ENHANCING STUDENTS' MATHEMATICAL COMPETENCY IN LEARNING THE GRAPH AND PROPERTIES OF THE SINE FUNCTION BY GOOGLE SHEETS APP ON SMARTPHONE

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Abstract

This study explores the integration of the Google Sheets app on smartphones to enhance students' mathematical competency in understanding the graph and properties of the sine function. The paper was an exploratory study involving 32 11th-grade students. The teaching intervention was structured into four phases: familiarizing with the Google Sheets app, creating the sine function value table, sketching the function graph, and analyzing the graph to deduce the sine function's properties. Data were collected through worksheets and audio -video recordings of group work, focusing on manifestations of mathematical competencies. The findings indicate that students completed the tasks and demonstrated significant competencies in mathematical reasoning and using digital tools. Students were able to identify and solve mathematical problems, utilize Google Sheets effectively, and use logical reasoning to enhance their understanding of the sine function. The study concludes that integrating Google Sheets into mathematics education not only aids in visualizing and comprehending mathematical concepts but also promotes interactive and collaborative learning environments, ultimately fostering a deeper understanding and proficiency in mathematics.

Keywords: *Mathematical competency, mobile learning, sine function, smartphone.*

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TĂNG CƯỜNG NĂNG LỰC TOÁN HỌC CỦA HỌC SINH TRONG HỌC TẬP ĐỒ THỊ HÀM SỐ VÀ TÍNH CHẤT CỦA HÀM SỐ SIN BẰNG ỨNG DỤNG GOOGLE SHEETS TRÊN ĐIỆN THOẠI DI ĐỘNG

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Tóm tắt

Nghiên cứu này khám phá việc tích hợp ứng dụng Google Sheets trên điện thoại thông minh để nâng cao năng lực toán học của học sinh trong việc học đồ thị và các tính chất của hàm sin. Bài viết là một nghiên cứu khám phá với sự tham gia của 32 học sinh lớp 11. Quá trình thực nghiệm giảng dạy được cấu trúc thành bốn giai đoạn: làm quen với ứng dụng Google Trang tính, tạo bảng giá trị hàm sin, vẽ đồ thị hàm số và phân tích đồ thị để khám phá các tính chất của hàm sin. Dữ liệu được thu thập thông qua các phiếu học tập và các bản ghi âm, ghi hình hoạt động làm việc nhóm, tập trung vào các biểu hiện của năng lực toán học. Các dữ liệu chỉ ra rằng học sinh đã hoàn thành các nhiệm vụ và thể hiện năng lực đáng kể về tư duy và lập luận toán học và sử dụng các công cụ kỹ thuật số trong học toán. Học sinh có thể xác định và giải các bài toán, sử dụng Google Sheets một cách hiệu quả cũng như suy luận logic để nâng cao hiểu biết về hàm sin. Nghiên cứu kết luận rằng việc tích hợp Google Sheets vào giáo dục toán học không chỉ hỗ trợ trực quan hóa và hiểu các khái niệm toán học mà còn thúc đẩy môi trường học tập tương tác và hợp tác, cuối cùng là thúc đẩy sự hiểu biết sâu sắc hơn và thành thạo toán học.

Từ khóa: *Điện thoại di động, hàm số sin, học tập di động, năng lực toán học.*

1. Introduction

1.1. Mathematical competency

The Ministry of Education and Training (2018a, p. 37) defines competency as "a personal attribute that is formed and developed through inherent qualities and the process of learning and training, enabling individuals to mobilize a synthesis of knowledge, skills, and other personal attributes such as interest, belief, and will, to successfully carry out a specific type of activity and achieve desired results under specific conditions." According to Nguyen and Hoang (2020), competency is a synthesis of knowledge, skills, and operational techniques, constituting the primary internal conditions that ensure quality and effective practical activities. Niss and Højgaard (2019, p.6) define 'mathematical competency' as "the profound readiness of a person to act appropriately in response to a specific mathematical challenge in certain situations." The 2018 General Education Program in Mathematics emphasizes five core components of mathematical competency: Mathematical thinking and reasoning competency, Mathematical problem-solving competency, Mathematical modeling competency, Mathematical communication competency, Mathematical aids and tools competency.

Digital technology has led to the widespread use of mathematical tools, ranging from simple calculators to complex computer software, facilitating a deeper understanding of mathematical concepts through interactive and engaging means. These tools help students visualize complex problems and abstract concepts, making them more accessible and easier to understand. For instance, dynamic geometry software allows for manipulating geometric shapes, providing a hands-on experience that textbooks alone cannot offer (Ferrara & Ferrari, 2019). Furthermore, by being competent in using these mathematical tools, students will acquire the necessary skills for the modern workplace, where technology and data analysis play crucial roles. Educational curriculums that incorporate these tools enhance learning outcomes and prepare students for future challenges by fostering an environment of technological adeptness and adaptability (Procházka et al., 2021). Besides, we cannot deny that mathematical thinking and reasoning are foundational skills that permeate all aspects of mathematics education, influencing how students understand, interact with, and apply knowledge across mathematics and various disciplines. This competency goes beyond mere number manipulation, touching on the ability to analyze, reason logically, and think critically, which are essential for academic success and lifelong learning. For instance, in the sciences, mathematical models are used to predict phenomena, while in the humanities, statistical evidence can support rhetorical arguments (Vanluydt et al., 2021).

Mathematical thinking and reasoning and Mathematical aids and tools competency are not just about learning mathematics; they are essential skills that enhance cognitive development, support learning across all disciplines, and equip students with the tools needed to succeed in a complex world. Thus, this study focuses on two primary competencies: mathematical thinking and reasoning competency and mathematical aids and tools competency.

1.2. Learning the Sine Function

According to Weber (2005), trigonometry is vital to the high school curriculum. Mastery of trigonometric functions is essential for comprehending concepts in Newtonian physics, architecture, surveying, and numerous engineering fields. Additionally, he noted that since trigonometry is one of the earliest subjects to integrate algebraic, geometric, and graphical reasoning, it serves as a crucial foundation for advancing the study of pre-calculus and calculus. This sentiment is echoed by Do and Dinh (2022), who stated that trigonometry is a complex and vital topic in the high school curriculum. Despite the many applications of Geometry and other subjects, many students still need help understanding trigonometry functions. Moreover, according to Nguyen (2014, p.1), "Trigonometry is one of the important mathematical topics and has many applications in physics hill," such as uniform circular motion and harmonic oscillation. He also noted that the current approach of Vietnamese textbooks is still heavily oriented towards mathematics, with no support for students to understand trigonometric functions clearly.

Innovative educational tools and methodologies have been developed to overcome the above limitations. Dynamic software and graphing calculators allow for real-time manipulation of variables and visual representation of the function, providing students with a more interactive and engaging learning experience. These tools help make abstract concepts more tangible by allowing students to see the immediate effects of changes in angles or wave frequencies on the sine curve. Research on learning the sine function globally has been a focal point in mathematics education, reflecting a concerted effort to enhance students' comprehension and application of this fundamental trigonometric function. Studies have spanned diverse educational contexts, employing various pedagogical strategies, including integrating technology, experiential learning approaches, and conceptual teaching methodologies. Pham et al. (2017), from various educational and research institutions in Vietnam and Australia, introduced a comprehensive study on the approaches to teaching the properties and graph of the trigonometric function sine; the study primarily investigates two methodologies for teaching the sine function: starting from its definition to build properties and then graphing, and vice versa, graphing first and then deriving properties from the graph. The authors advocated for student-active knowledge construction rather than passive absorption. They also argued that understanding trigonometric functions, a fundamental part of the mathematics curriculum, can be significantly enhanced through dynamic geometry software, facilitating a more engaging and interactive learning experience. Notably, the use of dynamic software tools like GeoGebra has been extensively explored by scholars such as Kepceoglu (2016), Mosese and Ogbonnaya (2021), Wahyudi et al. (2022) with evidence suggesting that these technologies can significantly improve students' understanding of the sine function's properties and applications in real-world scenarios.

1.3. Mobile applications in teaching and learning

Integrating mobile technology in educational contexts has been transformative, particularly in mathematics. Mobile apps have emerged as a significant tool in improving the learning outcomes, engagement, and accessibility of mathematical education. Mobile apps enhance student engagement in mathematics by providing interactive and user-friendly platforms. These apps often employ gamification elements, including points, badges, and leaderboards, designed to motivate students by leveraging their intrinsic competitive instincts (Plass et al., 2015). One of the primary benefits of mobile apps in education is their ability to tailor the learning experience to individual needs. Adaptive learning technologies incorporated within these apps can adjust the difficulty of tasks based on the learner's performance, thus providing a customized learning trajectory for each student (Walkington, 2013). This personalization helps ensure that students remain neither under-challenged nor overwhelmed, optimizing their learning potential. Given its abstract concepts and complex relationships, mathematics benefits immensely from visual aids. Mobile apps can provide dynamic visualizations of mathematical principles, crucial for understanding and applying these concepts effectively. For instance, GeoGebra offers graphing, geometry, and 3D modeling tools, enabling students to visualize and manipulate mathematical entities directly. This interaction enhances conceptual understanding and fosters an intuitive grasp of mathematical relationships. Despite their advantages, mobile apps in mathematics education face several challenges. A significant concern is the dependency they might foster, potentially impairing students' ability to solve mathematical problems without technological assistance. Moreover, the effectiveness of learning through apps heavily relies on the design and pedagogical soundness of the app itself, which can vary widely across the vast number of apps available (Bano et al., 2018).

Google Sheets, a prominent feature of the Google Workspace suite, has increasingly been recognized for its significant potential in mathematics education. As a versatile, cloud-based spreadsheet tool, it facilitates the computation and organization of data and enhances the collaborative learning experience in mathematics. Kunicki et al. (2019) pointed out the benefits of learning a spreadsheet application such as Google Sheets, such as making students more competitive in the job market in the future due to the high value placed on spreadsheet skills; students can access the app anywhere because Google Sheets uses cloud-based storage; from an economic perspective, Google Sheets is entirely free; and it is easy to share their exercise with other students and teachers/teaching assistants. Besides, most Vietnamese students have been exposed to Microsoft Excel - the predecessor of Google Sheets - when studying in Middle School, so using Google Sheets is quite convenient. For a long time, Microsoft Excel - the predecessor of Google Sheets - has been used by mathematical researchers as an effective tool for statistical probability, such as Schmuller (2013), Mélard (2014), Salkind and Frey (2021). The Google Sheets application inherits and develops many features suitable for Mathematical education, especially in calculating extensive data, drawing charts, graphs, etc. Kunicki et al. (2019) published a study showing the benefits of students using Google Sheets to learn about quantitative methods in Statistics. The article shows that students are enthusiastic about Google Sheets, that this software is warmly received, and that Google Sheets can be a viable option for teaching basic quantitative methods.

Moreover, Google Sheets has a chart feature set that greatly supports learning various charts. In particular, the scatter chart feature is very suitable for learning geometry on the Oxy plane, such as creating value tables, representing points, and supporting the prediction of function graphs in general and function graphs of trigonometric functions in particular. However, there currently needs to be more research on learning graphs and properties of trigonometric functions through experience with the Google Sheets app. The analysis identifies a notable scientific gap in the current research concerning using Google Sheets for mathematics educational purposes, specifically trigonometry functions, and more profound is a sine function. This gap is significant because understanding the sine function and graph representations is fundamental in trigonometry. That forms a critical component of the mathematics curriculum across various educational levels.

Therefore, this research is to answer the following question: How can the Google Sheets app on smartphones enhance mathematical competency in learning the graph and properties of the sine function?

2. Method

2.1. Participants and context

The study was implemented with 32 students who had good academic performance in Ho Chi Minh City, Vietnam. The students worked in 16 pairs.

The study takes place in September 2023 after students have completed the following areas of knowledge: trigonometric angles, trigonometric values of angles, trigonometric transformations, the concept of even/odd functions, periodic functions, and the definition of the sine function.

2.2. Learning activities

The teaching lasted 90 minutes and consisted of four phases; students worked in pairs in each phase. Complete the task on the worksheets using the Google Sheets app.

Table 1. Activity phases

Phase	Worksheet	Activities
Phase 0 (15 min.)	Worksheet 0	Get familiar with the Google Sheets app.
Phase 1 (25 min.)	Worksheet 1	Using the "= sin( )" command on the Google Sheets app, create a value table y=sin x corresponding to available x values.
	Worksheet 2	Sketch the function graphs y = sin x on [-π ; π] using the scatter chart feature.
Phase 2 (20 min.)	Worksheet 3	Use previous experience to sketch the function graphs y = sin x on R by connecting graph segments of a given length 2π.
Phase 3 (25 min.)	Worksheet 4	Observe the function y = sin x's graph on ℝ and use the Google Sheets application to answer questions in worksheet 4, making predictions about the function's properties y = sin x.

2.3. Collect and analyze data

In this research, we focus on events that enhance students' mathematics competencies and knowledge related to the graphs of functions and properties of functions through hands-on experiences utilizing the Google Sheets app.

Table 2. Mathematical competency framework

Competency	Defined by Niss and Højgaard (2019)	Under the 2018 General Education Program in Mathematics
Mathematical thinking and reasoning competency	"mathematical thinking competency engaging in mathematical inquiry as involving the ability to relate and pose general or characteristic types of mathematical questions and to understand the nature of the answers that might be expected for these questions." (p. 7). They also note that specific mathematical reasoning processes are not placed within this competency but are instead situated within a separate competency of theirs, "mathematical reasoning competency – evaluating and justifying mathematical assertions. The core of mathematical reasoning competency is to analyze or present arguments (i.e., sequences of statements linked by reasoning), either spoken or written, to justify mathematical assertions. This competency includes constructing justifications for mathematical statements and critically analyzing and evaluating existing or proposed justifications." (p. 8)	- Identify and detect mathematical problems that need to be solved. - Select and propose methods and solutions for problem-solving. - Utilize compatible mathematical knowledge and skills (including tools and algorithms) to solve the posed problems. - Evaluate the proposed solution and generalize it for similar problems.
Mathematical aids and tools competency.	The core of mathematics aids and tools competency is an individual's ability to utilize them in mathematical work and critically relate to their use and that of others. "This competency focuses on dealing with material aids and tools for mathematical activity, ranging from concrete physical objects and instruments, over specially designed papers and charts, to a wide spectrum of digital technologies designed to represent and facilitate mathematical work." (p. 10)	- Recognize the effects, usage rules, and how to preserve math learning tools and equipment (summary table of function types, models of trigonometric angles and arcs, models of cubes, sets of tools for creating circular faces...). - Can use calculators, software, technological means, and Internet resources to solve mathematical problems. - Evaluate how to use math learning tools and means to explore, discover, and solve mathematical problems.

Student activities were observed through various data sources, including screenshots, audio recordings, and worksheets.

Table 3. Competency demonstrations

Phase	Manifestations of Mathematical Competencies	Data
Phase 0 (15 min.)	**Competence in mathematical aids and tools** is demonstrated through using the Google Sheets app to create value tables and identify the function graph on a specific segment.	Screenshot of the groups' work results while completing worksheets 1 and 2. The link to access the groups' working spreadsheets.
Phase 1 (25 min.)	**Competence in mathematical** aids and tools is demonstrated through using the Google Sheets app to create value tables and identify the sine function graph on a specific segment.	Screenshots of the groups' work while completing worksheets 1 and 2.

	Mathematical thinking competency is shown by identifying similarities in creating value tables and determining the function's graph. This leads to reasoning and proposing methods to increase the number of points on the value table to represent the graph of one's function.	Audio recordings of discussions and group work while completing worksheet 2.
Phase 2 (20 min.)	**Mathematical thinking competency** is also shown by recognizing the similarities and differences between creating value tables and determining the function graph on the previously conducted segment and any given segment, thereby choosing appropriate points when creating the value table and determining the function graph.	Audio recordings of discussions and group work while completing worksheet 3. Screenshots of the groups' work while completing worksheet 3.
Phase 3 (25 min.)	**Mathematical thinking competency** is further demonstrated by: - Identifying the similarity among function graphs within the same cycle, thereby forming the knowledge that the function is periodic and determining its periodic cycle. - Posing and answering questions in worksheet 4 when observing the results displayed on the phone screen about the function graph and explaining the function's properties through visual imagery and mathematical knowledge.	The results of worksheet 4 for each group. Audio recordings of discussions and group work while completing worksheet 4.

3. Findings

Phase 0 is designed to guide and help students familiarize themselves with the Google Sheets app. Therefore, we will start analyzing the results from Phase 1.

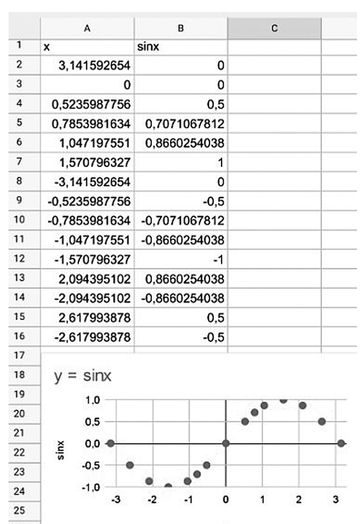
3.1. Phase 1

An overview reveals that all 16 pairs completed the tasks of inputting available data in column A, calculating the six values in column B, and representing the given points on the coordinate axis through the "Chart" feature.

Students began to show differentiation in their mathematical reasoning and problem-solving abilities in requirement 2.2 of worksheet number 2: "Provide the clearest image of the function graph y = sin x on [-π;π] on the Spreadsheet application". Out of the 16 groups, 13 could present solutions with two different levels of representation: adding the opposite values of the available consecutive numbers and scattering values from $\left[-\pi; -\frac{\pi}{2}\right]$ and $\left[\frac{\pi}{2}; \pi\right]$.

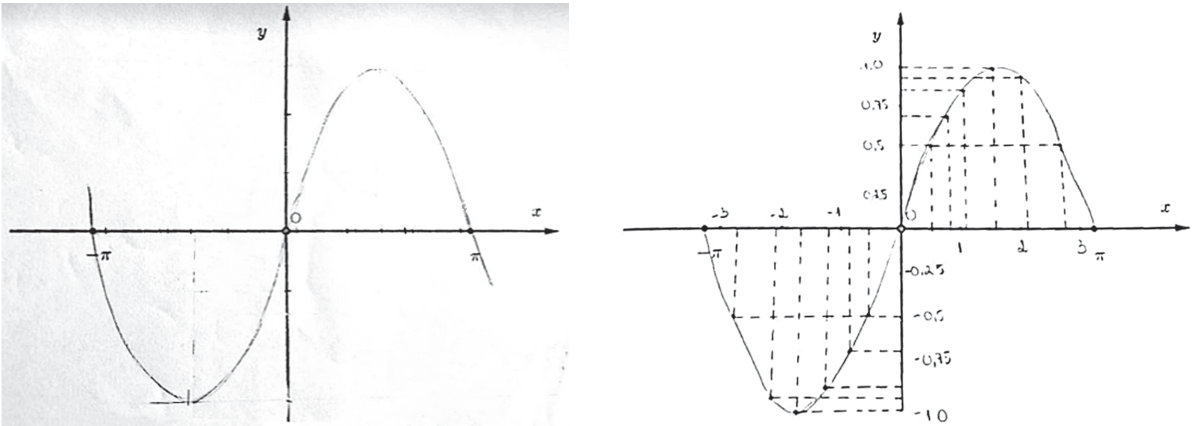
Based on the results of requirement 2.2, where groups sketched the function graphs y = sin x on [-π;π], 10 out of 16 groups accurately sketched the function graph y = sin x on [-π;π], while five groups only sketched the graph on $\left[-\frac{\pi}{2}; \frac{\pi}{2}\right]$.

The groups demonstrated mathematical thinking competency by being able to input given values and calculate the corresponding y values to create a value table for the function y = sin x and generate the function graph y = sin x on [-π;π].



	A	B	C
1	x	sinx	
2	3,141592654	0	
3	0	0	
4	0,5235987756	0,5	
5	0,7853981634	0,7071067812	
6	1,047197551	0,8660254038	
7	1,570796327	1	
8	-3,141592654	0	
9	-0,5235987756	-0,5	
10	-0,7853981634	-0,7071067812	
11	-1,047197551	-0,8660254038	
12	-1,570796327	-1	
13	2,094395102	0,8660254038	
14	-2,094395102	-0,8660254038	
15	2,617993878	0,5	
16	-2,617993878	-0,5	

Figure 1. Product of group 16 in question 2.2



a) Students sketched the graph after gaining experience from the practical activities

b) Students drew graphs with coordinates similar to the textbook

Figure 2. Students sketched the function graph after drawing graph y= sin *x* on [-π;π] by using Google Sheets.

Despite over 50% of the groups accurately sketching the function y = sin *x* on [-π;π] the graph, they still encountered difficulties. They took significant time to make decisions on adding points and how to add them. Additionally, the two groups accurately plotted the function graph with detailed coordinates rather than just a quick sketch after the experiential practice. These two groups may have read ahead in the Mathematics textbook or recalled the sine function graph mentioned in Physics and recreated the graph of the function y = sin *x*.

Mathematical thinking competency is demonstrated by identifying similarities in creating value tables and determining function graphs. This leads to the formulation of arguments and the development of methods to increase the number of points on the value table to more clearly represent one's function graph.

The practical results achieved in this phase serve as a crucial foundation for students to progress to the subsequent phases.

3.2. Phase 2

Building upon the experience and expertise gained from phase 1, in this phase, all 16 groups accurately executed the requirements outlined in worksheet number 3. Together, they completed the function graph y = sin *x* on [-7π;7π] graph, thus acquiring the ability to plot the function graph y = sin *x* on ℝ.

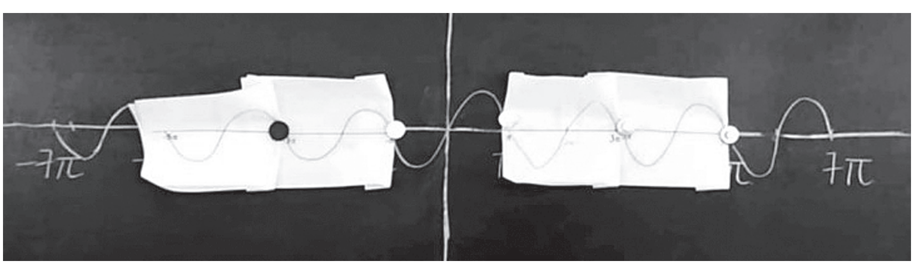


Figure 3. The whole class completed the graph of the function y = sin *x* on [-7π;7π]

3.3. Phase 3

The analysis of responses from worksheet 4 reveals the following insights:

- Out of 16 groups, 13 provided accurate answers regarding the range of the function y = sin *x* by examining both the value table and the function graph. Their mathematical thinking competency is evident in their ability to pose and answer questions from questions 4.1 to 4.3 of the worksheet 4, based on their observations of the graph displayed on their smartphone screens.

- All 16 groups correctly identified the period of the function graph. However, interviews revealed that many of these conclusions were based not solely from graph observations but also mostly relied on interdisciplinary knowledge, particularly from Physics. Mathematical thinking competency is displayed here by recognizing patterns among the graphs of functions within the same cycle, leading to the understanding of periodicity and determining the function's period.

- Only 1 out of 16 groups answered and explained correctly about the even and odd nature of the function graph. More than half of the groups still need to provide an answer regarding the even and odd nature. Among the groups that answered, 3 out of 16 gave incorrect answers, and 3 others answered correctly but explained incorrectly. Mathematical thinking competency is manifested in the ability to posing and answering question 4.5 in worksheet 4 upon observing the graph of the function y = sin *x*. This involves explaining the even and odd properties of the sine function using both visual analysis and mathematical reasoning.

4. Discussion and Conclusion

Integrating the Google Sheets mobile application into the mathematics curriculum represents an innovative approach to teaching the graphs and properties of the sine function. This study specifically aimed to enhance the competency of high school students in mathematical thinking and reasoning, as well as mathematical aids and tools, as outlined in the 2018 General Education Program in Mathematics (Ministry of Education and Training, 2018b). The competencies focus not only on the ability to manipulate numbers and formulas but also on applying these skills creatively and logically in problem-solving scenarios. Results from this study indicate a positive trend in students' abilities to grasp complex mathematical concepts through interactive and digital means. Similar findings were reported by Daher (2020), who noted significant improvements in students' understanding of trigonometric functions when using technology-based learning tools. Mosese and Ogbonnaya (2021) also observed that digital tools facilitate a deeper conceptual understanding of mathematical properties by providing dynamic visualization and real-time feedback.

Students in this study showed marked progress in their conceptual understanding of the graph and properties of the sine function through the Google Sheets app. This dual advancement underscores the effectiveness of blending traditional mathematical teaching with modern technological tools, enhancing abstract theoretical comprehension and practical technological skills.

This research highlights the significant potential of using Google Sheets to teach complex mathematical functions such as the sine function. The application supports the development of essential mathematical competencies and integrates seamlessly into classroom teaching due to its intuitive design and accessibility. The requirement for only half of the students to have pre-loaded mobile devices with the Google Sheets app without a constant internet connection makes this approach highly adaptable and scalable. However, specific challenges, such as the student's mastery of periodic functions and the properties of trigonometric functions, indicate areas for further instructional focus and curriculum adjustment. Additionally, teachers should carefully consider students' proficiency in using mobile applications, specifically the Google Sheets app, when implementing the proposed instructional process. Although the teacher introduced students to the Google Sheets app and let them familiarize themselves with the essential operations of the application in Worksheet 0 to prepare for upcoming activities, various issues may still arise during the execution of the main worksheets. These challenges can delay subsequent activities, hindering students' ability to absorb the intended knowledge. To mitigate this issue, teachers must provide thorough instructions and timely support during the initial worksheet activities and closely monitor groups to identify and assist those encountering difficulties. For students who are not yet adept at using mobile applications effectively, teachers may face significant challenges in implementing the outlined instructional process, potentially leading to inefficiencies. Suppose teachers still wish to have their students engage with this approach. In that case, they may need to allocate additional time for instruction and familiarization, possibly organizing an extracurricular session focused on helping students become proficient in the necessary operations and features of mobile applications, mainly the essential Google Sheets functions. This preparation would facilitate more efficient lesson planning and implementation for similar mathematical concepts in the future, such as graphs and properties of other trigonometric functions, exponential functions, logarithmic functions, and so on, as students would already be skilled in using the application, allowing teacher to skip Worksheet 0. For other knowledge objects, teachers should evaluate the lesson's difficulty and students' ability to use mobile applications effectively, ensuring that the teaching process aligns with the designated curriculum schedule and optimizes instructional time. Therefore, further studies across different demographic settings are recommended to validate its effectiveness in particularly Vietnam and universally.

This study advances our understanding of how digital tools can enhance mathematical education. It provides a practical framework that can be easily implemented in schools to improve students' competency in mathematics. The findings contribute valuable insights into the ongoing discourse on digital education, especially in integrating mobile technology in teaching complex subjects such as mathematics.

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APPENDICES

Phase 0: Get familiar with the Google Sheets app

Worksheet 0

A. Calculate sin *x* values using the Google Sheets app

0.1. Create a new spreadsheet in the Google Sheets app and name it following the format "Class-Function-sin."

0.2. Enter the following text in cell A1: *x*

Enter the following text in cell B1: sin *x*

0.3. Enter the π value into cell A2: =PI()

0.4. Enter the sine value of cell A2 into cell B2: = SIN(A2) x

B. Representing point pairs on the Chart

Perform the following tasks on the Google Sheets app.

0.5. Select cells A1 to B2 → Click the "+" icon in the top-right corner of the screen → Choose Chart.

0.6. Select Type

0.7. Choose Scatter → Click the "√" icon when done.

Phase 1: Experience in creating value tables and function graphs y = sin *x* on [-π;π] by using the Google Sheets app

Worksheet 1

Perform the following tasks on the Google Sheets app.

1.1. Sequentially enter values 0; $\frac{\pi}{6}$; $\frac{\pi}{4}$; $\frac{\pi}{3}$; $\frac{\pi}{2}$ into cells from A3 to A7.

1.2. Calculate the values in cells from B3 to B7.

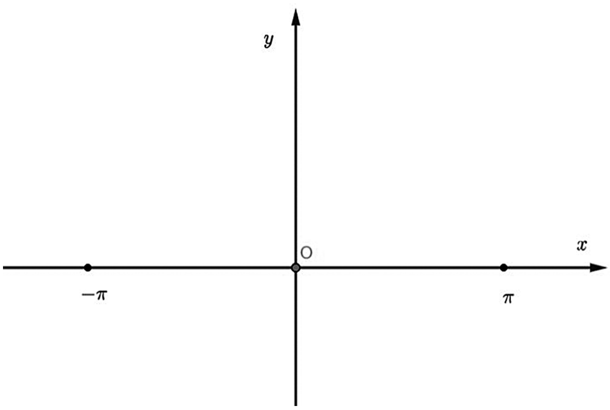
Worksheet 2

Perform the following tasks on the Google Sheets app.

2.1. Represent the six pairs of points already in columns A and B on a chart.

2.2. Suggest the most precise image of the function graph y = sin x on [-π;π] by using the Google Sheets app.

2.3. Quickly sketch the function graph y = sin x on [-π;π] with the horizontal axis below:



Phase 2: Formation of knowledge on plotting function graphs y = sin *x* on *R*

The teacher continues to distribute one learning sheet, number 3, to each group of students, who continue to work in teams and discuss finding a solution to provide "the clearest image" of the function graph y = sin x on the intervals [-5π;-3π], [-3π;-π], [-π;π], [π;3π] [3π;5π]; each group is assigned a different interval.

Worksheet 3

Perform the following tasks on the Google Sheets.

3.1. Open a new Spreadsheet in the current workbook:

Select the "+" icon in the bottom right corner of the working screen. Immediately, a new spreadsheet (Sheet 2) will be created.

3.2. Provide the most precise image of the function graph y = sin x on [π;3π] on Sheet 2.

3.3. Quickly sketch the function graph y = sin x on [π;3π] on the horizontal axis below:

3.4. Group representatives present their segment of the function graph on the chart paper.

Phase 3: Formation of properties of function y = sin *x*

Worksheet 4

4.1. The most significant value in column B is.........

4.2. The smallest value in column B is..........

4.3. Predict the values in column B that change within which segment or range?

4.4. Does this function have periodicity?

☐ Yes ☐ No

• If not, proceed to question 4.5.

• If yes, please indicate how many cycles the periodic graph has.

4.5. What about the function's even and odd properties? Use the graph below to explain your answer.