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CO-DESIGNING PYTHON-BASED INTERACTIVE MEDIA FOR TRIGONOMETRY LEARNING USING CHATGPT: A PRELIMINARY STUDY

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Abstract

Challenges in conceptual understanding and engagement persist in undergraduate trigonometry education, often due to static instructional methods and limited use of dynamic visual tools. Recent advances in artificial intelligence offer new opportunities for educators to independently design interactive instructional media, even without advanced programming expertise. Leveraging this potential, the present study aimed to develop and evaluate Python-based interactive media, integrating AI-generated content using the ADDIE design model. Data were collected through semi-structured interviews, Likert-scale questionnaires, and observations. Qualitative data were analysed thematically, while quantitative responses were summarised using descriptive statistics. The findings indicate that the interactive media was perceived as engaging in visualising trigonometric concepts, particularly sine and cosine, but revealed areas of confusion regarding the tangent function and challenges in self-directed learning. The study concludes that AI-assisted interactive media support conceptual understanding and student engagement, while also empowering educators to create personalised learning tools without requiring sophisticated technical skills. These results inform the design of accessible, technology-enhanced mathematics instruction

Keywords: *Interactive Media, Python, Trigonometry Learning*

INTRODUCTION

Instructional approaches that rely on static representations and rote memorization have been shown to contribute to persistent misconceptions and superficial understanding [1], [2]. This is particularly relevant in trigonometry, many students enter the classroom with silent struggles—confused, discouraged, or simply disconnected from what they learn. Instructional approaches, which frequently rely on static representations and rote memorization only, have been shown to contribute to persistent misconceptions and

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superficial understanding among learners [3], [4]. As a result, there is a growing need for innovative educational tools that can make trigonometric concepts more accessible, engaging, and meaningful.

Recent advancements in technology, particularly the emergence of programming languages such as Python and the integration of artificial intelligence (AI), offer promising avenues for addressing these challenges. Python's visualization capabilities enable the creation of dynamic and interactive learning environments that support deeper conceptual understanding [5], [6]. Moreover, the incorporation of AI in educational media has the potential to personalize learning experiences [7], provide adaptive feedback [8], and foster creative and reflective thinking skills [9]. Despite these promising developments, the application of Python-based interactive media and AI-driven content in undergraduate trigonometry instruction remains limited, especially in the context of teacher education programs.

The research gap lies in the scarcity of empirical studies that explore the design, implementation, and evaluation of interactive media integrating both Python and AI for trigonometry learning among prospective mathematics teachers. Previous studies have mainly focused on general mathematics learning tools or on interactive media without fully leveraging AI for content generation and personalization[10]. With the development of AI, teachers are expected to make use of it to create learning that suits the classroom's current needs. However, there is insufficient evidence regarding the effectiveness and practicality of such integrated media in supporting conceptual understanding and addressing students' misconceptions in trigonometry.

These developments prompt educators to reconsider how AI can support instructional design and enable adaptable learning experiences aligned with pedagogical goals and students' evolving needs. Thus, this study aims to address this gap by developing and evaluating an interactive media tool based on Python and AI-generated content for trigonometry instruction in a mathematics teacher education context. Specifically, the objectives of this research are: (1) to describe the process of developing the interactive media, (2) to assess prospective mathematics teachers' perceptions and conceptual understanding after using the tool, and (3) to identify the strengths and limitations of the developed media as a foundation for further refinement. By doing so, this study seeks to contribute to the growing body of knowledge on technology-enhanced mathematics education and provide practical recommendations for the design and implementation of innovative learning tools in the digital era.

METHOD

Participant

Four undergraduate students (two male and two female) enrolled in a mathematics education program at the university level participated in this study. All participants had completed coursework in trigonometry, as well as a comprehensive range of foundational and advanced mathematics courses. This selection process ensured that all participants

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possessed substantial mathematical knowledge and familiarity with both the content and pedagogy of secondary school mathematics, making them well-suited to evaluate the interactive media developed for this research.

Data Collection and Analysis

Data sources comprised (1) semi-structured interviews, and Likert-scale questionnaire, and (3) observational notes documenting user interactions with the media. The questionnaire, adapted from instruments previously validated in educational technology research [2], [11], yielded quantitative data regarding usability, engagement, and perceived learning outcomes.

Qualitative data from interview transcripts were analyzed inductively following Braun and Clarke [12] reflexive thematic analysis, which facilitated the identification of emergent themes related to conceptual understanding, affective engagement, and usability issues. Quantitative questionnaire responses were subjected to descriptive statistical analysis, including the calculation of mean scores and standard deviations for each item.

Research Design

This study employs a Research and Development (R&D) approach, as its primary objective is to design, develop, and evaluate an educational product. The development process follows the ADDIE framework—comprising Analysis, Design, Development, Implementation, and Evaluation.

Analyze

The initial phase of the ADDIE model focused on identifying learning challenges and defining instructional needs. Prior studies highlight the difficulties faced by prospective mathematics teachers in conceptualizing trigonometric functions, particularly sine, cosine, and tangent, due to the abstract and spatial nature of these concepts [4], [13]. Based on interview findings, lecturers have utilized visual explanations during instruction; however, these visuals were presented in static formats rather than through interactive media. These findings informed the need for a Python-based digital learning medium integrating AI assistance to personalize content delivery, enhance engagement, and support self-paced learning.

Design

The Flowchart in Figure 1 illustrating the application's structure: a start node and sidebar menu with five main modules. The design guides learners from fundamental concepts through interactive exploration to practice. The sidebar menu offers five sections—Unit Circle, Trigonometric Function, Visualization, Exercise, and Radian—each aligned with a specific pedagogical goal. For example, the Unit Circle module introduces angles and coordinate definitions before the Trigonometric Function module defines sine and cosine in that context, strongly scaffolding understanding by building from geometric intuition to analytic definitions.

The persistent sidebar design supports flexible navigation, enabling students to select modules freely while preserving context. In the Visualization module, learners manipulate an angle marker on an interactive unit circle plot. As the angle moves, dynamic labels display the corresponding sine and cosine

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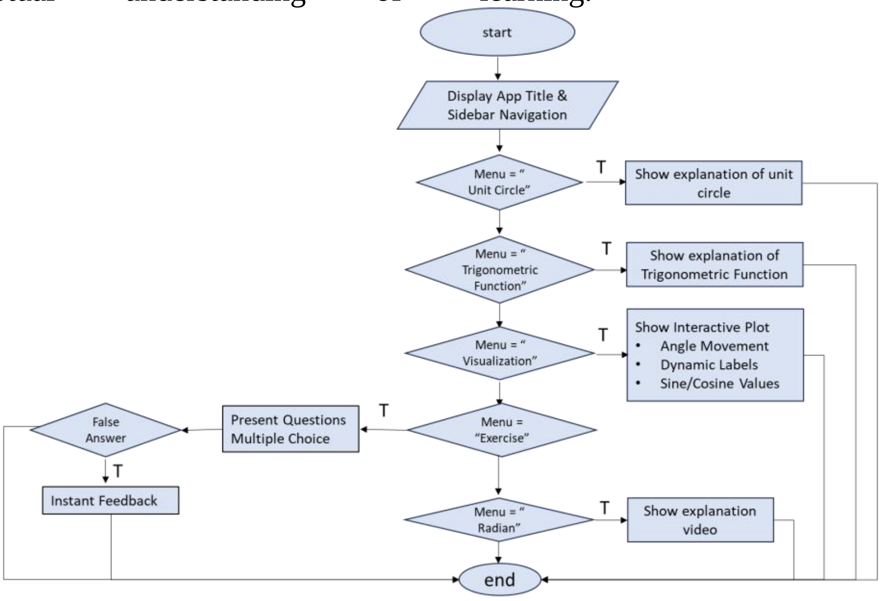
values, linking geometric and algebraic representations. This exploratory environment reinforces conceptual understanding of trigonometric relationships; research indicates that such interactive visualizations facilitate mathematics learning.



Note: T = true

Figure 1. Flowchart program

After exploring concepts, the Exercise module offers multiple-choice quizzes with immediate feedback on incorrect answers. This feedback helps learners correct misconceptions in real time, consistent with evidence that immediate feedback sustains student performance on challenging problems. Finally, the Radian section presents a concise video to clarify radian measure, connecting circular arc length to angle magnitude. The video emphasizes that a radian is defined by arc length on the unit circle, reinforcing its geometric basis. Overall, the flowchart-guided structure reflects a constructivist approach that also scaffolds knowledge and actively engages learners throughout.

Development

To support the development of the interactive trigonometry media, the author engaged in iterative consultations with an AI language model (ChatGPT) to refine both the pedagogical design and technical implementation of the tool. Through a series of prompt-driven interactions, the author received guidance on structuring Python-based visualizations of trigonometric functions, optimizing user interactivity, and aligning content with relevant didactical principles. The dialogue included discussions on the use of dynamic unit circle representations, integration of sine and cosine visualizations, and strategies to address common misconceptions. This collaborative process exemplifies how AI-assisted instructional design can facilitate the

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rapid development of educational media tailored to specific learning objectives.

To provide technical clarity for replication, the media was developed using Python with Matplotlib and NumPy as the primary libraries for visualization. Interactive manipulation of angles was implemented through Jupyter Notebook widgets, enabling real-time updates of trigonometric values on the unit circle. The application operated in a desktop environment, allowing users to adjust angle inputs and receive immediate visual feedback on sine, cosine, and tangent values. This configuration supported rapid prototyping and iterative refinement during development.

Below are the examples of the process

User : *"I want to create an interactive media using Python to help students visualize the unit circle and understand sine and cosine values dynamically. Can you help me with the code?"*

ChatGPT : *"Certainly! A good starting point is to use the Matplotlib library along with NumPy to create a dynamic visualization. We can plot the unit circle and use a slider to allow users to adjust the angle and observe how the corresponding sine and cosine values change. Here's a basic implementation..."*

User : *"Can we also include the coordinate values and a tangent line that updates as the angle changes?"*

ChatGPT : *"Yes, that's possible. We can annotate the coordinates on the circle and compute the tangent as the ratio of sine to cosine. For visualization, a tangent line can be added, but we must consider how to handle discontinuities at odd multiples of 90 degrees. I'll adjust the code accordingly..."*

Figure 2 captures a pivotal moment in the development of our Python-based interactive media for trigonometry learning. The left panel (a) showcases the dynamic unit circle visualization, a feature that allows users to manipulate angles and instantly observe the corresponding changes in trigonometric values. The core Python code powering this widget was initially generated with the assistance of an AI language model. While the AI provided a functional starting point, we found it necessary to refine and adapt the code to ensure that the visualization met the pedagogical needs of my students and aligned with the curriculum

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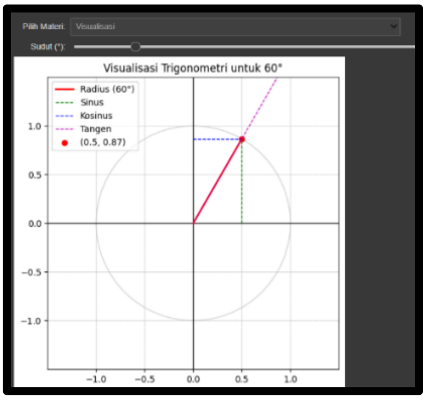

a

b

Figure 2 (a) Visualization of unit circle, (b), the screenshot illustrates the integration of instructional video content, which complements the interactive widgets by offering conceptual explanations about radian. The resulting media, as depicted in Fig. 2, embodies this synergy: it is both a product of technological innovation and a response to the authentic needs of learners in today's mathematics classroom

Implementation

The developed interactive media was implemented in a small-scale trial involving four undergraduate mathematics education students. Participants engaged with the media independently over two sessions, each lasting approximately 30 minutes. Before beginning, participants received brief written guidelines explaining the purpose of the media, navigation steps, and expected tasks.

To improve replicability, the implementation followed a structured activity flow consisting of three phases:

(1) Pre-use Orientation (5–10 minutes). Participants read written instructions, explored the sidebar structure, and familiarized themselves with the available modules without performing any learning tasks.

(2) Exploration (20–30 minutes). Participants interacted with the modules in the following recommended sequence:

(a) Unit Circle →
(b) Trigonometric Functions →
(c) Visualization →
(d) Exercise →
(e) Radian.

During this phase, students manipulated angle sliders, observed dynamic updates to trigonometric values, completed multiple-choice items with immediate feedback, and watched a short video explaining radian measures. No formal instruction was provided, but the researcher observed and recorded notes regarding participant navigation behavior and difficulties.

(3) Evaluation (20–30 minutes). After completing the learning modules, participants filled out a short questionnaire assessing usability, clarity, conceptual understanding, and perceived learning benefits. Immediately afterward, semi-structured interviews were conducted to collect qualitative feedback about usability, confusion

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points, and suggestions for improvement.

This structured activity flow enabled the evaluation of the media's usability and learning affordances in a realistic learning context without instructor intervention, focusing particularly on its potential to support conceptual understanding and self-directed learning.

Table 1. Quantitative data from the Likert-scale questionnaire

No	Questions	M1	M2	F1	F2	Avg
1	The media is easy to use and understand.	5	4	3	3	3.75
2	The media helped me understand the concept of angles and trigonometric functions.	3	4	2	4	3.25
3	The visual representations in the media helped me imagine trigonometric graphs.	4	4	5	4	4.25
4	The visual representations in the media helped me imagine trigonometric graphs.	2	4	3	3	3
5	I experienced confusion while using this media.	5	5	3	1	3.5
6	I found sine and cosine values easier to understand after using this media.	3	4	3	3	3.25
7	I would recommend this media to be used in trigonometry courses.	3	4	5	4	4
8	The media is suitable for self-directed learning by students.	4	4	2	3	3.25

Evaluate

The semi-structured interviews revealed that the interactive media was perceived as engaging and helpful, particularly in visualizing trigonometric concepts. However, several participants experienced confusion, especially regarding the tangent function and the initial use of the media without guidance.

The visualizations were highlighted as the most beneficial aspect, aiding students in understanding and validating trigonometric values. Suggestions for improvement included the addition of more detailed explanations, practice problems, and a tutorial feature. These insights will inform the further development of the media to better support diverse learners.

Most participants found the interactive media enjoyable and engaging. One participant described their experience with the app, "It was enjoyable because it made answering questions easier without having to memorize. However, I was still somewhat confused in determining the value of tangent." Another mentioned, "It was interesting, but the information provided was still quite limited." However, two participants expressed initial confusion, particularly due to the lack of guidance on how to use the media.

All participants highlighted the usefulness of the visualizations and definitions provided in the media. For example, a student noted:

I : Were there any parts of the program that helped

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you understand trigonometric concepts better?

M1 : "The visualization and definition sections were helpful because they showed the values of sin, cos, and tan."

Another participant appreciated the explanation that the coordinates on the unit circle represent $(\cos x, \sin x)$ „ which aided in visualizing trigonometric values. One participant emphasized that the media helped validate their prior knowledge. Some confusion was reported, particularly regarding the tangent function and the conversion of decimal to fractional values. One participant explained, "Determining tangent was confusing because there was no explanation about $\tan x$in the visualization." Another mentioned, "Sometimes I was confused about converting decimals to fractions in the visualization." Two participants indicated that their lack of prior understanding of trigonometry contributed to their confusion when using the media.

The media provided new insights, especially regarding the tangent function. One participant stated, "I gained a new understanding of $\tan x$." However, for those who had previously encountered similar visualizations in class, the media did not significantly alter their perception but was considered potentially helpful for school students. Another participant noted, "Previously, I just memorized the values, but after using this media, I found it somewhat helpful." Participants suggested several improvements, such as adding features to clarify the tangent function, providing more examples and practice questions, including more comprehensive explanations for students with weaker backgrounds in trigonometry and sading a tutorial or guidance feature.

The descriptive analysis of questionnaire responses from four mathematics education students revealed that the interactive media was generally perceived as easy to use (mean = 3.75) and visually effective in illustrating trigonometric graphs (mean = 4.25). However, some students experienced confusion (mean = 3.5), and the impact on conceptual understanding was moderate (mean = 3.25). While most participants would recommend the media for use in trigonometry courses (mean = 4.0), its suitability for self-directed learning was rated lower (mean = 3.25). These findings highlight the strengths of the visual components while indicating a need for improved clarity and support within the media. Given the small sample size, these insights are preliminary but valuable for guiding further development.

RESULT AND DISCUSSION

Interpretation of Visual Strengths

A consistent theme across interview responses was the effectiveness of the media's visualization features, particularly in helping students "see" and make sense of trigonometric concepts. This finding aligns with Multimedia Learning Theory, which posits that dual-channel (visual and verbal) processing enhances comprehension and retention, especially for abstract content [14]. In the case of trigonometry, where many students

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struggle to connect symbolic representations with spatial reasoning, visual supports such as a dynamic unit circle can bridge this gap effectively.

The interactive nature of the tool allowed students to adjust the angle manually and observe immediate changes in sine and cosine values. This functionality reflects the principle of interactive tools as cognitive tools, where technology serves not only as a delivery platform but also as a medium for exploration and hypothesis testing [15]. Through such interactivity, students engage in "learning by doing" [16], which is especially important for developing fluency in multiple representations—a key challenge in trigonometry education.

From a cognitive load perspective, such visual immediacy reduces intrinsic load by transforming abstract symbolic inputs (e.g., sin θ, cos θ) into intuitive visual forms. Students specifically noted that seeing the unit circle and its changing coordinates allowed them to internalize that (cos θ, sin θ) represents a point on the circle, reinforcing spatial understanding. This kind of representational coordination is essential for building conceptual schemas and aligns with Duval's view of mathematical understanding as a product of semiotic conversion [17].

Interestingly, even students who had previously encountered similar representations in class expressed that the media provided an additional layer of clarity due to its interactivity and manipulability. This reinforces the idea that multimodal, exploratory tools can serve both as primary and reinforcing instructional mechanisms, depending on learners' prior knowledge. It also highlights that engagement alone is insufficient; interactivity must be embedded within a cognitive framework that considers learners' developmental needs.

Confusion Around Tangent Function

Despite the media's success in visualizing sine and cosine, many students reported confusion surrounding the tangent function. This included both conceptual issues (e.g., the absence of a visual derivation from sine and cosine) and representational limitations (e.g., no graph or geometric interpretation of tangent on the circle). From the standpoint of Multimedia Learning Theory, this reflects a failure to support active processing—one of the theory's key principles. Without prompts or guidance to help learners select, organize, and integrate relevant information about tangent, the media left many students without sufficient cognitive support to make meaning.

This also highlights a shortfall in terms of interactive cognitive tools. The tool provided dynamic feedback for sine and cosine, but did not allow users to explore tangent behavior through visual comparison, manipulation, or layered representations. As a result, students were unable to construct meaningful links between tangent and the more familiar sine and cosine values. According to constructivist learning theory, such gaps in representational scaffolding can inhibit the development of robust mental models [18].

From a Cognitive Load Theory perspective, the absence of clear conceptual cues for tangent may increase extraneous load, as students must infer or recall missing information. This was exacerbated for

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learners without a strong prior conceptual foundation. The fact that some students described themselves as “lost” or “confused” when dealing with tan x suggests that the media did not provide adequate support to manage intrinsic complexity, a critical concern when designing tools for abstract mathematical domains. To address this gap, future versions of the media could integrate additional visual elements, such as plotting tangent values on a separate graph or dynamically showing the ratio of sine to cosine. Such modifications would not only provide representational coherence but also promote generative learning—where students build connections across multiple forms. This aligns with Mayer’s principles of segmenting and modality, that cognitive tools should support explanation-building.

Challenges in Self-Directed Learning

Although students acknowledged the visual and interactive benefits of the media, several participants experienced difficulty when engaging with the tool independently, particularly at the initial stage. This challenge is reflected in the lower average ratings for conceptual understanding (mean = 3.25) and suitability for self-directed learning (mean = 3.25), indicating that while the media supported engagement, it did not fully facilitate autonomous knowledge construction for all users.

These findings resonate with limitations identified in both constructivist learning theory and Multimedia Learning Theory. While interactive digital environments offer the potential for exploration and discovery, they also place cognitive demands on learners—especially those with limited prior knowledge. According to Mayer’s Multimedia Learning Theory, effective multimedia instruction must support active processing while recognizing the limited capacity of each cognitive channel [14]. In this study, the absence of guided prompts or structured progression may have increased extraneous load, particularly for students unfamiliar with the tangent function or radian measures.

Moreover, as Cognitive Load Theory [19] suggests, even well-designed visuals can fail to support learning if learners are left without instructional support to manage intrinsic load—that is, the inherent complexity of the content. Trigonometry involves interpreting angles in multiple units, transitioning between symbolic and geometric representations, and understanding periodic behavior. Without sufficient scaffolding, these demands can exceed students' working memory capacity, resulting in confusion or disengagement.

This insight aligns with interview responses in which students reported not knowing where to begin or how to use the interface effectively. A recurring suggestion from participants was the inclusion of a tutorial or onboarding feature. Such a component would help reduce extraneous load and support schema construction by breaking down complex interactions into manageable sequences, thereby increasing accessibility for novice learners.

AI-Assisted Development and Interactive Tools

A unique contribution of this study lies in the use of artificial

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intelligence (AI)—specifically large language models like ChatGPT—to assist in the development of the interactive media. AI-assisted code generation enabled efficient development aligned with instructional objectives without requiring advanced programming expertise. This process exemplifies the growing potential for AI to support teacher agency in educational technology design.

Within the context of interactive tools as cognitive tools, AI can serve not only learners but also educators by enabling the creation of customizable learning environments. As Jonassen [20] posits, tools that allow learners to visualize, organize, and manipulate knowledge are not merely delivery systems but extensions of cognition itself. The same principle applies to teachers as tool designers. With the support of AI-generated code, educators can articulate specific pedagogical needs—such as showing angle-based changes in sine and cosine—and quickly develop functional digital media that reflect those needs. This supports a bottom-up approach to media development grounded in classroom realities rather than top-down templates.

From a theoretical standpoint, such tools exemplify the constructivist paradigm in which learning is facilitated through interaction with artifacts. The Python-based visualizations created in this study allowed students to manipulate angle sliders and observe how values changed in real time. This mirrors the design principles found in interactive platforms like GeoGebra and Desmos, which have been shown to improve student understanding by supporting learning-by-doing [16], [18].

Furthermore, the use of AI supports adaptive scaffolding, as it allows for rapid iteration and personalization. In future versions of the tool, AI could be used not only for design but also for real-time learner support—generating hints, explanations, or dynamically adjusting tasks based on learner behavior. Such adaptive features are consistent with the goal of fostering self-regulated learning, as noted by Chang et al. [21], and could enhance both engagement and conceptual mastery.

CONCLUSION

The use of interactive media in this study was positively received by students, particularly the dynamic visualization of sine and cosine values on the unit circle. Participants reported that this specific feature allowed them to actively explore how changes in angle affected the values of trigonometric functions, thereby deepening their intuitive understanding. The media's interactivity supported their engagement with abstract concepts, making them more accessible and visually meaningful. Notably, the development of the interactive media was facilitated through the use of AI-assisted programming support, specifically leveraging tools like ChatGPT to generate and refine code. This approach enabled the rapid creation of customized visualizations based on precise instructional prompts, demonstrating the potential of AI to assist educators—even those with limited coding experience—in developing tailored digital resources. As a result, teachers can design and adapt interactive tools to align with specific classroom needs and learning objectives. This highlights a promising shift toward more teacher-driven, adaptive use of technology in mathematics education, where the flexibility of AI-assisted coding empowers educators to take personalization digital media in learning

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