Applying gamification to improve the quality of teaching and learning of Chemistry in high schools: A case study of Indonesia

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Abstract

This research aims to explore the effectiveness of using computer-assisted games as a learning media to improve the quality of learning in Chemistry. The research was conducted in Indonesia on high school students in three separate classes or groups, in three separate schools that were randomly selected. There were three stages of data collection – the pretest at the start of learning, continuous observations during the learning, and the post-test after the learning has completed. The responses obtained were analysed and compared between the control group and experimental groups that use gamification as the learning media. The results of the pre-test and post-test showed that learning activities and learning outcomes in the experimental groups have reached classical completeness. The contribution of this research provided evidence that gamification is an effective medium of instruction for teaching and learning of Chemistry.

Keywords: e-learning, remote learning, learning media, youth, children, home-school

Introduction

It is widely-accepted that the use of media not only helps the process of teaching and learning but also adds value to the learning activities (Alsawaier, 2018). With the advancement of technology and the pace of technology development, today computer-assisted learning can be easily applied to improve the quality of teaching and learning. Using the computer as a learning media it allows the delivery of the Chemistry lessons with computer-assisted games that improves interactivity associated with color, music, sound, and graphics. Computers can help students and teachers to visualise abstract ideas and principles, in the form of images or animations that allows enhanced learning to achieve deeper understanding. In the recent years, new computer languages have emerged to provide efficient coding and programming that in turn have supported the development of computer games for the purpose of teaching and learning. Chemistry lessons are no longer regarded as a staid and dry subject with the advent of gamification.

Compared with the traditional approach of teaching Chemistry, computer-assisted games are excellent for active learning in the classroom since it can engage and entertain students simultaneously. The integration of computer games with attractive mix of colours, sound and music has enriched the teaching of Chemistry, by making it more interesting and practical to students (Sousa Lima et al., 2019). Many previous studies have revealed that gamification enhances student motivation and learning outcomes significantly and have positive effects on problem-solving, achievement, interest, and engagement in task learning. An increased level of student motivation or improved student performance can be a result of the combination between learning activities and game applications (Sousa Lima et al., 2019). There is a significant difference between student learning of organic nomenclature supplemented with the application as a complementary educational tool (EG) and traditional student learning with lectures, textbooks, whiteboards, and slideshow presentations (CG).

Gamification is one type of learning media. The game has several advantages, namely, it can be challenging, fun, and very close to students (Sanchez et al., 2020). Anecdotal evidence suggest that there are 65% of junior high school students in Indonesia loiter in computer game centres immediately after school hours. This shows that students like playing computer games or they enjoy the camaraderie among gamers, and that computer games can be used to attract students to learn and can be used as a learning medium. Gamification with an embedded rewards system may further increase student engagement.

Materials and Methods

The research was conducted with 88 high school students in Surabaya, Indonesia. The Chemistry topic selected was Atoms and Molecules. Computer-assisted games were developed as the learning media and administered in three separate classes in three different schools. The three classes comprised of one Control Group with 28 students, and two Experimental Groups with 30 students each, to ensure test validity.

Three researchers were trained on observation methodology and send to the schools. They were deployed to conduct observations on students who were learning through gamification.

The determination of the control and the experimental groups was done randomly from the school population. The control group did not apply gamification in learning Chemistry (Atoms and Molecules), whereas the two experimental groups applied gamification to study the same topic. The teaching and learning session in each of the three classes was conducted for 90 minutes.

The research started with a pre-test for students in all the three classes that assessed the students' general ability with a set of questions, followed by 90 minutes of teaching and learning in all the three groups. Observations were made during the teaching and learning process on how students were using computer-assisted games to learn. After the learning of 90 minutes, the students were given a post-test consisting of the same questions as the pre-test.
The results of pre-test and post-test and observations were applied to assess the success of learning outcomes in the use of gamification. Learning activities are declared effective if: (a) student activities observed as "frequent," and that (b) learning outcomes have achieved classical completeness, experimental group learning outcomes have improved, (c) students give positive responses to class

activities, and that (d) teachers provides positive responses to the use of gamification to teach Chemistry.

The design of the pretest-posttest control-group design study is presented below.
Control O1 XC O2
Experiment O1 Xex O2
Xc = control treatment
Xex = experimental treatment

Theory

The application of gamification in education has developed rapidly, turning students to be active learners, and to reach specific objectives (López Carrillo et al., 2019). According to the study by Chung and Khe (2020), there are critical features in the learning environment through gamification that provides a high level of interaction and reaction, having a specific objective and proper procedure, thereby motivating and providing the right tools and conditions that are interesting. Education games should be effective and efficient learning strategies for teaching and learning (Petri et al., 2016). Through the game, students may demonstrate the ability to overcome problems and mastery of the knowledge and skills learned (Akkuzu & Uyulgan, 2016). The game can provide a diverse learning experience that can be relevant for a variety of classroom environment. The game is also an effective way to get students' attention to learn specific topics or skills (Smaldino et al., 2019).

Chemistry teachers could build gamification into their lesson plans because it provides a more effective student learning especially in the delivery of a technical subject, such as Chemistry. Besides the potential for pedagogical progress, gamification could be the new model for delivering a higher quality of teaching and learning. Student engagement is a plus factor of gamification. However, the level of success will depend on how gamification is used. Well-developed educational games, in addition to its potential for learning and entertainment, can promote interaction between peers (Bai, et al., 2020) and student groups.

Computer-assisted games can challenge teachers to improve their level of technology literacy thereby enhancing the ability to teach technology-enabled curriculum. Alsawaier (2018) stated that the use of computerized games for education can motivate students who grew up in the era of video games. Educational games that use digital technology and interactivity can create interesting learning, consequently affecting the learning outcomes. The fun and excitement created by games are motivating and provide a heighten potential for gamification as a learning media

(Zainuddin et al., 2020). Gamification can be defined as the process of applying elements of game design to a non-game context, where the interaction between the game mechanisms and personal disposition result in a fun and enjoyable experience (Tobon, 2020). The reason is the psychological state caused by the game - immersion, flow, involvement – can increase motivation and learning performance. In the field of education, it has been stated that through gamification, students can be motivated to learn in new ways and enjoy tasks that were originally boring (Parra-González et al., 2020).

Previous research has found that the use of games as a learning medium supports the trial-and-error process that allows mistakes and having freedom to fail without fear when studying, giving feedback, facilitating learning based on individual, visualize teaching materials and encouraging competition (Mena and Parreno, 2017; Lutfi et.al., 2019).

The results of previous studies show that the game as a learning medium creates a stimulating and healthy learning environment for students. Activities that are fun and entertaining usually increase a higher level of interest, involvement, achievement, and understanding or mastery of the material. Games can also be interesting and entertaining at the same time (Gafni et al., 2018). According to Toda et al. (2017), games that meet the requirements as learning media can create an effective learning environment and results in improved learning outcomes.

Results

Student Activities

The results of observing student activities with a scale of frequency assessment of student activities are presented in Table I.

Table I. Observation Results of Student Activities

Observed Aspects	Control Group		Experiment Group I		Experiment Group II	
	P 1	P 2	P 1	P 2	P 1	P 2
AQ - asking questions	4	4	4	4	3	3
GI- giving input on the problem being presented	3	3	3	3	3	3
FN - Find something new (different)	2	2	3	2	2	2

TCT - Try challenging tasks	2	3	2	3	3	3
EA - Explain answers found to other friends	2	2	2	2	3	3
WC - Willingness to come to the front of the class	2	2	2	2	2	2
QRC - Questioning the results of the teacher or student's work and comparing them with their own answers	2	2	2	2	3	3
Total	17	18	18	18	19	19
Average	2.50		2.57		2.71	

The result showed that the average activities was between 2.50 to 2.71. This is considered "frequent," which is higher than 0 to 2.40 and less than 3.0. In the three groups, the most significant activity was asking questions (AQ), giving input on the problem being presented (GI), and finding new / different knowledge (FN). This meant that during the learning process using gamification, the students were sufficiently motivated to engaged in activities frequently (in asking questions, giving opinions and exploring and finding new knowledge). There was a lack of willingness to present in front of the class which can occur because students were more active at their desks playing the computer-assisted game.

These results are aligned to the research by Tan and Hew (2016). In-class games encouraged students to achieve a higher level of engagement in the learning process as well as stimulated activities that support learning. Computer games developed as learning media adds to the potential for learning and entertainment, and encourages interaction between friends (Parra-González et al., 2020).

Results of Learning Outcomes

For the Control Group, the learning outcomes was tested for significance of the difference between the pre-test and post-test. The results obtained are presented in Table II.

Table II. Learning Outcomes of Control Group Students

Test	Number of Students		Score (max. 100)		sig	Average		Value of t count
		% Completion	Lowest	Highest			Df	
Pretest	30	3.33%	3.33	80	0.250	27.86	29	12.65
Posttest	30	20.0%	56.67	90	0.108	71.51		

1. As regulated by the Ministry of Education Indonesia, the evidence of mastery of learning by students is where they have passed the test with a minimum of 75 marks upon 100. In the control group, only 20% of 30 students passed the test at 75%. This meant that it has not met the minimum cut-off point and therefore there is absence of mastery of learning. Also, observations have confirmed that conventional learning media available in the classroom cannot help further improve the quality of learning experience to bring about a higher level of learning outcomes.
2. Based on the increase in the average scores of the pre-test and post-test, a paired t-test was conducted. A normality test was carried out and a t-test was conducted in pairs with the SPSS program. Using the normality test of Kolmogorov-Smirnov, the value of the initial sign test was 0.250 and the value of the final sign test was 0.108. The value is greater than 0.05, meaning the initial test score and final test score are normally distributed.
3. The t-value of 12.65 is in the rejection area of *Ho*, meaning that *Ha* is accepted. This meant that there is a difference in the average score of the initial test and the final test for Control group. This result showed that although learning Chemistry (Atoms and Molecules) using conventional media in class can significantly improve the final test score, but it did not achieved classical completeness.

For the experimental group I (EG I) obtained t-value of 15.44 and experimental group II (EG II) obtained t-value of 17.48. Both of t-value are in the rejection of Ho, meaning that between experimental group I and group II has average score difference of pre-test to average score of post-test.

The result of Classical Completeness of the three groups are shown in Figure 1.

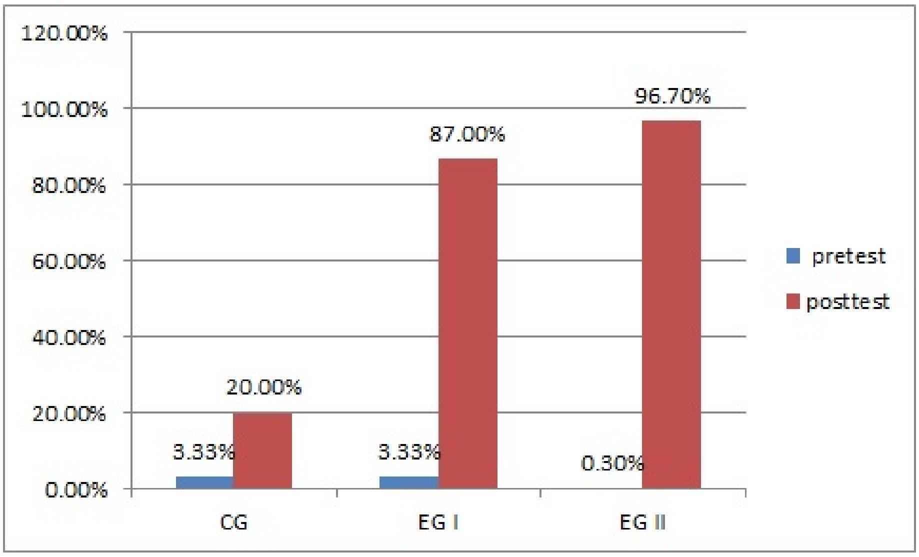

Figure 1. Classical Completeness of control group, experimental group I (EG I), and experimental group II (EG II).

Based on figure 1, describe that control group has not reach classical completeness, while experimental group I and group II has passed the classical completeness.

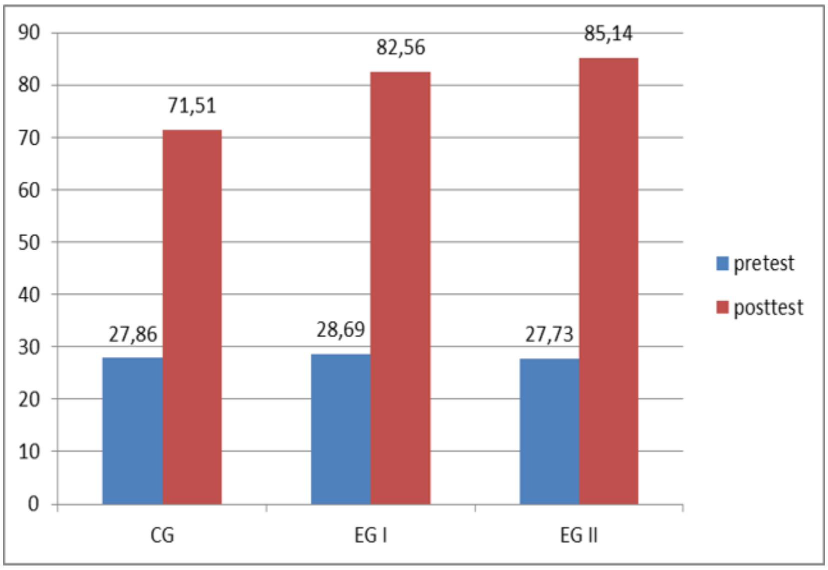

Figure 2. Score of pre-test and post-test in control group, experimental group I (EG I), and experimental group II (EG II).

Based on Figure 2, Shown that boh of experimental groups and control experimental are increased significance on pre-test score to post-test score. This result meanings is altough Chemical learning (Atoms and Molecules) using conventional media in the class can increase post–test score significanly but it can't reach the classical completenss.

In experimental group I and experimental group II, the results of using computer-assisted games as learning media area presented in Table III below.

Table III. Learning Outcomes of Student Experimental Group I & II

Score	Number of Students	Complete	Score (max. 100) Lowest	Score (max. 100) Highest	sig	Average	df	Value of t value
Pretest EG I	31	3.3%	3.3	80	0.121	28.69	30	15.440
Pretest EG I	31	87.0%	50	100	0.097	82.56		
Pretest EG II	31	0.3%	3.3	80	0.252	27.725	30	17.476
Posttest EG II	31	96.7%	70	100	0.400	85.142		

For the Experimental Groups I and II, the results revealed that the post-test score was 87% and 96.7%, it has passed the specified criteria of 80% for classical completeness. The price of normality test experimental group I using Kolmogrov-Smirnov on the pre-test score was 0.212 and the price of normality test on the post-test score is 0.097. Both are greater than 0.05, meaning that they are normally distributed.

To test the differences in the average score of the pre-test and the post-test in the experimental group I, the t test was paired with SPSS version 16. The normal distribution requirements were met and the following results were obtained.

Value of t is 15.44 and t table is 2.04, which means that t count is in the rejection area of Ho. This means Ha is accepted, meaning there is a significant difference between the average pretest and posttest scores in the experimental group I at a significance level of 5%.

The scores of student learning outcomes before and after learning, the experimental group II are presented in Table 3.

The value of the level of significance 5% is obtained in the pre-test is 0.252 and the post-test is 0.400. The value is greater than 0.05, meaning that the pre-test and post-test are normally distributed and can be paired with t-tests.

Value of t shows 17.476 in the rejection area Ho means Ha is accepted. This means that there is a significant difference between the average score of the initial test and the final test score. When examined, the student learning outcomes after learning shows that it has reached more than 80% completeness, so that it has fulfilled classical completeness.

The result of pre-test and post-test between control group and experimental groups are shown in Figure 3.

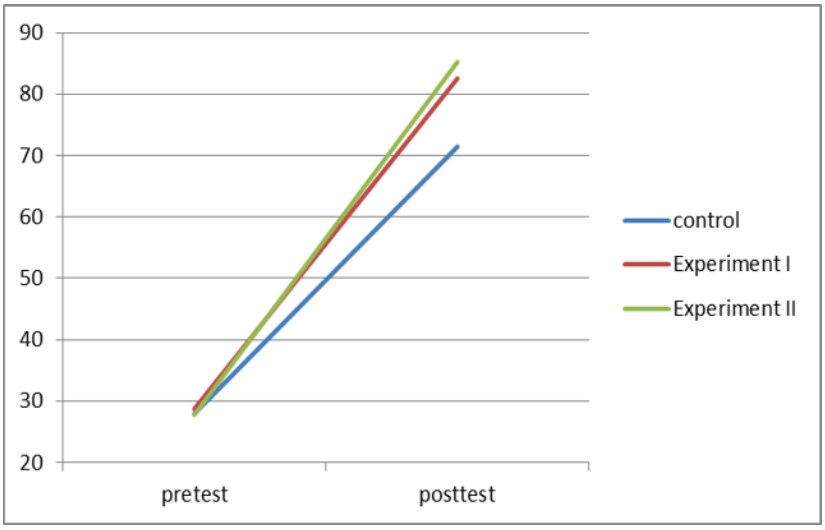

Figure 3. Score Control Group and Experimental Groups

Based on Figure 3, there is an increase in the average score of pre-test and the average score of post-test for the three groups. However, the increase was higher in the experiment groups.

Next, we compared the average score of the final control class with experimental groups I and II. As the final test score of the three groups has a normal distribution, it has fulfilled the requirement to conduct an independent t test.

Table IV. Independent t Test Results Final Test Score

Group	df	t count	t table (5%)	Conclusion
Control vs experiment I	59	4.192	2.00	Ho rejected
Control vs experiment II	59	6.560	2.00	Ho rejected
Experiment I vs experiment II	60	1.013	2.00	Ho accepted

Table IV shows the post-test average score of the control group. The average post-test scores of experimental Group I and of experimental group II were significantly different from the average post-test score of the control group. However, the average post-test score between experimental group I and experimental group II did not have a significant difference. This meant that the experimental groups achieved better scores than the control group. The experimental groups also achieved classical completeness.

These results are consistent with the results of Cadavid and Corcho (2018), who studied chemistry learning using computer-propelled games. In their study, students obtain an average yield of 4.1 upon 5.0 (that is 82%). This result is aligned with the results of several studies which state that the computer games can improve learning outcomes (Aşıksoy, 2018, Bai et.al., 2020).

Gamification also has a positive effect on problem solving, achievement in learning (Lin et al., 2018). When used properly, games can be a useful tool in learning the concepts of science (Rachels & Rockinson-Szapkiw, 2018). Activities in the game provide more training in intelligence, through sound, images, linguistics, kinesthetic, interpersonal, and intrapersonal intelligence (Alsawaier, 2018). Likewise, the results study showed that there were significant differences in the scores of learning outcomes between the experimental group and the control group, where which classroom learning could engaged the students better in learning where success depended on how the game was used.

Results of student responses to questionnaire

The questionnaire statement consists of positive statements and negative statements. The results of the questionnaire about students' responses to chemistry learning by using computer-propelled games as learning media are presented in Table V. The lower the scores obtained, the more the indication that students increasingly disliked the activity.

Table V. Results of Questionnaire of Control Group Students

Number	Statement	Score
1	I feel that learning Chemistry with the media has become easier	15 (50.00%)
	After learning Chemistry with the media, I became more happy with Chemistry	10 (33.33%)
	I want to study Chemistry again with the media	13 (43.33%)

	If it's permissible, I want to bring the media home to study at home	10 (33.33%)
	I want to tell friends or parents about learning Chemistry.	8 (26.70%)
2*	I felt that learning Chemistry was too long.	7 (23.33%)
	I feel that studying Chemistry with the media was boring.	6 (20.00%)
	I want to study Chemistry with the media immediately stopped.	5 (16.70%)

The score of the control group questionnaire obtained 5 to 15 upon 30 (that is respectively,16.70% to 50%), which indicated that the students did not give a positive response to the conventional learning that had taken place. The lower score (16.70%) indicated that the student's desire for learning chemistry tapered off. This meant that students do not like conventional learning with the media available in the class. The low scores indicated that students felt that the conventional learning is less interesting, the duration of the class was too long and hoped that the learning will stop soon.

The results of the student responses questionnaire on learning Chemistry (Atoms and Molecules) in the experimental groups I and II are presented in Table 6 below.

Table VI. Results of Student's Questionnaire

Number	**Statement**	**Score**	
		Group Experiment I	**Group Experiment II**
1	I feel that learning Chemistry with the media has become easier	30 (96.7%)	30 (93.75%)
	After learning Chemistry with the media, I became more happy with Chemistry	29 (93.5%)	30 (93.75%)
	I want to study Chemistry again with the media	31 (100%)	32 (100%)
	If it's permissible, I want to bring the media home to study at home	30 (96.7%)	29 (90.6%)
	I want to tell friends or parents about learning Chemistry.	29 (93.5%	28 (87.5%)
2*	I felt that learning Chemistry was too long.	31 (100%)	30 (93.75%)

	I feel that studying Chemistry with the media was boring.	30 (96.7%)	30 (93.75%)
	I want to study Chemistry with the media immediately stopped.	30 (96.7%)	31 (96.88%)

In the experimental group I, the lowest score was 93.5% and was above the minimum threshold of 75%, while the highest score was 100%. The results of the student questionnaire showed that learning using gamification has set a positive fulfilling response. In the experimental group II, the responses to the questionnaire revealed that students gave a positive reply to agreeing to the use of the computer games as a learning medium. This was reflected by a score between 87.5% to 100%.

The results of the questionnaire showed students studying Chemistry (Atoms and Molecules) had a richer learning experience that was facilitated by computer-assisted games as learning media, which added learning skills and made learning Chemistry interesting. Therefore, students felt they wanted to engage deeper into the subject by using computer-based games.

In summary, the results showed that gamification creates excitement in the classroom learning. This is in accordance with the opinion of Huang et al. (2018) about the use of games as a learning medium. The excitement is described as the rise of interest in full involvement, and the creation of meaning, understanding or mastery of matter, and create happy values for the learner.

Discussions

Computerized gaming integrated with student learning experiences can have a positive impact on learning motivation, providing a richer learning experience, and maintain learning motivation (Aşıksoy, 2018). Also, errors made in the game allow students to reflect and reuse play strategies to improve knowledge, which motivates them to try again (Baptista & Oliveira, 2019).

The results of the research are consistent with the results of several pieces of previous studies, that games in the classroom can be ascertained that students are more enthusiastic about learning and can provide learning motivation (Aşıksoy, 2018). The game can significantly increase the motivation of students to learn (Papp, 2017). The results of other studies state that the game can increase motivation and student learning enthusiasm in the learning process so that the learning process becomes more enjoyable (Alsawaier, 2018). The game can also attract and entertain players at the same time. When students are familiar with playing the game, students are eager to complete (Chung & Khe, 2020). Educators are looking for games to complement classroom learning, while game developers make games for learning media. All parties need to be involved to enable emotional and child development in games development for the learning purpose (Çakıroğlu et al, 2017). Most boys and girls overcome boredom or fatigue by playing games that reaches all levels of emotions and fatigue (Aşıksoy, 2018).

Students who learn with computer-assisted games can show better visual, psychomotor, and affective abilities (Sanchez et al., 2020), while other studies that obtain results from students studying with simulation games can better master abstract and conceptual knowledge related to electromagnetism (Dichev & Dicheva, 2017). This shows a good game for science learning.

According to Papp (2017), the computer game has fulfilled the requirements as a learning medium that can create an effective learning environment. The results above also show that the game that has been developed has succeeded in creating active students and motivates students to continue learning. Learning with computer-propelled games as learning media allows students to build knowledge from ambiguous, trial and error which becomes new knowledge (Bai et al., 2020). This is consistent with Piaget's fundamental insight that individuals construct their own understanding; learning is a constructive process. Vygotsky believed that cultural tools including computers played a very important role in cognitive development. Constructivism argues that students can construct or construct their knowledge with active processes of students and utilize learning resources in a variety of ways, and provide opportunities for students to collaborate (Huang & Hew, 2018), these activities are in computer-assisted games.

Learning by using games as learning media can be used to provide a rich learning environment to help learners build higher level knowledge and skills through ambiguous, challenging, and opportunities (Sanchez et al., 2020). During play, students engage in high-level cognitive activities to encourage attention, activity and retention by trial and error (Bai et al., 2020).

The game developed provides students with easy learning and makes the learning easy to understand, learn, and understand; provide student attractiveness both appearance, color choice, and content; having benefits means that the game contains benefits for understanding the material; and has a match with student learning needs (Jagušt, et al., 2018).

It would be compelling to undertake research for subjects other than Chemistry, especially subjects that do not require demonstrations of experiments such as Literature, Languages or Critical Thinking.

Future research could also be conducted to determine whether student learning experience and student behavior can be improved by embedding gamification to teaching and learning.

Conclusions

Based on the research and discussion, it can be concluded that the use of computer-assisted as a learning media for Chemistry can be beneficial to improved learning outcomes through better student engagement and creating a motivating environment. The following attest to the conclusion:

1. Student activities during learning with games as learning media is a better reflection of student-centered learning.
2. Student learning outcomes, where the experimental group achieved mastery of the subject taught based on post-test score, and was significantly better than the control group.
3. The response of students in the experimental group gave a positive response to the use of the game as a learning media for Chemistry and expressed a higher level of student engagement.
4. The use of computer-propelled games as a learning media for Chemistry can complement teaching or act as an alternative mode of teaching while retaining the student-centered learning approach.
5. Gamification helps to achieve a mastery of learning outcomes, where teachers can design games into their teaching to improve students' learning experience in Chemistry, and create an environment of education with entertainment.

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