Pegem Journal of Education and Instruction, Vol. 11, No. 4, 2021 (pp. 209-218)

CrossMark

REVIEW ARTICLE WWW.PEGEGOG.NET

A Systematic Review on Pupils' Misconceptions and Errors in Trigonometry

Nurjailam Hamzah[1], Siti Mistima Maat[1*], Zanaton Ikhsan[1]

[1]Faculty of Education, University of Kebangsaan, Malaysia

Abstract

Systematic literature review (SLR) relies on a thorough and auditable methodology to reduce bias and ensure high reliability. This bias can be reduced through four main processes namely identification, screening, eligibility and inclusion. The SLRs discussed in this article are related to Pupils' misconceptions and errors in trigonometry. The articles used in this review were accessed from January 2011 to January 2021. Five databases were used to screen past study articles, namely Scopus, ERIC, Dimensions, Web of Science (WoS), and Google Scholar. The systematic literature review procedure included search strategies, selection criteria, selection process, data collection, and data analysis. A total of 26 articles were identified through set criteria such as year of publication and type of language. The study found articles that determine the misconceptions in trigonometry and ways to eliminate them. The findings also discovered that learning trigonometry using manipulative materials and digital form software could eliminate misconceptions. Therefore, further research is needed and more general keywords should be used to identify the appropriate methods in determining and eliminating misconceptions in learning trigonometric components.

Keywords: Misconceptions, error, trigonometry components, mathematical concepts, mathematical achievement

Introduction

From the cognitive point of view, students are already capable of thinking abstractly at the formal operation level, as highlighted by Piaget. At the same time, students should be able to think systematically to solve problems. Teachers also face problems related to a concept or skill in mathematics (Luneta & Giannakopoulos, 2019) where this lack of knowledge plays an important role in misconceptions (Ozkan & Ozkan, 2012). Many studies in the mathematics education field explain that misconceptions are like "snowballs" (Makonye & Luneta, 2014). This misconception will continue to occur to most students in more complex learning topics. Existing knowledge related to mathematical concepts that are not well mastered by students will give a negative impact on new learning topics. This is because each new learning topic will involve a variety of new mathematical concepts. Such misconceptions need to be identified by teachers immediately so that misconceptions can be reduced on the next topic (Rohani et al., 2014).

The teaching and learning process plays an important role in helping students to overcome misconceptions. Teachers need to have a variety of teaching strategies by focusing on the misconceptions faced by their students (Chua et al., 2016). This is because diverse teaching strategies in identifying misconceptions can result in sustained positive achievement as compared to teachers who adopt traditional teaching methods (Makonye & Luneta, 2014). Therefore, the systematic literature review (SLR) in this study should focus on helping students on identifying and eliminating misconceptions.

Materials and Methods

The study used the flow diagram of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) in the selection of articles related to determining the types of misconception and misconceptions elimination. Five databases were used in the screening of past study articles, namely Scopus, ERIC, Dimensions, Web of Science (WoS), Google Scholar. The systematic literature review procedure included search strategies, selection criteria, selection process, data collection, and data analysis of articles.

Article Search Strategy

Leading databases, namely Scopus, ERIC, Dimensions, WoS, and Google Scholar were used in searching articles for the SLRs conducted. The search began with identifying only English keywords that match the misconceptions. Misconception words that are synonymous with misconceptions such as concept errors and misunderstandings are also used in the search strings using the Boolean operator OR. The same method was also used for the keywords trigonometry and mathematics. The next step was using the Boolean operator

Corresponding Author e-mail: sitimistima@ukm.edu.my

https://orcid.org/0000-0002-5507-9081

How to cite this article: Hamzah N, Maat SM, Ikhsan Z, (2021). A Systematic Review on Pupils' Misconceptions and Errors in Trigonometry. Pegem Journal of Education and Instruction, Vol. 11, No. 4, 2021, 209-218

Source of support: Nil

Conflict of interest: None.

DOI: 10.47750/pegegog.11.04.20

Received: 30.06.2021

Accepted: 31.08.2021 **Publication:** 01.10.2021

AND to combine the three keywords, namely misconception, trigonometry, and mathematics to find related articles. The article search includes articles published from January 2011 to January 2021. Based on these keywords, the articles presented in the database were related to misconceptions for trigonometric components in mathematics learning. Table 1 shows the search methods performed using Boolean operators in each database and the number of articles found.

Article Selection Criteria

In order to obtain articles that meet the research criteria, the articles selected were set in terms of publication year, language, type of reference material and field of study. Table 2 shows the criteria for acceptance and rejection of articles. The criteria selected for the year of publication was within the latest 10 years from January 2011 to January 2021. The selection of articles was limited to 10 years because topics and current issues are still being discussed within the time frame. Next, all articles included in this study were articles in English from the selected databases. Selected articles were in English because the selected databases only publish articles in English. Meanwhile, the study conducted only used journal articles and excluded theses, proceedings, conferences, books, and research highlights in the selection of reference materials. Journal articles were used as a reference material in this study because they have complete and detailed reporting.

Article Selection Process

Figure 1 shows a flow diagram of the article selection process adapted from the PRISMA flow diagram (Tawfik et al., 2019). A total of 301 articles were identified from five databases in this study. Thereafter, the articles were screened using pre-defined criteria before entering the qualification stage for a more thorough and detailed screening.

Next, based on the accompanying article selection process flow diagram, there were four additional criteria for article exclusion before the SLR can finally be conducted. First, was articles that do not have full text. Second, was title of articles that does not fit the context of the study. Third, was similar articles from five databases, and fourth, was articles that do not meet the acceptance criteria of the study, such as articles that do not have empirical data and reviews. Meanwhile, for the additional acceptance criteria, the first was articles that have full text, the second was the title of the articles meets the context of the study, the third was the articles examined were appropriate to the study context and have no duplication. The final process included articles that meet the acceptance criteria, such as articles that have empirical data and were not in the form of reviews.

A search on databases such as WoS, Scopus, Dimensions, ERIC, and Google Scholar found a total of 29, 219, 10, 30, and 13 articles, respectively. The process of removing several identical articles that exist in the search volume was done whereby 110 duplicate articles were found. Duplication of articles occurred in terms of title name, author name, year, and similar content. The remaining number of articles after this process was only 191.

Subsequently, a total of 87 articles unrelated to the study were removed. The articles were removed since the information provided on the title and abstract was irrelevant to the research study. Unrelated articles on misconceptions that occurred in the topic of trigonometry learning were eliminated. A total of 104 articles remained for review at the next evaluation process.

A total of 26 relevant articles were found for thorough analysis after reading the articles' contents, namely the title, abstract, citation, method, study findings, and conclusion. Meanwhile, a total of 78 articles were excluded in this process, which included non-research articles, namely articles that

Table 1: The search string used for the systematic review process

Database	*Keywords used*	*Numbers of Articles Found*
SCOPUS	"misconception*" OR "error*" AND "trigonometry" AND "mathematics*" AND (LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012) OR LIMIT-TO (PUBYEAR,2011))	219
Web of Science (WOS)	TS=(("misconceptions" OR "error*") AND («trigonometry»))) AND LANGUAGE: (English) AND DOCUMENT TYPES:(Article) Indexes=SCI-XPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI Timespan=2011-2021	29
Dimensions	"misconception" OR "misconceptions" OR "errors" OR "error" AND "trigonometry" AND "mathematics" AND 2021 OR 2020 OR 2019 OR 2018 OR 2017 OR 2016 OR 2015 OR 2014 OR 2013 OR 2012 OR 2011 AND Article	10
ERIC	"misconception" OR "error" OR "errors" AND "trigonometry" since 2011	30
Google Scholar	allintitle: ("trigonometry") ("misconception" OR "misconceptions" OR "error" OR "errors")	13

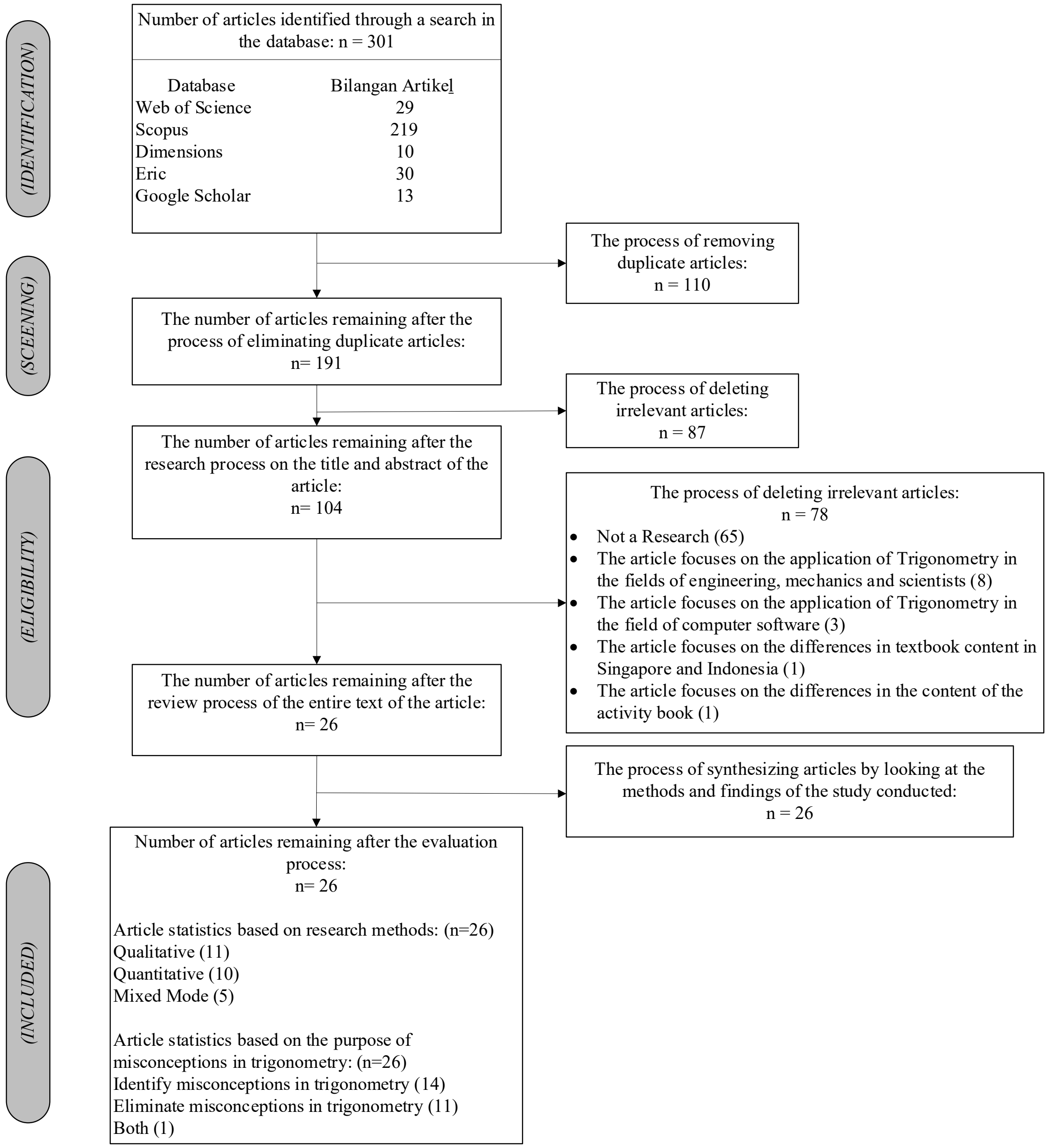

Figure 1: The PRISMA flow diagram of the study

Table 2: Criteria for acceptance and rejection of articles

Criteria	*Acceptance*	*Rejection*
Year of Publication	Publications from January 2011 to January 2021	Publication before January 2011.
Language	English Language	Malay Language, Indonesian Language and others language
Type of Reference Material	Journal Articles	Theses, Proceedings, Conferences, Books
Field of Study in Journal Articles	Trigonometry in mathematics learning	Apart from trigonometry in mathematics learning

focused only on the application of trigonometry in the fields of engineering, mechanics, scientists, and computer software; articles that only compared trigonometry topics in textbooks; and articles that focused on differences in activity book content.

The elimination of articles was done by examining the content on the reliability of each instrument conducted on the pilot study, data collection methods, and study findings. The remaining articles in this final evaluation process are only 26 articles. Based on Figure 1, the qualitative method was implemented in 11 articles, whereas the quantitative method was implemented in 10 articles. The mixed-mode research method was used in five remaining articles. In addition, the article analysis statistics show that 14 articles are related to determining misconceptions. Meanwhile, the remaining 11 articles are related to eliminating misconceptions. The PRISMA flow diagram also shows that only one article was chosen to identify and to eliminate misconceptions in trigonometry components.

The number of studies in determining the misconceptions that occur is higher than the studies in eliminating misconceptions. This is because the process of determining the misconceptions plays an important role in obtaining information related to conceptual knowledge and procedural skills that are available among students (Law et al. 2015). Since the misconceptions that occur are a challenge to students, thus a few steps to determine the misconceptions need to be done by teachers at the beginning stage of learning (Luneta & Giannakopoulos, 2019; Veloo et al., 2015).Therefore, after undergoing screening and research on the articles that have been downloaded, 26 articles were identified. A total of 26 articles have met all the selection criteria and were included in the SLR study conducted.

Data Collection And Data Analysis

Data collection was conducted using 30 articles obtained from five leading databases, namely WoS, Scopus, Dimensions, ERIC, and Google Scholar. The data were collected by extracting the title, author name, year, purpose of the study, and misconceptions in learning trigonometry for each previous study article into a table constructed. Data analysis was conducted using the constructed table and by categorising the misconceptions in learning trigonometry used by each article. Furthermore, the results of the data analysis conducted will be presented in the form of tables and bar graphs. Table 3 shows the list of past study articles along with the name of the author used in the study conducted. All selected articles were based on pre-determined acceptance and rejection criteria. Based on the data analysis of the SLR studies conducted, the most frequent misconceptions in learning trigonometry will be used to form the conceptual framework for the research. The conceptual framework constructed can be used as a reference and to contribute to the literature section of the study in the future. Table 3 shows an analysis of studies on misconceptions in trigonometry. A total of 11, 10, and 5 articles, respectively were articles conducted through quantitative, qualitative, and mixed methods. Of the total of 26 articles, 14, 11, and 1 articles were conducted, respectively with the aim of determining the type of misconception, eliminating misconception, and with both purposes.

Findings and Discussion of The Study

The main objective of the SLR study is to identify the types of misconceptions that involve trigonometric components. The second objective is to identify methods, strategies or techniques used to eliminate misconceptions in the trigonometric component. In addition, the study also developed a conceptual framework based on the most frequently used methods in determining misconceptions by past researchers.

Determining Misconceptions

A total of 11 articles from the SLR used tests in determining misconceptions. Three of the articles used diagnostic tests in determining misconceptions found among students (Ahmad et al., 2018; Andika et al., 2017; Mensah, 2017). In addition, there are 13 articles from the literature review highlights that showed past researchers conducting interviews in determining misconceptions. The interviews conducted were aimed at determining the types of errors and misconceptions involved when solving problems related to trigonometry (Mensah, 2017). Next, there are seven articles from the SLR that used observational methods in determining the types of

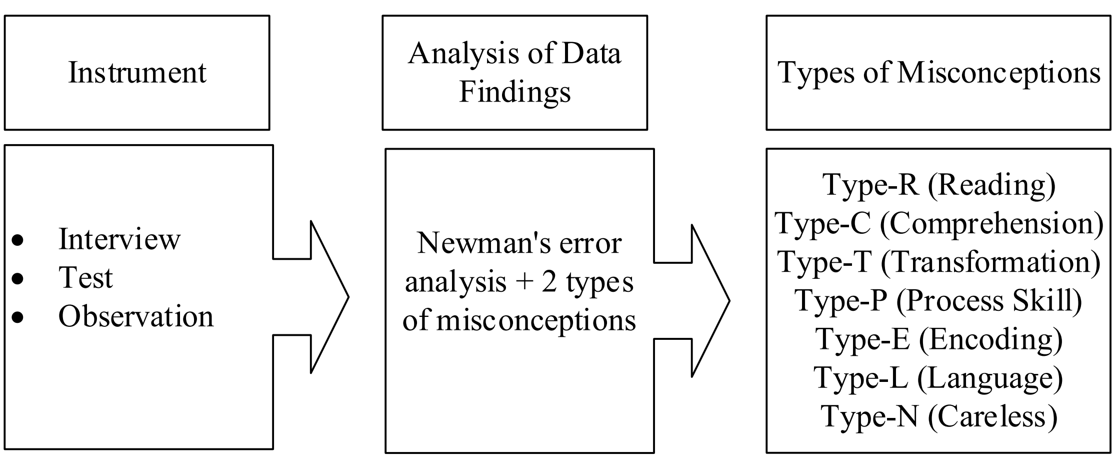

Figure 2: The conceptual framework in determining types of misconceptions

Table 3: An analysis of studies on misconceptions in trigonometry (n=26)

No.	*Authors / Years*	*Title*	*QN*	*QL*	*MM*	*D*	*E*
1.	(Ulyani & Qohar, 2021)	Development of manipulative media to improve students' motivation and learning outcomes on the trigonometry topic	√				√
2.	(Nanmumpuni & Retnawati, 2021)	Analysis of Senior High School Student's Difficulty in Resolving Trigonometry Conceptual Problems			√	√	
3.	(Ngu & Phan, 2020) mathematics is considered as being "pure theoretical" (Becher, 1987	Learning to Solve Trigonometry Problems That Involve Algebraic Transformation Skills via Learning by Analogy and Learning by Comparison		√			√
4.	(Hadi & Faradillah, 2020)	Application of Discovery Learning Method in Mathematical Proof of Students in Trigonometry.	√				√
5.	(Hidayati, 2020)	Analysis of Student Errors in Solving Trigonometry Problems		√		√	
6.	(Prabowo et al., 2019)	Field-independence versus field-dependence: A serious game on trigonometry learning	√				√
7.	(Sari & Wutsqa, 2019)	Analysis of student's error in resolving the Pythagoras problems	√			√	
8.	(Aminudin et al., 2019)	Engaging problems on trigonometry: Why were student hard to think critically?		√		√	
9.	(Maknun et al., 2019)	From ratios of right triangle to unit circle: An introduction to trigonometric functions		√		√	
10.	(Fahrudin et al., 2019)	Profile of students' errors in trigonometry equations.			√	√	
11.	(Bernard et al., 2019)	Development of high school student work sheets using VBA for microsoft word trigonometry materials	√				√
12.	(Ahmad et al., 2018)	The Analysis of Student Error in Solve the Problem of Spherical Trigonometry Application		√		√	
13.	(Prabowo et al., 2018)	Interactive Multimedia-based Teaching Material for Trigonometry.	√				√
14.	(Nabie et al., 2018)94 males	Trigonometric Concepts : Pre-Service Teachers	√			√	
15.	(Dewanto et al., 2018)	Studentsr Error Analysis in Solving The Math Word Problems of High Order Thinking Skills (HOTS) Type on Trigonometry Application		√		√	
16.	(Usman & Hussaini, 2017)	Analysis of Students' Error in Learning of Trigonometry Among Senior Secondary School Students in Zaria Metropolis, Nigeria		√		√	
17.	(Andika et al., 2017)	Analysing Diagnostic Assessment on the Ratio of Sine in a Right Triangle			√	√	
No.	Authors / Years	Title	QN	QL	MM	D	E
18.	(Mensah, 2017)	Ghanaian Senior High School Students' Error in Learning of Trigonometry.		√		√	
19.	(Karthikeyan, 2017)	Trigonometry Learning For the School Students in Mathematics		√		√	
20.	(Centillas & Larisma, 2016)	Error Analysis of Trigonometry Students in a Technological University			√	√	√
21.	(May & Courtney, 2016)	Developing meaning in trigonometry	√				√
22.	(Ibrahim & llyas, 2016)	Teaching a concept with GeoGebra: Periodicity of trigonometric functions	√				√
23.	(Jorda & De los Santos, 2015)	Effect of computer game-based learning on the performance in trigonometry of the ESEP high school students			√		√
24.	(Siyepu, 2015)	Analysis of errors in derivatives of trigonometric functions		√		√	
25.	(Yusha'u, 2013a)	Difficult Topics in Junior Secondary School Mathematics : Practical Aspect of Teaching and Learning Trigonometry		√			√
26.	(Tuna & Kacar, 2013)	The effect of 5E learning cycle model in teaching trigonometry on students' academic achievement and the permanence of their knowledge.	√				√

misconceptions found in the learning of trigonometry. The findings of the literature review found that an article was conducted observationally on students' results in trigonometry (Nanmumpuni & Retnawati, 2021). Furthermore, there are five studies conducted through observation on students during the teaching and learning process related to trigonometry (Andika et al., 2017; Dewanto et al., 2018; Karthikeyan, 2017; Maknun et al., 2019; Nanmumpuni & Retnawati, 2021); and observations of students' working solution related to trigonometry (Fahrudin et al., 2019).

Six researchers used Newman's error analysis method in determining the types of misconceptions and errors of students in the topic of trigonometry (Ahmad et al., 2018; Centillas & Larisma, 2016; Fahrudin et al., 2019; Mensah, 2017; Sari & Wutsqa, 2019; Usman & Hussaini, 2017). This Newman error analysis method has become a frequent choice of researchers in the last five years through the SLR. Usman and Hussaini (2017) used the Newman Error Hierarchy Model in determining the misconceptions that occurred among students. The findings showed that students often made mistakes at the transformation and process skills levels. A total of 83% of 508 students made mistakes in solving trigonometry questions involving right-angled triangles, while 85% of 556 students made mistakes in solving trigonometry questions involving the use of formulas. Table 4 shows an analysis of studies on determining misconceptions in trigonometry.

Based on the study of Dewanto et al. (2018), three types of misconceptions and errors were found, namely (Error Type-I) difficulty in understanding the problem statement, (Error Type-II) difficulty in applying the concept of trigonometry, and (Error Type-III) difficulty in calculations. Type-I error often occurs in studies where students have difficulty in giving an accurate interpretation of the problem to be solved. The Type-II error in the study occurs when students fail to select the correct trigonometric formula using either the sin law or the cosine law. Failure to use the correct trigonometric formula indicates that students are still weak in mastering the concept of trigonometry. Next, Type-III errors in the study were detected when students showed computational errors in determining the 60° inclination angle which also affected the 30° angle value.

Table 4: An analysis of studies on determining misconceptions in trigonometry

Authors / Years	*Interview*	*Test*	*Observation*
(Nanmumpuni & Retnawati, 2021)	√	√	√
(Hidayati, 2020)		√	√
(Sari & Wutsqa, 2019)		√	
(Maknun et al., 2019)	√		√
(Fahrudin et al., 2019)	√	√	√
(Aminudin et al., 2019)	√	√	
(Ahmad et al., 2018)	√	√	
(Nabie et al., 2018)94 males	√		
(Dewanto et al., 2018)	√	√	√
(Usman & Hussaini, 2017)	√	√	
(Andika et al., 2017)	√	√	√
(Mensah, 2017)	√	√	
(Karthikeyan, 2017)	√	√	√
(Centillas & Larisma, 2016)	√		
(Siyepu, 2015	√		

Sari and Wutsqa (2019) listed seven types of misconceptions and errors in trigonometry learning. The types of misconceptions and errors are Type-R, Type-C, Type-T, Type-P, Type-E, Type-L, and Type-N. Type-R occurs when students do not know the meaning or terminology found in the question. Type-C, on the other hand, refers to students' misunderstanding of the intent of the question. For this type of error, students fail to write what is there and what is being questioned in the problem-solving question. Meanwhile, Type-T refers to students' mistakes in applying the correct trigonometric formula or using the wrong strategy while solving trigonometry questions. Type-P errors occur when students do not perform calculations algorithmically. Type-E error refers to a student's error in giving an accurate justification based on the intent of the question. Students who failed to understand the intent of the question primarily involving the use of English were categorised as Type-L errors. Type-N errors refer to unintentional errors. These seven types of misconceptions and errors often occur among students when studying trigonometry.

In other studies, Karthikeyan (2017) categorised three types of misconceptions. The first type of misconception in the study refers to misconceptions related to concepts that produce mathematical objects and symbols. Sin x is a concept and symbol in trigonometry. The second type of misconception refers to misconceptions related to a process or operation. For example, the calculation operation for Sin 30° is different from the operation to obtain the value for Sin 30°. The third misconception refers to a combination of processes and concepts or the ability to think of mathematical operations and objects. For example, Sin x is also known as a function and a value.

Figure 2 shows the conceptual framework in determining types of misconceptions. The conceptual framework shows the instruments that can be used in determining the types of misconceptions. Among the instruments that can be used are tests, observations, and interviews. Newman's error analysis was selected by adding two types of errors, as suggested by Sari and Wutsqa (2019). The seven types of errors that can be seen during the findings analysis process are Type-R (Reading), Type-C (Comprehension), Type-T (Transformation), Type-P (Process Skill), Type-E (Encoding), Type-L (Language), and Type-N (Careless).

Eliminating Misconceptions

Various techniques and strategies can be used as interventions in teaching activities in order to eliminate misconceptions of trigonometry that often occur among students (Yasin, 2017). Tuna and Kaçar (2013) used a constructivism model by involving the 5E phase cycle, as shown in Figure 3. Phase 5E refers to engagement, exploration, explanation, elaboration, and evaluation. Several studies using this 5E phase cycle have successfully improved learning-related capabilities and application of concepts as well as improved students' understanding and achievement (Çepni & Şahin, 2012). There are also studies that used the 5E model showing changes in student behaviour and reinforcement of student understanding in trigonometry (Tezer & Cumhur, 2017). A quasi-experimental study involving two study groups found significant differences of which students in the experimental group who used the 5E learning model with the constructivism approach showed an increase in the post-test scores as compared to students in the control group (Tuna & Kaçar, 2013).

During the teaching and learning process, mathematics teachers need to allow students to explore and gather information related to the concept of trigonometry. Teachers should also ask students to justify the answers obtained as they solve trigonometry-related questions. In addition, common misconceptions and mistakes made can be self-identified by students when solving questions involving the application of trigonometry. A student-centred constructivism approach needs to be implemented as an effort to help students to improve their understanding of the learning topic of trigonometry (Tuna & Kacar, 2013).

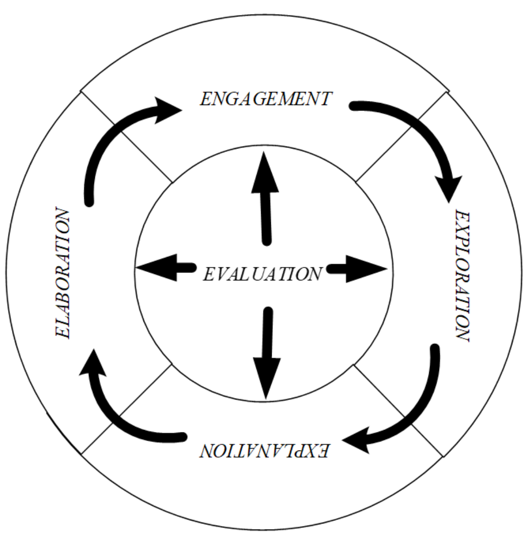

Figure 3. 5E Learning Model
Source: Tuna & Kaçar (2013)

May and Courtney (2016) designed four activities for four-day periods to achieve the desired objectives after the teaching session is implemented. The first activity carried out is an activity to help students in relating the concept of trigonometry with the concept of algebra. The second activity carried out is to understand how a mathematical process or idea is developed. Third, May and Courtney (2016) have implemented activities aimed at understanding the basic principles and features of mathematics logically. This step is important because mathematical concepts are developed in the right way rather than assumptions. The fourth activity is the most important activity where students collaborate in solving questions that involve high-level thinking skills. In addition, through this activity, teachers can encourage brainstorming among students. The activities designed by May and Courtney (2016) are briefly described in Table 5.)

Ulyani and Qohar (2021), in their study found that the use of manipulative materials in the teaching of trigonometry can improve students' understanding of trigonometry. Among the manipulative tools used in constructing manipulative materials were scissors, glue, cardboard, and markers. The manipulative materials constructed by the students in their study were the rotation of a circle, three types of trigonometric triangles, and a comparison of sine, cos, and tan. The findings of the study showed a positive result was obtained. Among them, students gave a positive response in each aspect assessed. Furthermore, learning by using manipulative tools can improve the quality of learning outcomes. Ulyani and Qohar (2021) explained that learning through manipulative materials can make the learning of trigonometry easier to understand.

Moreover learning by incorporating elements of play is able to improve students' understanding in trigonometry (Bernard et al., 2019; Ibrahim & llyas, 2016; Jorda & Santos, 2015; Prabowo et al., 2018,2019; Yusha'u, 2013). Prabowo et al. (2018) have built a trigonometry learning application that incorporates various technological elements, such as audio, image, animation, and video. This android-game

Table 5: An analysis of studies on determining misconceptions in trigonometry

Teaching Components	*Teaching Description*	*Time*
Activity 1	Complete the data	First day
Activities 2A & 2B	Basic Identities of Trigonometry	Second Day
Activity 3	Making Relationships in Trigonometry	Third Day
Activity 4	Determining Equations for Trigonometric Functions	Forth day

Source: May & Courtney (2016)

Table 6: Interventions used by researchers on eliminating misconceptions in trigonometry

Interventions Subjects	*Authors / Years*
Using 5E Learning Models	(Tuna & Kacar, 2013
Using Learning Media / Manipulative Materials/Digital Games	(Ulyani & Qohar, 2021) (Prabowo et al., 2018) (Prabowo et al., 2019) (Ibrahim & llyas, 2016) (Bernard et al., 2019) (Jorda & De los Santos, 2015) (Yusha'u, 2013
Discovery or Mastery Learning	(Ngu & Phan, 2020) (Hadi & Faradillah, 2020)

application can increase the understanding of trigonometry among students as well as help teachers as a learning aid in the teaching process involving trigonometry components. A study by Jorda and Santos (2015) using game-based learning showed that the level of student performance increased in mastering some concepts of trigonometry. This is because the thinking in a game and the game-based learning involving trigonometry are similar in the use of words, pictures, and similarities in managing tasks. A quasi-experimental study conducted by Ibrahim and Ilyas (2016) showed that learning using GeoGebra in the experimental group was able to improve students' understanding in trigonometry as compared to the control group using traditional methods.

In order to develop students' understanding in learning trigonometry, Ngu and Phan (2020)mathematics is considered as being "pure theoretical" (Becher, 1987 suggested that teachers use two different methods in the process of teaching trigonometry. Learning by analogy and learning by comparison are two methods that can improve students' understanding of trigonometry. This is because students are often confused in solving algebra expression problems where the solution is the same as in solving arithmetic problems. Therefore, teachers must always be relevant in ensuring that students' misconceptions in trigonometry can be eliminated immediately.

Table 6 shows the interventions used by researchers in their study as an effort to improve students' understanding and to eliminate misconceptions in trigonometry. The seven studies used manipulative materials and learning aids in the teaching process involving trigonometry (Bernard et al., 2019; Ibrahim & llyas, 2016; Jorda & Santos, 2015; Prabowo et al., 2018;2019; Yusha'u, 2013)). Only one study used 5E learning strategies (Tuna & Kacar, 2013), while two studies were conducted with discovery or mastery learning (Hadi & Faradillah, 2020; Ngu & Phan, 2020).

Therefore, learning trigonometry using manipulative materials and digital form software can eliminate misconceptions. This is because through digital games, a lot of practices and quick feedbacks can be obtained from students. Therefore, learning using digital games can increase the level of understanding of students as well as reduce misconceptions that occur among students. The use of technology-rich educational resources becomes one of the features of interventions that researchers can undertake with the aim of eliminating misconceptions.

The SLR study conducted can be improved so that the study findings obtained are more accurate and detailed. Furthermore, systematic research and examination should be conducted to study the best methods in determining the types of misconceptions and interventions in eliminating student misconceptions in trigonometry that have not been explored through SLR studies. This is so because if there are other effective methods, the conceptual framework developed needs to be changed and refined based on the latest research findings. Therefore, based on the improvements carried out, the results of future studies will be more robust and will contribute to the methods of determining the types of misconceptions and interventions in eliminating misconceptions in trigonometry during the PdP process.

Conclusion

The SLR study conducted involved five leading databases, namely Scopus, ERIC, Dimensions, WoS, and Google Scholar. Based on the databases used, a total of 26 articles have been identified that met the selection criteria. The articles obtained were categorised according to the purpose of the misconception either to determine the misconception or to eliminate the misconception. The results of the analysis conducted showed that the articles to determine misconceptions exceeded the articles to eliminate misconceptions in trigonometry. Moreover, six researchers used Newman's error analysis method in determining the types of misconceptions and errors made by students in the topic of trigonometry. Then, the conceptual framework developed includes the instruments, analysis of data findings, and types of misconceptions. Interventions used by researchers in eliminating misconceptions in trigonometry can also be determined by the use of manipulative materials and games which has become one of the intervention options in eliminating misconceptions. Therefore, in future studies, researchers can use more general keywords to identify appropriate methods in determining and eliminating misconceptions in learning involving trigonometric components. Therefore, learning trigonometry using manipulative materials and digital form software can eliminate misconceptions. This is because through digital games, a lot of practices and quick feedbacks can be obtained from students. Therefore, learning using digital games can increase the level of students' understanding as well as reduce misconceptions that occur among students. The use of technology-rich educational resources becomes one of the features of interventions that researchers can undertake with the aim of eliminating misconceptions.

Acknowledgement

This research was funded by the Faculty of Education, Universiti Kebangsaan Malaysia, GG-2020-016

References

Ahmad, H., Febryanti, F., Muthmainnah, M., Yakin, A. Al & Sarbi, S. 2018. The Analysis of Student Error in Solve the Problem of Spherical Trigonometry Application. *Journal of Physics: Conference Series* 1114(1). doi:10.1088/1742-6596/1114/1/012114

Aminudin, M., Nusantara, T., Parta, I. N., Rahardjo, S., As'Ari, A. R. & Subanji. 2019. Engaging problems on trigonometry: Why were student hard to think critically? *Journal of Physics: Conference Series* 1188(1). doi:10.1088/1742-6596/1188/1/012038

Andika, R., Juandi, D. & Rosjanuardi, R. 2017. Analysing Diagnostic Assessment on the Ratio of Sine in a Right Triangle. *Journal of Physics: Conference Series* 895(1). doi:10.1088/1742-6596/895/1/012095

Bernard, M., Sumarna, A., Rolina, R. & Akbar, P. 2019. Development of high school student work sheets using VBA for microsoft word trigonometry materials. *Journal of Physics: Conference Series* 1315(1). doi:10.1088/1742-6596/1315/1/012031

Centillas Jr., C. L. & Larisma, C. C. M. 2016. Error Analysis of Trigonometry Students in a Technological University. *JPAIR Institutional Research* 7(1): 56–66. doi:10.7719/irj.v7i1.372

Çepni, S. & Şahin, Ç. 2012. Effect of Different Teaching Methods and Techniques Embedded in the 5E Instructional Model on Students ' Learning about Buoyancy Force. *Eurasian Journal of Physics and Chemistry Education* 4(2): 97–127.

Chua, G. L. L., Shahrill, M. & Tan, A. 2016. Common misconceptions of algebraic problems: Identifying trends and proposing possible remedial measures. *Advanced Science Letters* 22(5–6): 1547–1550. doi:10.1166/asl.2016.6675

Dewanto, M. D., Budiyono, B. & Pratiwi, H. 2018. Studentsr Error Analysis in Solving The Math Word Problems of High Order Thinking Skills (HOTS) Type on Trigonometry Application. *Atlantis Press*. 218(ICoMSE 2017): 195–200. doi:10.2991/icomse-17.2018.34

Fahrudin, D., Mardiyana & Pramudya, I. 2019. Profile of students' errors in trigonometry equations. *Journal of Physics: Conference Series* 1188(1). doi:10.1088/1742-6596/1188/1/012044

Hadi, W. & Faradillah, A. 2020. Application of Discovery Learning Method in Mathematical Proof of Students in Trigonometry. *Desimal: Jurnal Matematika* 3(1): 73–82. doi:10.24042/djm.v3i1.5713

Hidayati, U. 2020. Analysis of Student Errors in Solving Trigonometry Problems. *Journal of Mathematics Education* 5(1): 54–60.

Ibrahim, K. & llyas, Y. 2016. Teaching a concept with GeoGebra: Periodicity of trigonometric functions*. *Educational Research and Reviews* 11(8): 573–581. doi:10.5897/err2016.2701

Jorda, E. R. & De los Santos, O. C. 2015. Effect of computer game-based learning on the performance in trigonometry of the ESEP high school students. *Technological University of the Philippines* 1–9. Retrieved from http://www.makeuseof.com/tag/5-reasons-

Karthikeyan, R. 2017. Trigonometry Learning For the School Students in Mathematics. *Iconic Research and Engineering Journals* 1(5): 44–49.

Law, F. F., Shahrill, M. & Mundia, L. 2015. Investigating students' conceptual knowledge and procedural skills in the learning of college level trigonometry. *Research Journal of Applied Sciences, Engineering and Technology* 9(11): 952–962. doi:10.19026/rjaset.9.2588

Luneta, K. & Giannakopoulos, P. 2019. Problem Solving In Mathematics: Use of Teaching and Learning Theories versus the Psychology of Teaching and Learning Mathematics. *ATINER's Conference Paper Proceedings Series* MAT2019-01: 1–15.

Maknun, C. L., Rosjanuardi, R. & Jupri, A. 2019. From ratios of right triangle to unit circle: An introduction to trigonometric functions. *Journal of Physics: Conference Series* 1157(2). doi:10.1088/1742-6596/1157/2/022124

Makonye, J. P. & Luneta, K. 2014. Mathematical errors in differential calculus tasks in the Senior School Certificate Examinations in South Africa. *Education as Change* 18(1): 119–136. doi:10.1080/16823206.2013.847014

May, V. & Courtney, S. 2016. Developing meaning in trigonometry. *Illinois Mathematics Teacher* 63(1): 25–33.

May, Valerie & Courtney, S. 2016. Developing Meaning in Trigonometry. *Illinois Mathematics Teacher* 25–33.

Mensah, F. S. 2017. Ghanaian senior high school students ' error in learning of trigonometry ghanaian senior high school students ' rrror in learning of trigonometry. *International Journal of Environmental & Science Education* 12(8): 1709–1717.

Mensah, F. S. 2017. Ghanaian Senior High School Students' Error in Learning of Trigonometry. *International Journal Of Environmental & Science Education* 12(8): 1709–1717.

Nabie, M. J., Akayuure, P., Ibrahim-bariham, U. A. & Sofo, S. 2018. Trigonometric Concepts : Pre-Service Teachers '. *Journal on Mathematics Education* 9(2): 169–182.

Nanmumpuni, H. P. & Retnawati, H. 2021. Analysis of Senior High School Student's Difficulty in Resolving Trigonometry Conceptual Problems. *Journal of Physics: Conference Series* 1776(1). doi:10.1088/1742-6596/1776/1/012012

Ngu, B. H. & Phan, H. P. 2020. Learning to Solve Trigonometry Problems That Involve Algebraic Transformation Skills via Learning by Analogy and Learning by Comparison. *Frontiers in Psychology* 11(September): 1–11. doi:10.3389/fpsyg.2020.558773

Ozkan, E. M. & Ozkan, A. 2012. Misconception in exponential numbers in IST and IIND level primary school mathematics. *Procedia - Social and Behavioral Sciences* 46(2012): 65–69.

Prabowo, A., Anggoro, R. P., Adiyanto, R. & Rahmawati, U. 2018. Interactive Multimedia-based Teaching Material for Trigonometry. *Journal of Physics: Conference Series* 1097(1). doi:10.1088/1742-6596/1097/1/012138

Prabowo, A., Usodo, B. & Pambudi, I. 2019. Field-independence versus field-dependence: A serious game on trigonometry learning. *Journal of Physics: Conference Series* 1188(1). doi:10.1088/1742-6596/1188/1/012100

Rohani, A. W., Riyan, H. & Effandi, Z. 2014. Analisis kesilapan dalam pembelajaran pengamiran. *Jurnal Pendidikan Matematik* 2(2): 14–30.

Sari, R. H. Y. & Wutsqa, D. U. 2019. Analysis of student's error in resolving the Pythagoras problems. *Journal of Physics: Conference Series* 1320(1). doi:10.1088/1742-6596/1320/1/012056

Siyepu, S. W. 2015. Analysis of errors in derivatives of trigonometric functions. *International Journal of STEM Education* 2(1). doi:10.1186/s40594-015-0029-5

Tawfik, G. M., Dila, K. A. S., Mohamed, M. Y. F., Tam, D. N. H., Kien, N. D., Ahmed, A. M. & Huy, N. T. 2019. A step by step guide for conducting a systematic review and meta-analysis with simulation data. *Tropical Medicine and Health* 47(1): 1–9. doi:10.1186/s41182-019-0165-6

Tezer, M. & Cumhur, M. 2017. Mathematics through the 5E instructional model and mathematical modelling: The geometrical objects. *Eurasia Journal of Mathematics, Science and Technology Education* 13(8): 4789–4804. doi:10.12973/eurasia.2017.00965a

Tuna, A. & Kacar, A. 2013. The effect of 5E learning cycle model in teaching trigonometry on students' academic achievement and the permanence of their knowledge. *International Journal on New Trends in Education and Their Implications* 4(1): 73–87.

Ulyani, O. & Qohar, A. 2021. Development of manipulative media to improve students' motivation and learning outcomes on the trigonometry topic. *AIP Conference Proceedings* 2330(March). doi:10.1063/5.0043142

Usman, M. H. & Hussaini, M. M. 2017. Analysis of Students' Error in Learning of Trigonometry Among Senior Secondary School Students in Zaria Metropolis, Nigeria. *IOSR Journal of Mathematics* 13(02): 01–04. doi:10.9790/5728-1302040104

Veloo, A., Krishnasamy, H. N. & Wan Abdullah, W. S. 2015. Types of student errors in mathematical symbols, graphs and problem-solving. *Asian Social Science* 11(15): 324–334. doi:10.5539/ass.v11n15p324

Yasin, A. 2017. a Review of Research on the Misconceptions in Mathematics Education. *Education Research Highlights in Mathematics, Science and Technology* (2017): 21–31.

Yusha'u, M. A. 2013. Difficult Topics in Junior Secondary School Mathematics : Practical Aspect of Teaching and Learning Trigonometry. *Scientific Journal of Pure and Applied Science* 2: 161–174.