Using Digital Tools and Real-Life Interactive Activities to Teach Trigonometric Functions

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Abstract: Achieving meaningful educational outcomes requires scalable strategies for mastering mathematical concepts and skills, with student engagement at the core. This paper examines the use of comprehensive, technology-enhanced activities designed to promote active learning and deeper conceptual understanding. Specifically, it focuses on the integration of Desmos, an online graphing calculator, into mathematics instruction. The study explores whether combining Desmos with a hands-on approach to teaching trigonometric functions helps students connect abstract concepts to real-world applications. Findings underscore the effectiveness of digital tools like Desmos in increasing student engagement and improving student performance—particularly in the context of graphing and interpreting trigonometric functions.

Keywords: Student engagement, student performance**,** real-world mathematical application problems, Desmos activities, trigonometric functions

INTRODUCTION

In teaching mathematics, a key objective is identifying students' challenges and designing effective resources, methodologies, and assessments to close learning gaps, making education more equitable and inclusive. This manuscript focuses on teaching experiences in a College Algebra and Trigonometry course, where many students face challenges with graphing and interpreting trigonometric functions especially in the context of real-world applications.

A research project conducted during the Fall 2022 and Spring 2023 semesters investigated whether using the Desmos online graphing calculator helps students understand, visualize and interpret trigonometric functions and especially in the context of real-world problems. The Algebra and Trigonometry course's learning objectives, outlined in the department syllabus, emphasized making connections between real-life problems and formulas, graphs, or tables. These objectives also included solving problems using algebraic, numerical, or graphical methods, and employing tools like Desmos.

Multiple assessments were used, including pre-tests, post-tests, final exam questions focused on trigonometric functions and overall exam results.

This manuscript examines the benefits of integrating Desmos into lessons that incorporate real-life applications and graph transformations, using an active learning approach. Desmos allows instructors to design interactive activities, embed media, ask questions, and provide feedback. Students can manipulate graphs, share answers, and collaborate, while instructors can monitor progress and facilitate discussions through the platform's dashboard. The investigation focuses on the teaching and learning of trigonometric functions, given their well-documented difficulty for students. The purpose of this study is to determine whether the use of the Desmos online graphing calculator enhances students' understanding, visualization, and interpretation of trigonometric functions, particularly in the context of real-world problems.

LITERATURE REVIEW

This study is informed by constructivist theory (e.g., Steffe & Gale, 1995), and problem-based learning (Hmelo-Silver, 2004), all of which emphasize meaningful, collaborative community engagement and meaning-making. It is also influenced by current understandings of how people learn (Bransford et al., 2000) and the importance of active learner engagement with tasks. Active learning, as Bonwell & Eison (1991) suggest, encourages engagement through problem-solving, discussions, and group work. Freeman et al. (2014) found that active engagement with problem-solving enhances both student comprehension and performance. Contextual learning, rooted in situated learning theory (Lave & Wenger, 1991), stresses that knowledge is more effectively acquired when it is embedded in real-world contexts. This approach is also central to problem-based learning (PBL), where students engage with real-world situations to apply their knowledge (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004).

In the evolving landscape of higher education mathematics, digital tools have become essential for enhancing student engagement, conceptual understanding, and real-world application of abstract ideas (Hoyles, 2018). Among these tools, Desmos has emerged as a transformative platform for teaching function transformations and graphing in courses such as College Algebra, Precalculus, and Calculus. By offering dynamic, interactive visualizations, Desmos enables students to immediately see the effects of modifying parameters within function equations, deepening their intuition about shifts, stretches, reflections, and compressions (Mane, 2025). Research shows that utilizing Desmos not only improves students' graphing skills but also fosters inquiry-based learning and critical thinking (Chechan et al., 2023).

The benefits of incorporating Desmos into higher education mathematics courses extend beyond visualization. Desmos supports collaborative learning, offers immediate feedback, and allows for exploration of complex mathematical behaviors in an accessible and engaging way. Studies have found that students using Desmos perform better on tasks involving graph interpretation and transformation compared to those using traditional methods (Pinheiro & Ippolito, 2021). Furthermore, Desmos' Activity Builder (Desmos, 2025b) can facilitate deeper understanding by guiding students through scaffolded explorations of mathematical concepts (e.g., see Desmos, 2025a, Unit 1: Benefits of Utilizing Desmos). By integrating Desmos into higher education curricula, instructors not only bridge the gap between abstract mathematics and tangible understanding but also cultivate a more equitable and engaging learning environment for diverse student populations.

METHODS

Study Context

The study compares two sections of the Algebra and Trigonometry course taught in Fall 2022 — MAT 115.C28 and MAT 115.C58. The first one actively used Desmos, and the second one did not use Desmos. In Spring 2023, another two sections were compared — MAT 115.C42, which used Desmos and MAT115.C55, which did not use Desmos.

The purpose of the study was to determine whether students from the course sections that used Desmos and Desmos activities performed better on questions related to graphing and interpreting trigonometric functions in the context of real-word applications. The research question that the study focuses on is: RQ: How does the use of Desmos impact student performance on trigonometric function problems, compared to traditional instruction?

The activities focused on graphing functions such as *(1)* $f(x) = a \cdot sin(bx - c) + d$*, and (2)* $g(x) = a \cdot cos(bx - c) + d$, function transformations, and interpretations in the context of real-world applications. All classroom activities were structured to promote best practices and inclusive learning across all course sections during each semester. In the sections using Desmos, Desmos was utilized to engage students interactively, allowing students to perform dynamic visualizations and to receive real-time feedback on graphing transformations. This helped students manipulate equations and see instant changes. It also helped the creation of a collaborative and exploratory, hands-on learning environment. The visual and interactive elements allowed students to explore mathematical ideas, with the instructor guiding their progress through the Desmos dashboard.

In contrast, the sections that didn't utilize Desmos followed a more traditional approach, where students used manual graphing of functions using graph paper and/or TI-83 or TI-84 Plus calculators. While this approach reinforced precision in calculations and graphing techniques, it lacked the immediacy of visual representations and feedback that Desmos afforded.

A typical classroom format for the sections which used or didn't use Desmos included the following practices:

1. Students watched an assigned video before coming to class.
2. A short pre-test was administered in the beginning of the class.

3. Students worked on classroom activities involving real-world applications.
4. Students were assigned to complete a homework assignment after the class.
5. Post- test was administered in the beginning of the following session for all classes.
6. Both sections of the course followed the same class format except that one of the sections worked on the classroom activities with Desmos, the other section completed the activities without using Desmos.

Below there are some of the challenges of a designed Desmos activity used in all class sections:

Desmos Activities

The following activities were designed to explore *graphing trigonometric functions of the form: (1)* $f(x) = a \cdot sin(bx - c) + d$, *(2)* $g(x) = a \cdot cos(bx - c) + d$, *where a,b,c,d are real numbers.*

1- Watch the video "The Ferris Wheel Rotation and Periodic Trigonometric Functions" as an introduction to make connections between trigonometric functions and some real-world applications. Explore and share other examples of trigonometric functions. (https://travelaway.me/most-famous-ferris-wheels/).

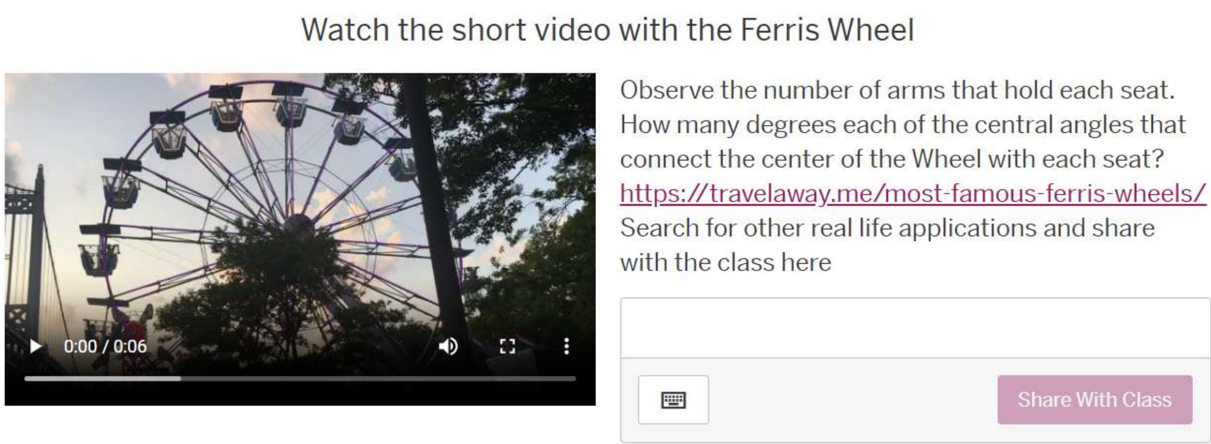

Figure 1: Ferris Wheel video

2- Observe the rotation of the Ferry Wheel and the position of a person seating in one of the seats (a point). (Observe both counterclockwise rotation and clockwise rotation). Determine the domain and the range of sine and cosine functions. (Students utilize sliders in Desmos to manipulate and observe the rotations, graphing, and transformations of sine and cosine functions)

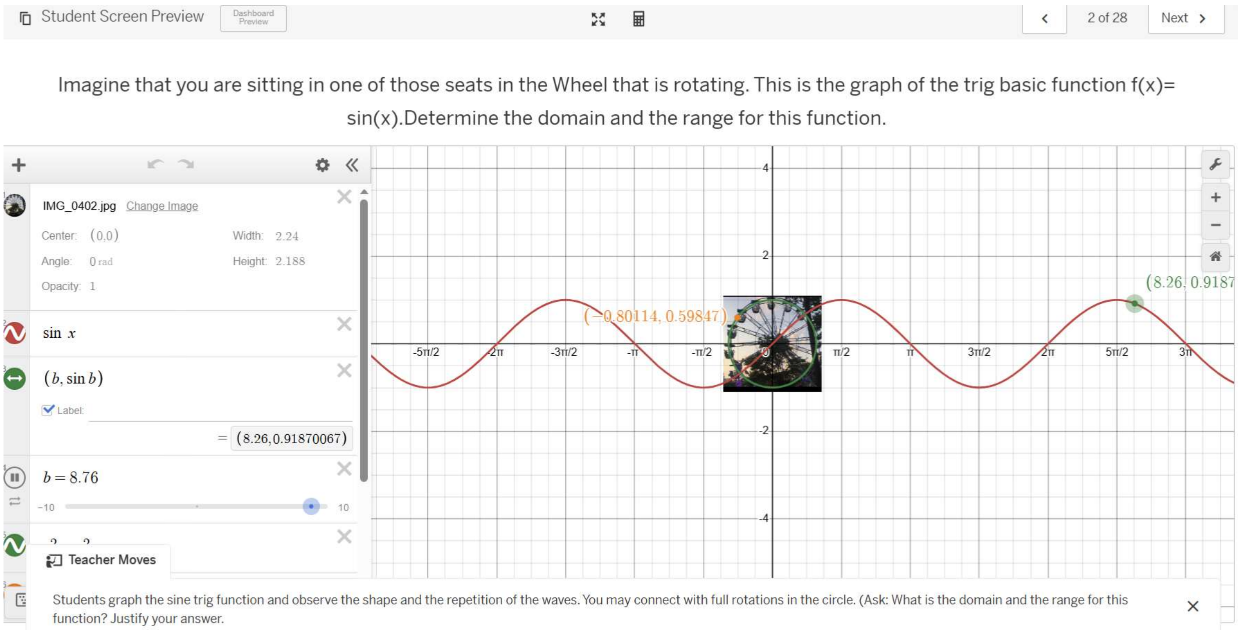

Figure 2: Connecting Ferris Wheel rotation to sine functions

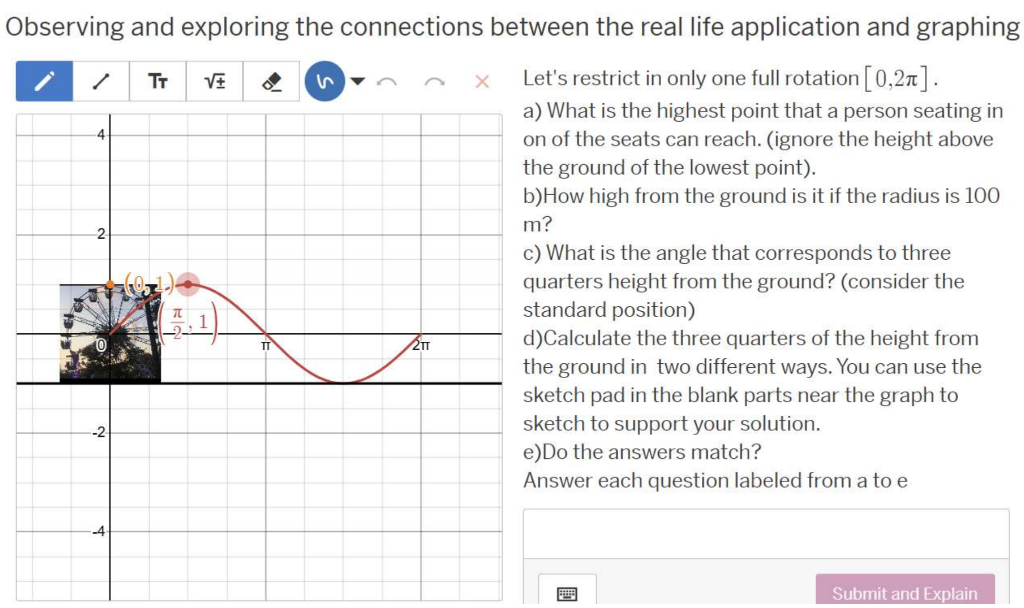

Figure 3: Exploring sine functions with Desmos

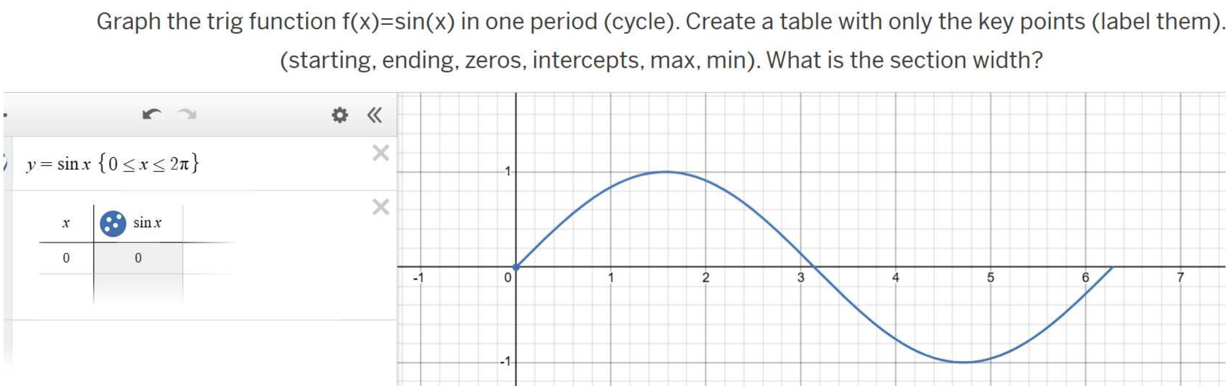

Figure 4: Graphing a sine function and connecting to a table with key points on the graph

3-

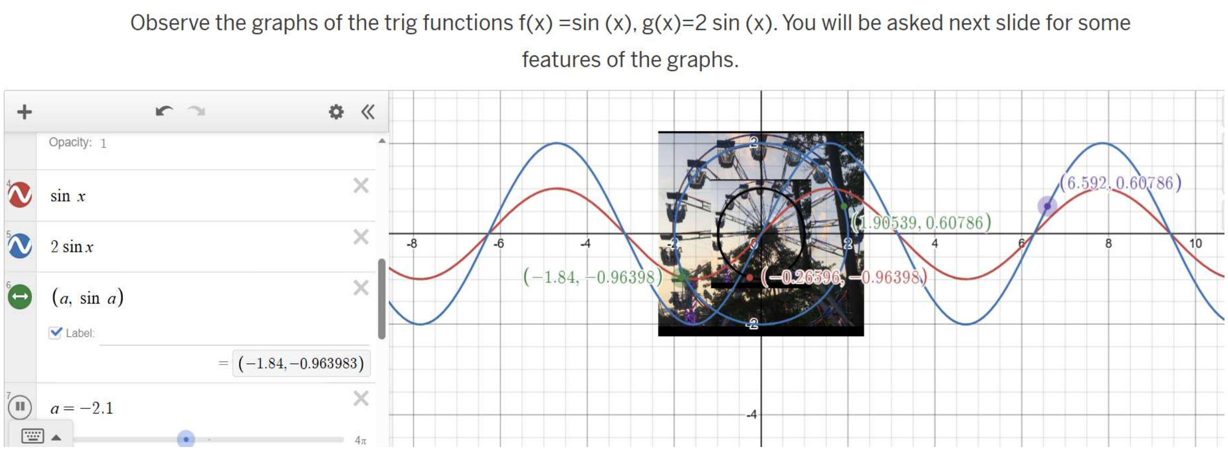

Figure 5: Comparing f(x) = sin(x) and g(x)= 2sin(x)

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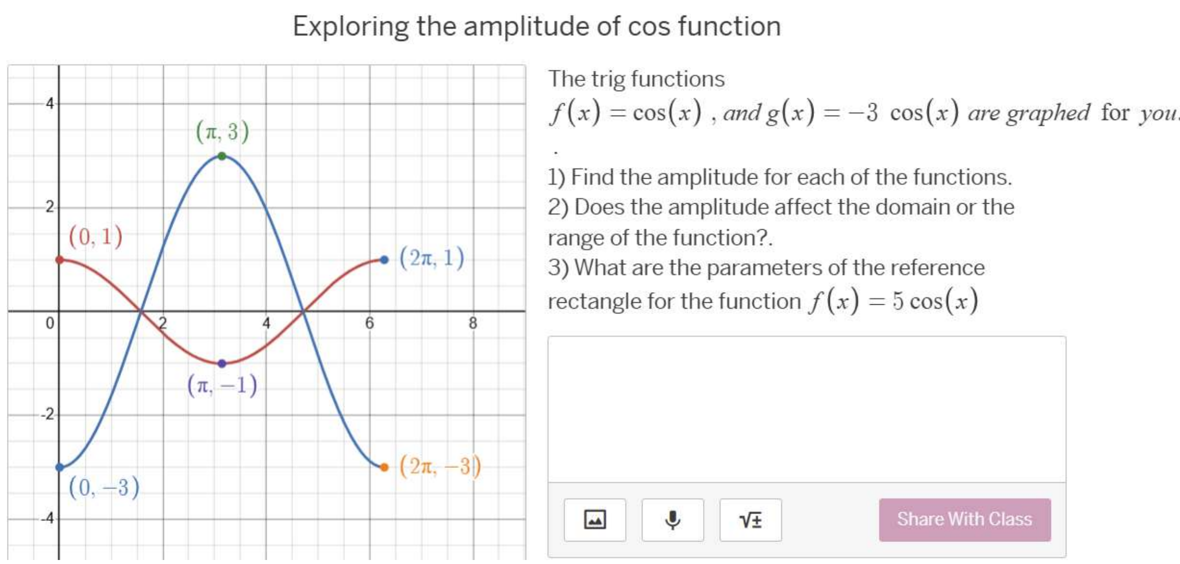

Figure 6: Exploring the amplitude of f(x) = cos(x)

5-

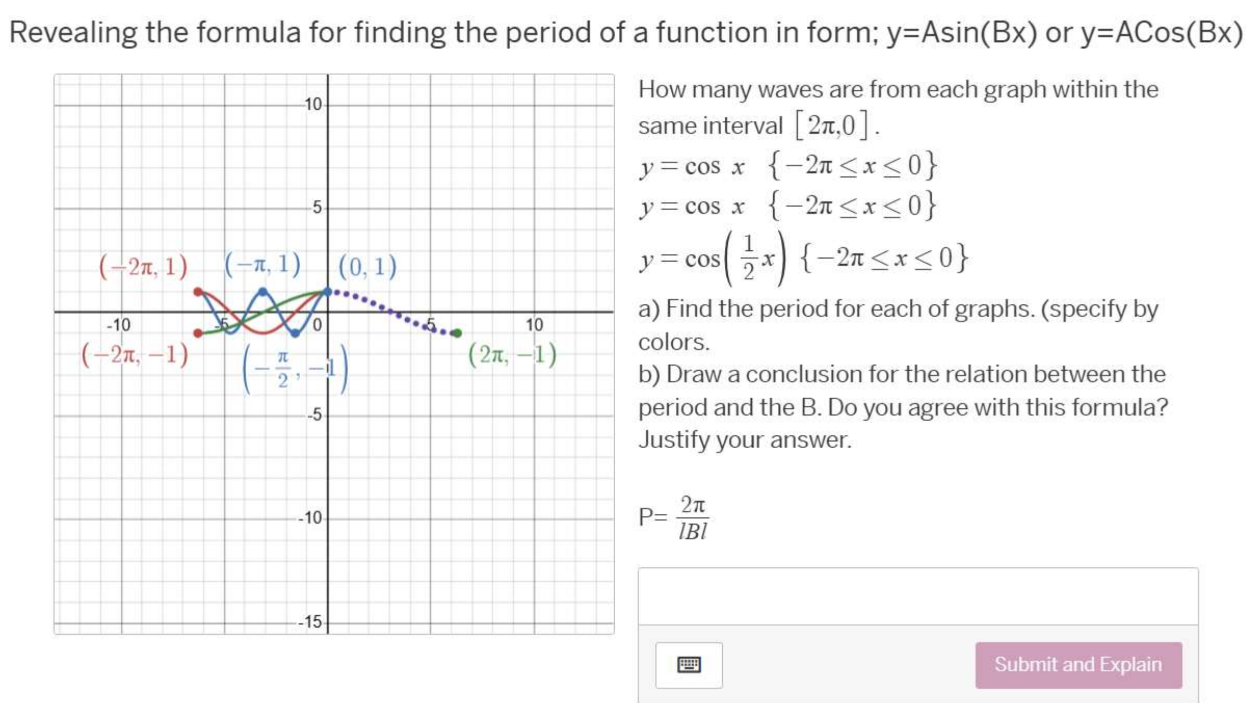

Figure 7: Exploring the period of sine and cosine functions

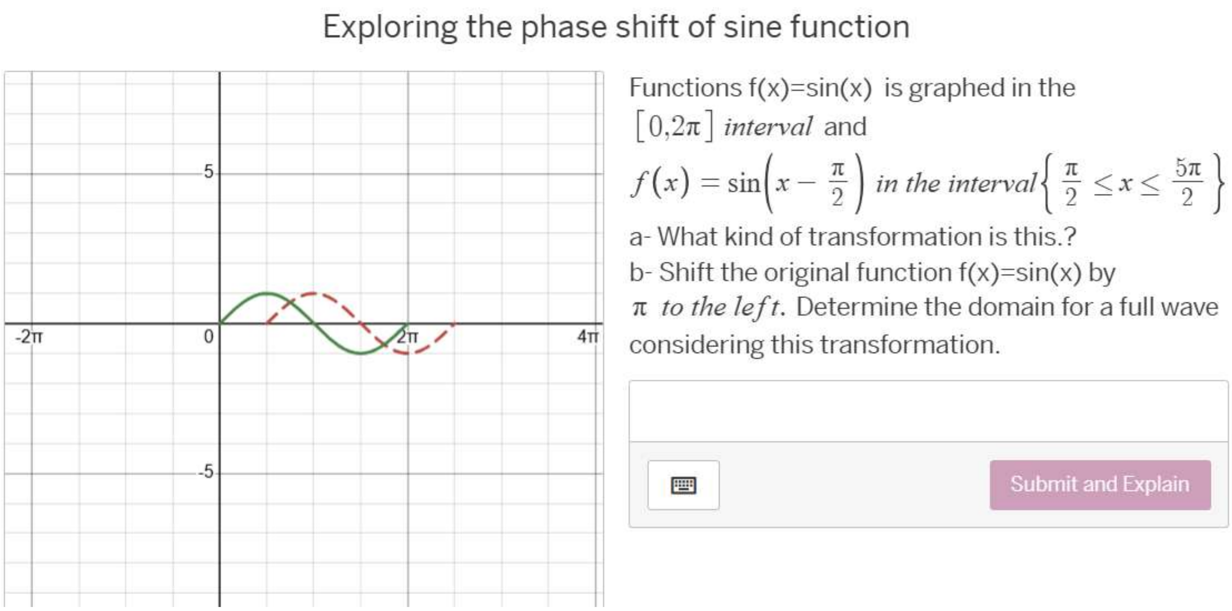

Figure 8: Exploring phase shifts of sine functions

Study Participants

The participants in this study were students enrolled in the Algebra and Trigonometry course sections MAT 115.C28 and MAT 115.C58 during Fall 2022, and sections MAT 115.C42 and MAT 115.C55 during Spring 2023. Students registered for these sections based on their own preferences.

	Learning Trigonometry using Desmos	Learning Trigonometry without Desmos
Fall 2022	MAT 115.C28	MAT 115.C58
Spring 2023	MAT 115.C42	MAT 115.C55

Table 1: Sections of Algebra and Trigonometry Involved in the Study

Description

The study employs a quasi-experimental, pretest-pos-test design. Participants were not randomly assigned to conditions, as they enrolled in course sections of their own choosing. To establish baseline equivalence between the two selected groups (course sections), a pre-test was administered focusing on the study's key measure: student performance on trigonometric function questions, assessed through their test scores. The aim was to ensure the groups were as comparable as possible prior to instruction. The educational intervention involved integrating Desmos-based activities into instruction on trigonometric functions for the experimental group during Fall 2022 and Spring 2023. In contrast, the control groups received traditional instruction without the use of Desmos. The instructional content and instructor were consistent across all groups. Post-tests were administered at the conclusion of the trigonometric functions' unit. During Fall 2022 and Spring 2023, pre-test and post-test scores, along with scores on trigonometry questions from the final exams, were recorded for course sections that used Desmos and those that did not. Additionally, average group performance on trigonometric questions from the final exams was recorded and compared to help validate the post-test results.

RESULTS

For the purposes of the study, two sections of MAT 115 were compared in Fall 2022 and Spring 2023. In Fall 2022, pre-tests were administered to both groups before the trigonometric functions' unit.

Both groups, MAT 115-C28 and MAT 115-C58 had the same average pre-test score of 55, providing a consistent baseline for analysis. The section, MAT 115-C28, which incorporated Desmos into their lessons on trigonometric functions, achieved an average post-test score of 83, reflecting a 28-point increase. In contrast, the second section, MAT 115-C58, which did not use Desmos, saw a more modest improvement. Their post-test average rose to 70, resulting in a 15-point gain. Figure 9 below summarizes these findings.

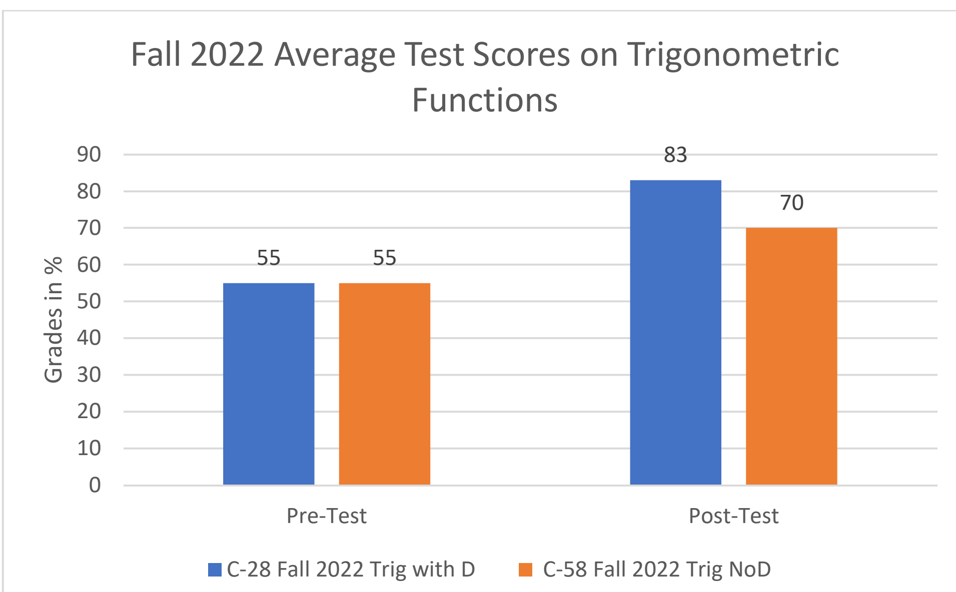

Figure 9: Comparison of average pre- and post-test scores in Fall 2022

In Spring 2023, another comparison was conducted to evaluate the effectiveness of Desmos in supporting student learning in trigonometry. Two other sections of MAT 115 were compared—one that integrated Desmos into instruction and one that did not.

Section MAT 115-C42, which used Desmos, began the term with an average pre-test score of 39. By the end of the course, students in this group had achieved a post-test average of 88, reflecting a 49-point improvement. In contrast, section MAT 115-C55 did not use Desmos in their instruction. Students in this group had a similar starting point, with an average pre-test score of 38. Their post-test average rose to 78, showing a 40-point gain. Figure 10 below shows these findings.

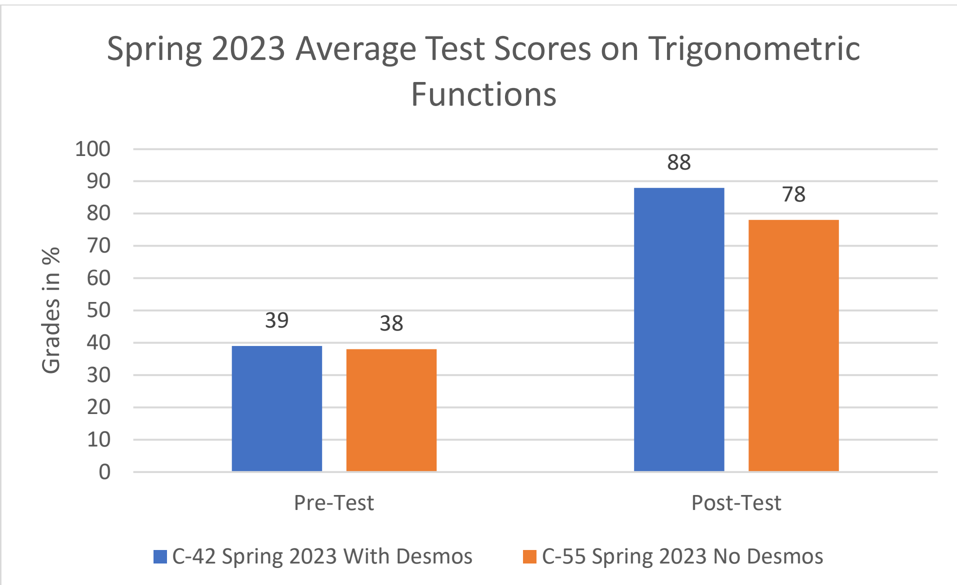

Figure 10: Comparison of average pre- and post-test scores in Spring 2023

Finally, in both semesters the trigonometry section of the final exam was used to confirm the post-test results. In Fall 2022, section MAT 115-C28, which incorporated Desmos, achieved an average score of 82 on the trigonometry portion of the final exam. In contrast, section MAT 115-C58, which did not use Desmos, had a significantly lower average of 60 on the same portion of the exam.

In Fall 2022, section MAT 115-C28, which incorporated Desmos, achieved an average score of 82 on the trigonometry portion of the final exam. In contrast, section MAT 115-C58, which did not use Desmos, had a significantly lower average of 60 on the same portion of the exam. In Spring 2023, section MAT 115-C42, which used Desmos, achieved an average score of 71 on the trigonometry portion of the final exam. In contrast, which did not use Desmos, MAT 115-C55 had a slightly lower average of 69 on the same portion of the exam.

Semester	Course	Pre-Test Average %	Post-Test Average %	Final Exam Trig Average % (score/total)
Fall 2022	Trigonometry with Desmos (MAT 115-C28)	55	83	82
	Trigonometry with-out Desmos (MAT 115-C58)	55	70	60
Spring 2023	Trigonometry with Desmos (MAT 115-C42)	39	88	71
	Trigonometry with-out Desmos (MAT 115-C55)	38	78	69

Table 2: Summary of pre-test, post-test and final exam trigonometry section average scores

Across both semesters, the data consistently shows that students who used Desmos experienced greater gains between pre- and post-tests and generally performed better on the trigonometry portion of the final exam. These results suggest that integrating Desmos into trigonometry instruction not only enhances immediate learning but also contributes to better long-term retention and application of trigonometric concepts.

DISCUSSION

One of the key advantages of using Desmos in the classroom is that it enables instructors to closely monitor each student's progress through features like the dashboard. Tools such as the 'overlay' and 'summary' options allow teachers to quickly identify misunderstandings, pinpoint errors, and provide timely feedback—greatly enhancing the learning experience.

Findings from the Fall 2022 and Spring 2023 semesters consistently demonstrated the positive impact of Desmos activities on student performance, particularly in relation to trigonometric functions. The integration of Desmos not only improved student understanding of trigonometric concepts but also fostered greater engagement, collaboration, and an exploratory approach to learning.

It is important to emphasize that using Desmos does not replace traditional methods such as graphing by hand with paper and pencil. Students are still encouraged to practice manual graphing to build foundational skills. However, Desmos enhances the learning process by allowing students to explore mathematical ideas more efficiently, minimizing repetitive calculations that can hinder progress. For instance, while creating tables or graphing functions manually can be time-consuming, Desmos simplifies these tasks. After sketching a function by hand, students can use Desmos to quickly investigate transformations. Additionally, the platform includes a sketchpad feature that simulates the feel of working on paper, helping to integrate technology into traditional learning practices in a seamless way.

Despite these advantages, several challenges emerged during the study. A lack of prior knowledge among some students led to gaps in understanding and slowed their progress. Although Desmos supports self-paced learning, ensuring the entire class moves forward cohesively requires careful planning and classroom management. Allowing students extra time outside of class to complete assignments can help, but this approach is less effective if students do not complete the work independently.

Assessment and feedback posed another set of challenges. Evaluating tasks—especially those involving student explanations, interpretations, and open-ended responses—can be time-consuming and demand significant effort. One strategy to address this is grouping common issues and discussing them during class, which can make the feedback process more efficient and impactful.

CONCLUSION

Research conducted over two semesters indicates that incorporating Desmos activities significantly enhanced student performance, particularly in understanding trigonometric functions. The data suggests that early integration of Desmos contributes to improved overall course outcomes and deeper engagement with mathematical concepts. These findings highlight Desmos as an effective tool for enhancing mathematics education. Introducing technology-driven activities early in the curriculum provides substantial educational benefits, including increased student engagement and achievement. Interactive features, such as manipulating constants and using sliders, proved far more engaging than traditional approaches. While some challenges remain, such as maintaining consistent pacing and providing detailed feedback, overall participation and engagement improved noticeably.

To maximize student success, it is recommended that Desmos activities be implemented at the beginning of the semester across various mathematical topics. Future research could investigate the long-term effects of such interventions and their effectiveness in different areas of mathematics and educational contexts. In conclusion, integrating Desmos into mathematics instruction has a clear, positive impact on student learning and performance, especially when introduced early. Despite logistical challenges, the benefits to student understanding, engagement, and retention are compelling.

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APPENDIX

Below are the slides of one Desmos activity designed by the author and used in the study.

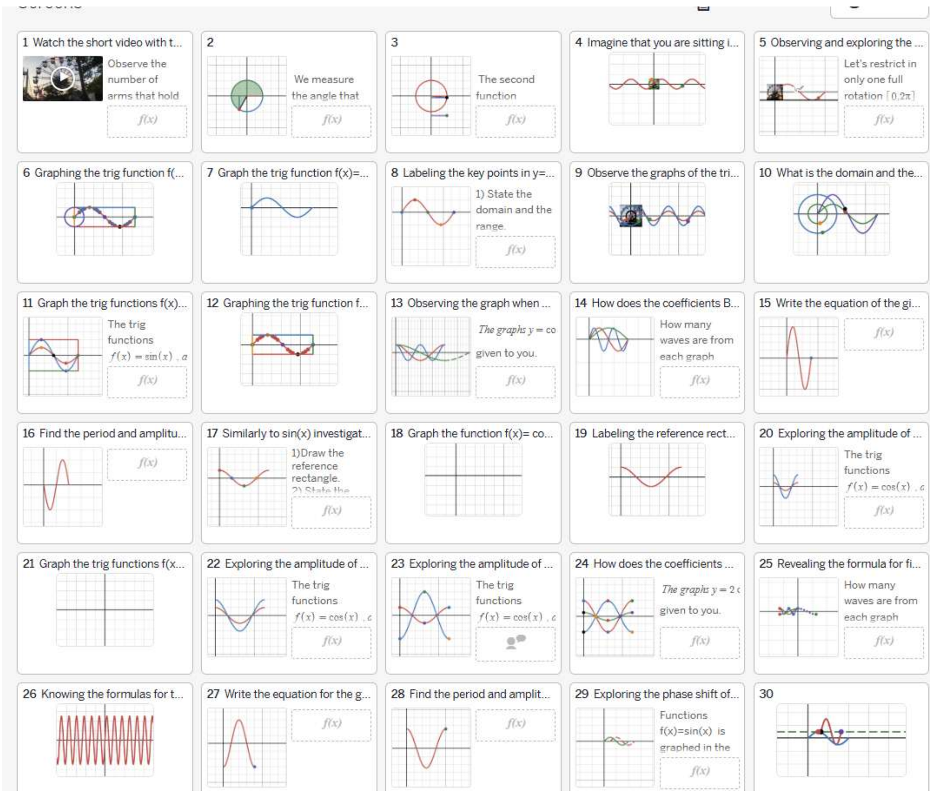
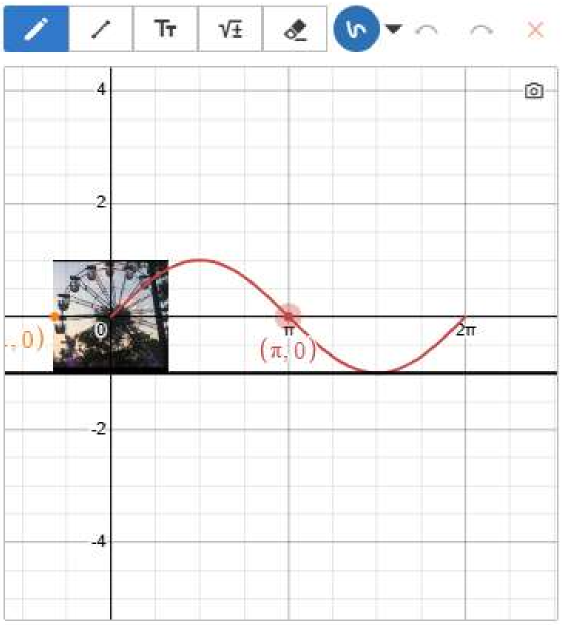


Figure A1. A Desmos activity with multiple slides

Several anonymized samples of students' responses to this activity in Desmos were selected and are shown below. These responses can be projected for class discussion. Displaying these responses allows students to compare different approaches, identify common mistakes, and collaboratively discuss corrections. Facilitating these discussions encourages peer learning, promotes deeper understanding of problem-solving strategies, and helps students refine their own thinking. Visualizing correct solutions alongside common errors enhances conceptual understanding and supports students in drawing meaningful conclusions from their work.

Observing and exploring the connections between the real life application and graphing



Let's restrict in only one full rotation $[0, 2\pi]$.

a) What is the highest point that a person seating in on of the seats can reach. (ignore the height above the ground of the lowest point).

b)How high from the ground is it if the radius is 100 m?

c) What is the angle that corresponds to three quarters height from the ground? (consider the standard position)

d)Calculate the three quarters of the height from the ground in two different ways. You can use the sketch pad in the blank parts near the graph to sketch to support your solution.

e)Do the answers match?

Answer each question labeled from a to e

$100m$, $200m$, $\frac{\pi}{6}$ or $\frac{5\pi}{6}$,

Edit my response

Explain your thinking.

a) the highest point a person can reach is 100m above the center

b)the center of the Ferris wheel is at height 100m the same as the radius so the highest point is center height + radius = 100+100 =200m

c)H: 0.75 x 200 = 150m

y= r sin(O)+r

150=100sin(o)+100

sin(O)=150-100/100

sin(O)=0.5

Figure A2. A student's response: Exploring connecting between a Ferris Wheel rotation and a trigonometric function graph

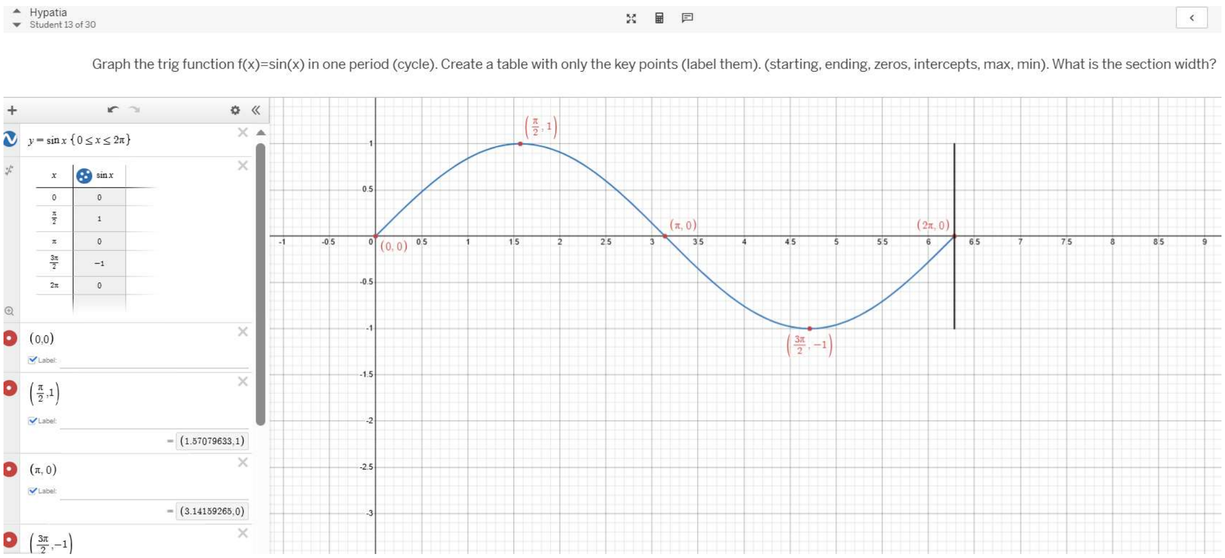


Figure A3. A student's response: Creating a table with key points of the graph

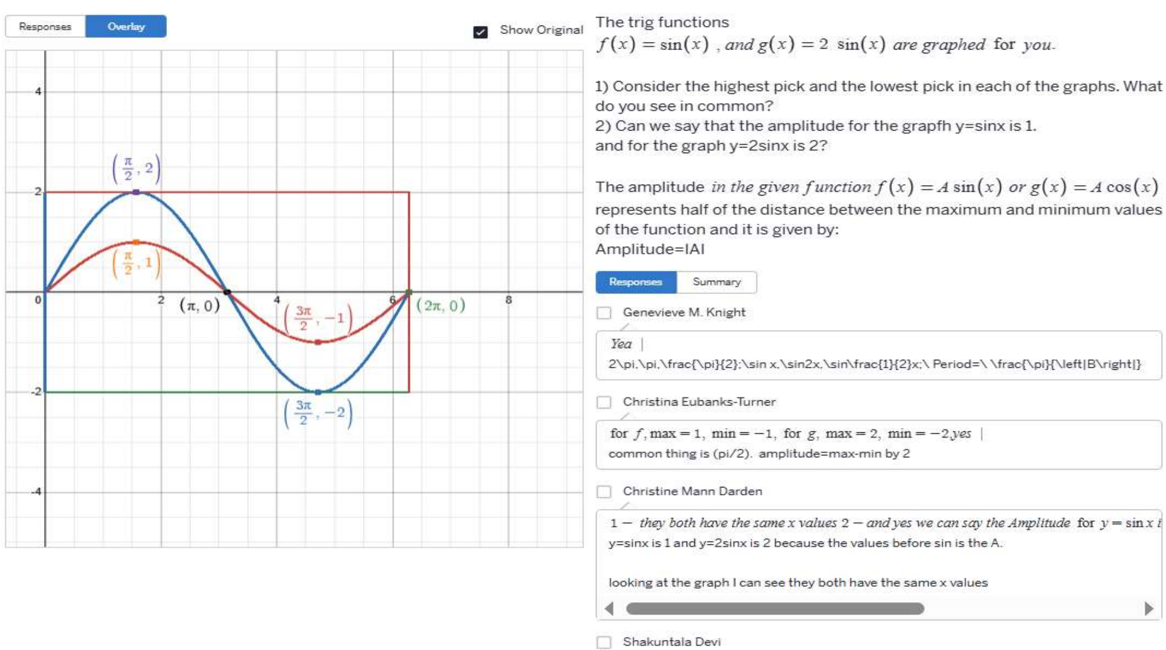


Figure A4. A student's response: Comparing graphs of two sine functions

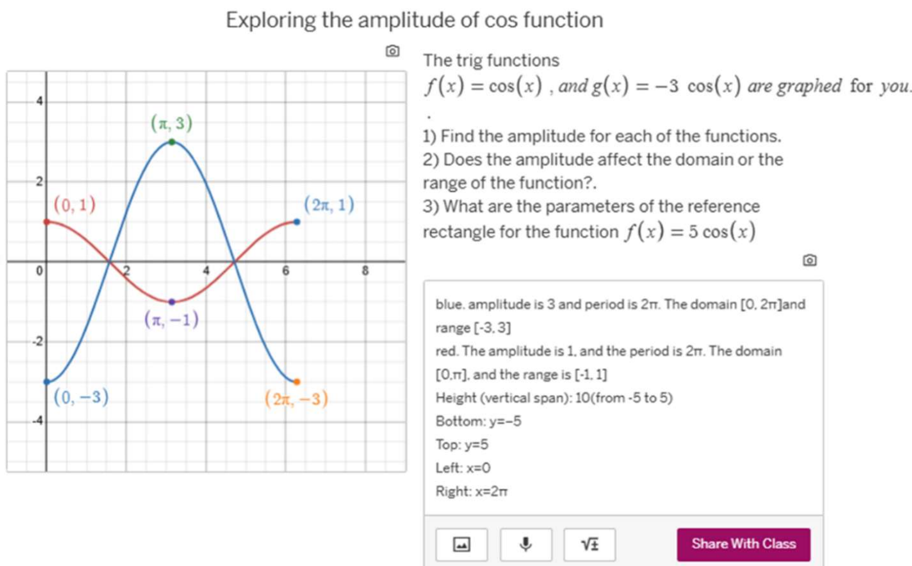


Figure A5: A student's response: Exploring amplitude of cosine functions

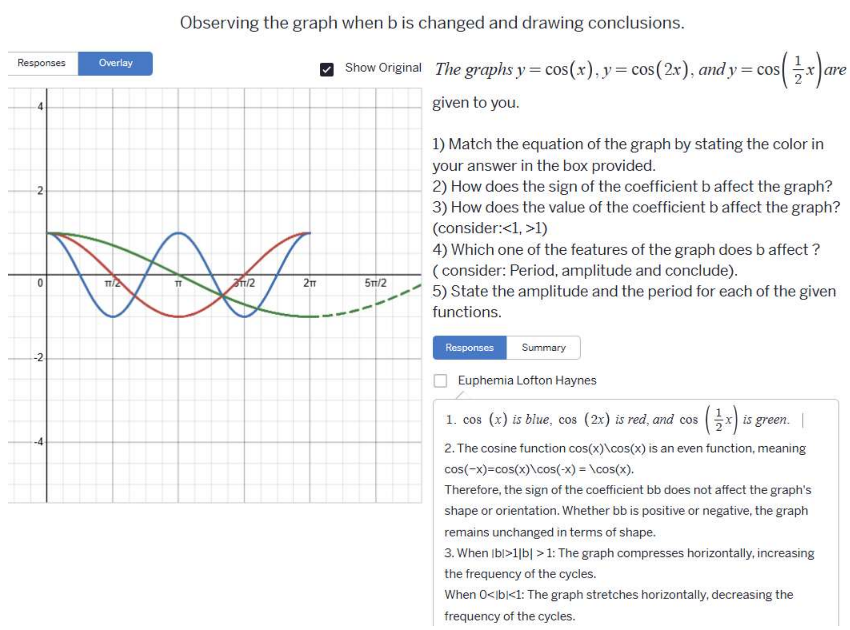


Figure A6: A student's response: Exploring amplitude and period of cosine functions

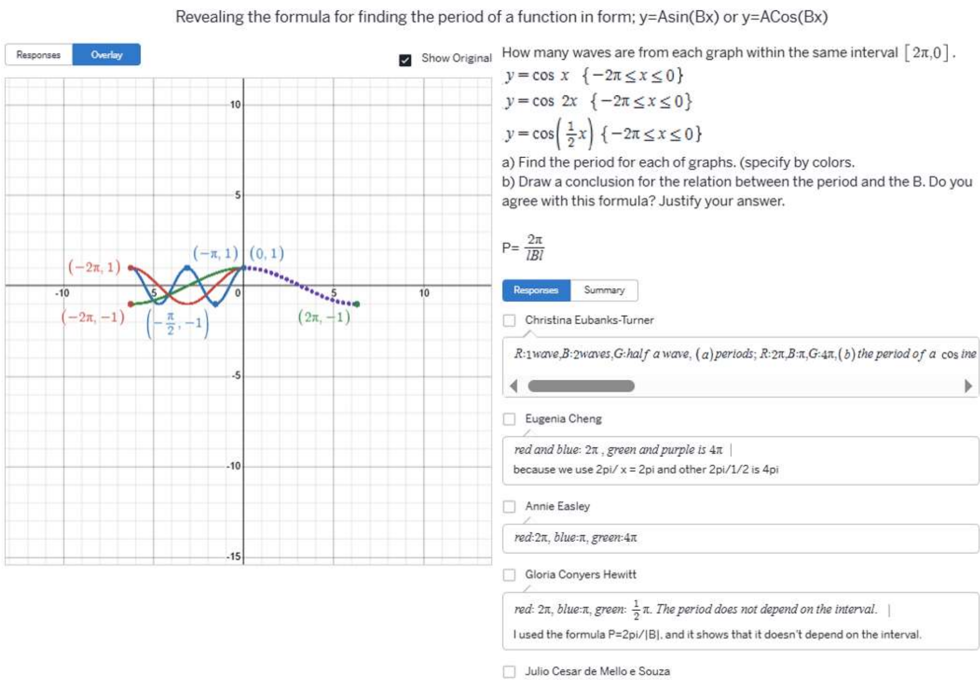


Figure A7. A student's response: Exploring period of cosine functions

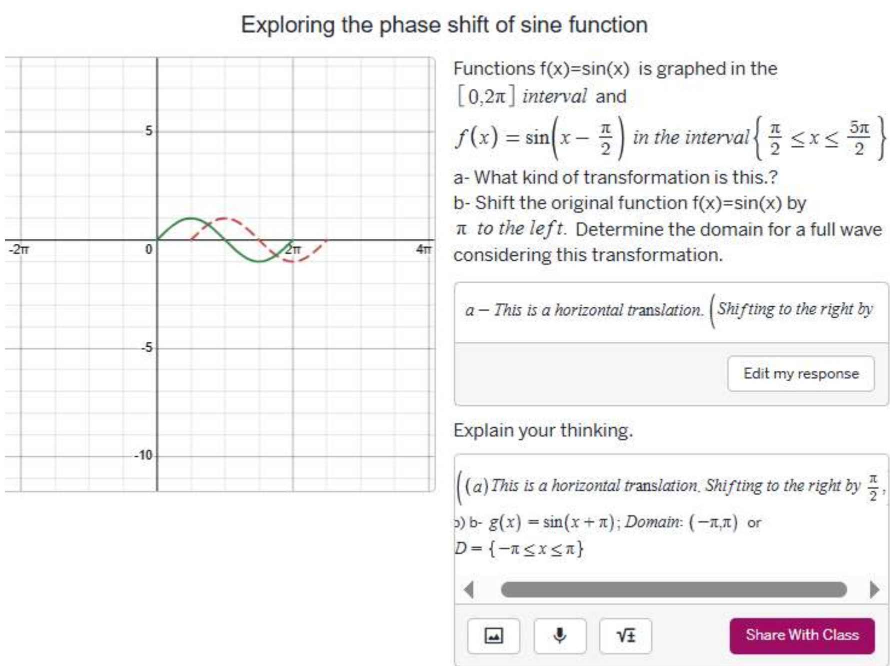


Figure A8. A student's response: Exploring phase shift of sine function

About the Author

Lucie Mingla specializes in math education, applied mathematics, digital technology, and logic, with degrees from the University of Tirana and Mercy University in New York. She actively presents at national and international conferences, including CUNY, AMATYC, MAA, ICTCM (Pearson) and the Global Education Conferences, emphasizing digital tools and global learning through COIL. Her publications and grant work focus on innovative, sustainable, and inclusive teaching, including Open Educational Resources and interdisciplinary math applications. At LaGuardia, she leads the "Math is Everywhere" initiative and contributes nationally through AMATYC IMPACT Live and standards revision efforts.