Augmented reality-based student’s worksheets on algebra word problems

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Abstract. Students working on a word problem sometimes missed the answer for some reasons. The most common reason is that the students misinterpreted the question. Word problems sometimes mention a vocabulary that is somewhat difficult to define by the students. Besides, word problems, especially algebra word problems, are not easy to be visualised because the comparative vocabularies used are confusing for some students. As a result, they end up with incorrect conclusions instead. As such, this study aims to create augmented reality-based student’s worksheets to assist the students to visualise algebra word problems using animations. This is a design and development study, which consists five stages. The first stage is investigating students’ needs (amid covid-19 pandemic in particular). After that, the augmented reality-based student’s worksheets are designed by considering the investigating result. Next, the worksheets are constructed before being tested and evaluated. Based on the evaluation, the worksheets are revised then finally it is ready to be implemented. The recent progress of the research is that the augmented reality-based student’s worksheets has been revised and ready to be implemented. The worksheets allow students to study from home by scanning codes using their devices (android smartphones are advised) then video animations will appear and explain the algebra word problems they are working on.

1. Introduction

In a conference, a mathematics teacher told me that some of his students were not able to understand and sometimes confused with an algebra word problem. To illustrate, he gave me the following example of algebra word problems that his students frequently missed (the original question was in Bahasa Indonesia, but I translated it into English).

“Alex has some candies and Jo has 5 more candies than Alex’s. If they have 15 candies altogether, how many candies does Alex have?”

Some students only focused on the numbers given in the question. As a result, they thought Jo’s plus 5 candies equals Alex’s. In fact, since Jo has 5 more candies than Alex’s, the equation should be Alex’s plus 5 candies equals Jo’s or Jo’s take away 5 candies equals Alex’s. In this case, visual representations play a pivotal role in helping the students to understand the situation described in the question because such comparative words as “more than”, “less than”, “two times higher than” and the like are often confusing the students [1]. Visual representations such as graphic organisers can help the students to visualize the information given in the question so that they could barely understand the question and hence they will easily write the equations to find the correct solution [2].
2. Literature Review
Word problems are sometimes misunderstood by students, particularly those who only focus on the numbers mentioned in the questions. They neglected describing words that give important information regarding what is given in the questions. Therefore, it is essential to review how students understand mathematics and the languages.

2.1. Students’ understanding based on arbitrary and necessary things
Arbitrary things in mathematics are names, conventions, and labels that students have to memorise, while necessary things are mathematical concepts of which students should be aware [3]. A research found out that there are three levels of students’ understanding based on arbitrary and necessary things [4].

2.1.1. Level 1. Students could memorise what is arbitrary, but they were not aware of the necessary things. At this level, the students need further assistance to help them understanding and being aware of the necessary things. Hence, the mathematics teachers play an important role to achieve the goal. Otherwise, because of the pandemic, a tool should take the teachers’ role to assist the students learning at home.

2.1.2. Level 2. Students could remember arbitrary things and be aware of necessary things, but they were sometimes confused when solving different problems that they used to do. The students in this level have passed the first level but too early to categorise them into the level 3 students. Even though they are already aware of what is necessary, it seems that they only memorise the procedures instead of understanding the concept.

2.1.3. Level 3. Students could memorise arbitrary things and became fully aware of necessary things at the same time. This is the level in which we want our students to be. In the case of word problems, we want the students to be fully aware and to understand the questions so that they can work on it and find the solutions eventually.

In order to help students to reach the third level of understanding, mathematics teachers should assist them. In the case of algebra word problems, mathematics teachers could assist the students by providing them with visual representations.

2.2. The role of visual representations
Visualisation has been recognised as an important tool for teaching and learning mathematics as it reflects the abstract situations through the creation, interpretation, and reflection of images and pictures [5]. Nowadays, due to the advanced development of technology, the visualisations can be in a form of video and animation that could potentially help students understand mathematics better. This was approved by a study revealing that students who learnt mathematics by using visual representations got higher performance than those who did not [6]. Visual representations not only help the students to imagine the abstract concept, but also to help them to simplify confusing information given in a word problem.

Living in the midst of covid-19 pandemic and supported by the advanced technology, students in this day and age need more sophisticated way of learning. By considering the positive and negative effects that the students might end up with, the technology should be easy to use and designed to meet the needs of the students. As such, this research created a student’s worksheet, which is augmented reality-based. A meta-analysis study showed that most of the reviewed studies (from 2010 to 2017) related to the use of augmented reality in teaching and learning activities were focusing solely on how augmented reality could affect students’ conceptual understanding whereas only a small number of them were conducted to assist students during learning activities [7]. It suggests that more study should focus on how augmented reality might help students studying from home, during covid-19 pandemic in particular. This study will be one of the few.
3. Methods
This research is a design and development study that consists of five stages, which are described as the following.

3.1. Investigation
First of all, we collected data regarding students’ difficulties on how they solve algebra word problems. This stage aims to reveal the context amid the covid-19 pandemic and online learning that the students experience in order for us to relate the student’s worksheet design. The data collection was made via online and offline (with safe protocol) by giving the students an algebra word problem, followed by an interview. Ten junior high school students in year 7 from Makassar, Indonesia in this stage.

3.2. Design
After analysing the current students’ understanding and difficulties when solving algebra word problems, we designed a student’s worksheet followed by the design of the augmented reality. The designs were created based on the students’ needs found in the previous stage.

3.3. Construction
At this stage, we created the design made previously. This process not only considers the designs, but also concerns about the current curriculum used in Indonesia and mostly importantly the pandemic where students should study from home.

3.4. Testing, Evaluation, and Revision
After finishing the augmented reality-based student’s worksheet, we asked experts to test and evaluate it so as to have a valid worksheet for students. Before the implementation stage, a revision was made based on the experts’ tests, evaluations, and suggestions for improvement.

3.5. Implementation
The final stage is implementing the augmented reality-based student’s worksheet that was revised into a larger scale. At this stage, 20 junior high school students in year 7 from Makassar, Indonesia, have participated. The of them had participated in the first stage.

4. Results
The data of this study were collected by interviewing students and mathematics teachers in the first and the final stages. Also, experts’ comments on the initial worksheets were gathered at the fourth stage in order to validate the application and worksheet. The following shows the findings from the first to the final stages.

4.1. Students’ difficulties on solving algebra word problems
Based on the data collected from interviews in the investigation stage, the result shows that there are three types of difficulties that the students encounter when trying to solve an algebra word problem given to them, which is somewhat akin to the question in the introduction section of this paper. The difficulties are:

4.1.1. Misunderstanding the question. Some students could not solve the algebra word problem because they did not fully understand the information described in the question [8]. These students were not able to write equations, but they tend to guess the answer instead. When asked “why?”, they could give a short explanation that indicates that they misunderstood the word problem. Interestingly, one of them just simply answered “I do not know, just guessing”.

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4.1.2. *Writing the equation incorrectly.* These students admitted that they understand the questions, but when asked to write the equations, they gave wrong answers, which often contradict the information from the question [9]. Since they wrote incorrect equations, the answer they got was wrong as well.

4.1.3. *Miscalculating.* Some students made a mistake when attempting to substitute an equation to another [10]. In fact, they already understand the questions and could write correct equations, but they just need to be more careful when solving the equations.

4.2. *Students’ comments on the augmented reality-based worksheet*

Students’ comments after using the worksheet are varied. However, there are at least three perspectives that are interesting to explore further because they related to the difficulties that have been found out in the investigation stage. The comments are:

4.2.1. *The animations are imaginable.* Most of the students think that the animations provided by the augmented reality help them to imagine the situations described in the questions. Besides, they found out that the step-by-step guidance to write the equations and then to find the solutions was definitely helpful. When asked “why is it helpful?”, they answered “because it helps me to understand the question step by step”.

4.2.2. *Solving word problems without the help of augmented reality.* After studying the worksheet, some students could work on word problems independently. They said that even though there are no more animations, they still can imagine the situations in the questions. Writing down the information given and what is asked is essential to make the equations and to find the solutions.

4.2.3. *Further assistance is required.* A few students still need further assistance to solve an algebra word problem. Although these students think that the augmented reality was very helpful, they still need visual representations such as pictures or images to help them visualising the question. They said “It is still hard to just imagine it. I need to see it directly”.

5. *Discussions and recommendations*

The findings reveal that the augmented reality-based student’s worksheet helped the students to visualise and imagine the situations in the algebra word problems given to them. Since there were three difficulties that the students experienced when trying to solve the word problems, the worksheet was designed to help the students that have such difficulties. There is a step-by-step instruction that is animated in the worksheet. First of all, the animation illustrates the given information and what is asked in the word problems. Next, it shows how to formulate the equations and then finally describes how to find the solutions (substitution and elimination methods).

Based on the evidence from the implementation stage, the step-by-step instruction is definitely helpful for the students. For example, the students who were not able to understand the questions finally could grasp the given information due to the help of the animations. Furthermore, the instruction also could assist the students who were previously unable to formulate the equations to be eventually capable of doing it. However, the third difficulty, which is about miscalculating, seemingly depends on the students’ awareness to be more careful even though the animations already explain how to substitute one equation to another or how to eliminate a variable.

Finally, even though the augmented reality-based worksheet could help the students to visualise the algebra word problems, the effects on them afterwards are not the same. While some of them have been able to independently work on word problems without the help of the animations, there are a small number of them who still need assistance to help them visualising the questions, either through images or pictures. If possible, the students should be advised to draw the visual representations themselves until the ultimately could work on it independently.
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