p-ISSN: 2086-4280
e-ISSN: 2527-8827

Phet Assisted Trigonometric Worksheet for Students' Trigonometric Adaptive Thinking

Rina Oktaviyanthi[1*], Usep Sholahudin[2]

[1*,2]Mathematics Education, Universitas Serang Raya
Jalan Raya Cilegon No.Km. 5, Serang, Banten, Indonesia
[1]rinaokta@unsera.ac.id; [2]s.usep@yahoo.com

Article received: 2023-01-08, revised: 2023-04-19, published: 2023-04-30

Abstrak

Fakta menunjukkan kesulitan dalam belajar geometri di universitas yaitu kesulitan menentukan fungsi Trigonometri untuk sudut negatif atau lebih besar dari 90 derajat, dan kesulitan menerjemahkan beberapa representasi fungsi Trigonometri. Masalah yang melibatkan kemampuan berpikir Trigonometri dapat diselesaikan dengan menampilkan perekayasaan informasi gambar, diagram atau animasi. Salah satu media dengan yang dapat menstimulasi berpikir Trigonometri adalah PhET Simulation. Media digital dapat menunjukkan performa yang lebih baik jika didukung lembar kerja untuk memandu proses pengikatan ilmu pengetahuan. Tujuan penelitian ini adalah bagaimana proses perancangan worksheet yang mengintegrasikan pemanfaatan media interaktif Phet Simulation. Penelitian pengembangan dijadikan sebagai pendekatan penelitian yang meliputi tiga bagian yakni problem and design solution analysis, product specification and development, serta prototype evaluation and limited test. Pengujian validator ahli memiliki indikasi bahwa lembar kerja yang dikembangkan memenuhi standar pengujian ahli untuk digunakan dalam menyelesaikan masalah Trigonometri. Pengujian terbatas pada subjek penelitian menunjukkan instrumen yang diuji memenuhi standar valid dan reliabel.
Kata Kunci: Lembar Kerja Matematika; Simulasi Phet; Trigonometri.

Abstract

The facts show that the difficulties in learning geometry at university was difficulty to determine Trigonometry functions for negative angles or greater than 90 degrees, and difficulty to translate some representations of Trigonometry functions. Problems involving Trigonometry thinking skills are most likely solved by presenting manipulated images, diagrams and animations. One media to stimulate Trigonometry thinking is PhET Simulation. Additionally, a digital media is believed to improve the performance if it is supported by worksheets to guide the knowledge construction process. Therefore, the purpose of the study was to investigate the designing process of integrating the use of interactive media Phet Simulation. Developmental research was used as the research approach encompassing three sections, namely problem and design solution analysis, product specification and development, and prototype evaluation and limited test. The expert validator tests indicated the worksheet developed met the requirement as a solution in solving Trigonometry problems. Limited test to the research subjects confirmed that the instruments were tested valid and reliable.
Keywords: Mathematics Worksheet; Phet Simulation; Trigonometry.

I. INTRODUCTION

Trigonometry is a branch of mathematics that deals with various properties of Trigonometric functions and the application of these functions to determine unknown angles and sides of triangles (Kamber & Takaci, 2017; Fauziah & Puspitasari, 2022). It is widely used in architecture, engineering and science, adopting the concepts to set the direction of a transportation wheel, determine the navigation and the distance of the coast from a point at sea (Van Brummelen, 2021). Teaching the concept of Trigonometry at various levels of education is necessary due to its widespread implementation in various fields (De Cassai et al., 2018; Gradini, Yustinaningrum, & Safitri, 2022). Excellent and proficient Trigonometry skills provide opportunities to work on complex angles and dimensions in a short time (Ngcobo et al., 2019; Taufiq & Agustito, 2021). At the university level, especially the Mathematics Education curriculum in the University of Serang Raya, the purpose of teaching Trigonometry concepts is to allow students to use comparisons, functions, equations and Trigonometric identities in problem solving. Trigonometry concepts are required to learn because algebraic knowledge and geometry skills as its constituents could encourage the ability to solve complex design-related problems (Serpe & Frassia, 2021; Sundayana & Parani, 2023). Therefore, developing students' learning potential on the concept of Trigonometry is the top priority in the learning process to improve the theoretical and practical knowledge as tools to solve problems (Laja, 2022).

While learning Trigonometry concepts, studnts usuall encounter challenges and obstacles. From the preliminary research conducted in 2019-2022, some data related to learning outcomes and student responses in learning the concept of Trigonometry were identified. Some challagenges identified included (1) the difficulty to determine Trigonometry function for a negative angle and greater than 90 degree, (2) the diffifulty to interpret a variety of Trigonometry representation as sides of right triangles inscribed in the unit circle or as function graphs or as angles and or as numerical values of functions, (3) the difficulty to estimate the value of the Trigonometric function of any given angles without using a calculator, and, (4) the difficulty to deduce the plus, minus and zero signs of Trigonometric functions for any given angles using only the concept of the unit circle. Implicitly, these points of difficulties are problems related to Trigonometric thinking skills (Trigonometric Thinking) (Moore, 2012; Zaslavsky, 2019; Setiawan & Prihatnani, 2020). According to Gur (2009) and Galitskaya & Drigas (2019), Trigonometric thinking is the processing of information involving the concepts of shape, space and mathematical ideas such as deduction ratios and mathematical proofs related to the relationship between the sides and angles of a triangle that function as a problem-solving tool. Kamber & Takaci (2017) stated that Trigonometric understanding through practices of trigonometric thinking enouraged studeents' mental thinking thoroughly and comprehensively as a support for real-life problem-solving skills. Thus, teaching students to think Trigonometrically in

p-ISSN: 2086-4280
e-ISSN: 2527-8827

learning occupies a critical part to support the students' potential and provide learning experiences to solve problems.

Sidike et al., (2018) and Majeed et al., (2020) stated that problems involving trigonometric thinking skills were most likely to be solved by presenting trigonometric concepts through manipulated images, diagrams or animations. Supported by Bender et al., 2019), most of the human brain's memory capture lasted longer through concrete imagery than abstract ones. Interactive simulation learning media according to Zavitsanou & Drigas (2021) were strongly suggested to encourage the students' memorizing ability by exposing them to the actual representation of a concept.

One of the interactive simulation media with a visual display that can stimulate Trigonometric thinking is PhET Simulation (Figure 1.). The simulation is html-based and able to be accessed through this link https://phet.colorado.edu/sims/html/trig-tour/latest/trig-tour_all.html as an open learning source.

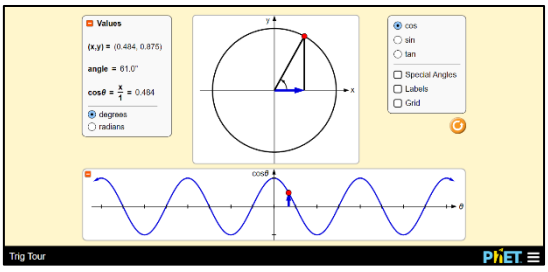

Figure 1. Interactive Media of PhET Trigonometry Simulation.

According to the founder and developer, Carl Wieman from the University of Colorado, PhET Simulation, which was first developed in 2002, facilitates the development of students' understanding of mathematical concepts, one of which is Trigonometry, through virtual manipulation and interactive simulations (Maryati, 2015; Correia et al., 2018). Based on Reiten & Reiten (2020) and Shin et al., (2021), the use of manipulation and simulation was in line with the constructivist principles which indirectly assisted learners to construct their own knowledge and understanding. Thus, the use of PhET interactive simulation learning media is expected to stimulate the development and enhancement of students' Trigonometric thinking skills.

A digital media, either interactive or non-interactive, will likely show better performances if it is supported by auxiliary media such as worksheets to guide the process of binding knowledge (Oktaviyanthi et al., 2018). The use of students' worksheet also allow them to improve their working memory, attention, and focus in processing the information received by the short-teerm memory and later to be forwarded to the long-term memory (Lee et al., 2021; Lestari & Afriansyah, 2022). The implementation of worksheets in exploring abstract concepts that are unique to mathematics has the opportunity to provide learning assistance to students in constructing problem solving. Teachers might adjust the learners' needs to the curriculum targets through the development of adaptive worksheet frameworks derived from problems encoutered by learners. Therefore, encouraging the use of worksheets affiliated with interactive media is an opportunity to support the improvement of student performance in mastering mathematical concepts including Trigonometry.

Research focus on the utilization of interactive media in mathematics has been conducted throughout the last three years. To mention Sabirova et al., (2019) dan Rohaeti et al., (2019), those studies dealt with the virtues of web-based interactive learning and interactive learning media development with visual basic application approach. On the other hand, Radović et al., 2018) and Demitriadou et al., 2020) emphasized the studies on the Geogebra implementation results assisted by interactive textbook and comparative study between virtual and augmented reality learning. Meanwhile, studies by Wijaya et al., (2021) and Zhao et al., (2021) emphasized the improvement of interactive mathematics learning on creative thinking and metacognitive skills. From the last few studies, few studies investigated the development of worksheets with interactive media PhET Simulation on the Trigonometry concepts as a medium for students' Trigonometry adaptive thinking. Thus, the main focus and tendency of current study was to develop worksheets with the help of PhET Simulation for students' Trigonometry adaptive thinking skills.

II. METHODS

The study highlighted the designing process of PhET assisted Trigonometric worksheets. Thus, the developmental research approach was applied to achieve the objectives of the study. The stages of development research adopted Mills & Gay (2019), Stahl & King (2020) and Oktaviyanthi & Agus (2021) encompassing three stages, namely problem and design solution analysis, product specification and development, and prototype evaluation and limited test. Below are the descriptions of each stage:

1. 1st Stage: Problem and Design Solution Analysis

The objectives of the first stage consist of two aspects, namely (1) exploring the core problem through the problem analysis process with the target achievement in the form of obtaining a critical point of difficulties encountered by students in learning Trigonometry, and (2) recognizing the characteristics of the solution through the design solution analysis process to obtain the target achievement, namely a conceptual design for problem solving.

2. 2nd Stage: Product Specification and Development

The objectives of the second stage include two perspectives, namely (1) confirming the solution idea through the product specification process to obtain the type and structure of the right solution appropriate to the problem encountered, and (2) manifesting the confirmed solution idea through the product development process to produce a testable instrument prototype.

3. 3rd Stage: Prototype Evaluation and Limited Test

The objectives of the third stage include two parts (1) assessing the substance and structure of the prototype by expert validators through the prototype evaluation process to construct a testable and valid prototype for limited testing, and (2) testing the prototype on potential users through the prototype limited test process to produce a ready-to-use prototype.

This developmental research of PhET assisted Trigonometric worksheet involved five expert validators consisting of three

p-ISSN: 2086-4280
e-ISSN: 2527-8827

mathematicians and two mathematics teachers. The mathematicians assessed and the objectives of the study and the use of mathematic symbols. On the other hand, the mathematics teachers assessed and evaluated the appropriateness of the worksheet construction and framework to the objectives and purposes of the study. Furthermore, the limited trial test was conducted to 85 first-year students at the University of Serang Raya who were taking Calculus I course.

The data on the assessment of the content and structure of the prototype were collected using a questionnaire consisting of 12 statements with a scale of 2 (0 for Disagree and 1 for Agree) according to the rules of the Q-Cochran statistical test. evaluated the appropriateness of the mathematic concepts in the worksheets to According to McCrum-Gardner (2008) dan Mishra, Pandey, Singh, Keshri, & Sabaretnam (2019) Q-Cochran test was used for research samples that constitute dichotomy measurement such as success and failure, agree or disagree. Thus, the questionnaire was designed to provide two options, namely 0 (disagree) dan 1 (agree) using Q-Cochran. Furthermore, the aspects of the questionnaire were developed based on the research purposes and objectives as directed by Krosnick (2017) and Oktaviyanthi & Agus (2021). The outline of the questionnaire statements is listed in Table 1.

Tabel 1.
The Assessment Aspects of Phet *Assisted Trigonometric Worksheet*

Review points	Description	Number of questionnaires
The appropriateness of mathematic concepts	The appropriateness of the PhET assisted Trigonometric worksheet content with the rules for determining Trigonometric functions for negative angles and angles greater than 90 degrees.	1
	The appropriateness of the content of the PhET assisted Trigonometric worksheet with the concept of the differences in representing Trigonometric functions as sides of a right triangle written in the unit circle or as a function graph or as an angle and or as the numerical value of the function.	2
	The appropriateness of the content of the PhET assisted Trigonometric worksheet with the idea of estimating the value of the Trigonometric function of any given angles without using a calculator.	3
	The appropriateness of the content of PhET assisted Trigonometric worksheet with the theory of deducing plus, minus and zero signs from Trigonometric functions for any given angles using only the concept of unit circle.	4
Framework accuracy of PhET *Assisted Trigonometric Worksheet*	The accuracy of the rules for determining Trigonometric functions for negative angles and angles greater than 90 degrees with the framework contained in the PhET assisted Trigonometric worksheet.	5
	The conceptual accuracy of the difference in representing Trigonometric functions as sides of a right triangle written in a unit circle or as a function graph or as angles and or as numerical values of functions with structured commands PhET assisted Trigonometric worksheet.	6
	The accuracy of the idea of estimating the value of the Trigonometric function of any given angle without using a calculator with the estimation form items.	7

	Theoretical accuracy of deducing plus, minus and zero signs from Trigonometric functions for any given angles using only the concept of unit circle with circle and graph display formats.	8
Language consistency	The consistency of using statement patterns or question forms in PhET *assisted Trigonometric worksheet*	9
	The consistency of the vocabularies and sentence structures in PhET *assisted Trigonometric worksheet*	10
	The consistency of the language of the statement or question in PhET *assisted Trigonometric worksheet*	11
	The consistency of inclusion of mathematical characters and attributes, terminology and phrases of concepts under study in PhET *assisted Trigonometric worksheet*	12

The limited test data were collected through the responses of the participants in using the designed worksheet prototype. The guidelines to quantify the participants' responses to the use of worksheets are presented in Table 2. The analysis was carried out using the Cronbach Alpha Statistical test.

Tabel 2.
Guidelines to Quantify the Participants' Responses

Students' challenges	Indicators	Description	Value
Determining Trigonometric functions for negative angles and angles greater than 90 degrees	Students are able to determine the Trigonometric functions for negative angles and angles greater than 90 degrees	Incorrect Correct answer, no argument Correct answer with argument	0 1 2
Interpreting some representations of Trigonometric functions	Students are able to interpret some representation of Trigonometry functions	Incorrect Correct answer, no argument Correct answer with argument	0 1 2
Estimating the value of the Trigonometric function of any given angle without using a calculator	Students are able to estimate the value of the Trigonometric function of any given angle without using a calculator	Incorrect Correct answer, no argument Correct answer with argument	0 1 2
Deducing the plus, minus and zero signs of Trigonometric functions for any given angle using only the concept of unit circle	Students are able to deduce the plus, minus and zero signs of Trigonometric functions for any given angle using only the concept of unit circle	Incorrect Correct answer, no argument Correct answer with argument	0 1 2

There were two types of data generated in this developmental research (1) performance data testing on contents and structure of prototypes, and (2) performance data testing on participants. The research data analysis techniques implemented were (1) Q-Cochran comparative statistical test on the sample of content and structure tests of prototypes by expert validators and (2) Cronbach Alpha statistical test on the sample of limited tests by the participants.

III. RESULT AND DISCUSSION

A. *1st Stage: Problem and Design Solution Analysis*

The main research question was derived from the problem analysis process through preliminary studies in the form of observations of formative grades, classroom

p-ISSN: 2086-4280
e-ISSN: 2527-8827

observations, and directed focused interviews on students' challenges that indicated a decrease among the students' performance in Trigonometry courses in a period of 2019 to 2022. Some critical points of the problems confirmed as challenges in learning Trigonometry are summarized as follows:

1. The students encountered some difficulties to determine Trigonometric functions for negative angles and angles greater than 90 degrees.
2. There were some challenges in the interpretation process of Trigonometry functions as sides of a right triangle in the unit circle or a function graph or as an angle and or as a numerical value of a function.
3. The students were having problems with estimating the value of the Trigonometry functions of a particular angles without using a calculator.
4. The students were having difficulties with deducing plus, minus, and zero signs in Trigonometry functions of a particular angle using the circle unit concept.

Based on the problems above, further identification and investigation were conducted on the accuracy and appropriateness of the structure and contents of the worksheet to the objectives. The conceptualized designs to overcome the studnets' challenges in Trigonometry are presented as the following description:

1. To solve point 1, it was chosen the type of problem that demonstrated the comparison of values for the angle formed from the combination of each positive or negative x value and positive or negative y value and showed the visualization of the image to see the differences so that a regularity or pattern could be drawn.

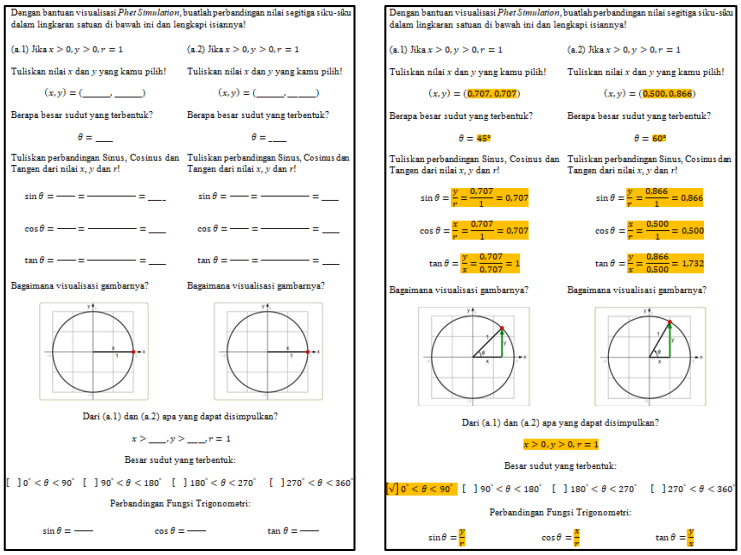

Figure 2. Worksheet View (Left) and A Sample Response (Right).

2. To address point 2, a structured problem flow was developed with a variety of representations of the Trigonometric function of an angle that

allowed the user to review the similarity of the process so that it could be interpreted for each of the Sine, Cosine and Tangent rules.

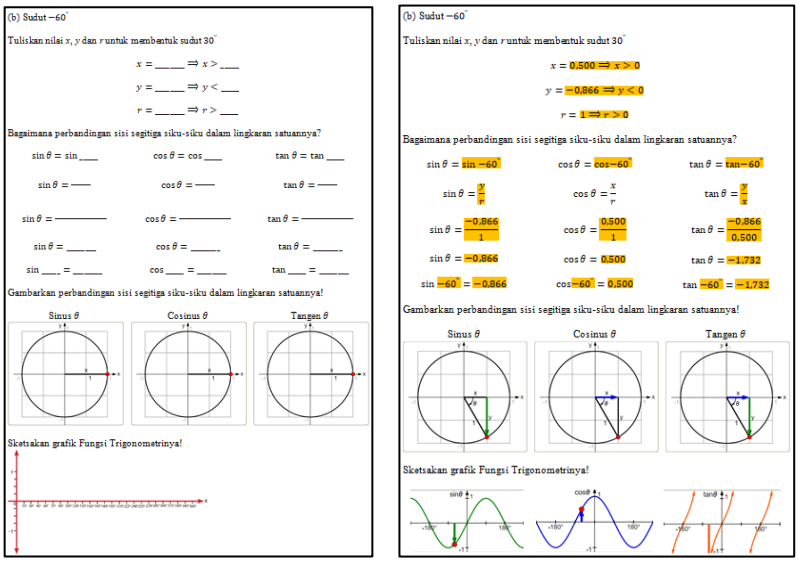

Figure 3. Worksheet View of Question 2 (Left) and The Sample Response (Right).

3. To address point 3, an item was designed to allow the user to estimate the comparative values of an angle by estimating the coordinate point *x* and *y* from the visualization of a right triangle in a unit circle.

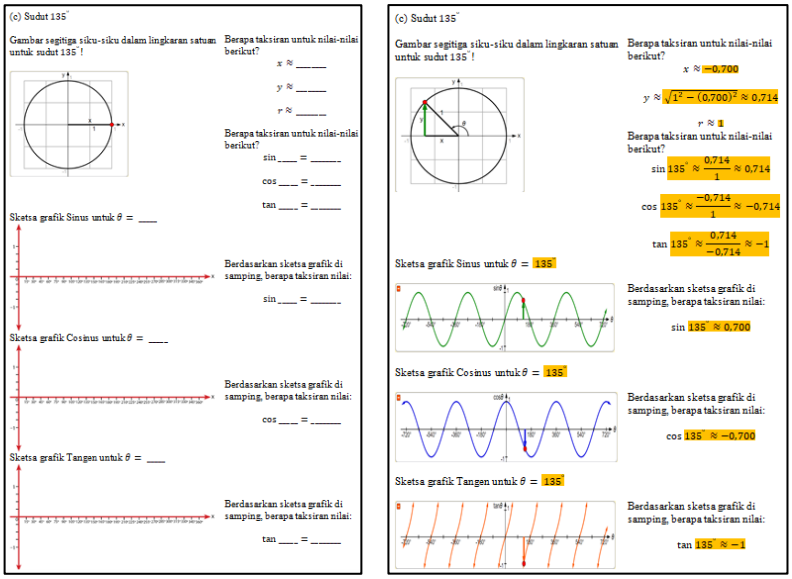

Figure 4. Worksheet View of Question 3 (Left) and The Sample Response (Right).

4. To address point 4, an item was designed to simultaneously show a comparative value of a right triangle of an angle of a unit circle with Trigonometry values in a graph function of Sine, Cosine and Tangent.

p-ISSN: 2086-4280
e-ISSN: 2527-8827

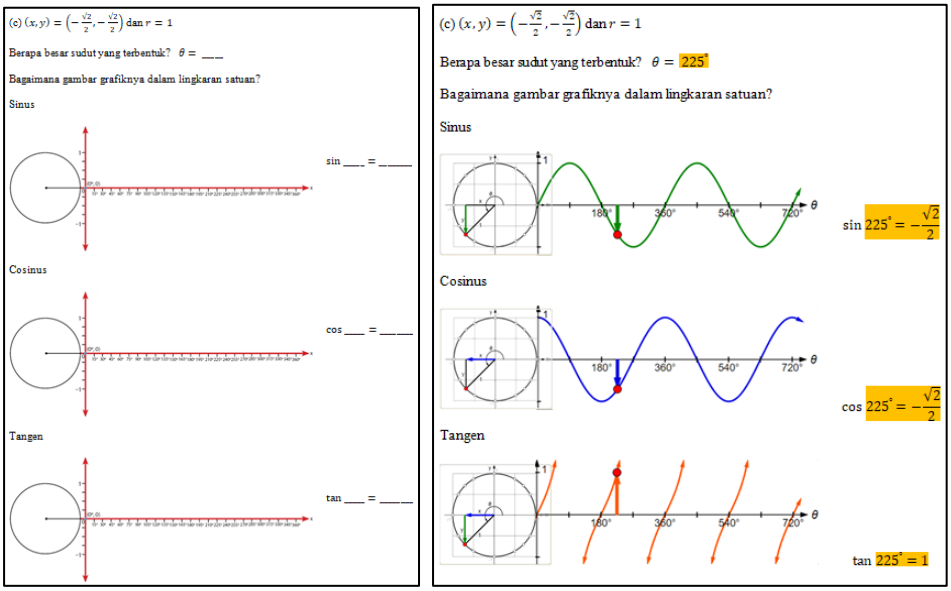

Figure 5. Worksheet View of Question 4 (Left) and The Sample Response (Right).

B. *2nd Stage: Product Specification and Development*

The solution idea in the form of a conceptual design established in the first stage of this research was then specified and developed in line with the specificity of the problem and the research objectives. The results obtained in the second stage of the research are shown through the following review:

a) A type of items of a comparative value from the combination value of each x positive or negative and positive or negative was presented and it illustrated the visualization of the item to show the differences that allowed the user to draw a conclusion or a partern.

b) A type of structured item with a variety of representations of the Trigonometric function of an angle that allowed users to review the similarity of the process was presented to form interpretation for each of the Sine, Cosine and Tangent rule.

c) A type of items that allowed the user to estimate the ratio value of an angle simply by estimating the x and y coordinates from the visualization of a right triangle within a unit circle was presented.

d) A type of items that elicite the simultaneous comparison of the value of a right triangle of an angle in a unit circle with the Trigonometric value on the graph of the Sine, Cosine and Tangent functions was presented.

C. *3rd Stage: Prototype Evaluation and Limited Test*

The prototype of PhET assisted Trigonometric worksheet developed in the second stage was then assessed by the experts and tested on a limited user. The assessment emphasized the validity of concept appropriateness, structural accuracy and language consistency through uniformity and readability tests of the prototype. The validators used the same questionnaires to test the prototype. Testing was carried out using the Q-Cochran

Statistical test and the test results are presented in Table 3.

Tabel 3.
The Results of Validity Test With *Q-Cochran*

The prototype	Significance Value *Q-Cochran* Test		
	The concept appropriateness	The structural accuracy	The language consistency
PhET *assisted Trigonometric worksheet*	0.059	0.077	0.068

Null hypothesis (H_0) in the statistical test of *Q-Cochran* stated that the frequency balance of all the answers was identical among the five validators in assessing the instrument through the questionnaire statement item responses. With the significant level of 5% the area of H_0 was accepted if the *p-value* $\geq$ 0.05. in the table 3. The significant level of *Q-Cochran* $\geq$ 0.05 meaning that H_0 was accepted. H_0 rejections could be interpreted that the five validators gave the same responses or identical consideration of the instrument being measured. In other words, the PhET assisted Trigonometric worksheet developed had the opportunity to solve the core problems of the students who were the participants of the research.

Further test was aimed at the participants of the study as the main users of PhET assisted Trigonometric worksheet. 85 students gave responses regarding the prototype by responding to the items on the worksheet. The results were then analyzed using *Cronbach Alpha* to test the validity and reliability of the instruments. The results showed r_{count} of the validity and reliability of the instruments regarding the items from point 1 to 4 on the worksheet presented in the following Table 4.

Tabel 4.
The Limited Test Results of The Participants

r_{count}	Results	Conclusion	r_{hitung}	Results	Conclusion
0.5621	r_{count} > 0.2133	Valid	0.6715	r_{count} > 0.2110	Reliable
0.2231			0.7403		
0.3214			0.5307		
0.2371			0.3156		

An instrument is considered valid if $r_{count} > r_{critical}$. The $r_{critical}$ value of 85 participants with the significant level 5% was 0.2133. Based on the value obtained, the prototype developed met the validity standard of an instrument. Meanwhile, an instrument is considered reliable if the value of $r_{count} > r_{critical}$, which $r_{critical}$ is the coefficient value of *product moment* of the participants, which means 85 students value was 0.2110. Therefore, the content of the prototype developed met the reliability standard of an instrument. The invention of this developmental research was PhET *assisted Trigonometric worksheet* based on the challenges encountered by the students while learning Trigonometry concepts and met the requirement of a minimal criterion of a valid and reliable instrument.

The utilization of worksheets in mathematics learning activities, especially on abstract concepts that require the help of high media visibility, provides quite a lot of support and positive responses from students. Several studies that focused on the worksheet development confirmed the

p-ISSN: 2086-4280
e-ISSN: 2527-8827

actual support and active participation of worksheet utilization to enhance students' mathematical abilities. It is in line with Howley (2020) stating that the presence of worksheets made thinking instructions more adaptive to the learners' needs. On the other hand Subekti & Prahmana (2021) argued that the worksheets that were prepared did not only facilitate the transparency of mathematical concepts but also encouraged students' motivation in examining the topic being studied. Furthermore Schlatter et al., (2022) argued that the integration of guided questions or questions in the contents of the worksheet could be a catalyst to accelerate students' understanding of a particular concept. The prototype of the study resulted in the form of PhET assisted Trigonometric worksheet was one of the media that could be utilized by teachers as a cognitive stimulus for students to build a framework to think and understand mathematical concepts, especially Trigonometry.

IV. CONCLUSION

The PhET assisted Trigonometric worksheet development process which consisted of three stages namely problem and design solution analysis, product specification and development and prototype evaluation and limited test generated a prototype that met the test criteria of expert validators and achieved the standard qualifications of validity and reliability of a feasible instrument. The value of expert validity test was *p-value* $\geq$ 0.05 spesifically 0.059 for the appropriatenss of the concept, 0.077 for the structural accuracy and 0.068 for the language consistency indicating that PhET *assisted Trigonometric worksheet* was probably the answer to address the challenges encountered by the students in learning Trigonometry concepts. Furthermore, the limited test to the users was conducted to ensure the validity and reliability of the worksheet being developed. The test showed $r_{count} > r_{critical}$ meant that the instrument being tested met the validity and reliability requirements. The recommendation of this study included (1) *worksheet* could be utilized to assist students to determine the Trigonometry functions of negative angles and angles greater than 90 degree, (2) *worksheet* might benefit students to address their challenges in interpreting some representations of the trigonometry functions, (3) *worksheet* might address students' challenges in estimating the valued of the Trigonometry functions of a particular angle without using a calculator, and (4) *worksheet* might assist students to deduce plus, minus, and zero from the Trigonometry function. It is expected that the results of this study could contribute to mathematics learning and teaching, especially the use of worksheet to assist students in the learning process.

REFERENCES

Bender, M., Romei, V., & Sauseng, P. (2019). Slow theta tACS of the right parietal cortex enhances contralateral visual working memory capacity. *Brain topography*, *32*(3), 477-481.

Correia, A. P., Koehler, N., Thompson, A., & Phye, G. (2019). The application of PhET simulation to teach gas behavior on the submicroscopic level: secondary school

students' perceptions. *Research in Science & Technological Education*, *37*(2), 193-217.

De Cassai, A., Sandei, L., & Carron, M. (2018). Trigonometry in daily ultrasound practice. *Critical Care*, *22*(1), 1-2.

Demitriadou, E., Stavroulia, K. E., & Lanitis, A. (2020). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education and information technologies*, *25*(1), 381-401.

Fauziah, R., & Puspitasari, N. (2022). Kesulitan Belajar Matematika Siswa SMA pada Pokok Bahasan Persamaan Trigonometri di Kampung Pasanggrahan. *Plusminus: Jurnal Pendidikan Matematika*, *2*(2), 325-334.

Galitskaya, V., & Drigas, A. (2019). ICTs and Geometry. *Int. J. Eng. Pedagog.*, *9*(5), 103-111.

Gradini, E., Yustinaningrum, B., & Safitri, D. (2022). Kesalahan Siswa Dalam Memecahkan Masalah Trigonometri Ditinjau dari Indikator Polya. *Mosharafa: Jurnal Pendidikan Matematika*, *11*(1), 49-60.

Gur, H. (2009). Trigonometry Learning. *New Horizons in Education*, *57*(1), 67-80.

Howley, I. (2020). Adapting guided inquiry learning worksheets for emergency remote learning. *Information and Learning Sciences*, *121*(7/8), 549-557.

Kamber, D., & Takaci, D. (2018). On problematic aspects in learning trigonometry. *International Journal of Mathematical Education in Science and Technology*, *49*(2), 161-175.

Krosnick, J. A. (2017). Questionnaire design. In *The Palgrave handbook of survey research* (pp. 439-455). Palgrave Macmillan, Cham.

Yosepha, P. W. L. (2022). Analisis Kesulitan Mahasiswa Pendidikan Matematika dalam Menyelesaikan Soal Limit Trigonometri. *Mosharafa: Jurnal Pendidikan Matematika*, *11*(1), 37-48.

Lee, K. H., Choi, Y. Y., & Jung, E. S. (2020). Effectiveness of an oral health education programme for older adults using a workbook. *Gerodontology*, *37*(4), 374-382.

Lestari, L., & Afriansyah, E. A. (2022). Kesalahan siswa dalam menyelesaikan soal cerita tentang bangun ruang sisi lengkung menggunakan prosedur newman. *Jurnal Inovasi Pembelajaran Matematika: PowerMathEdu*, *1*(2), 125-138.

Maryati, I. (2015). Efektivitas Metode Pembelajaran Think Talk Write untuk Meningkatkan Kulaitas Perkuliahan Aljabar dan Trigonometri. *Mosharafa: Jurnal Pendidikan Matematika*, *4*(3), 112-120.

Majeed, A., Abbas, M., Qayyum, F., Miura, K. T., Misro, M. Y., & Nazir, T. (2020). Geometric modeling using new Cubic trigonometric B-Spline functions with shape parameter. *Mathematics*, *8*(12), 2102.

Mills, G. E., & Gay, L. R. (2019). *Educational research: Competencies for analysis and applications*. Pearson. One Lake Street, Upper Saddle River, New Jersey 07458.

Moore, K. C. (2012). Coherence, quantitative reasoning, and the trigonometry of students. *Quantitative reasoning and mathematical modeling:*

p-ISSN: 2086-4280
e-ISSN: 2527-8827

A driver for STEM integrated education and teaching in context, *2*, 75-92.

Ngcobo, A. Z., Madonsela, S. P., & Brijlall, D. (2019). The teaching and learning of trigonometry. *The Independent Journal of Teaching and Learning*, *14*(2), 72-91.

Oktaviyanthi, R., Herman, T., & Dahlan, J. A. (2018). How Does Pre-Service Mathematics Teacher Prove the Limit of A Function by Formal Definition?. *Journal on Mathematics Education*, *9*(2), 195-212.

Oktaviyanthi, R., & Agus, R. N. (2021). Guided Worksheet Formal Definition of Limit: An Instrument Development Process. *AL-ISHLAH: Jurnal Pendidikan*, *13*(1), 449-461.

Radović, S., Radojičić, M., Veljković, K., & Marić, M. (2020). Examining the effects of Geogebra applets on mathematics learning using interactive mathematics textbook. *Interactive Learning Environments*, *28*(1), 32-49.

Reiten, L. (2020). Why and how secondary mathematics teachers implement virtual manipulatives. *Contemporary Issues in Technology and Teacher Education*, *20*(1), 55-84.

Rohaeti, E. E., Bernard, M., & Primandhika, R. B. (2019). Developing interactive learning media for school level mathematics through open-ended approach aided by visual basic application for excel. *Journal on Mathematics Education*, *10*(1), 59-68.

Sabirova, E. G., Fedorova, T. V., & Sandalova, N. N. (2019). Features and advantages of using websites in teaching mathematics (Interactive educational platform UCHI. ru). *Eurasia Journal of Mathematics, Science and Technology Education*, *15*(5), em1729.

Schlatter, E., Molenaar, I., & Lazonder, A. W. (2022). Adapting scientific reasoning instruction to children's needs: effects on learning processes and learning outcomes. *International Journal of Science Education*, 1-24.

Serpe, A., & Frassia, M. G. (2021). Artefacts Teach-Math. The meaning construction of trigonometric functions. *Atti della Accademia Peloritana dei Pericolanti-Classe di Scienze Fisiche, Matematiche e Naturali*, *99*(S1), 15.

Setiawan, Y., & Prihatnani, E. (2020). Perbandingan TAI dan NHT terhadap Hasil Belajar Trigonometri Ditinjau dari Kecerdasan Interpersonal. *Mosharafa: Jurnal Pendidikan Matematika*, *9*(2), 299-310.

Shin, M., Park, J., Grimes, R., & Bryant, D. P. (2021). Effects of using virtual manipulatives for students with disabilities: Three-level multilevel modeling for single-case data. *Exceptional Children*, *87*(4), 418-437.

Sidike, P., Sagan, V., Qumsiyeh, M., Maimaitijiang, M., Essa, A., & Asari, V. (2018). Adaptive trigonometric transformation function with image contrast and color enhancement: Application to unmanned aerial system imagery. *IEEE Geoscience and Remote Sensing Letters*, *15*(3), 404-408.

Stahl, N. A., & King, J. R. (2020). Expanding approaches for research: Understanding and using trustworthiness in qualitative

research. *Journal of Developmental Education*, *44*(1), 26-28.

Subekti, M. A. S., & Prahmana, R. C. I. (2021). Developing interactive electronic student worksheets through discovery learning and critical thinking skills during pandemic era. *Mathematics Teaching-Research Journal*, *13*(2), 137-176.

Sundayana, R., & Parani, C. E. (2023). Analyzing Students' Errors in Solving Trigonometric Problems Using Newman's Procedure Based on Students' Cognitive Style. *Mosharafa: Jurnal Pendidikan Matematika*, *12*(1), 135-144.

Taufiq, I., & Agustito, D. (2021). Uji Kelayakan Modul Trigonometri Berbasis Ajaran Tamansiswa. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(2), 281-290.

Van Brummelen, G. (2021). The Mathematics of the Heavens and the Earth. In *The Mathematics of the Heavens and the Earth*. Princeton University Press.

Wieman, C. E., Adams, W. K., Loeblein, P., & Perkins, K. K. (2010). Teaching physics using PhET simulations. *The Physics Teacher*, *48*(4), 225-227.

Wijaya, T., Zhou, Y., Ware, A., & Hermita, N. (2021). Improving the Creative Thinking Skills of the Next Generation of Mathematics Teachers Using Dynamic Mathematics Software. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(13), 212-226.

Zaslavsky, O. (2019). There is more to examples than meets the eye: Thinking with and through mathematical examples in different settings. *The Journal of Mathematical Behavior*, *53*, 245-255.

Zavitsanou, A. M., & Drigas, A. (2021). Attention and Working Memory. *Int. J. Recent Contributions Eng. Sci. IT*, *9*(1), 81-91.

Zhao, J., Hwang, G. J., Chang, S. C., Yang, Q. F., & Nokkaew, A. (2021). Effects of gamified interactive e-books on students' flipped learning performance, motivation, and meta-cognition tendency in a mathematics course. *Educational Technology Research and Development*, *69*(6), 3255-3280.

AUTHORS' BIOGRAPHY

Dr. Rina Oktaviyanthi, M.Pd.

Lecturer in the Mathematics Education Study Program at Serang Raya University. Bachelor of Mathematics Education Study, Indonesian University of Education, graduated in 2007; Study Masters in Mathematics Education, State University of Surabaya, graduated in 2011; Study Doctoral Degree in Mathematics Education, Indonesian University of Education, graduated in 2019.

Usep Sholahudin, S.T., M.Si.

Lecturer in the Mathematics Education Study Program at Serang Raya University. Study S1 Ocean Engineering Bandung Institute of Technology Graduated in 2000; Master of Applied Mathematics, Bogor Agricultural University, Graduated in 2012.