Impact of Computer Simulation Assisted Virtual Experiment Module in Learning Hydrogen Atom in Senior High School

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Abstract. This study aims to (1) develop virtual-experimental software based on augmented reality as an interactive learning medium, which can be used as a teaching tool to improve the students' mastery of physics concepts, (2) test the comparative advantage of Hydrogen Atom learning with a virtual approach experiment based on augmented reality with ordinary learning models on senior high school students’ learning outcomes. The research was categorized as quasi-experimental research which used a non-equivalent pre-test post-test control group. The research instrument used was a learning outcome test. The research data were analyzed by using covariance analysis (ANACOVA). The results of this study showed that the learning outcomes of students who studied with the AR-based virtual in the experimental learning model group were higher than students who studied in the conventional learning model group.

1. Introduction
Physics as one of the elements in science that has a very vital and strategic role in the development of technology in the future [1]. Until now, physics learning at the senior school level is generally still seen as difficult subject and becomes a subject that students are not interested in. It is due to the lack of attractiveness of the physics learning package in the classroom, which leads to low learning outcomes achieved by students. One of the factors that suspected to be the main problem of the low learning outcomes achieved by students is misconceptions.

Misconceptions are prior knowledge that is formed through informal learning in the process of understanding everyday experiences and interpreting a concept that is incompatible with the scientific concepts. This prior knowledge is generally resistant in learning [2]. Based on ref [3], learning concepts don’t pay attention to students' initial concepts will make students’ misconceptions more complex and tend to persist, that might influence students’ learning outcomes. Various physics learning approaches have been developed as a strategy of changing students 'concepts of physics (strategy of conceptual change) to direct students' conceptions.

Various physics learning approaches have been developed as a strategy of changing students 'physics concepts (strategy of conceptual change) to lead students' conceptions from everyday knowledge to scientific knowledge. That is a learning approach which is based on an inquiry approach through experimental activities. Computers can be used functionally to support physics learning activities with a virtual-experimental approach [4]-[6]. Virtual-experiment that based on augmented reality can be utilized to visualize abstract physical reality with animation modeling [7]. In addition,
learning with the use of computer simulations will provide many advantages in the learning process such as fun, so that students are naturally motivated to engage and participate actively in the learning [8]-[10]. From the background above, a virtual-experimental based augmented reality was developed and tested its’ comparative advantage of Hydrogen Atom learning

2. Methodology

This study was categorized as quasi-experimental research which used a non-equivalent pre-test post-test control group. The population in this study were all students of class II State of Senior High School 3 in Singaraja, as many as 136 students in the 2018/2019 academic year. The research sample was taken by simple random sampling of 54 students. In which there 28 students in the experimental groups (class II4), and in the control group (class II3) as many as 26 people. This research procedure comprises the following stages; (1) identifying students’ initial learning outcomes (pre-test), (2) developing virtual experimental software based on augmented reality, (3) designing learning tools, (4) implementing learning designs and (5) evaluating outcome learning (post-test) (see Table 1).

| Table 1. Research Paradigm |
|-----------------------------|
| Group | Pretest | Treatment | Posttest |
| Experiment | Q1 | X1 | Q2 |
| Control | Q3 | - | Q4 |

The research instrument used was a learning outcome test, which was validated through expert judgment and content validity. Learning outcome tests were arranged based on student success indicators that were adjusted to the learning material, at the cognitive levels C1, C2, C3, and C4. The test is constructed in the form of an essay test which consists of 10 items. Each item has a rating range of 0-4. The value of content validity by using Gregory's analysis is obtained $VI = 0.87$. Furthermore, the results of the learning outcomes instrument trial are as shown in Table 2. The initial learning outcome data were obtained before treatment was given to both classes using the pre-test, while the physics learning outcomes data were collected from the result of post-test after the treatment was given to both students in the control class and experimental class.

| Table 2. The Trial Results of the Learning Outcomes Test |
|-------------|
| No | Item Internal Consistency (r > 0.30) | Difference Index (IDB > 0.20) | Item Difficulty Index (IKB = 0.30-0.70) |
| | criteria | IDB | criteria | IKB | criteria |
| 1 | 0.340 | consistent | 0.25 | low | 0.50 | medium |
| 2 | 0.356 | consistent | 0.20 | low | 0.70 | easy |
| 3 | 0.565 | consistent | 0.75 | high | 0.50 | medium |
| 4 | 0.356 | consistent | 0.29 | low | 0.56 | medium |
| 5 | 0.352 | consistent | 0.25 | low | 0.44 | medium |
| 6 | 0.400 | consistent | 0.20 | low | 0.60 | medium |
| 7 | 0.556 | consistent | 0.3 | low | 0.60 | medium |
| 8 | 0.658 | consistent | 0.40 | medium | 0.20 | difficult |
| 9 | 0.690 | consistent | 0.54 | medium | 0.52 | medium |
| 10 | 0.665 | consistent | 0.50 | medium | 0.50 | medium |
The research data were analyzed by using covariance analysis (ANACOVA). The significance of differences in the physics learning outcomes between groups of AR-based virtual experimental learning models and conventional learning models were analyzed by using the LSD method.

3. Results and Discussion

The results of the development of an experimental virtual module based on augmented reality (AR) as an interactive learning media, are shown in Figure 1. The validation of content experts, media experts, and design experts of experimental virtual module are good qualified. This experimental virtual module was implemented in the experimental class (II4) in Hydrogen Atom learning, while in the control class (II3), the learning process is carried out conventionally.

![Figure 1. Virtual Augmented Reality-based Experiment Module](image)

The results of the data on students’ preliminary learning outcomes (pre-test) and learning outcomes after the implementation of learning (post-test) in the conventional learning model group and the AR-based virtual experimental learning model group are shown in Table 3. The average score (M) of students’ initial learning outcomes (pretest) in the conventional learning model group is 16.15 which is in very low qualifications with a standard deviation of 3.69. Meanwhile, the average value of students’ initial learning outcomes (pretest) in the group learning model with virtual experiment AR-based is 16.43 which is in very low qualifications with a standard deviation of 6.25. Those results indicate that the average score of students’ early learning outcomes (pretest) in the virtual experiment learning model group with AR is higher than the conventional learning model group. Furthermore, the average score (M) of students’ initial learning outcomes (posttest) in the conventional learning model group is 55.58 which is in sufficient qualifications with the standard deviation of 8.52. Meanwhile, the average score of students’ learning outcomes after treatment (posttest) with the AR-based virtual in the experimental learning model group is 60.00 that is in sufficient qualification with the standard deviation of 8.33.

| Class | Learning Model         | Pre-test          |          | Post-test          |          |
|-------|------------------------|-------------------|----------|-------------------|----------|
|       |                        | M  | SD      | qualification   | M  | SD      | qualification   |
| II4   | Conventional           | 16.15 | 3.69 | very low | 55.58 | 8.52 | sufficient |
| II3   | Virtual Eksperimen     | 16.43 | 6.25 | very low | 60.00 | 8.33 | sufficient |

The normality test of the data distribution was tested on all data of physics' learning outcomes. It was tested to both the conventional learning model group and the AR-based experimental virtual learning model group, as shown in Table 4.
The variance homogeneity test between groups aims to measure whether the data group of students’ learning outcomes has the same variant between the experimental group and the control group. The homogeneity test of variance between groups were tested by using Leneve’s test on the equality of error variance (see Table 5).

### Table 5. Test of Homogeneity of Variance

| Test                  | Model                              | Levene Statistic | df1 | df2 | Sig. |
|-----------------------|------------------------------------|-----------------|-----|-----|------|
| Pre-test learning outcomes | Based on Mean                       | 3.806           | 1   | 52  | 0.056|
|                       | Based on Median                     | 3.246           | 1   | 52  | 0.077|
|                       | Based on Median and with            | 3.246           | 1   | 42  | 0.079|
|                       | Based on trimmed mean               | 3.642           | 1   | 52  | 0.062|
| Post-test learning outcomes | Based on Mean                       | 0.339           | 1   | 52  | 0.563|
|                       | Based on Median                     | 0.210           | 1   | 52  | 0.649|
|                       | Based on Median and with            | 0.210           | 1   | 48  | 0.649|
|                       | Based on trimmed mean               | 0.264           | 1   | 52  | 0.609|

The linearity test was conducted to show the relation between the covariate variable (students’ initial learning outcomes) and the dependent variable (students’ learning outcomes). The results of the linearity test for the conventional learning model group and the AR-based virtual experimental learning model is shown in Table 6. The effect of initial physics learning outcomes on the dependent variable in this study, namely students’ physics learning outcomes, shows the statistical value of F * = 16.664 (p<0.005). The results indicate that there is a significant effect between the covariates on students’ physics learning outcomes.

The effect of the independent variable on the dependent variable, namely students’ physics learning outcomes, obtained a statistical value of F * = 4.359 with a significance of 0.042, and the calculated R-Squared value of 0.297.

Ho: [μ1 Y1] = [μ2 Y2]: there is no difference in learning outcomes between students who are taught using the AR-based experimental virtual learning model and students who are taught using conventional learning models. (rejected)

Ha: [μ1 Y1] ≠ [μ2 Y2]: there are differences in learning outcomes between students who are taught using the AR-based experimental virtual learning model and students who are taught using conventional learning models. (accepted)
The results of the study prove that there are differences in the students’ learning outcomes between students who were taught by using the AR-based experimental virtual learning model and students with conventional learning models. The AR-based experimental virtual learning model is superior to conventional learning models in terms of achieving students’ learning outcomes. The results of the descriptive analysis show that the initial learning outcomes of students who learned with AR-based virtual experimental learning models and conventional learning models have different mean values. Students who participated in the AR-based virtual experimental learning model group have an average score of 16.43 with a standard deviation of 6.25. Meanwhile, students who were in the conventional learning model group have an average value of 16.15 with a standard deviation of 3.69.

In general, the pretest mean score of students who were taught by using the AR-based virtual experimental learning model was higher than students taught by using conventional learning model. However, the pretest average score obtained by students in both groups is still consider as very low.
The low students' learning outcomes can be caused by many factors, both factors from within and outside the individual. There was an increase in the average value of the students' posttest results after the treatment was carried out. Descriptively, the group of students who learned in the AR-based virtual experimental learning model class had higher learning outcomes than students who were in the conventional learning model class. This is based on the average level of the data presented in Table 3, where the average learning outcomes of students who were in the AR-based virtual experimental learning model class is 60.00 which is categorized as sufficient, while in the conventional learning model class the average students’ learning outcomes is 55.58 which is categorized as sufficient. Although the students’ learning outcomes in these two groups were in the same category, the average value of students’ learning outcomes who took part in the AR-based virtual experimental learning model class was still higher than the group of students who were in the conventional learning model class.

Based on the result of covariance analysis in this study, it appears that there is a significant difference between the AR-based experimental virtual learning model group and the conventional learning model group on students’ learning outcomes. This difference can be seen from the statistical value $F^* = 4.359$ with a significance number of 0.042 which is lower than the significance level of 0.05 $(p <0.05)$, and the calculated R-Squared value of 0.297. This statistical value means that there are differences in learning outcomes between students who are taught by using the AR-based virtual experimental learning model and students who are taught by using conventional learning models in learning physics. Therefore, it can be said that students’ learning outcomes are significantly influenced by the learning model used by the teacher. These results indicate that the learning outcomes achieved by students who were in the AR-based virtual experimental learning model class are better than students who took learning in the conventional learning model class. The results of the follow-up LSD test show that the learning outcomes of students who studied in the AR-based virtual experimental learning model group were higher than students who studied in the conventional learning model group $(LSD = 1.614; \Delta\mu = 1.681)$. Accordingly, the effect of AR-based virtual experimental learning model on the students’ learning outcomes is statistically superior when compared to the conventional learning models. Based on the results of descriptive analysis and one-way covariance analysis, it can be concluded that the AR-based virtual experimental learning model has a better effect than the conventional learning model.

4. Conclusion

There are differences in students’ learning outcomes between students who were taught by using the AR-based virtual experimental learning model and students who were taught by using the cooperative learning model. This difference can be seen from the statistical value $F^* = 4.359$ with a significance number of 0.042 which is lower than the significance level of 0.05 $(p <0.05)$, and the calculated R-Squared value of 0.297. The group of students who studied using the AR-based virtual experimental learning model showed relatively higher learning outcomes than the group of students who studied using the conventional learning model. The results of the follow-up LSD test show that the students’ learning outcomes in the AR-based virtual experimental learning model group were higher than students who studied in the conventional learning model group $(LSD = 1.614; \Delta\mu = 1.681)$. In the learning process by using the AR-based virtual experimental learning model, the teacher should be able to use learning media such as simulations or animations that can make students are motivated to engage in the learning and interested in participating in the learning process. The use of experimental virtual learning model based on AR should be carried out continuously so that students are able to improve their both skills in developing their reasoning and in solving problems. This will help students to enhance their learning outcomes.
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