applying GeoGebra and effective communication skills is an area that is yet to be fully investigated.

Additionally, in contemporary educational settings, especially in a multi-national classroom, teachers face numerous challenges related to classroom management, including maintaining international student engagement, facilitating effective communication, managing diverse learning paces, and addressing varying levels of language proficiency (Ashton-Hay, 2016; Gabdullina et al., 2024; Morris & Kozuch, 2024). Traditional teaching methods often struggle to meet the diverse needs of students, leading to disengagement and increased behavioural issues. Mathematical apps, such as GeoGebra, Desmos, and others, have emerged as innovative tools that leverage technology to enhance classroom management (Dhivya & Iyer, 2024). However, the extent to which these applications effectively address specific classroom management issues remains underexplored. This study aims to investigate how GeoGebra contributes to improved classroom management by enhancing student engagement, fostering effective communication, promoting collaborative learning, and mitigating distractions. By exploring the relationship between GeoGebra and classroom management, this research seeks to provide insights into best practices for integrating technology into teaching, ultimately enhancing the learning experience for students and improving overall classroom dynamics.

RESEARCH OBJECTIVES

The main objective of this study is to explore how classroom management, particularly in a multi-national classroom with international students, is enhanced with the use of technology such as GeoGebra. The particular emphasis will be on learning the concepts of mutually exclusive and non-mutually exclusive occurrences in probability theory. The study is guided by the following research question: how does the use of GeoGebra in probability lessons help teachers manage a classroom involving international students?

METHODOLOGY AND RESEARCH DESIGN

The research employs a qualitative followed by a quantitative method. The case study design was used through classroom observation and structured interviews (Merriam & Tisdell, 2015; Yin, 2015). The case study will explore the teaching management elements when technological interventions (GeoGebra) are used in teaching and learning sessions. Subsequently, the experimental design will measure the effect outcomes (Fischer et al., 2023; Kirk, 2009). The test scores will serve as a quantitative measure of the intervention's effectiveness, allowing for a comprehensive evaluation of student's progress after integrating GeoGebra (White & Sabarwal, 2014). These various data collection techniques and triangulation are used to increase the trustworthiness of the research findings.

Sampling

The sample was selected using a purposive sampling technique based on intended case characteristics, such as international post-graduate students of an education programme. The participants in this study comprise a cohort of 16 master's students from different countries (i.e., Malaysia, China, and Japan) enrolled in the Master of Mathematics Education with Technology programme in one of the Malaysian universities, and the students were taking a course in statistics and probability teaching technology.

Data Collection

1. Classroom observation

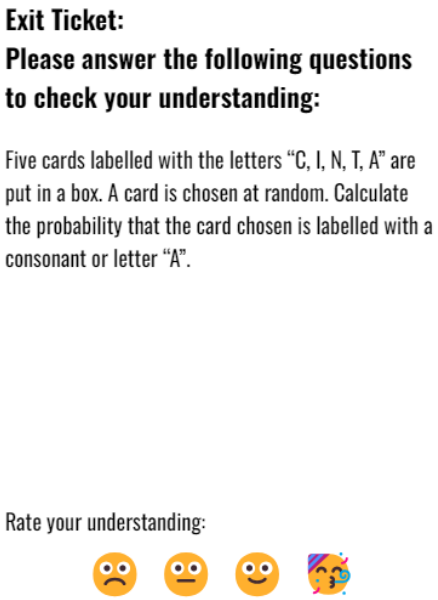
A classroom observation was conducted to gain insights into the dynamics of student interactions and the overall

classroom environment during the implementation of GeoGebra. Observational data focused on student engagement, communication patterns, and behaviour during the lesson. This qualitative approach provides context to the quantitative findings from tests and exit tickets, highlighting how GeoGebra influences classroom management and student participation. The observation was recorded systematically, noting instances of collaboration, distraction, and the application of problem-solving strategies as students work with the software.

2. Exit tickets

According to Prieto and Escobar (2016), exit tickets are a formative assessment tool that provides students with challenging questions at the end of a class, prompting self-evaluation of their learning progress. They encourage students to synthesise class material while offering valuable feedback to teachers about student understanding. In this study, exit tickets assessed students' grasp of probability concepts post-GeoGebra activities. The exit ticket featured problem-solving questions related to non-mutually exclusive and mutually exclusive probability. A rating system was included to gauge students' comprehension of the material throughout the activity.

Figure 1. *Exit Ticket to Evaluate Students' Understanding*



Data Analysis

Qualitative data were analysed using thematic analysis. Recorded observation data were transcribed into elements based on the indicators shown by participants during the class session. Codes were assigned to the same indicator characteristics as element codes (En), and the same elements were grouped under theme codes (Tn). The quantitative data were analysed using a one-sample t-test of the test scores obtained from pre-tests and post-tests of the intervention. The quantitative data illustrate the effectiveness of the intervention on participants' problem-solving skills, while the qualitative data highlight elements of this effectiveness, which were further explored and confirmed through interviews.

FINDINGS

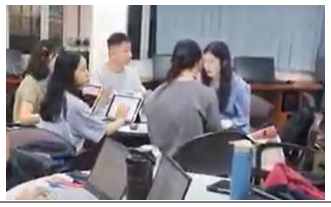
Observation data are coded to answer the question of how the use of GeoGebra in probability lessons helps teachers manage a classroom with international students. The following are the emerging themes:

Theme 1 (T1): Managing Classroom Communication

The integration of GeoGebra in probability lessons helps with managing classroom communication. The classroom observation revealed several challenges in managing students' interactions, particularly in ensuring focused communication. A few students were observed to be engaged in off-topic discussions, which disrupted the learning flow. Additionally, some groups were engaged in group discussions while the teacher was explaining key concepts. Other than that, it was also observed that students with weaker communication skills tended to rely heavily on their peers and frequently requested help from the group members to understand and complete the tasks given. This frequent request for help also disrupted some students' concentration.

To manage classroom communication challenges, the teacher used a structured approach using GeoGebra-based activities that required students' input. The teacher posed targeted questions that directed the students' attention toward solving the problem in GeoGebra, which resulted in reduced engagement in side conversations. Group discussions were guided by specific prompts to change focus and random communication to constructive dialogue. Additionally, the teacher assigned different parts of the task to each group member. This approach was used to reduce the reliance on students with stronger communication skills to provide input in solving the task. Table 1 shows the challenges and management of classroom communication using GeoGebra.

Table 1. *List of T1 Elements*

Time	Recorded capture	Data Interpretation	Element (En)
6:37		The teacher gets the students to answer the questions	E1: Instructor-student interaction
7:18		The students are engaged in side conversations with their friends while the teacher is teaching.	E2: Losing concentration in class
7:29		The students are engaged in a group discussion on their own while the teacher is explaining	E3: Creating space for group discussion
8:17		The teacher poses question to the students to gain their attention	E4: Gaining students' feedback

21:17		A student requests peer guidance	E5: Peer guidance
25:24		The students are engaged in group discussions to solve the task.	E6: Group solution

Theme 2 (T2): Managing Class Time

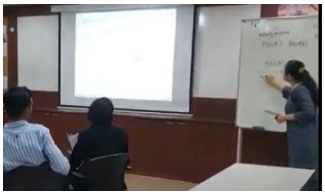
Integrating GeoGebra into the lesson allowed the teacher to structure and time the lesson efficiently. At the start of the lesson, the teacher allocated time for recalling students' prior knowledge of probability concepts, particularly mutually and non-mutually exclusive events, before introducing GeoGebra's features and functions. This approach ensured that students clearly understood the content and the tool they would be using. After dividing students into groups, the teacher explained the task, detailing how GeoGebra would be used to solve the problems. The structured time allocation for each lesson phase—exploring GeoGebra, group discussions, and sharing solutions—allowed students to work steadily without feeling rushed. The interactive nature of GeoGebra helped students complete their tasks more efficiently, as they could quickly visualise concepts and test different solutions without lengthy manual calculations.

Throughout the lesson, the teacher effectively managed time by monitoring students' progress, offering quick explanations to groups showing confusion, and posing questions to re-engage distracted or off-task students, such as chit-chatting with friends or using smartphones. By directing students' attention back to GeoGebra and focusing on the task, the teacher minimised time lost to distractions. GeoGebra also streamlined task completion, as students could easily manipulate graphs and probabilities in real-time, speeding up the problem-solving process. The teacher introduced a time buffer to handle technical difficulties or misunderstandings without disrupting the lesson flow. For instance, when students struggled with a particular concept, the teacher provided brief, targeted explanations while ensuring students completed the task on time. By leveraging GeoGebra's interactive capabilities and clear task structure, the teacher maintained the lesson's pace, allowing for sufficient time for exploration, group discussion, and summarising the lesson at the end. This use of technology not only ensured efficient time management but also allowed for flexibility in addressing challenges, ensuring that the lesson ran smoothly, and the objectives were met. Table 2 shows the challenges and management of class time.

Table 2. *List of T2 Elements*

Time	Picture / Video	Interpretation	Element Code (En)
0:38		The teacher recalls students' prior knowledge of mutually and non-mutually exclusive events	E7: Brainstorming

2:29		The students are divided into a few groups by the teacher.	E8: Teamwork
2:44		The teacher allocates time for the students to complete the task.	E9: Time allocation
4:05		The teacher explains how to use GeoGebra in answering the task	E10: Giving instruction
4:43		The teacher explains to students who have misunderstanding	E11: Misunderstanding
6:37		The teacher gets the students to answer the questions	E12: Interaction
7:18		The students are engaged in side conversations with their friends while the teacher is teaching.	E13: Losing concentration in class
7:55		The students use their smartphones for off-task activities	E14: Lack of motivation

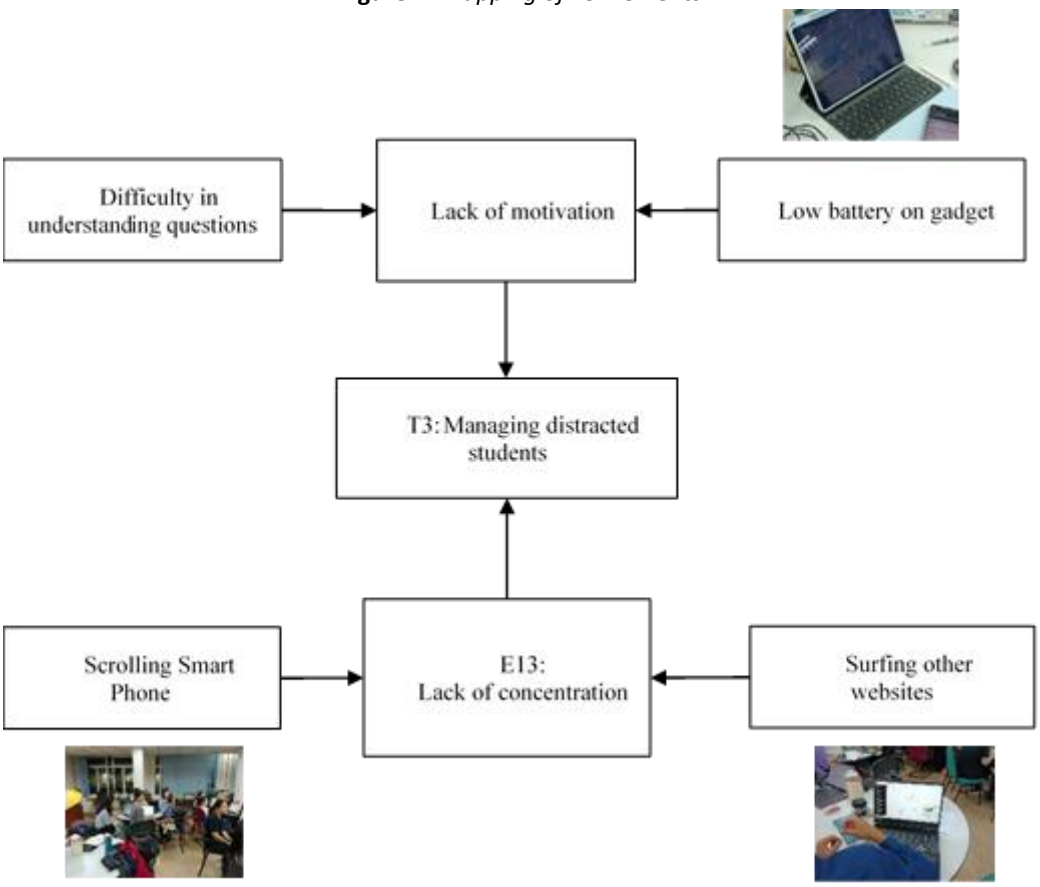
8:17		The teacher poses questions to the students to gain their attention	E15: Gaining feedback
11:20		The teacher introduces the uses of technology in teaching	E16: Implementation of technology
28:10		The teacher summarises the lesson	E17: Lesson summary

Theme 3 (T3): Managing Distracted Students

During the observation, several students were initially distracted—some were playing games, scrolling through unrelated websites, or engaging in off-topic conversations while the teacher was giving instructions. This behaviour negatively impacted their concentration and engagement with the lesson. However, GeoGebra proved to be an effective tool in mitigating these disruptions. When students began to lose focus, the teacher strategically used GeoGebra's interactive features to draw their attention back to the task and helped shift their focus from unrelated activities to solving the problem at hand. The visual and hands-on nature of the tool made it easier for students to follow along, reducing their tendency to get distracted. In response to students' confusion over the posed probability question, the teacher used GeoGebra to clarify the concept and provide a concise lesson summary. This approach helped re-engage students who were initially confused or disengaged and involved distracted students more actively, ensuring their participation and bringing them back into the lesson flow.

Even when technical issues such as low device battery interrupted some students' use of GeoGebra, the teacher maintained a firm but calm demeanour and intervened by addressing the disruptions directly and guiding students back to the lesson. This helped maintain their engagement even when they couldn't directly interact with the tool.

Figure 2. *Mapping of T3 Elements*

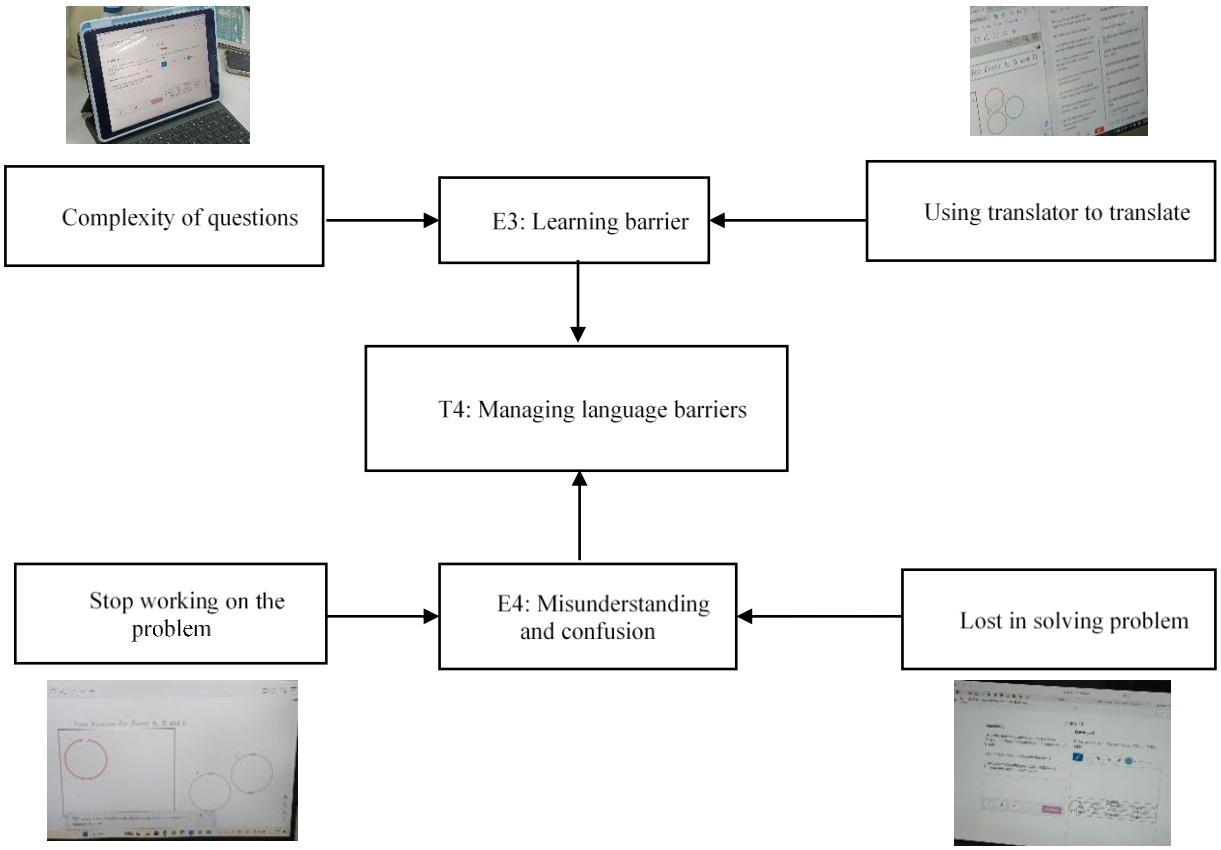


Theme 4 (T4): Managing Language Barriers

In addition to the complexity of the probability questions, some students faced challenges due to language barriers, particularly those with limited proficiency in English, as shown in Figure 3. However, GeoGebra's visual and interactive features helped bridge this gap by providing an alternative way for students to understand the concepts without relying heavily on language. Instead of needing to fully grasp the English instructions, students can explore and manipulate graphs and figures in GeoGebra, which helps them comprehend key mathematical ideas through visual representation. For example, when solving problems related to mutually and non-mutually exclusive events, students who struggled with English could follow the task by observing the changes in the graph as they adjusted parameters in GeoGebra. This reduced their reliance on verbal instructions and allowed them to engage with the material more independently. Moreover, GeoGebra's intuitive interface provided students with language barriers a common platform for learning, regardless of their English proficiency. The tool's clear, visual output helped them follow along with the lesson, even when they encountered difficulty understanding specific words or instructions. While these students still needed occasional support of translation applications, GeoGebra's visuals minimised the extent to which language barriers slowed their progress.

To further support these students, the teacher rephrased instructions and used the visual demonstrations within GeoGebra to clarify concepts. This dual approach—combining verbal rephrasing with visual reinforcement—helped manage the language barrier more effectively, enabling students from diverse linguistic backgrounds to engage with the lesson and participate in group discussions.

Figure 3. *Mapping of T4 Elements*

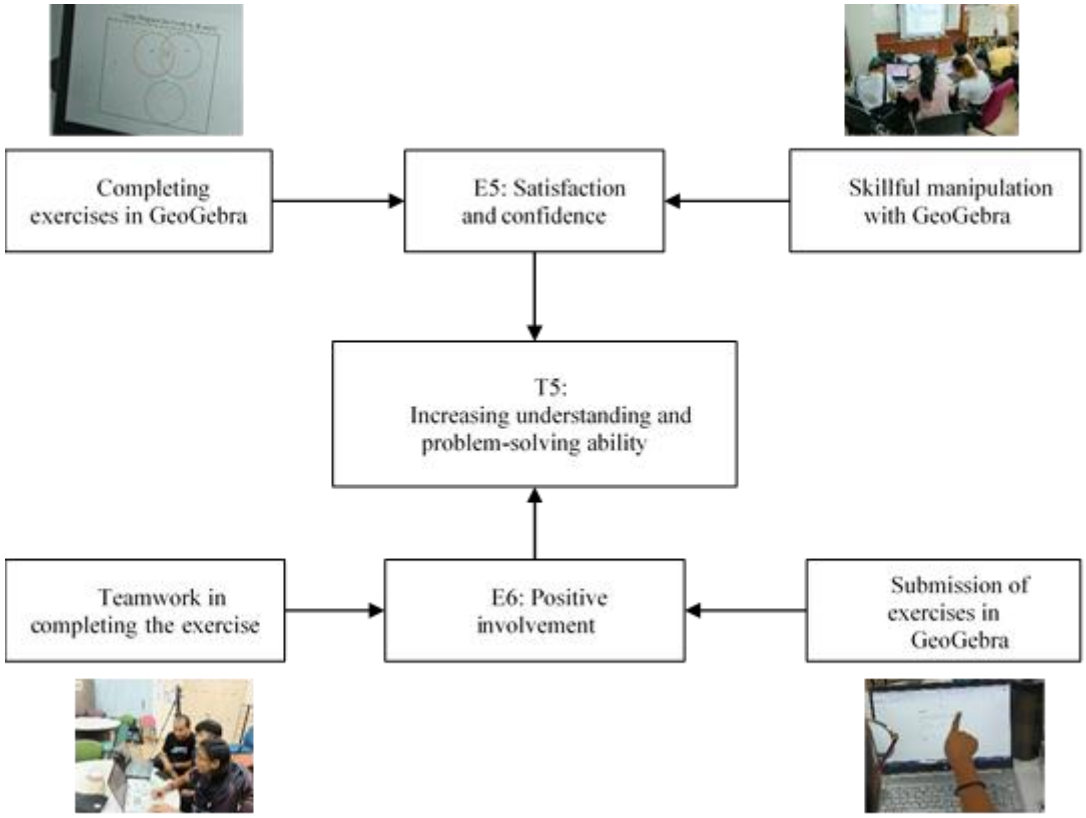


Theme 5 (T5): Increasing Understanding and Problem-solving Ability

Based on the comparison between pre-test and post-test results, it was found that the standard deviation of the post-test results was 1.1529, which is lower than the standard deviation of the pre-test results, which was 1.4705. This marked improvement in students' performance proved the positive impact of GeoGebra on students' understanding of probability concepts and their confidence in tackling complex problems. The classroom observation also revealed that students exhibited good manipulation of GeoGebra and completed exercises in GeoGebra. This not only led to increased understanding but also increased satisfaction and confidence in their answers as they could approach problems with greater clarity. GeoGebra's visual representations and interactive features allowed students to see the relationships between events more clearly, enhanced their comprehension, and increased their scores in the post-test.

The pre-test and post-test results analysis revealed notable improvements in students' problem-solving abilities when dealing with probability questions involving mutually exclusive and non-mutually exclusive events. The lower standard deviation obtained in the post-test compared to the higher standard deviation obtained in the pre-test proves this. Classroom observation also revealed the gradual improvement of students' problem-solving ability as the lesson progressed, as shown in Figure 4. GeoGebra's interactive visual aids helped students better understand the structure of the questions and enabled them to approach the problem systematically. By the post-test, students showed a greater ability to solve complex problems, which was demonstrated by their improved accuracy and efficiency as a result of this hands-on experience in exploring various solution pathways.

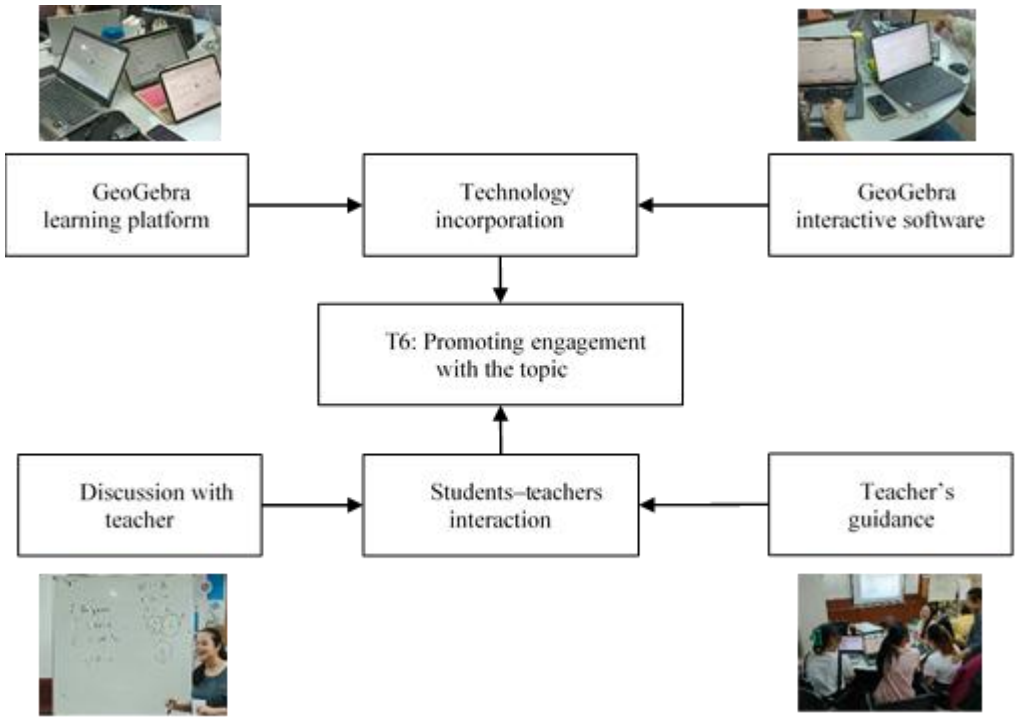
Figure 4. *Mapping of T5 Elements*



Theme 6 (T6): Promoting Engagement with the Topic

Classroom observations revealed a high engagement with learning the subject matter, as shown in Figure 5. Incorporating technology, specifically GeoGebra learning platforms, helped bridge the gap in understanding and made students interested in the topic. Additionally, through active student-teacher interaction, where the teacher provided guidance and facilitated discussion, students participated more. This interactive approach increased students' involvement and engagement with the lesson and led to overall improved performance, as evidenced by their post-test results.

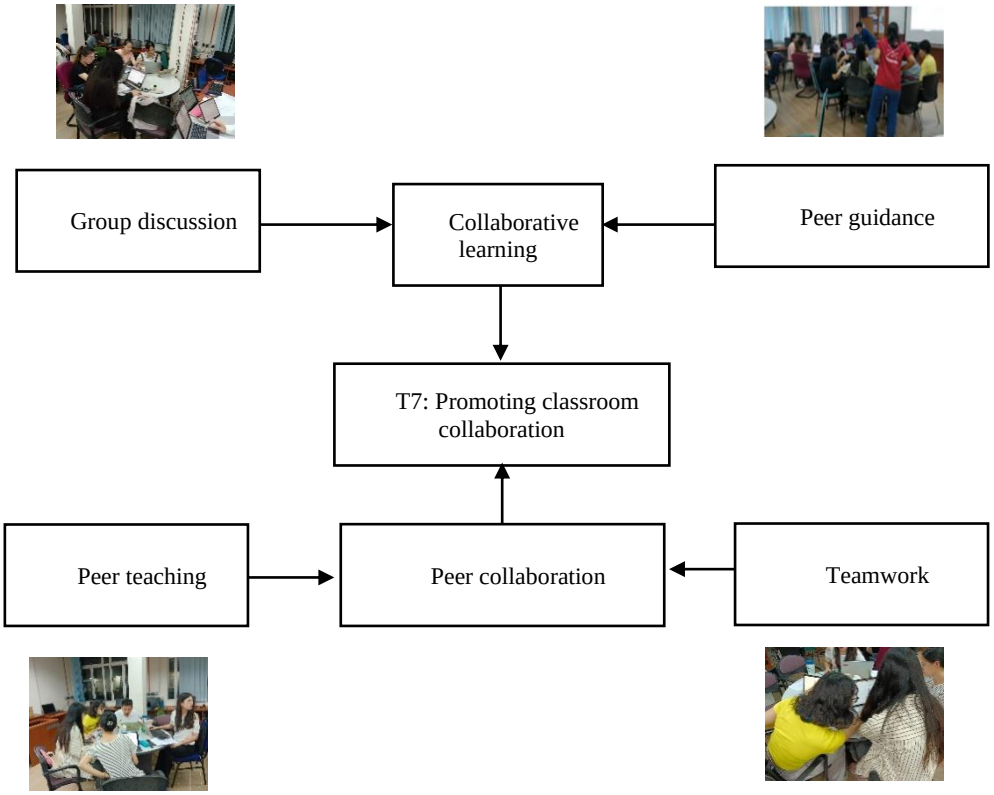
Figure 5. *Mapping of T6 Elements*



Theme 7 (T7): Promoting Classroom Collaboration

During the lesson, it was observed that GeoGebra helped foster classroom collaboration. Students engaged in peer collaboration frequently, where students with a stronger grasp of the topic and better command of GeoGebra provided peer teaching and peer guidance to their group members who were struggling to grasp complex probability concepts. GeoGebra's interactive interface also encouraged students to work together to solve problems and allowed them to share ideas and approaches. Additionally, collaborative learning was evident as students participated in group discussions and teamwork while using GeoGebra to model probability events. The tool's dynamic visualisations helped students see the impact of their collective decisions, and this created a supportive environment where students relied on one another to explore different strategies and solutions, as shown in Figure 6.

Figure 6. *Mapping of T7 Elements*



Pre-Test and Post-Test Analysis

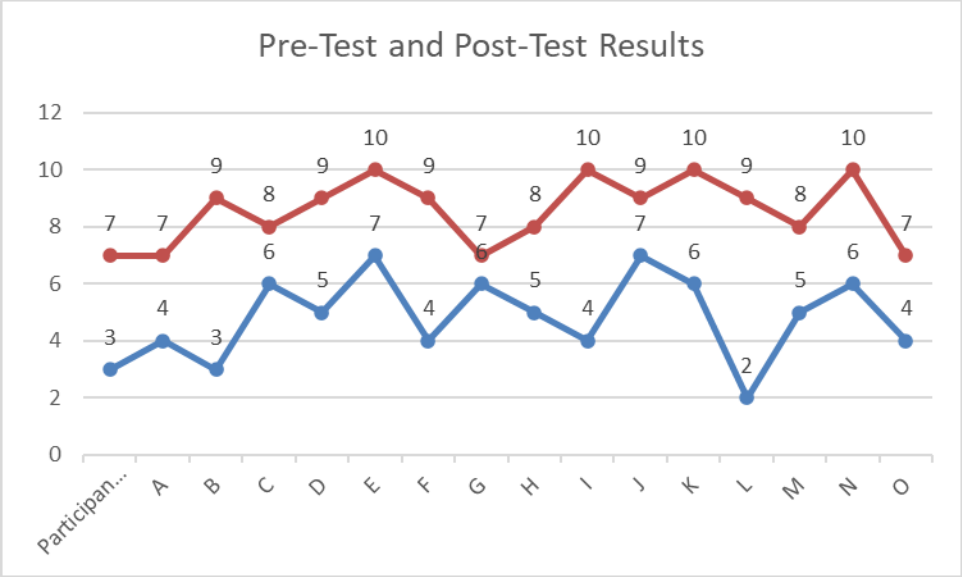
In this study, data was collected from 16 participants. Two tasks were administered: a pre-test and a post-test containing statistics problem-solving questions. The pre-test was given before the intervention, while the post-test was administered after the experiment. Each test was scored out of 10 marks. The pre-and post-test results for all participants were recorded. Table 3 shows the analysis of the results, and Figure 7 graphically illustrates the pattern observed in the pre-test and post-test results.

Table 3. *Data Collected Based on Participants' Pre-Test and Post-Test Results*

Participants	Gender	Pre-Test	Post-Test
A	Female	3	7
B	Female	4	7
C	Female	3	9
D	Female	6	8
E	Female	5	9
F	Male	7	10
G	Female	4	9
H	Female	6	7
I	Male	5	8

J	Male	4	10
K	Female	7	9
L	Female	6	10
M	Female	2	9
N	Female	5	8
O	Male	6	10
P	Female	4	7

Figure 7. *Line Graph for Pre-Test and Post-Test*



Based on the results of the data analysis, a clear comparison between the two data sets is evident. As shown in Table 4, the post-test results exhibit a lower standard deviation, indicating that the intervention (the activity) was effective in improving classroom performance.

Table 4. *Data Analysis for Pre-Test and Post-Test*

	Pre-Test	**Post-Test**
Mean	4.813	8.563
Standard Deviation (SD)	1.471	1.153
N	16	16

Table 4 demonstrates that the pre-test yielded a mean score of 4.813 (SD = 1.471), while the post-test achieved a mean score of 8.563 (SD = 1.153). The mean score difference between the groups was 3.750, with a two-tailed p-value of less than 0.0001. According to conventional criteria, this difference is considered statistically significant. Moreover, comparing problem-solving abilities using GeoGebra versus without GeoGebra revealed a significant difference, with a t-value of 9.3026, indicating that the improvement in mean scores from the pre-test to the post-test was statistically significant. This finding underscores the effectiveness of using GeoGebra in enhancing problem-solving abilities in statistics. Additionally, insights from the interview sessions revealed that most participants attributed this effectiveness to improved classroom management, as explored through qualitative data summarised in Table 5.

Table 5. *Descriptions of Classroom Management Elements*

Elements	Classroom Management Elements	Agreement
E7: Brainstorming	Recalling students' prior knowledge on mutually and non-mutually exclusive events	All participants
E8: Teamwork	Dividing participants into groups	Some participants
E9: Time allocation	Allocating time for students to complete the task	Some participants
E10: Giving instruction	Explaining how to use GeoGebra in solving the task	All participants
E12: Interaction	Getting students to answer the questions	Most participants
E16: Gaining feedback	Posing questions to students to gain their attention	Most participants
E17: Implementation of technology	Introducing the uses of technology in teaching	All participants
E18: Peer guidance	Student requesting peer guidance	Most participants
E19: Group discussion	Students having group discussions to solve the task	All participants
E20: Lesson summary	Summarising the lesson	Some participants

DISCUSSION

Managing Classroom Communication

Integrating GeoGebra in teaching probability has proven to be an effective tool for managing classroom communication, particularly in addressing some common challenges observed in student interactions. Classroom observation shows that during lessons, students often engage in off-topic discussions with their group members or hold ongoing group discussions even while the teacher is explaining. Additionally, students with weaker communication skills tend to rely heavily on their peers for guidance, leading to imbalances in group participation. Research by Wang et al. (2023) shows that interactive tools like GeoGebra help minimise off-topic conversations by encouraging students to stay focused on the task. During classroom observation, giving GeoGebra-based activity

reduced students' engagement in unrelated chitchat when they were actively solving problems on the platform. For example, when students were asked to use GeoGebra to visualise mutually exclusive events, they became more focused on manipulating the tool, which shifted their group discussions toward interpreting the visual data rather than chatting about unrelated topics. This focused interaction helped manage the classroom environment, ensuring students stayed engaged with the task.

Technology can help manage classroom communication by equalising participation among students with varying communication abilities (Gioiosa & Kinkela, 2019). Students with weaker communication skills in the observed classroom often relied heavily on their peers, leading to unequal contributions during group work. However, when GeoGebra was used to break down tasks into manageable roles, these students could participate more effectively. This structured collaboration reduced the over-reliance on stronger communicators and balanced group interactions.

Time Management

Good time management is crucial in ensuring the successful integration of GeoGebra in learning probability. A well-structured lesson with ample buffer time allows students to fully explore GeoGebra features and allows teachers to provide comprehensive guidance on the problem-solving process while leaving sufficient time for trial and error and discussion. For example, the observed lesson showed that students were given ample time to recall their understanding of mutually exclusive and non-mutually exclusive events and familiarise themselves with GeoGebra's tools before interacting with their group members to solve the problem. Research by Radovic et al. (2020) shows that interactive technologies like GeoGebra allow students to visualise mathematical problems in real-time, significantly reducing the time spent on solving complex calculations. This efficiency enables teachers to better manage activity time, as students can explore different problem-solving strategies without requiring lengthy manual computations. In the classroom observation, students used GeoGebra to solve probability tasks related to mutually and non-mutually exclusive events. Instead of manually calculating probabilities or drawing figures, students could visualise the outcomes dynamically, which sped up the process. This allowed the teacher to allocate more time for discussions and explanations, ensuring that the lesson stayed on track without sacrificing depth of understanding.

According to a study by Leonardi and Bailey (2008), technology that offers task-specific tools helps manage time by structuring activities into smaller, manageable segments. Educational platforms like GeoGebra allow teachers to break down complex tasks into steps that can be completed within a specific timeframe, leading to better time management during lessons. During the observation, the teacher divided the class into groups and gave specific tasks using GeoGebra. The clear, task-specific use of the tool helped students stay focused and complete their work within the allotted time, reducing time wasted on confusion or off-topic conversations. This structured approach allowed smooth transitions between lesson phases—such as discussions, exploration, and problem-solving.

Research by Kay and LeSage (2010) shows that time management in classrooms is enhanced by real-time feedback offered by technology tools. Tools like GeoGebra provide immediate feedback when students manipulate variables or make adjustments, allowing them to quickly see the impact of their choices and correct mistakes on the spot without waiting for teacher intervention. In the observed lesson, the teacher monitored students' progress and quickly addressed misunderstandings as they worked through the task on GeoGebra. By providing immediate visual feedback through the software, the teacher minimised the time spent on lengthy explanations or manual corrections, ensuring students stayed on task and completed their activities on time. This timeliness allowed the teacher to effectively manage classroom activity, even when students faced confusion.

Managing Distracted Students

An inadequately managed classroom can limit efficient communication, destroy cooperative efforts, and negatively affect the learning environment (Hohenwarter et al., 2004). Disruptions such as off-task behaviours, technical challenges and lack of understanding of the task can lead to disengagement. As seen in the observation, some students struggled to concentrate on the task due to technical challenges, unrelated smartphone activities, and off-

task discussions. Improper classroom management could diminish students' ability to explore and experiment with GeoGebra. Research shows that interactive technology tools, such as GeoGebra, help manage distracted students by offering engaging visuals that capture their attention. According to a study by Van den Hoven et al. (2024), visual and interactive content delivered through educational technology makes abstract concepts more tangible, reducing distractions and promoting focus. In the classroom observation, students distracted by games or unrelated browsing were re-engaged when the teacher used GeoGebra. Its interactive and visually engaging nature helped refocus the students and encouraged them to actively participate in solving the problem.

A study by Matteson and Grant (2024) shows that technology that offers real-time feedback can help refocus distracted students by providing immediate interaction with the material. Tools like GeoGebra enable teachers to monitor students' progress and give direct and timely feedback that addresses confusion and refocuses attention. During the observation, the teacher used GeoGebra to visualise the problem and explain key concepts to distracted and confused students. This immediate interaction between the teacher and the students through the tool reduced their confusion and brought them back to the task, refocusing their attention on understanding the key concepts through active problem-solving.

Teachers are vital in establishing clear expectations, maintaining consistent guidelines, and quickly dealing with behavioural difficulties to create a favourable learning environment. When students are focused, attentive, and on-task, they can fully engage with the interactive features of GeoGebra, which leads to deeper understanding and better problem-solving outcomes. Well-managed classrooms allow students to stay organised, follow instructions, and collaborate better. For instance, clear expectations on device usage help prevent students from becoming distracted by off-task content. Other strong classroom management strategies that can be employed include anticipating common technical issues and having backup options, assigning roles to each group member to ensure equal participation, and frequent progress monitoring to prevent off-task behaviours.

Managing Language Barriers

Multimodal learning tools and technologies that combine text, visuals, and interactive elements help reduce the impact of language barriers by offering different modes of communication and provide the effectiveness of visual learning tools in overcoming language barriers, as students can grasp complex concepts through visual representations rather than relying solely on verbal or written instructions (Watts-Taffe, 2022). Technologies like GeoGebra provide dynamic visuals that aid comprehension for students with limited language proficiency. In the classroom observation, students struggling with English could still follow the probability lesson using GeoGebra's visual interface. As they manipulated variables and observed changes in graphs, they gained a deeper understanding of mutually and non-mutually exclusive events without needing to understand the teacher's verbal instructions fully. This visual representation helped bridge the gap for students facing language difficulties, allowing them to engage with the content actively.

According to a study by Wang and Na (2023), interactive technology tools reduce students' reliance on language translation by providing immediate, tangible outcomes through interaction. In multilingual classrooms, this reduces the time spent translating instructions or concepts, helping students stay focused on the task. Some students in the observation used translators to understand the teacher's instructions, which slowed their progress. However, once they began using GeoGebra, the tool's interactive features allowed them to engage directly with the task without fully translating every instruction. This reduced their dependency on translations, allowing them to focus more on solving the probability problems visually rather than getting bogged down by language barriers.

Increasing Understanding and Problem-Solving Ability

Utilising technology, specifically tools like GeoGebra, has successfully improved engagement and comprehension of probability concepts. GeoGebra's interactive features enable students to clearly understand abstract probability events, enhancing the dynamic nature and accessibility of the learning experience (Glencross, 2022). GeoGebra's visualisation features provide a dynamic platform for exploring and comprehending complex probability situations,

particularly those involving non-mutually exclusive events (Bilgin, 2013). The tool's interactive element not only captures students' attention but also fosters a deeper understanding of probability (Bogatinoska, 2016).

This is proven by the post-test conducted in this study and the classroom observation. Students who actively interacted with GeoGebra demonstrated a stronger understanding of probability concepts, as shown by their ability to apply mathematical understanding to real-world problems. The tool's dynamic visualisation capabilities were adequate in clarifying intricate probability scenarios, enhancing the understanding of the subject matter. GeoGebra significantly enhances students' problem-solving abilities by providing an interactive environment where they can visualise and manipulate probability scenarios. In questions involving mutually exclusive events, GeoGebra provides visual confirmation that helps reinforce their understanding of probability concepts, which makes it easier for them to apply this knowledge to different problem sets. GeoGebra graphical features allow students to visualise abstract concepts for non-mutually exclusive events. Through trial and error, students can adjust inputs and parameters in GeoGebra to see its changes, enhancing their problem-solving strategies.

The tool's ability to provide immediate feedback through real-time visualisations encourages students to explore multiple problem-solving approaches. Additionally, it allows students to work at their own pace, enabling them to approach problems more methodically and refine their problem-solving techniques. As a consequence, this develops their critical thinking skills.

Promoting Engagement with the Topic

GeoGebra's interactive and dynamic features allow students to explore the concepts of mutually and non-mutually exclusive events in real time, thus increasing their engagement with the topic and enhancing their involvement in the learning process. The visual nature of GeoGebra enables students to interact with complex probability problems by manipulating variables and observing how changes affect outcomes. This hands-on approach makes learning more accessible and interesting, thus encouraging students to engage more deeply with the material. Uyen et al. (2021) found that the continuous teaching of functions with the assistance of GeoGebra software positively affects students' attitudes, motivation for learning, and learning outcomes in mathematics. Even students from rural, high-poverty and under-resourced schools can improve their content knowledge and engage deeply with the lesson when GeoGebra is integrated (Mthethwa et al., 2020). Incorporating technology such as GeoGebra promotes active learning. Instead of passively listening to lectures, students become active participants in their learning, as observed in the classroom in this study. They can explore different probability outcomes and scenarios, which make the abstract nature of mutually exclusive and non-mutually exclusive events more tangible. Additionally, the teacher's role in facilitating discussions and guiding students through GeoGebra activities increases engagement. Combining technology and student-teacher interaction creates a collaborative environment that increases students' interest and promotes critical thinking.

Promoting Classroom Collaboration

The effectiveness of classroom collaboration depends upon a teacher's ability to provide a comprehensive and engaging learning environment. Teachers who foster student participation, support meaningful conversations, and create an awareness of community in the classroom make a major difference in a cooperative learning environment. The collaborative environment promotes the sharing of ideas and enriches the overall educational experience (Hohenwarter, 2008). GeoGebra naturally fosters collaboration in the classroom by offering an interactive platform where students can collectively visualise and manipulate mathematical concepts in real-time. GeoGebra provides opportunities for students to engage in peer teaching, peer guidance, group discussions and teamwork, which allow them to approach problems collaboratively by discussing various strategies and solutions (Kuchkarova, 2024). Additionally, the tool's visual and interactive nature enables group members to experiment with different scenarios and offers immediate feedback that promotes active learning.

RECOMMENDATIONS

The results of this study underscore the important role that GeoGebra play in improving various aspects of teaching and learning statistics. For educators, this suggests that incorporating dynamic software tools can help overcome common classroom challenges, such as facilitating communication, minimising distractions, and breaking down language barriers. The broader implications for educators involve the potential for using technology to tailor learning experiences to individual needs. GeoGebra enables students to explore and manipulate mathematical concepts, which supports diverse learning styles and boosts engagement. Moreover, technology can be especially valuable in classrooms with students from diverse linguistic backgrounds, as visual representations can help bridge language gaps. This approach not only aids cognitive development but also fosters inclusivity and equity in the learning process.

To effectively integrate GeoGebra as a tool for enhancing classroom management, educators should be provided with ongoing training to ensure they possess the appropriate skills to integrate these technologies seamlessly into their lesson plans. Additionally, educators should create clear, engaging, and purposeful prompts that guide students through the problem-solving process using GeoGebra. These prompts should encourage critical thinking and exploration, helping students discover mathematical concepts themselves while keeping them focused and engaged. GeoGebra allows educators to design interactive activities that serve as formative assessments. Educators can use these tools to provide immediate feedback to students, allowing for more personalised learning and the opportunity to refine their understanding as they progress. Educators should design tasks that gradually increase complexity to ensure students build a strong foundation. GeoGebra can scaffold learning by starting with simpler, foundational problems and progressively guiding students toward more complex challenges, all while providing support through prompts and hints as needed.

CONCLUSION

This study has explored how GeoGebra is a valuable tool in enhancing classroom management by addressing multiple challenges that teachers face in diverse and dynamic learning environments and for their Professional learning community's practices (Hassan et al., 2022). Firstly, it supports classroom communication by providing a shared visual platform where students can engage with complex mathematical concepts, reducing misunderstandings and improving collaboration, even among weaker communication skills. Secondly, GeoGebra helps mitigate the issue of distracted students by offering interactive, hands-on activities that capture attention and keep students focused on problem-solving, thereby reducing idle time and off-task behaviours. Moreover, its interactive features facilitate time management and classroom leadership by streamlining problem-solving processes and ensuring smoother transitions between lesson activities. GeoGebra enables teachers to structure lessons more effectively, allocating sufficient time for exploration, discussion, and task completion while allowing flexibility to handle unexpected challenges. Additionally, GeoGebra is crucial in overcoming language barriers in multi-national classrooms. Its visual and interactive nature reduces students' dependence on language proficiency, enabling them to engage with the material regardless of their linguistic background.

It was also evident that GeoGebra increases students' understanding and problem-solving ability and promotes engagement with the topic and classroom collaboration. To maximise the benefits of GeoGebra, in particular for learning mutually exclusive and non-mutually exclusive events, teachers should incorporate GeoGebra early in the curriculum, provide structured instructions on how to operate GeoGebra while allowing independent exploration of the tool and create activities that relate to modelling real-life scenarios such as required for STEM education. This could be done by enhancing school management with STEM leadership awareness (Bajuri, 2023).

This study holds significance as it showcases the transformative role of technology, specifically GeoGebra, in enhancing mathematics education. It offers crucial insights into leveraging digital tools to refine teaching methods

and elevate learning experiences by tackling key challenges, including student engagement, inclusivity, and classroom efficiency. It underscores the importance of adopting innovative approaches that address diverse learning needs while cultivating essential 21st-century skills. By turning abstract concepts into tangible visualisations, GeoGebra enables students to grasp probability more effectively, boosting their confidence and fostering a greater interest in mathematics. Additionally, the study highlights the value of connecting education to real-world applications. Through activities that replicate practical scenarios, it demonstrates how technology can prepare students for future opportunities in various fields. This methodology not only enhances problem-solving capabilities but also nurtures critical thinking, creativity, and collaboration—skills essential for success in a technology-driven profession. Ultimately, this research provides educators with a framework for integrating technology into curricula effectively. It illustrates how tools like GeoGebra can transform mathematics education by improving its quality, accessibility, and relevance.

The research limitation is its focus on one specific aspect of probability, which is a mutually exclusive and non-mutually exclusive events concept, which potentially overlooked how GeoGebra could be applied to other mathematical concepts of real-life application. This exposure will help students and promote their STEM knowledge and skills for their career sustainability (Bajuri, 2021). Future research should explore the application of GeoGebra across a wider range of mathematical topics to understand its broader impact on learning probability. Future research could also track the sustained effects of GeoGebra on student performance and engagement over time. Lastly, exploring teacher professional training programs that focus on integrating technologies into the curriculum and balancing technology with traditional teaching methods would provide insights into best practices for enhancing student outcomes.

DECLARATIONS

Author Contributions

Each author made substantial contributions to the research design and data analysis and has drafted the work and approved the submitted version. All authors agree to be personally accountable for the author's contributions and to ensure that questions related to the interpretation or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to the ethics applications stating that "data will not be preserved for possible future use in another project either by yourself or another researcher".

Conflict of Interest

The authors declare that they have no competing interests.

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