# *Augmented Reality-based Mathematics Worksheet for Online Learning During Covid-19 Pandemic*

**Soma Salim S[1], Fitrah A. Darmawan[2], Jainuddin[3]**
Mathematics Education Department, Universitas Bosowa[1,3]
Mechatronics Education Department, Universitas Negeri[2] Makassar[2]

Email: soma@universitasbosowa.ac.id[1]

**Abstract.** The aim of this study is to create and develop an augmented reality-based mathematics worksheet that can be used for online learning during covid-19 pandemic. The application created has been tested using three out of eight characteristics of ISO 25010 quality standards, which are functional suitability, compatibility, and usability. The results show that the augmented reality-based mathematics worksheet has a very high quality. Further explanations regarding the application and its implications are discussed.

**Keywords:** *Mathematics Worksheet, Augmented Reality, Online Learning, Covid-19 Pandemic*

**INDONESIAN JOURNAL OF EDUCATIONAL STUDIES (IJES)**

**E-ISSN: 2621-6744**
**P-ISSN: 2621-6736**

**Submitted** : 28th September 2020
**Revised** : 2nd November 2020
**Accepted** : 21st December 2020

## INTRODUCTION

The worldwide spreading of the coronavirus disease 2019 (covid-19) has caused changes in humans activities. In Indonesia, the first covid-19 case was in the beginning of March 2020 precisely in Jakarta where two Indonesian citizens were confirmed positive. After that, the number of covid-19 cases continuously increases so that the ministry of education had instructed to close schools and students can only study from home. This pandemic gives a rise to a more innovative online learning that teachers should implement into their virtual classrooms.

There are several methods that teachers use during virtual learning. They might either use video conference or upload learning materials through education websites/platforms. Video conferencing requires a stable internet connection (otherwise it will not run smoothly) as it is done synchronously where students watch their teachers teaching on the screen directly. On the other hand, if teachers upload learning materials (e-books, videos, and/or texts) on the internet, the students could download them and study whenever they are ready.

In some parts of Indonesia, the internet connection is not stable, which is why some teachers prefer the second method. Besides, it saves their internet data because this method allows them to upload only small-sized files. However, they ought to create learning materials that are interesting so that the students could understand the subject they are studying. For this reason, this research aims to create and develop an augmented reality-based mathematics worksheet as one of alternative learning materials during covid-19 pandemic.

### Augmented Reality

There are a number of studies conducted about augmented reality application to support learning process, which can affect both the educational settings and the students as well (Chen et al, 2017). In mathematics, for example, augmented reality technology is often used to explain geometry both two dimensional objects and three dimensional objects beacause this subject needs visualisation to help students understanding the concept (İbili et al, 2020). There have been many android applications related to geometry that can be accessed in smartphones. However, research about the use of augmented reality to explain or to assist students to solve algebra word problems is still limited (Ibáñez and Delgado-Kloos, 2018). Since visualisation is also essential for students to understand the situations in algebra word problems, hence augmented reality could possibly be helpful for students as well.

Before creating the augmented reality application, it is important to figure out how students understand a mathematical concept. There are three levels of students' understanding based on arbitrary and necessary things in mathematics (Salim, 2019; Hewitt, 2001):

*Level 1*

Students memorise arbitrary mathematics yet not become aware of necessary mathematics. At this level, students remember the mathematical terms and names, but they need further help to assist them understanding what is

necessary. Hence, the augmented reality should be designed to guide students solving algebra word problems.

*Level 2*

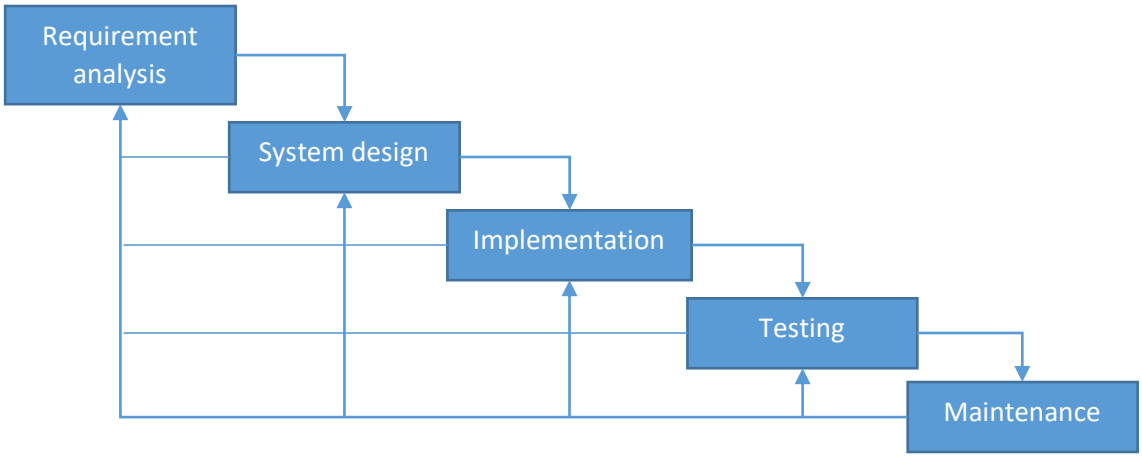
Students in this level also remember what is arbitrary in mathematics and they are already aware of the necessary things. However, when they are given questions that are different from what they used to solve, they sometimes get confused and cannot find the correct answers. The reason is that the students might understand the mathematical concept instrumentally, not relationally (Skemp, 2006).

*Level 3*

The highest level is when students memorise what is arbitrary and become aware of what is necessary. This is point where teachers should lead their students' understanding to be. To reach this level, visual representations such as augmented reality program play a pivotal role to help the students become aware of a mathematical concept.

**RESEARCH METHOD**

This research is a development study that aims to create and develop an android application that is augmented reality-based for mathematics worksheet. The development system used is waterfall model consisting of five stages: requirement analysis, system design, implementation, testing, and maintenance (Buchori, 2017).




*Picture 1. Waterfall Model Process*

First of all, this study analyses literatures that are related to the subject, which is agebra. Moreover, students' difficulties related to this subject were explored through online observation and interview to ensure that the worksheet can help them studying with the absence of their teachers. After analysing all of the requirements, the next stage is designing the system in order to breakdown all features needed in the software application. This process is essential to connect the users' needs and the activities in the system. When the system has been designed, the next stage is the implementation which means the process of creating and developing the application using marked-based tracking method. This method is

selected because it is better than the other method, which is markerless-based tracking.

The next step is testing the application so as to verify and validate the system. This process aims to figure out the errors that might occur when using the application. The test used ISO 25010 quality standards consisting of eight quality characteristics: functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability because it has been proven sufficient for software quality assessment (Hovorushchenko, 2018). However, this research only examined three important characteristics, which are functional suitability, compatibility, and usability. Functional suitability consists of three indicators: functional completeness, functional correctness, and functional appropriateness, while the indicators of compatibility include co-existance and interoperability. Moreover, compatibility has four testing indicators, which are appropriateness recognisability, learnability, operability, and accessibility. Furthermore, questionnaires were made based on the indicators of each characteristic. Finally, the testing score are categorised as shown in Table 1.

*Table 1. Testing Score Categorisation*

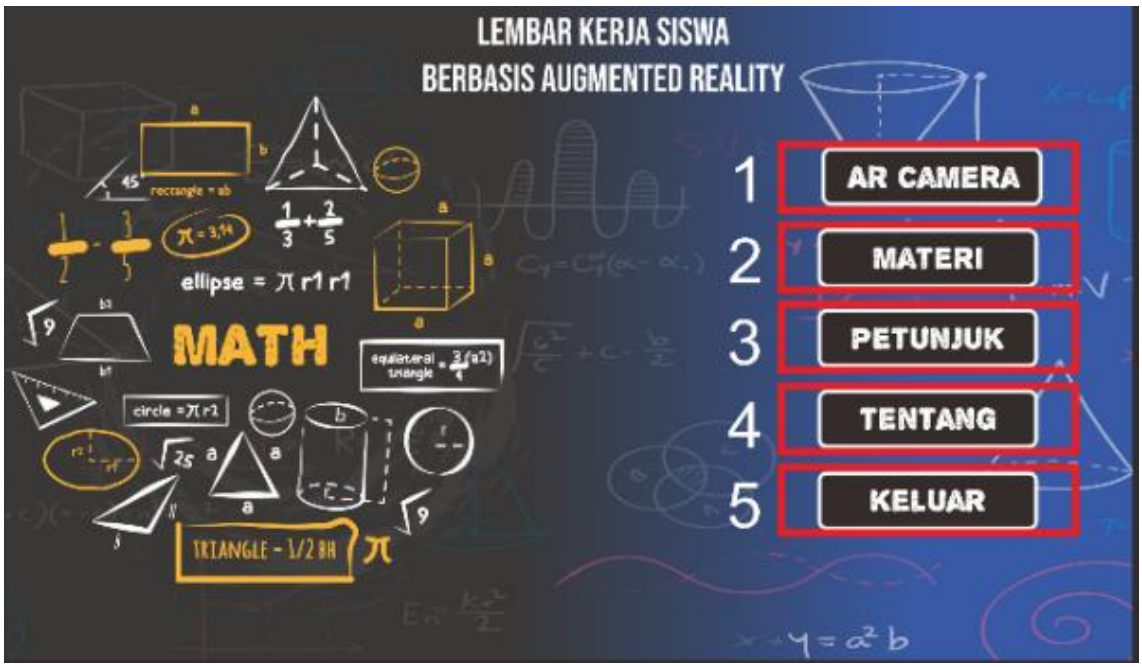
| No. | Score (%) | Categories |
|---|---|---|
| **1** | 0-21 | Very Low |
| **2** | 21-40 | Low |
| **3** | 41-60 | Medium |
| **4** | 61-80 | High |
| **5** | 81-100 | Very High |

The last stage of the waterfall model is maintenance, including installation process. The maintenance process aims to fix previously unidentified errors and small bugs that might occur in the future, or to develop additional features for future development based on users' feedbacks. Besides, the system development is required when there are some external factors related to the learning process or the advanced development of augmented reality technology.

## RESULT AND DISCUSSION

The final product of this research is an augmented reality-based mathematics worksheet focusing in algebra for year 7 students (secondary school students). The worksheet is printed whereas the augmented reality application for android smartphones is constructed using unity 3D, vuforia, adobe premiere, and blender. The application has five features: AR Camera, material (*materi*), manual (*petunjuk*), about (*tentang*) and exit (*keluar*) as shown in the Picture 2. Augmented Reality Camera is used to scan images provided in the mathematics worksheets (see Picture 3). The augmented reality three-dimensional animations appear on the smartphone screen followed by voice explaining how to solve the algebra word problems given

in the worksheet. In addition, the mathematics worksheet is available on the Material while the Manual gives information regarding how to use the five features in the application. Moreover, information about this application is provided in *Tentang*, which explains the team who made this application and if the users want to leave the application, they just need to touch *Keluar* on the screen.



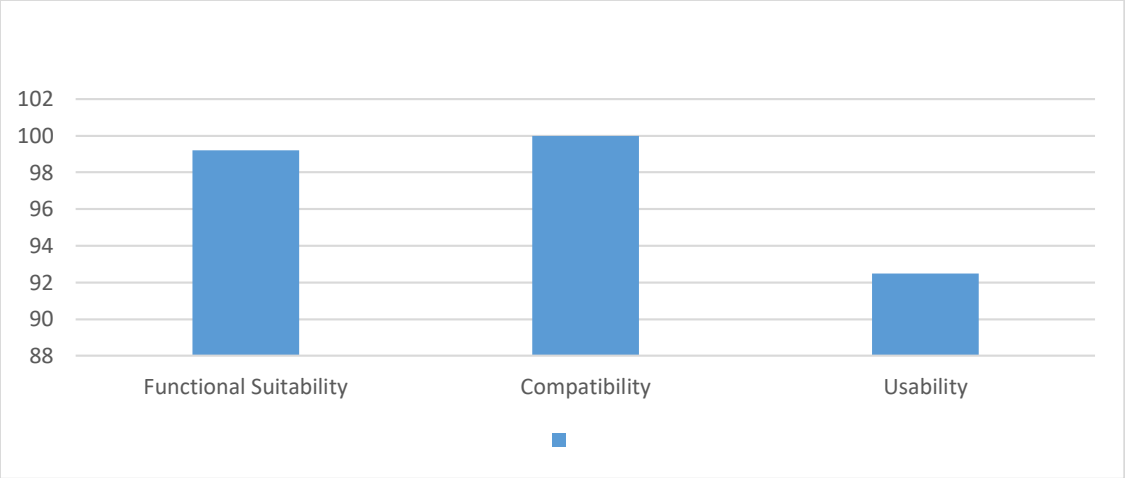

*Picture 2. The Application's Features*


*Picture 3. Examples of Images in the Worksheet as the Markers*

**Testing Results**

There were three tests that had been conducted to find out the android application as mentioned before. The tests are functional suitability, performance efficiency, and compatibility. The following bar chart shows the testing results. Overall, the testing results have indicated that the application has qualified the standard to use in smartphones where the compatibility test obtains the perfect

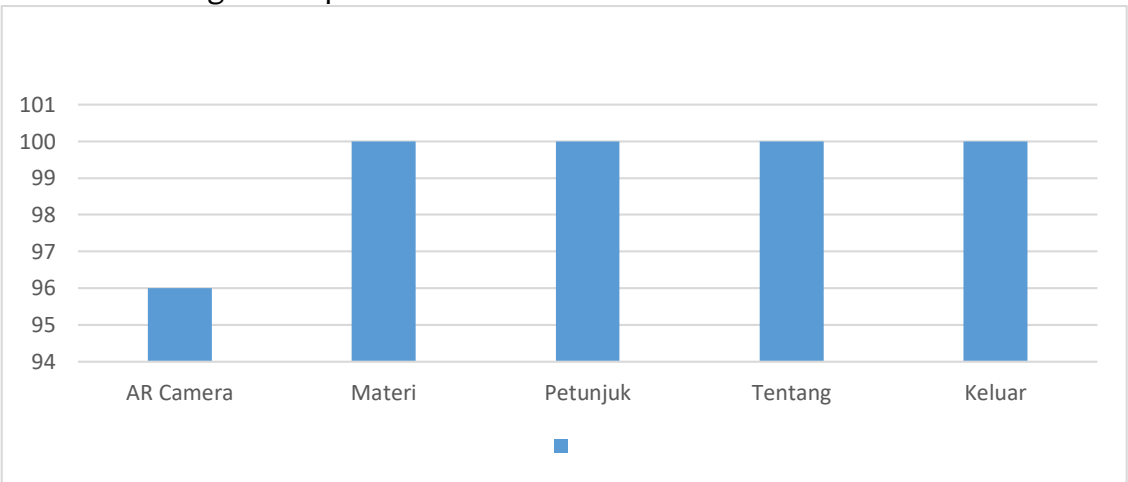
score, which is 100%. This figure is followed by functional suitability which counts for 99.2% while the usability test is less than that, which is only 89.15%. However, the results are categorised as very high, which means that the application has a very good quality. More detailed information about each testing is described in the following paragraphs.




*Picture 4. Testing Results (in Percentage)*

*Functional Suitability*

There are five aspects that have been tested for functional suitability, which are Augmented Reality Camera (AR Camera), material (*materi*), manual (*petunjuk*), about (*tentang*) and exit (*keluar*). Based on the test that has been done by 5 experts, the result shows that the average percentage of the functional suitability test is 99.2%. For the first aspect, AR Camera, the percentage is 96% whereas the percentage of the remaining four aspects is 100% each.

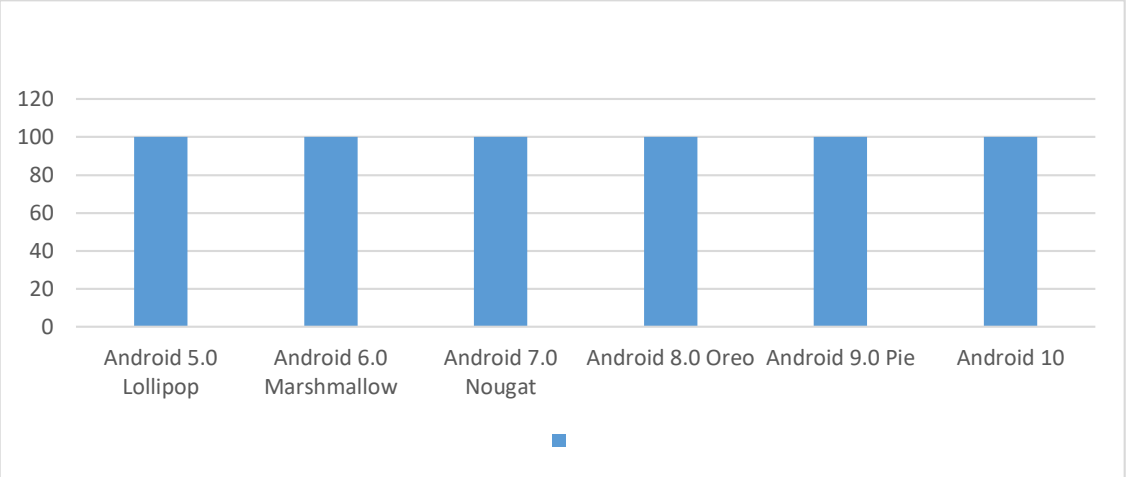



*Picture 5. Functional Suitability Testing Results (in Percentage)*

*Compatibility*

The next test is about Compatibility, which measures whether the application works in smartphones with various types of androids, starting from Android 5.0

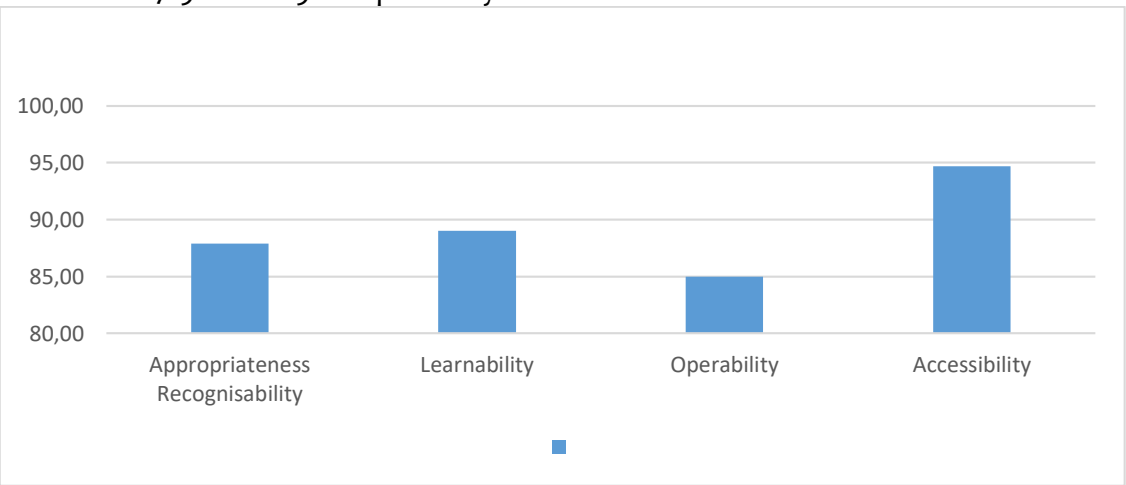
Lollipop to the most recent type, Android 10. Overall, it can be concluded that this application can be installed and used in those types of android smartphones as listed in the following picture. This implies that android smartphone users can use it for educational purpose. However, as most students in Indonesia use android smartphones, this research only focuses on developing android applications, which means that this application does not suitable for iOS. Further development needed to create an application for iOS smartphones.




*Picture 6. Compatibility Testing Results (in Percentage)*

*Usability*

For the usability, the aspects tested are appropriateness recognisability, learnability, operability, and accessibility. Ten respondents (students) have used the application and the data collected through online questionnaire due to Covid-19 Pandemic. Overall, the average percentage of the usability test is 89.15%. The highest percentage comes from the accessibility, which counts for 94,7%, while the operability can only reach 85%, the lowest score among the other aspects. Moreover, both the appropriateness recognisability and the learnability scores are fairly similar, which are 87.9% and 89% respectively.




*Picture 7. Usability Testing Results (in Percentage)*

Based on the three tests that are derived from ISO 25010 quality standards, which are functional suitability, compatibility, and usability, the augmented reality-based mathematics worksheet can be categorised as a very high-quality android application because the percentages of all tests range from 80% to 100% (more detail percentage for each test has been described in the testing results). This means that the augmented reality-based mathematics worksheet is suitable, compatible, and usable for use based on the ISO 25010 quality standards.

Overall, the functional sutability of the five features in the application is very high. Of the five features, only augmented reality camera (AR Camera) has a percentage that is quite lower than the other four features that work perfectly. This is because sometimes the AR camera feature could not recognise the pictures as a result of the low light. In contrast, the other four features (*Materi, Petunjuk, Tentang,* and *Keluar*) achieve the perfect score of 100% even though they are not the main feature of the application.

On the other hand, the compatibility of the augmented reality-based mathematics worksheet tested on six different types of android smartphones is very high as well with perfect score for all the types of smartphones (Android 5.0 Lollipop, Android 6.0 Marshmallow, Android 7.0 Nougat, Android 8.0 Oreo, Android 9.0 Pie, and Android 10). This implies that based the compatibility test the augmented reality-based mathematics worksheet can be used in virtually all of recent android smartphones.

In addition, the usability that consists of four indicators (appropriateness recognisability, learnability, operability, and accessibility) is also very high. Even though the percentages of each indicator are varied, the range is still between 80% and 100%. Of the four indicators, Operability has the lowest percentage because the specification of the students' smartphone is different, which leads to a small bug causing the application not running smoothly even though it still works.

**Implications**

The augmented reality-based mathematics worksheet developed in this study aims to support students' learning experience during covid-19 pandemic. As such, the features provided in the application focus on the use of augmented reality camera paired with the mathematics worksheet where the students can learn how to solve algebra word problems in the worksheet through animations that appear in their smartphone screens once they scan the images provided in the worksheet. Also, the students can listen to the explanations regarding how to solve the word problems at the same time they watch the animations. This implies that the students can learn through visual representations as well as audio that explains the visual animations, meaning that those whose learning styles are visual and audio could optimise their learning processes. Besides, there is a space provided in the mathematics worksheet where the students can write down step by step solutions explained in the audio and visual animations. This aims to support students with kinesthetic learning style. All in all, the three types of learning styles that mainly describe how most students learn can be included in the augmented reality-based mathematics worksheet.

Mostly importantly, the augmented reality-based mathematics worksheet could save more internet data and can be used in remote places in which the internet connection is not stable since the audio-visual animations are already attached to the application. This means that once the application is installed on their android smartphones, internet data is not anymore required to play the animations. Thus, the augmented reality-based mathematics worksheet could improve the quality of remote learning during covid-19 pandemic. Moreover, this can still be used for future development learning that combines offline and online learning, also known as blended learning.

The other benefit of the augmented reality-based mathematics worksheet is the flexibility which means that the students can study whenever and wherever they are ready to learn. Besides, the students can watch the audio-visual animations multiple times so that those who do not understand the explanations still can repeat them and learn them again several times as many as they need. This implies that slow learner students can catch up with the students who learn faster. However, the teachers and parents should also be ready to assist them whenever they need help as well as control the students' progress to make sure they can understand the mathematics concept explained.

## CONCLUSION

Based on the tests using ISO 25010 quality standards (functional suitability, compatibility, and usability), the results reveal that the quality of the augmented reality-based mathematics worksheet is categorised as very high given that the percentage of the scores ranges from 81% to 100%. The percentage of the functional suitability test is 99.2% whereas that of the compatibility test counts for 100%, which is the highest score over the other tests. Moreover, the score of the usability test reaches 89.15%, which is the lowest score among the others. Future development is needed to improve the quality of the camera. In addition, creating an application for iOS smartphones is recommended for future research and development in order to reach more users in the implementation.

On the other hand, the augmented reality-based mathematics worksheet developed in this research could possibly reach more students with different learning styles (audio, visual, and kinesthetic) due to the features and characteristics of the application. The other benefit that migh arise from the use of the augmented reality-based mathematics worksheet is the efficiency of internat data use because the it does not require a stable internat connection to run. The last but not least benefit is the flexibility where the students can access it whenever and wherever they want, which implies the augmented reality-based mathematics worksheet could be used in belended learning or flipped learning.

## REFERENCES

Buchori, A., Setyosari, P., Dasna, I. W., & Ulfa, S. (2017). Mobile Augmented Reality Media Design with Waterfall Model for Learning Geometry in College. *International Journal of Applied Engineering Research*, 12(13), 3773-3780. http://www.ripublication.com/ijaer17/ijaerv12n13_29.pdf

Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using Augmented Reality in Education from 2011 to 2016. *Innovations in smart learning*, pp. 13-18. doi: 10.1007/978-981-10-2419-1_2

Hewitt, D. (2001). Arbitrary and necessary: Part 3 educating awareness. For the Learning of Mathematics, 21(2), 37-49. https://www.jstor.org/stable/40248361

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, *123*, 109-123. https://doi.org/10.1016/j.compedu.2018.05.002

İbili, E., Çat, M., Resnyansky, D., Şahin, S., & Billinghurst, M. (2020). An assessment of geometry teaching supported with augmented reality teaching materials to enhance students' 3D geometry thinking skills. *International Journal of Mathematical Education in Science and Technology*, *51*(2), 224-246. doi: 10.35619/iiu.v2i11.212

Salim, S. S. (2019). Identifying students' understanding of missing angles in parallel lines: a case study of year 7 students in The United Kingdom. *Journal of Physics: Conference Series*, 1321(2), p. 022102. doi: 10.1088/1742-6596/1321/2/022102

Skemp, R. R. (2006). Relational understanding and instrumental understanding. *Mathematics teaching in the middle school*, *12*(2), 88-95. https://doi.org/10.5951/MTMS.12.2.0088

Hovorushchenko, T. (2018). Methodology of evaluating the sufficiency of information for software quality assessment according to ISO 25010. *Journal of Information and Organizational Sciences*, *42*(1), 63-85. https://www.ceeol.com/search/article-detail?id=677629