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Gamification and academic ability impact on students' metacognition and critical thinking skills

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Abstract: In educational settings, the metacognitive skills and critical thinking abilities of students often show room for improvement. This research aims to find out the influence of gamification methods and academic ability on metacognitive skills and critical thinking ability of high school students in Biology subjects. The independent variable in this research is the application of the Gamification method and a different method, namely the Synchronous-asynchronous method. The moderator variable is the difference in students' academic ability. The dependent variables are metacognitive and critical thinking skills. The instrument used to collect data is a test question developed to measure metacognitive and critical thinking skills. The study comprised two distinct stages. Firstly, the Dick & Carey development steps were used for development research. Secondly, a quasi-experiment was conducted using a 2x2 factorial design with 62 students divided into two groups. The research data was analyzed using the MANOVA statistical analysis technique. Based on the research results, it can be recommended that the Gamification learning method needs to be applied in the classroom with attention to the student's academic abilities.

Keywords: academic ability, critical thinking ability, gamification, metacognitive skills

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1. Introduction

The rapid development of digital technology has not only made tasks and work easier, but has also made entertainment and gaming more accessible (Wangi et al., 2018). Games have become an essential part of the lives of children and teenagers. Gamification is a term coined by Nick Pelling in 2002 where games are used as learning tools for students in various disciplines (Newzoo, 2017). Gamification involves incorporating computer game elements such as points, leaderboards and badges into non-game contexts to capitalize on the motivation provided by the game environment (Lister, 2015). It involves incorporating game elements into non-game contexts to increase motivation and engagement in learning (Alsawaier, 2018). Many domains have an interest in this concept as gaming behavior is marked by voluntary interactive behavior for long periods (Doherty et al., 2017). Its application in education is still growing (Dicheva et al., 2015).

Gamification is a new approach to learning that facilitates learning and encourages motivation by using game elements, game mechanics, and a game mindset (Reigeluth, 2016). In gamification, students do not play the entire game from start to finish but instead, engage in activities that include game elements such as earning points, overcoming challenges, or receiving badges for completing tasks (Reigeluth et al., 2016). The idea is to integrate elements commonly found in games into the learning environment (Kapp, 2014). Gamification provides elements that attract students' attention because in learning, concepts, and knowledge are learned through activities that were previously considered a

game so they are considered to be able to increase student involvement in the learning process, including in biology learning (Ibarra-Herrera et al., 2019). Moving from the engaging aspects of gamification to the critical development of thinking skills, it's important to see how gamification can boost these advanced skills. The shift from game-based learning to enhancing critical thinking and metacognition highlights the potential of using gamification not just for fun, but as a tool to improve learning outcomes, especially in biology.

Metacognitive skills show high-level thinking skills because they include active control of students' cognitive processes in learning, which are closely related to intelligence so that learning and thinking done by a person becomes more effective and efficient (Livingstone, 2003). There is a correlation between metacognition and thinking skills and between metacognition and critical thinking (Corebima, 2009). Critical thinking is one of the high-level skills that is the goal of world education today, but this skill is not well-developed in students (Fatmawati et al., 2019). Critical thinking is the most valuable skill that schools can pass on to their graduates and is the goal of learning at all levels of the discipline. Critical thinking ability can be developed either directly or indirectly in Biology learning. Biology learning that is directed at constructivism learning that forms meaningful learning does not go well without learning that allows learning to think critically.

Another factor that is considered to influence the process and understanding of concepts in learning is students' academic abilities (Bahri et al., 2016), because each individual differs from one another in many aspects, variation is an undeniable natural principle, where each individual is a unit that is different from one another. Likewise with academic abilities, it is also natural that in one class students have varying academic abilities. Different academic abilities produce different experiences in addressing student learning (Leasa, 2017) during the process of building new experiences in learning.

Previous research shows that the majority of students prefer the Gamification approach to conventional lecture methods (Henning et al., 2017). It was also found that gamification can support improving metacognitive skills (Tang & Kay, 2014). Other research also reveals that there is an increase in critical thinking skills in journalism students through the Gamification platform, which provides a 'Meaningful Gamification' experience through clear goals, challenges, feedback, competition and collaboration, actual assessment and visible status, access/disclosure of content, restrictions on orientation time, freedom of choice, and the identity and role of the bar (Huang & Yeh, 2017). Other research has explored the influence of Gamification elements in improving students' critical thinking through online discussions, with results showing differences in the level of critical thinking at the beginning and end of each group's discussion (Tzelepi et al., 2020). However, investigations into the impact of integrating gamification with academic competencies on both metacognitive and critical thinking abilities concurrently remain scarce. Hence, the objective of this study is to examine the impact of gamification strategies and academic proficiency on the enhancement of metacognitive skills and critical thinking capabilities among secondary school students within the context of Biology education. This research also highlights that although there is an initial assumption about the interaction between gamification methods and academic ability on students' metacognitive skills, this research found that there is no significant interaction. This provides a new contribution to the understanding of the influence of learning methods and academic ability on student skills in the context of Biology education.

2. Materials and Methods

This research is quasi-experimental research preceded by development research. Learning tools developed in the form of a syllabus, Learning Implementation Plan, and Gamification website. The instrument for measuring metacognitive skills uses a written test with a scale of 0–7 based on a rubric developed by Corebima (2009). Meanwhile, critical thinking ability is measured using a written test with a scale of 0–5 based on the critical thinking assessment rubric. The hypothesis being tested is the application of the Gamification method to students with different abilities towards the metacognitive skills and

critical thinking ability of high school students in Bima City. The independent variable in this study is the application of the Gamification learning model, the dependent variable is metacognitive skills and critical thinking ability. At the same time, the moderator variable is high academic ability as factor A and low academic ability as factor B. Based on this, the research design used is a 2x2 factorial design. The data for this research was collected in the odd semester of 2020/2021. The data collected in this study is quantitative data in the form of (1) scores of metacognitive skills, (2) scores of critical thinking ability, (3) the value of understanding biology concepts.

Gamification website design contains website production designs in the form of workflow sketches as outlined in the form of flowcharts and interface design sketches in the form of storyboards. The initial design of interactive multimedia contains lesson plans, learning materials, assessment instruments, and instructions for use by both teachers and students. Expert validation tests were carried out to collect data used to identify deficiencies in the initial draft of the Gamification website based on the criteria in the data collection instrument. At this stage, validation of learning Gamification products is carried out, including responses from learning material experts, and learning media experts. Each type of assessment provides different information to the developer so that it can be used in determining the feasibility of the website produced in learning activities. Product validation is carried out after the overall Gamification learning product developed has been revised. Expert validation consists of two learning material experts and one learning media expert. The suggestions, input, and responses of each expert contained in the research questionnaire were used as the basis for revising the learning gamification products that had been developed. Group trials were carried out after the overall Gamification learning Gamification products developed had been revised. Group tests were carried out to determine the effectiveness of learning Gamification products in achieving learning objectives. The group test phase involved 30 students.

Research data concerning the Gamification method and different academic abilities and their effect on metacognitive skills and critical thinking abilities use Manova 2x2 analysis. data from the 2x2 factorial quasi-experimental research to test the hypothesis formulated using the 2x2 MANOVA assisted by the SPSS version 23 statistical analysis program at a significant level of 0.5%.

3. Results

On the main display (landing page), there are navigation buttons that can be used to explore all the information in Gamification starting from registration to the final level of Gamification. The initial part, namely the login menu, displays a rolling image containing a welcome greeting and motivational words as an introduction to the learning gamification website which is automatically displayed alternately as long as the navigation button has not been pressed. In this initial section there are also two navigation buttons, namely: the 'Enter Class' and 'Register' navigation buttons. As shown in Figure 1.

Figure 1. Landing page

After inputting your identity and profile according to the registration format displayed, to start exploring the Gamification website, students must select the Figure 2 adventure level.

Figure 2. Student main menu

After completing the challenge and pressing the finish button, the results page will be displayed. Students who have not met the KKM must repeat the material by pressing the 'repeat' button, the duration of time to repeat is 50% of the normal time. Apart from that, there are also motivational words displayed randomly. Students who have met the KKM advance to the checkpoint or next level Figure 3. Then, students can see the achievements they have achieved and the awards they have received in the form of medals and badges (Figure 4).

Figure 3. The result

Figure 4. The result

Metacognitive skills and students' critical thinking abilities data are measured by using a test that is integrated with a concept understanding test before and after learning activities. Next, data was collected by several procedures, namely: (1) Conducting observation and preliminary study, (2) Dividing the sample into 2 groups, namely the group of students who were taught by the Synchronous-asynchronous method and the group of students who were taught by the Gamification method, (3) Determine the schedule, (4) Carry out pre-tests on both groups, namely the group of students who are taught by the Synchronous-asynchronous method and the group of students who are taught by the Gamification method, (5) The teacher explains to students about the method used, (6) The subject teacher provides material using Synchronous-asynchronous and Gamification methods in each group, (7) Carry out post-test activities. Comparisons to the findings of previous studies must be included. Research data, before testing using MANOVA must first fulfill the prerequisite test, namely the data normality test and data homogeneity test. The results of the assumption test using the Kolmogorov-Smirnov test, and the homogeneity test using the SPSS version 20 application are presented in Table 1.

Table 1. Summary of normality test results in both the experimental group and the control group

Variabels	Online Class		Gamification Class		Conclusion
	Pre-test	*Post-test*	*Pre-test*	*Post-test*	
Metacognitive skills	0.056	0.200	0.133	0.200	Normal
Critical thinking ability	0.082	0.052	0.125	0.200	Normal

Based on the results of Table 1, it can be seen that the data shows the lowest significance value of 0.052 and the highest significance value of 0.2. Overall, the results of the pre-test and post-test normality on the Metacognitive Skills variable and the Critical Thinking Ability variable have a significance value greater than 0. 05, it can be concluded that all data from these variables are normally distributed and the Manova test can be carried out.

Table 2. Summary of Levene's test homogeneity test results

Variable	F	df1	df2	sig	Conclusion
Pretest	0.011	1	60	0.421	Homogen
Posttest	0.02	1	60	0.197	Homogen

The results of the pre-test and post-test studies shown in Table 2 show that the results of the homogeneity test using Levene's test obtained the lowest significance value of 0.074 and the highest sig value of 0.861. From the table it is obtained that a significant value is greater than 0.05, therefore the Metacognitive Skills and Critical Thinking Ability variables are homogeneous and feasible for the MANOVA test.

The results of the F test between the Gamification method and different academic abilities towards students' metacognitive skills in Biology subject for the pre-test group obtained an F value of 0.046 and a significant 0.830 while the F table for df1 and df2 at a significant level of 1.872. Because the value of F value<F table (0.046<4.010) and significant 0.830>0.05, then H0 is accepted and H1 is rejected, or it can be concluded that there is no interaction between the Gamification method and academic abilities on students' metacognitive skills in Biology subjects.

The results of the F test between the Gamification method and different academic abilities towards students' critical thinking ability in Biology subject for the pre-test group obtained an F value of 12.974 and a significant 0.001 while F table for df1 and df2 at a significant level of 793. Therefore, the value of F value >F table (12.974>4.010) and significant 0.001<0.05, then H1 is accepted and H0 is rejected, or it can be concluded that there

is an interaction between the Gamification method and academic ability on students' critical thinking ability in Biology subject.

Table 3. Summary of MANOVA test results

Source	Dependent Variable	df	F	Sig.	Noncent. Parameter	Observed Power
Corrected	metacognitive Y1	3	24.181	0.000	72.542	1
Model	critical thinking Y2	3	43.776	0.000	131.327	1
Intercept	metacognitive Y1	1	7.75E+03	0.000	7746.889	1
	critical thinking Y2	1	4.17E+03	0.000	4172.792	1
Method	metacognitive Y1	1	22.08	0.000	22.08	0.996
	critical thinking Y2	1	72.871	0.000	72.871	1
Academic	metacognitive Y1	1	49.407	0.000	49.407	1
ability	critical thinking Y2	1	28.986	0.000	28.986	1
Method*	metacognitive Y1	1	0.046	0.83	0.046	0.055
Academic	critical thinking Y2	1	12.974	0.001	12.974	0.943
Error	metacognitive Y1	58				
	critical thinking Y2	58				
Total	metacognitive Y1	62				
	critical thinking Y2	62				
Corrected	metacognitive Y1	61				
Total	critical thinking Y2	61				

The results of the metacognitive skill F test obtained an F value of 22.080 and a significance of 0.000, a significance of 0.000 <0.05, thus H1 is accepted and H0 is rejected, and it can be concluded that there are significant differences in the metacognitive skills of students who use the Gamification method and those who use the Synchronous-asynchronous method in Biology subjects. The results of the F test for critical thinking ability obtained an F value of 72.871 and a significant 0.000, a significance of 0.000 <0.05 then H1 was accepted and H0 was rejected, or it was concluded that there was a significant difference in the critical thinking abilities of students who used the Gamification method and those who used the Synchronous-asynchronous method in Biology subject. The results of the F test post-test of metacognitive skills between students who have high academic ability and low academic ability in Biology subjects, the F value value is 49.407 and is significant 0.000 so that it is significant 0.000 <0.05 then H1 is accepted and H0 is rejected or it can be concluded that there is significant differences in the metacognitive skills of students who have high academic ability and low academic ability in Biology subject. The results of the post-test F test for critical thinking of students who have high academic ability and low academic ability obtained an F value of 28.986 and a significant 0.000 so that it is significant 0.000 <0.05, then H1 is accepted and H0 is rejected, it can be concluded that there is a significant difference in ability critical thinking students who have high academic ability and low academic ability in Biology subject.

4. Discussion

The findings of this research analysis convey that gamification significantly impacts the measured dependent variable In line with the previous research which states that learning methods greatly influence the development of students' thinking and metacognitive skills (Tindowen et al., 2017). In line with the opinion which states that metacognitive skills affect the effectiveness of completing assignments by students (Listiana et al.,

2016). Various studies have also proven that the use of learning methods, especially Gamification, is very effective for metacognitive skills. This study discusses how the Gamification method is more effective than the synchronous-asynchronous method in improving students' metacognitive skills, especially in Biology subjects. One study suggested that metacognitive refers to students' awareness to understand their academic strengths and academic weaknesses, then from cognitive resources students can submit to the need to fulfill the demands of certain tasks (Taghizadeh, 2016).

With this Gamification method, it is continuously believed to be able to improve students' metacognitive skills. The use of learning methods is very effective in managing student learning and providing guidance and support (Kokotsaki et al., 2016). From this presentation, it can be concluded that the use of learning methods can regulate and provide guidance and support for students in solving problems in learning. The Gamification method is very effective in improving critical thinking ability. Another publication concluded the results of their research that there was an effect of using learning strategies or methods on learning outcomes (Wonda et al., 2016). The Gamification-based learning method is more effective than the Synchronous-asynchronous method. Furthermore, the use of learning methods was very effective in increasing thinking skills (Hassan et al., 2011). The results of this study indicate that differences in students' critical thinking abilities are inseparable from students' academic abilities.

Research results by Smith et al., (2023) show that gamification designs that are structured and provide freedom for more open reflection have different effects on increasing metacognitive awareness. However, overall metacognitive awareness did not increase for all students. Then, in other research, it was found that the use of 'Escape Room' gamification in an educational context can make a positive contribution to the development of metacognitive skills, teamwork, problem-solving, and creativity in students (Amatori & Rosa, 2023). Furthermore, research by Reina-Guzmán et al., (2022) concluded that learning models, including gamification, increase engagement and the development of cognitive, metacognitive, praxis, and attitude skills while improving the microbiology learning experience for Biological Science students. Research conducted by Kamarudin et al., (2022) revealed that gamification allows students to increase attention retention, develop creativity, and meet their cognitive needs. This encourages experimentation, discovery, learning through mistakes, understanding, and repetition. Gamification of AI coding activities may be an effective way to improve cognitive skills by helping students learn faster and apply what they know. Furthermore, research by Dwyer (2018) reveals that the use of gamification in learning can increase student engagement and critical thinking skills in first-year composition courses. By utilizing game elements such as 'Quests, Side Quests', and the 'Job Class system', students can develop metacognitive abilities, explore information, and make independent decisions in their learning process. Additionally, the use of gamification also gives students the freedom to choose their topics and writing style, which can increase their level of engagement and motivation in class. Thus, this gamification approach can help students feel more involved, increase their understanding of the learning process, and strengthen their critical thinking skills in an academic context.

An approach using learning methods is very suitable for honing critical thinking ability (Yanchar & Slife, 2004). The ability to think critically also depends on the type of learning strategy given and depends on the extent to which students have academic abilities (Akinoglu & Baykin, 2015). Critical thinking abilities are very important in building thinking tendencies to solve complex problems. To optimize the empowerment of critical thinking ability, it is not enough for the teacher to rely on the implementation of learning strategies alone, the implementation of learning strategies will be far more effective if they pay attention to students' academic learning abilities. The learning method is related to academic ability. In the implementation of the Gamification method which focuses on the learning process of complex but contextual problem-solving activities, students who have low academic ability are certainly quite difficult and slow in solving the problems given. Likewise in the implementation of online learning methods, students who have high aca-

demic abilities tend to be more active in conveying their ideas, ideas, and opinions in discussions. Students who have low academic abilities tend to be passive in discussions and don't even pay attention to the ongoing discussion process. Therefore, teachers need to pay attention to the factors of students' academic abilities in carrying out the learning process with any method so that expectations regarding students can have high academic ability to excel and critical thinking ability can be realized.

5. Conclusions

Based on the results of the research, it can be stated that the research implications are that choosing the right learning method can affect students' metacognitive skills and critical thinking ability, thus enabling the achievement of higher learning outcomes. The Gamification method can be applied to Biology subjects, especially in the matter of movement systems and the circulatory system. The absence of interaction between the gamification method and academic abilities on students' metacognitive skills indicates that there is no confirmation of the variables of students' academic abilities so there are other variables that are not discussed in this study which also influence the improvement of students' metacognitive skills. The initial hypothesis concluded that there was an interaction between the gamification method and students' academic abilities on metacognitive skills, but in this study, it was concluded that there was no interaction caused by several factors, namely differences in students' conditions and the influence of other variables that could not be avoided by researchers so that the results of the study were not there is interaction. So, there is a need for further research related to metacognitive skills, and must pay attention to the condition of students so that the measurement of students' metacognitive skills can be measured properly.

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