Exploring The Effects of GeoGebra on Student Engagement in Learning Trigonometry

Binita Bhatia[1] and Dr. Anita Dani[2]

[1] Manipal Global NXT University, Kuala Lampur, Malaysia
[2] Manipal Global NXT University, Kuala Lampur, Malaysia
BB18376@campus.globalnxt.edu.my

Abstract. The study delineates effective instructional strategies that cater to diverse learning styles and foster a student-centered learning environment. The research focuses on the adaptation of teaching styles to meet the needs of diverse student population, and the creation of an inclusive classroom culture. The study assesses how educators can implement differentiation in curriculum content, teaching practices, and assessment methods. Concurrently, the student perspective provides insights into the lived experiences of learners highlighting the importance of representation, accessibility, and the recognition of individuality in fostering a sense of belonging and academic success. The research utilizes surveys, to capture the experiences of participants, offering a rich qualitative analysis. The research reports findings from a snapshot of teaching episodes. Additionally, researchers implemented a systematic pedagogical approach based on the principles of STEM, using technology like GeoGebra which was adopted for teaching cross-disciplinary topics, such as trigonometry.

Keywords: STEM, Student Perspective, Trigonometry, Learning Styles, GeoGebra

N.-J. Howard et al. (eds.), *Proceedings of the HCT International General Education Conference (HCTIGEC 2024)*,
Atlantis Highlights in Social Sciences, Education and Humanities 32,
https://doi.org/10.2991/978-94-6463-660-4_5

1 Introduction

In the realm of contemporary education, the fields of Science, Technology, Engineering, and Mathematics (STEM) stand as pillars of innovation and progress, driving advancements in virtually every aspect of modern society. STEM teachers' roles extend beyond the confines of traditional pedagogy, encompassing a dynamic blend of facilitation, mentorship, and inspiration. Through the application of scientific methods, mathematical reasoning, and engineering principles, students are expected to emerge not merely as consumers of knowledge but as creators. They are presumed to be equipped to tackle the grand challenges of the 21st century with ingenuity and resolve. STEM educators encounter a plethora of challenges that demand deft navigation and innovative solutions. From addressing diverse learning needs to integrating emerging technologies into the curriculum, teachers grapple with the demands of an ever-changing educational landscape. Integrating technology into STEM education can enhance student engagement and motivation. Interactive multimedia content, gamified learning experiences, and the novelty of using technology in the classroom can spark curiosity and enthusiasm for learning. Students always question any option at the beginning of the lesson itself and they always have one main question 'Why do we need this in real life?' A lack of real-life applications for mathematical concepts can lead to disinterest in learning.

VARK model known as Visual, Auditory, Reading/Writing, and Kinesthetic is for catering to different learning preferences which can be seen in many multi-modal learning software's [1]. A dynamic mathematics software, such as GeoGebra can be used effectively to provide individual learning experience appropriate for learner's preferred learning style. GeoGebra allows students to visually explore mathematical concepts through interactive graphs, diagrams, and geometric constructions. Visual learners benefit from seeing mathematical relationships visually represented, which can deepen their understanding. While GeoGebra primarily focuses on visual representations, teachers can supplement its use with verbal explanations and discussions during classroom instruction.

Smith [2] explored the pivotal role of educators as facilitators of inquiry-based learning within STEM education. Their study delves into diverse strategies and optimal methods for crafting activities and experiments aimed at fostering inquiry, critical thinking, and problem-solving skills among students. Drawing upon both educational learning theories and empirical research, the article offers insights into effective instructional approaches and classroom techniques tailored to engage students in hands-on exploration of scientific concepts, mathematical principles, and engineering challenges. Using case studies and illustrative examples, Smith also demonstrates how inquiry-based learning can be effectively implemented across various STEM disciplines to elevate student learning outcomes and cultivate a deeper comprehension of intricate phenomena. This scholarly work presents valuable guidance for STEM educators endeavoring to integrate inquiry-based learning methodologies into their teaching methodologies, thereby empowering students to actively participate in their own educational journey. For instance, teachers can narrate their actions as they demonstrate concepts using GeoGebra, providing auditory cues for auditory learners. GeoGebra provides opportunities for students to engage with mathematical texts and written instructions as they work through problems or explore concepts. Additionally, teachers can incorporate written explanations and annotations within GeoGebra activities to support reading/writing learners. While GeoGebra is primarily a visual tool, students can engage in kinesthetic learning by physically interacting with the software, manipulating objects on the screen, and experimenting with different parameters. This hands-on exploration can appeal to kinesthetic learners who benefit from tactile experiences.

Teachers can incorporate GeoGebra for their students to work collaboratively using the GeoGebra software to explore and apply the concepts of trigonometry, a simple example is translations in trigonometric equation such as:

$$y = asin(bx + c) \ + d. \tag{1}$$

The graphical representation of this graph is represented as a sequence of transformations. It is observed that, many students find it difficult to visualize the sequence of transformation, interactive tools like GeoGebra provides scaffolding.

To summarize, GeoGebra's versatility aligns with the VARK model by offering a range of modalities for students to engage with mathematical concepts, accommodating diverse learning preferences and enhancing learning outcomes.

In this paper, students' different learning styles which will be incorporated into the lesson while overcoming any challenges students face in attaining the learning outcomes.

The research aims to investigate to the following two descriptive questions:

1. What challenges do students face in learning trigonometric functions within the new instructional sequence?
2. Is differentiated learning effective in reducing anxiety in learning the topic of trigonometry?

2 LITERATURE REVIEW

The purpose of trigonometry is to provide mathematical techniques and tools for analyzing relationships between angles and sides in triangles, as well as for solving problems in various fields of science, engineering, and mathematics. Overall, trigonometry plays a crucial role in various STEM disciplines, providing students with essential mathematical tools to solve real-world problems and make meaningful connections between theoretical concepts and practical applications.
Trigonometry is an important subject in secondary mathematics education and beyond, even though its scope may change from country to country at secondary school level [3]. The importance of Trigonometry is that it is crucial for physics, engineering, and architecture; in addition, it connects algebra, geometry, and graphical reasoning, laying the groundwork for calculus. Blackett & Tall [4] have discussed the importance of a solid foundation and prerequisite skills since there are several challenges for young adults in learning trigonometry that it requires translating between visual representations (diagrams) and numerical relationships (trigonometric functions); there are also some unfamiliar functions that cannot be solved with basic arithmetic.

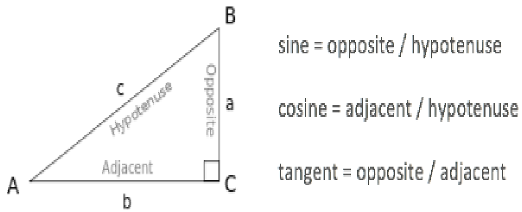


Fig. 1. A simple diagram for Trigonometry taught in Mathematics.

In the realm of geometry, particularly concerning triangles, the sine, cosine, and tangent of an acute angle are defined as the ratios of specific pairs of sides within a right triangle as shown in **Fig. 1**. This method of introducing trigonometric functions is commonly known as the ratio method. Additionally, the concept of a right-angle triangle is frequently incorporated into the unit circle, where angles are interpreted as rotation angles. In the Dutch mathematics [5] curriculum, the ratio method is studied for right triangles at lower level and followed up by the unit circle at the beginning of upper level. An important benefit of incorporating ICT (Information and communication and technology) is its capacity to enable students to investigate the correlations between numerical and visual portrayals of trigonometric ratios within right triangles, as well as the associations between graphical depictions of trigonometric functions and the placements of points on the unit circle [6]. The ratio method is particularly useful in scenarios where direct measurement of angles or sides may not be possible, such as in practical applications involving heights, distances, or angles that are difficult to access directly. Additionally, the ratio method forms the foundation for understanding and applying trigonometric concepts in various fields such as engineering, physics, and navigation.

Kendall and Stacey [7] stated that they preferred that basic trigonometry be introduced using the unit circle (seen below in **Fig. 2**) of trigonometric function, connecting them to the ratio definitions and then adopting the techniques of the ratio method for the solution of problems about triangles. There are many advantages to the unit circle method such as it deals with obtuse angles, negative angles, and angles of any size; it avoids working with ratios, since these have been proven difficult for students [8]; sine values and cosine values are not restricted to positive values; supports reasoning about various properties of trigonometric functions such as periodicity and trigonometric equalities.

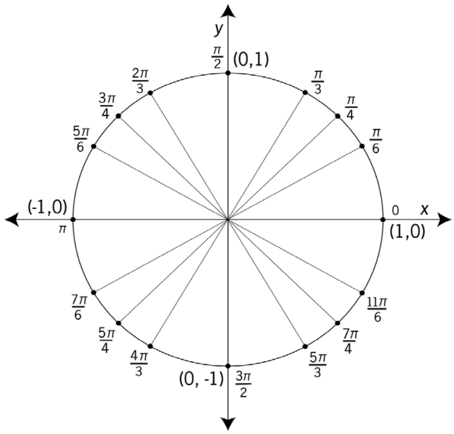


Fig. 2. Unit Circle [9]

The complex nature of trigonometry makes it challenging for students to understand the topic deeply and conceptually. Trigonometric functions are unique because they cannot be figured out using basic arithmetic like other functions with algebraic formulas; in addition, students have difficulty using sine and cosine functions defined over the domain of real numbers; Analytical definitions of trigonometric functions are of little help at secondary school [10].

Teachers in the fields of STEM typically possess specialized knowledge and expertise to guide students through complex topics, providing explanations and resources to help students understand concepts. As facilitators of inquiry-based learning, STEM educators orchestrate immersive experiences that beckon students to explore, experiment, and engage with the intricacies of scientific phenomena, technological marvels, engineering challenges, and mathematical problems. Crucially, STEM teachers are champions of critical thinking and problem-solving, instilling in their students the essential skills requisite for success in an ever-evolving landscape. By presenting authentic, real-world challenges, they compel learners to wield the tools of analysis, evaluation, and innovation, empowering them to dissect problems, devise solutions, and iterate upon their designs. Teachers foster a collaborative learning environment where students work together in teams to tackle complex problems and projects. They encourage creativity and innovation, empowering students to propose novel solutions and explore new areas of research within their respective fields.

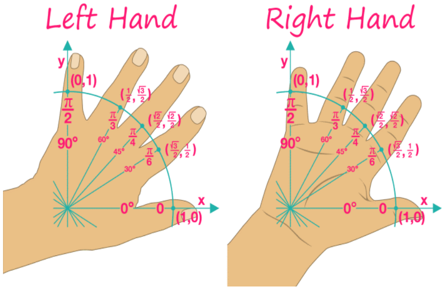


Fig. 3. Simply explanation of trigonometry for the students understanding without use of tools [11]

The suggested teaching method for trigonometry prioritizes conceptual comprehension, particularly emphasizing the coherence of angle measurement within trigonometric concepts. This approach advocates utilizing arcs of a unit circle to link unit circle trigonometry with graphs of trigonometric functions. Furthermore, it proposes employing the metaphor of traveling along the perimeter of geometric shapes such as regular polygons or circles to aid students in forming coherent interpretations centered on arcs of a unit circle. By connecting abstract ideas with tangible visualizations and real-life comparisons, this strategy aims to deepen students' grasp of trigonometry. Referring to **Fig. 3**, it shows how students can use any hand to find the angle in the first quadrant while using the thumbs as angle 0° as the polar axis. This can be helpful for both right hand writers and left-hand writers. Below seen **Fig. 4** shows how trigonometry deals with the study of the relationship between the sides and angles of the right-angle triangle. Hence, it helps to find the missing or unknown angles or sides of a right triangle using the trigonometric formulas, functions, or trigonometric identities, all in relation with the Unit Circle connecting the context. Being familiar with the concepts of trigonometry will help any reader to be able to relate the definition of trigonometry and its applications in different fields.

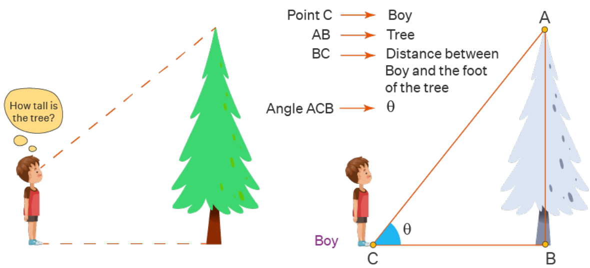


Fig. 4. Trigonometry in Real Life Physics Question [12]

Relating the **Fig. 4** to find the Angle of Elevation, the missing angle (θ) would represent the angle of elevation. This angle measured between the horizontal line (ground) and the observer's line of sight to a higher point (represented by point A in the diagram). Tangent Function (tan): We know the length adjacent to the angle of elevation (segment BC) and need to solve for the opposite side (height of the tree, segment AB). The tangent function (tan) is suitable for this scenario, where the formula used is $\tan\theta = \frac{AB}{BC}$ (height of tree/distance of the tree from the boy). (2)

The real-life application can be finding the height of a tree, where a person is standing on flat ground (represented by segment BC) and observing a tall tree (represented by segment AB) at an angle of elevation (represented by θ) and the height of the tree is unknown (represented by segment AB). The distance is measured between the boy standing and the base of the tree (segment BC). By using trigonometry and the provided information (distance the boy is standing from the tree and the length of segment BC) the required height can be estimated using the known values.

In this section, a review of empirical research in STEM education is presented.

In STEM education, educators emphasize the cultivation of critical thinking and problem-solving abilities among students. They introduce real-world challenges and prompt learners to scrutinize data, devise hypotheses, and engineer solutions employing scientific methodologies and mathematical logic [13]. Through empirical research, the unique pedagogical content knowledge (PCK) and subject matter knowledge (SMK) that STEM teachers bring to their practice was explored [14]. By creating a collaborative and supportive environment, educators empower students to excel academically and become future leaders in science, technology, engineering, and mathematics.

Trigonometry lessons typically start by building a foundation on right triangles and the Pythagorean theorem. Using visual aids like diagrams, graphs, and even interactive tools to help students visualize the concepts. Using real life examples where trigonometry was connected to real-world applications, making it more relevant for students and incorporating activities and group work, making the learning process more interactive and engaging. Teachers leverage technology to enhance the learning experience in STEM education. They incorporate simulation software, data analysis tools, and virtual laboratories to provide students with opportunities for experimentation and exploration in a digital environment [15].

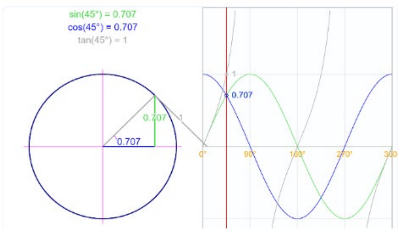


Fig. 5. Introducing Trigonometry using Tools [16]

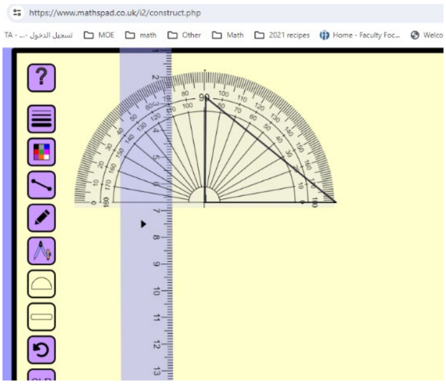


Fig. 6. Trigonometry using online tools [17]

The tools shown in **Fig. 5** and **Fig. 6** are just a few examples of what educators can use for students, whilst an online class or face to face, this allows blended learning and collaboration between students. Students can use these tools to collaborate with one another for better understanding of the concept, they can use the websites to understand the concepts of trigonometry virtually at any time without having access to the real tools of compass, ruler, or protractor. As technology is changing frequently, we can access multiple resources to engage students in learning and achieving the learning outcomes. The authors [15] highlights the benefits of technology integration for promoting active learning, fostering critical thinking, and enhancing student engagement in STEM disciplines; they also discussed strategies for effectively incorporating technology into teaching practices and overcoming potential challenges Adopting student-centered, inquiry-based pedagogies enhances quality of technology integration. A brief review of such pedagogies is presented next.

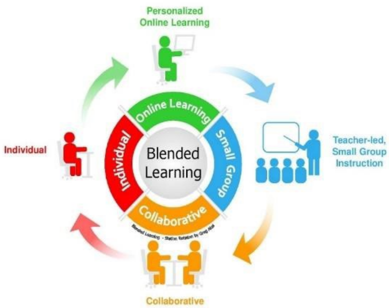


Fig. 7. Blended Learning Model [18]

Fig. 7 above is a Blended Learning Model, which incorporates concepts such as individual online learning and collaborative small groups is the Flipped Classroom model

[19]. With the help of blended learning, traditional teaching methods are inverted, assigning students with pre-class activities at home, such as watching prerecorded lectures or completing online modules, before coming to class allowing them to utilize the class time for collaborating in small group activities, discussions, and hands-on exercises facilitated by the instructor. This is very efficient is any concept especially in a subject like mathematics where students also get time to prepare before the class. Inquiry-Based Learning (IBL) for trigonometry fosters a dynamic learning environment where students explore concepts through questioning and investigation [20]. They delve into real-world problems, applying trigonometric principles to scenarios such as measuring angles outdoors. Through interdisciplinary connections, students discover how trigonometry intersects with fields like physics and engineering, enriching their understanding through research and projects. For example, a study [21] found that teachers believed blended learning improved student motivation, engagement, and academic performance. Similarly, a study reported that teachers valued the flexibility and adaptability of blended learning, which allowed for personalized learning experiences tailored to individual student needs [22]. However, teachers' perspectives are not always positive. Some teachers expressed concerns about the quality and suitability of online content and the workload associated with preparing and delivering blended learning materials. Teachers reported that they found it challenging to manage student learning in a blended learning environment, with some expressing concerns about maintaining academic rigor. Teachers' motivation to use blended learning is a key factor in its success.

Fig. 8. The VARK model [23]

Above mentioned **Fig. 8**, illustrates The VARK model, developed by Neil Fleming in 1987, categorizes learners into four primary styles: Visual, Auditory, Reading/Writing, and Kinesthetic.

- Visual learners prefer to learn through visual aids such as charts, diagrams, maps, and videos. They tend to grasp information more effectively when it is presented in a visual format.
- Auditory learners learn best through listening and verbal explanations. They benefit from lectures, discussions, and audio recordings, and may remember information more accurately when they hear it rather than see it.
- Reading/Writing learners excel in written communication and prefer to learn through reading and writing activities. They often rely on textbooks, written instructions, and note-taking to understand and retain information.
- Kinesthetic learners learn best through hands-on experiences and physical activities. They thrive in environments where they can engage in practical tasks, experiments, and simulations.

The VARK model suggests that individuals may prefer one or more of these learning styles, although most educators utilize a combination of styles depending on the context and content of the learning material. Understanding one's preferred learning style according to the VARK model can help individuals and educators tailor their study and teaching methods to optimize learning outcomes. Every student has their level of mathematical competency and learning style; and as an educator, the ability and need in utilizing the diverse learning styles to foster a student-centered environment is essential for teaching Trigonometry Considering the VARK model, it is important to incorporate with the diverse learning styles and fostering a student-centered environment. Trigonometry is a foundational subject in high school math, but it can be tricky for students to grasp at first. Students feel anxiety when they hear the word ‘Trigonometry’. Math anxiety can be a crippling force for students, especially when it comes to performance. It fosters a cycle of negative thoughts and physical symptoms that can significantly impact test scores and overall engagement with the subject [24]. At the heart of this issue lies a fear of failure. Students become convinced they are "not good at math" leading to constant doubt that clouds their judgement during exams and assignments. The pressure to perform well in front of teachers and peers only intensifies this anxiety, making it difficult to focus and think clearly [25]. The consequences of math anxiety on performance are undeniable. Lower test scores become a reality as students struggle to apply their knowledge while battling their anxieties [26]. With the right strategies and support in place, students can learn to manage their anxieties and develop a more positive and productive relationship with mathematics.

It has been researched that the quality of the online materials, the ability to interact with peers and instructors, and the flexibility of the approach were significant motivators for students, but it is also noted that the lack of support from instructors and technical difficulties were barriers to participation [27]. Students frequently harbor misconceptions stemming from math anxiety, attributing their struggles to low performance in math. However, the key missing element is often long-term memory retention. To solidify their understanding, students must actively engage with the concepts and practice numerous questions. Students engage in cognitive development, emphasizing the critical need for enhanced cognition, which serves as a bridge between understanding concepts and applying them.

When comparing to traditional methods, modern teaching methods can be more time-consuming as educators need to be prepared for any technical difficulties. Cost of technology comes at a price currently, so it is important to take that into consideration. Sometimes student lack motivation to use technology and to apply it within the classroom or at the convenience of their own home. Web-based software, such as GeoGebra, are easy and free to use.

Demir and Heck proposed an innovative approach to teaching trigonometry where they propose a sequence or activities that can help students to develop a deeper understanding of trigonometric functions. The focus could be on overcoming common difficulties students face or creating a more engaging and effective learning experience [5]. Kissane and Kemp [6] has sampled the available technologies that learners or teachers may have access to for teaching and learning trigonometry in the early years of the twenty-first century, to illustrate the claim that there are many ways in which teaching and learning might change, when compared with earlier approaches. One major change is the opportunity provided by technology to help students engage with trigonometric concepts; a second major change is that students can interact directly with trigonometrical ideas through the medium of technology in a more active way than is possible with paper and pencil alone. While the possibilities in any classroom will of course be dependent on which technologies are available, there seems to be much to be gained from the use of the least sophisticated technology, that of the graphics calculator. The graphical calculators can be incredibly helpful tools for learning and understanding trigonometric functions in graphical representations, problem solving and verifying answers. Some graphical calculators offer advanced features specifically designed for trigonometry. These might include unit circle visualizations, table generation for function values, or complex number calculations useful in certain trigonometric applications. This is a tool that itself requires its own lesson along with each topic.

It was explored that the significance of preparing students for successful careers in STEM fields through comprehensive educational approaches [28]. It is important to highlight the growing demand for STEM professionals in various industries and the importance of equipping students with not only technical knowledge but also professional skills and experiences. Students need to be able to learn to be able to integrate their skills in their careers including internships, co-op programs, industry partnerships, and professional development opportunities. While students faced difficulties, they also overcame them to be able be ready for their learning including tests.

3 METHODOLOGY

This research is based on inclusion of technology leveraging digital tools to enhance understanding and exploration of trigonometry. This is done using research for platforms like GeoGebra that enable students to dynamically manipulate geometric shapes, aiding in the comprehension of trigonometric relationships. Additionally observing how students can engage with online simulations or applets that highlight practical applications of trigonometry in real-world contexts.

The target population is female high school UAE nationals, between the age of 14-16 in grade eleven. The topic of trigonometry was taught in one of the classes consisting of 24 students. These students have a history of high achievement in Mathematics as a subject in their primary and junior high school years.

The research aims to investigate to the following two descriptive questions:

1. What challenges do students face in learning trigonometric functions within the new instructional sequence?
2. Is differentiated learning effective in reducing anxiety in learning the topic of trigonometry?

The main aim of the lesson is to deepen the understanding of trigonometric ratios (sine, cosine, tangent) through real-world applications. The objective of the lesson is to be able to define and explain the trigonometric ratios for any angle in a right triangle, and to be able to apply trigonometric ration to solve real-world problems in various contexts. Before starting trigonometry lessons, the teacher gave the students a 30-minute test to assess their existing knowledge. This test focused on their understanding of triangles, functions, and how to interpret graphs. The results show that after the pre-test, some students had difficulty in analyzing one-to-one functions which led to a minor adjustment in the teaching materials related to functions having only one output for each input to incorporate ease in learning. The lessons incorporated a student-centered approach, where students actively built their knowledge by interacting with peers, and their regular teacher. The lessons heavily relied on paired work followed by whole-class discussions. GeoGebra applets as seen in **Fig. 9** were used as visual aids alongside tasks presented in worksheets. The first lesson specifically involved students working in pairs.

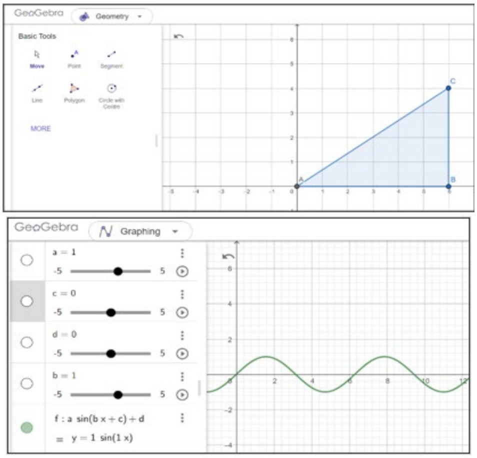


Fig. 9. Trigonometry use with tools such as GeoGebra [29]

Students were given a pre-session survey to assess their level of confidence and anxiety. **Table 1** below shows classroom practices.

Table 1. Classroom practice and their applications.

Classroom Practice	**Application**
Build a solid foundation	Ensure students are comfortable with algebra and geometry before diving into trigonometry.
Break down complex concepts	Introduce new concepts gradually, and break them down into smaller, more manageable steps
Focus on visual representations	The researcher has used diagrams, animations, or interactive tools to help students connect the visual aspects with mathematical concepts.
Relate to real-world applications	Show students how trigonometry is used in practical fields to make the subject more engaging.
Practice with problems	Provide many opportunities for students to practice applying trigonometric concepts to solve problems.

The lesson incorporates group work to foster collaboration and engagement. Students were divided into groups of 3-4 where they were assigned to explore and write their observation from GeoGebra of any right triangle that they can make with three points as shown in **Fig. 9**. They were assigned roles within the group of facilitator, timekeeper, recorder, and reporter. With this responsibility they felt that they had to achieve a goal, which made the group work easier. They were given twenty minutes to do their research on tools available online such as GeoGebra. The students were encouraged to discuss and share their findings and analyze how they used the trigonometric functions.

While students worked in groups it was observed that they demonstrated effective group work through collaboration and engagement in achieving enhanced understanding of trigonometric applications and their communication skills between students enhanced their ability to connect abstract mathematical concepts to practical situations. Upon completion of the activity, they were assessing each other as a group, they gave each other constructive criticism and it was reflected upon allowing them to have more improved assessments. The teacher recorded important observations and discussion emerged through students' interactions while working in groups. These observations are recorded as teaching journal entries. Many students struggled to grasp the concept of clockwise and anticlockwise rotations when measuring angles and visualizing obtuse angles and their trigonometric ratios. While a standard protractor measure angles up to 180 degrees, a circular representation can handle angles of any size, including those greater than 360 degrees. This offers a valuable tool to overcome these challenges and enhance understanding of angular measurement and trigonometry.

The analysis of student's responses to worksheet tasks in combination with of the group discussions revealed that in general the students were quite successful when working on most tasks. Differentiation strategies like formula sheets and teacher guidance were implemented for students who needed assistance. Some students mastered all concepts with little support from the teacher, but others needed extra aid. However, these interventions proved insufficient in overcoming all students' difficulties. Some difficulties the students faced are trying to understand why the graphs of trigonometric functions appear like waves. These polar or sinusoidal graphs are compared to the rectangular (x, y) graphs. The polar coordinate system will use a unit circle with its corresponding grid and will specify angles in either degrees or radians.

At the end of the session a formative quiz was conducted, and the post-session survey was administered.

4 Discussion

The objective of the case study was to evaluate the progression of students' conceptual understanding and development following the introduction of the new trigonometry learning trajectory. The challenges the students faced in learning trigonometry functions, analyzing their opinions before and after learning the lesson. In this section, we provide responses to these questions based on the analysis of the gathered data.

During the lesson, it was observed that students were able to overcome their fear of learning the topic through collaborative activities, though students struggle to grasp some concepts, they very well enjoyed relating it to real-world connections, while mixed emotions impact their learning in mathematics. The research analyzes the effectiveness of different strategies, such as providing formula sheets, offering tiered assignments, or employing visual aids tailored to diverse learning styles, while exploring how differentiation caters to students with varying levels of prior knowledge, learning styles, or processing abilities. There was a common question students had regarding the periodicity of trigonometric graph as seen in Figure 1, which was answered by showing the students the nature of the graph of trigonometric functions and GeoGebra was used to explain the same. A survey was done for the students by the teacher before the teaching of the topic of trigonometry, the results are in **Table 2** and **Table 3**. The survey show the questions and results of students completing the survey and the percentage of the options selected by them.

As seen in **Table 2** and **Table 3**, we observe that students feel less anxious as the lesson progresses. They can think more clearly and as seen that there is an 85% positive response where students are not scared of mathematics and 92% believed they were good at solving math problems. Their confidence increased in learning advanced mathematics. While the instructional approach for trigonometry initially challenged students, differentiated instruction tailored to individual needs to effectively reduce their anxiety towards the topic.

Table 2. Results of Survey before Teaching the topic of trigonometry

Questions.	**Strongly Agree.**	**Agree.**	**Neutral.**	**Disagree.**	**Strongly Disagree.**
I get a great deal of satisfaction out of solving a mathematics problem.	29%	29%	43%	0%	0%
My mind goes blank, and I am unable to think clearly when working with mathematics.	0%	0%	43%	43%	14%

Mathematics does not scare me at all.	14%	29%	29%	29%	0%
I am confident that I could learn advanced mathematics.	57%	14%	29%	0%	0%
I would prefer to do an assignment in math than to write an essay.	29%	29%	14%	0%	29%
I would like to avoid taking mathematics courses in college.	14%	14%	29%	0%	43%
I am comfortable answering questions in math class.	14%	29%	29%	14%	14%
I believe I am good at solving math problems.	14%	29%	43%	14%	0%

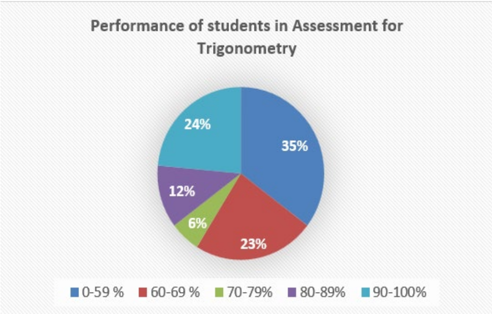
Table 3. Results of Survey after teaching the topic of trigonometry

Questions.	**Strongly Agree.**	**Agree.**	**Neutral.**	**Disagree.**	**Strongly Disagree.**
I get a great deal of satisfaction out of solving a mathematics problem.	23%	38%	38%	0%	0%
My mind goes blank, and I am unable to think clearly when working with mathematics.	0%	15%	31%	38%	15%
Mathematics does not scare me at all.	23%	23%	38%	15%	0%

I am confident that I could learn advanced mathematics.	46%	46%	8%	0%	0%
I would prefer to do an assignment in math than to write an essay.	23%	15%	38%	8%	15%
I would like to avoid taking mathematics courses in college.	15%	38%	8%	8%	31%
I am comfortable answering questions in math class.	23%	23%	46%	0%	0%
I believe I am good at solving math problems.	8%	54%	31%	8%	0%

A 50-minute trigonometry test, assessing students' knowledge on basic functions or concepts of the curriculum aligned with the model of trigonometric understanding, evaluated student comprehension post-instructional sequence. The test included both online test of 6 questions and a written test of 4 questions, connecting the concepts of trigonometry in a right-angle triangle, verifying identities and expressions. The results of the tests shown in **Fig. 10** are of which were conducted each week showed that 65% of students were able to achieve all learning objectives of the lesson. Even while 35% were unable to do so at first, with continuous practice and guidance, they were then capable of achieving a better score in their following tests.

Students are given tests that show their passing percentage results from this they have achieved their learning outcomes; attainment of these learning outcomes quantify this fact. The results of which show below in **Fig. 10** showing the achievement of the learning outcomes.



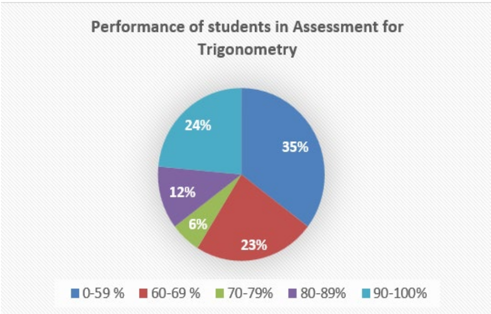


Fig. 10. 65% of students attained the learning outcome the Application of Trigonometry

Qualitative analysis was conducted on the data recorded in teacher's teaching journal to address the research questions regarding students' concept development and understanding of sine and cosine functions. Students in trigonometry often face a multitude of challenges, including grasping abstract concepts like relating angles to ratios, visualizing the unit circle, memorizing trigonometric formulas, and applying their knowledge to solve complex problems.

5 CONCLUSION

Research opportunities, and academic success strategies value one-on-one interactions with professors who are approachable and supportive. Robnett, Chemers & Zurbriggen [30] underline the importance of mentorship and guidance at higher education levels for student success in STEM education.

Technology enhances STEM education by providing students with opportunities for enhanced learning experiences, access to resources, hands-on exploration, collaborative learning, and preparation for future careers in STEM fields. By leveraging technology effectively, educators can engage and empower students to become skilled problem-solvers, innovators, and lifelong learners in the STEM disciplines.

The results in **Table 3** (survey) and **Fig. 10** (tests) suggest that after completing the lesson, students felt confident applying the concepts to real-world situations, demonstrating successful learning outcomes. Utilizing all available resources, including technology from schools and external websites in student-centered pedagogy is effective in STEM education. This integrated learning model helps assess how students leverage technology for learning. Transitioning students from knowledge to application is particularly important. This starts when the learner is becoming an efficient student, doing all that they need to do as a responsible student. With the help of the teacher, the knowledge is transformed into skills that they can apply within the classroom and formative and summative assessments and the final goal here is to transition the students from higher education to becoming a professional, to be able to apply the skills learned in real-life.

There are certain limitations to this study as the sample size for the data set was a small number of students. Results from a small sample size cannot be generalized hence this would need to be repeated on a different data set and expand the sample size by taking student or teacher interviews and setting assignments with more exploration on the topic. More research would be done on how student perceive learning topics in mathematics while using blended learning method.

References

[1] Yasoña, R. M., & Gonzales, M. A. (2022). Enhancing Mathematical Skills Of The Students Through Digi-Tech Apps. Enhancing Mathematical Skills Of The Students Through Digi-Tech Apps, 10, 104(1), 13-13. doi:DOI: 10.47119/IJRP1001041720223547

[2] Smith, S., & et. al. (2018). Transformative stem teacher education supporting teacher identity developemnt through design and making. Journal of the World Federation of Associations for Teacher Education, 2(3a), 69. Retrieved from https://pledge2teach.com/wp-content/uploads/2020/01/Teachers-Matter-Preparing-Innovative-Teachers-Conference-Proceedings.pdf#page=70

[3] Delice, A., & Roper, T. (2006). Implications of a comparative study for mathematics education in the English education system. Teaching Mathematics and its Applications, 25(2), 64-72. doi:10.1093/teamat/hri007

[4] Blackett, V., & Tall, D. O. (1991). Gender and the versatile learning of trigonometry using computer software. In Proceedings of the 15th Conference of the International Group for the Psychology of Mathematics Education, 1, 144-151. Retrieved from https://homepages.warwick.ac.uk/staff/David.Tall/pdfs/dot1991g-blackett-trig-pme.pdf

[5] Demir, Ö., & Heck, A. (2013). A new learning trajectory for trigonometric functions. *In Proceedings of the 11th international conference on technology in mathematics teaching*, 119-124. doi:https://staff.fnwi.uva.nl/a.j.p.heck/Research/art/ICTMT11.pdf

[6] Kissane, B., & Kemp, M. (2009). Teaching and learning trigonometry with technology. 14th Asian Technology Conference in Mathematics. Retrieved from https://s3-ap-southeast-1.amazonaws.com/ap-st01.ext.exlibris-group.com/61MUN_INST/storage/alma/31/9D/69/79/C0/3C/3B/4E/F1/74/F7/10/D8/82/F8/CC/teaching_and_learning_trigonometry.pdf?response-content-type=application%2Fpdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X

[7] Kendall, M., & Stacey, K. (1997). Teaching trigonometry. Vinculum, 34(1), 4–8., 34(1), 4–8. Retrieved from https://fusecontent.education.vic.gov.au/5add73b5-69c3-4e05-8ae2-154fc2dc2b02/kendalstacey-trig.pdf

[8] Hart, K. M., & Küchemann, D. (1981). Children's Understanding of Mathematics: 11-16. In Children's Understanding of Mathematics: 11-16 (Vol. 11(1), pp. 28-33). London: John Murray, 1981. Retrieved from https://www.researchgate.net/publication/309033356_Chapter_8_Algebra

[9] Unit circle labeled at special angles. (2012, February 15). Retrieved from ClipArt ETC: https://etc.usf.edu/clipart/43200/43204/unit-circle12_43204.htm

[10] Van Asch, A. G., & Van der Blij, F. (1997). Goniometry between geometry and analysis. International Journal of Mathematical Education in Science and Technology, 28(1), 85-96. doi:https://doi.org/10.1080/0020739970280108

[11] The unit circle - hand trick. (n.d.). Retrieved from GeometryCoach.com: https://geometrycoach.com/the-unit-circle-hand-trick/

[12] Trigonometry - What is trigonometry? Formulas, table, examples. (n.d.). Retrieved from Cuemath: https://www.cuemath.com/trigonometry/

[13] Khalil, N. M., & Osman, K. (2017). STEM-21CS Module: Fostering 21st Century Skills through Integrated STEM. K-12 STEM Education, 3(3), 225-233. Retrieved from https://www.learntechlib.org/p/209552/.

[14] Tutak, F. A., & Adams, T. L. (2015). A study of geometry content knowledge of elementary preservice teachers. International Electronic Journal of Elementary Education, 7(3), 301-318.

[15] Amunga, J. (2021). Leveraging technology to enhance STEM education amidst the Covid-19 pandemic: An overview of pertinent concerns. Technium Social Science Journal, 18, 40-55. Retrieved from http://41.89.220.4/bitstream/handle/123456789/92/amunga.pdf?sequence=1&isAllowed=y

[16] Interactive Unit Circle. (n.d.). Retrieved from Math is fun: https://www.mathsisfun.com/algebra/trig-interactive-unit-circle.html

[17] Constructions tool. (n.d.). Retrieved from Mathspad: https://www.mathspad.co.uk/i2/construct.php

[18] St. Aloysius Gonzaga School. (n.d.). Retrieved from St. Aloysius Gonzaga School: http://www.staloysiusla.org

[19] Capone, R., De Caterina, P., & Mazza, G. A. (2017). Blended learning, flipped classroom and virtual environment: challenges and opportunities for the 21st century students. Edulearn17 Proceedings, 10478-10482. Retrieved from https://www.researchgate.net/profile/Roberto-Capone-4/publication/318299598_Blended_Learning_Flipped_Classroom_and_Virtual_Environment_Challenges_and_Opportunities_for_the_21st_Century_Students/links/59612b26aca2728c11d9e2e0/Blended-Learning-Flipped-Class

[20] Frasinescu, I. (2018). Understanding inquiry, an inquiry into understanding: a conception of Inquiry Based Learning in mathematics. Montreal: (Doctoral dissertation, Concordia University). Retrieved from https://spectrum.library.concordia.ca/id/eprint/984272/1/Frasinescu_MTM_F2018.pdf

[21] Aksal, F. A., Aksal, Z. A., & Isman, A. (2004). Roles of the Students and Teachers in Distance Education. Turkish Online Journal of Distance Education, 5(4), 1-10. Retrieved from https://dergipark.org.tr/en/download/article-file/156563

[22] Aslan, A., & Zhu, C. (2015). Aslan, A., & Zhu, C. (2015). Pre-Service Teachers' Perceptions of ICT Integration in Teacher Education in Turkey. Turkish Online Journal of Educational Technology-TOJET, 34, 14(3), 97-110. doi:https://doi.org/10.1007/s13394-020-00359-2

[23] The Learning Styles Edition. (2022, June 21). Retrieved from Why is this interesting?: https://whyisthisinteresting.substack.com/p/the-learning-styles-edition

[24] Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. Journal of Psychoeducational Assessment,, 27(3), 197–205. doi:https://doi.org/10.1177/0734282908330580

[25] Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. Journal for research in mathematics education, 21(1), 33-46. doi:https://doi.org/10.5951/jresematheduc.21.1.0033

[26] Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The abbreviated math anxiety scale (AMAS) construction, validity, and reliability. 10(2), 178-182. doi:DOI: 10.1177/1073191103252351

[27] Kamraju, M., & et. al. (2024). Exploring the Impact of Online Education on Higher Education. ASEAN Journal on Science and Technology for Development., 3, 27-36. Retrieved from https://ejournal.bumipublikasinusantara.id/index.php/ajert

[28] Blotnicky, K. A., Franz-Odendaal, T., French, F., & et al. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education, 5*, 22. doi:https://doi.org/10.1186/s40594-018-0118-3

[29] GeoGebra. (n.d.). Retrieved from GeoGebra - the world's favorite, free math tools used by over 100 million students and teachers: https://www.geogebra.org/

[30] Robnett, R. D., Chemers, M. M., & Zurbriggen, E. L. (2015). Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. *Journal of Research in Science Teaching*, 52(6), 847-867. doi:https://doi.org/10.1002/tea.21221