SCHOOL OF EDUCATION RESEARCH JOURNAL

RESEARCH ARTICLE

Game–Aided Instruction: Enhancing Critical Thinking Through Logical–Mathematical Games

Evan P. Taja-on

School of Education, San Isidro College, Malaybalay City, Bukidnon

Correspondence to: etajaon@sic.edu.ph

Received: March 12, 2021; **Revised**: March 23, 2021; **Accepted**: April 22, 2021

DOI: 10.13140/RG.2.2.16436.17288

ABSTRACT

Game-based learning includes instruction and discipline that inculcates authentic game experiences (Cicchino, 2015). This research investigated the use of game-based learning on enhancing the critical thinking of college mathematics students enrolled in the subject Mathematics in the Modern World for the time span of 5–months. The Study Utilized the logical-mathematical games that enhanced their critical thinking and decision-making on mathematical problems. The collection of the data included for the most part, the content tests, the score of the students on the given logical mathematical games, their rating on the critical thinking rubric, and an unstructured interview. The results revealed that game-aided instruction has a highly significant impact on the students' academic performance and critical thinking ability. The result further shows that game-aided instruction is more effective when compared to a learner-centered instruction. Also, the result shows a very strong correlation on the students' game score and critical thinking rating, with a coefficient value of $r = 0.905$. The result also suggests that age and gender have no significant part to play when thinking critically. This positive impact of logical-mathematical games can be attributed to its active game-play mechanics, player interaction and discussion, and its engaging and fun nature making it a good motivational tool.

Key words: *Critical Thinking, Logical-Mathematical Games, Game-Aided Instruction*

INTRODUCTION

Critical Thinking safeguards anyone from falsehood and lies, which is a skill that needs to be taught and mastered and it is alarming to know that students lack the skill to think critically (Nicholoson, 2019). Students who think critically in Mathematics make reasoned judgments or decisions concerning what to think or what to try to do. Mainly, students reconsider the grounds for judgment to come back up with thoughtful decisions and conclusions. Students do not just assume a rule without assessing its relevance or implications to a situation or problem that they are in (Tips for Teacher, 2013).

Critical thinking is commonly related to problem-solving, but an association with problem-solving and critical thinking exists. A distinction connecting these two concepts is that critical thinking involves the reasoning on an open-ended problem and problem-solving takes into account the commonly narrow scope (Kurfiss, 1988). Critical thinking could be a mixture of skills that are essential in analyzing and evaluating a collection of knowledge. Critical thinking could be a systematic and active process that establishes a ground for understanding and evaluating arguments (Alkharusi, Sulaimani, & Neisler, 2019). A visible association between critical thinking and games is that "a student cannot learn well unless they think well" (Playmeo, Critical Thinking). Playmeo (n.d.) claimed that naturally, a strong and enjoyable aspect of developing the strength of individual skill in problem-solving is to use the utilization of fun games.

Most, if not all students understand the concept of games, gameplay mechanics, and the inclusion of rules in certain games. Students (even adults) play games on hours on end only for the mere fun of it or simply to pass the time (Prisner, 2014). The formal depiction of a game opens the player, the data that they need, the preferences they choose, the strategies that are available to every player, and the way these factors would influence the results of the sport. Prisner (2014) stated that a game is an abstract version of reality, often mathematical, believing to yield some understanding of real-world scenarios or situations.

Craven (2013) said that logical games require and individual to promptly analyze a collection of complex facts with numerous variables and to utilize those facts to related problems. Reed and Young (2018) claimed that mathematical games provide a structure and process in problem-solving to interact with learners to achieve a selected goal. The study conducted by Plass, Homer, & Kinzer (2015) describes learning that comes with some game elements is characterized as playful learning which focuses on the activity or task by the learner. Game-Based Learning mostly emphasize that it is a sort of gameplay possessing an outlined learning outcome (Shaffer, Halverson, Squire, & Gee, 2005). Within the process of designing the academic games involve the balancing of material that must be covered within the educational time with the appetency to prioritize gameplay (Plass, Perlin, & Nordlinger, 2010). The study of Cicchino (2015) concluded that utilizing Game-Based Learning (GBL) could be a very effective tool for educators within the development of the students' critical thinking inside the classroom setting.

One of the 21st-century skills is Critical Thinking and Mathematics is a subject that requires the students to think critically. To foster this skill into college students, the researcher aims to utilize games, specifically logical-mathematical games, which require students to think critically before making a decision or coming up with a conclusion. The end goal of this research is to develop the twenty-first-century skill in critical thinking into the first-year college students.

CONCEPTUAL FRAMEWORK

The study anchors on the concepts that "*students learn through the process of playing the games*" and that using games in the lessons would help the students in learning (Education World, 2013). This study adheres to two learning theories: constructivist learning theory and experiential learning theory. Games are social activity that provide an avenue for individuals to express their distinctive point of view

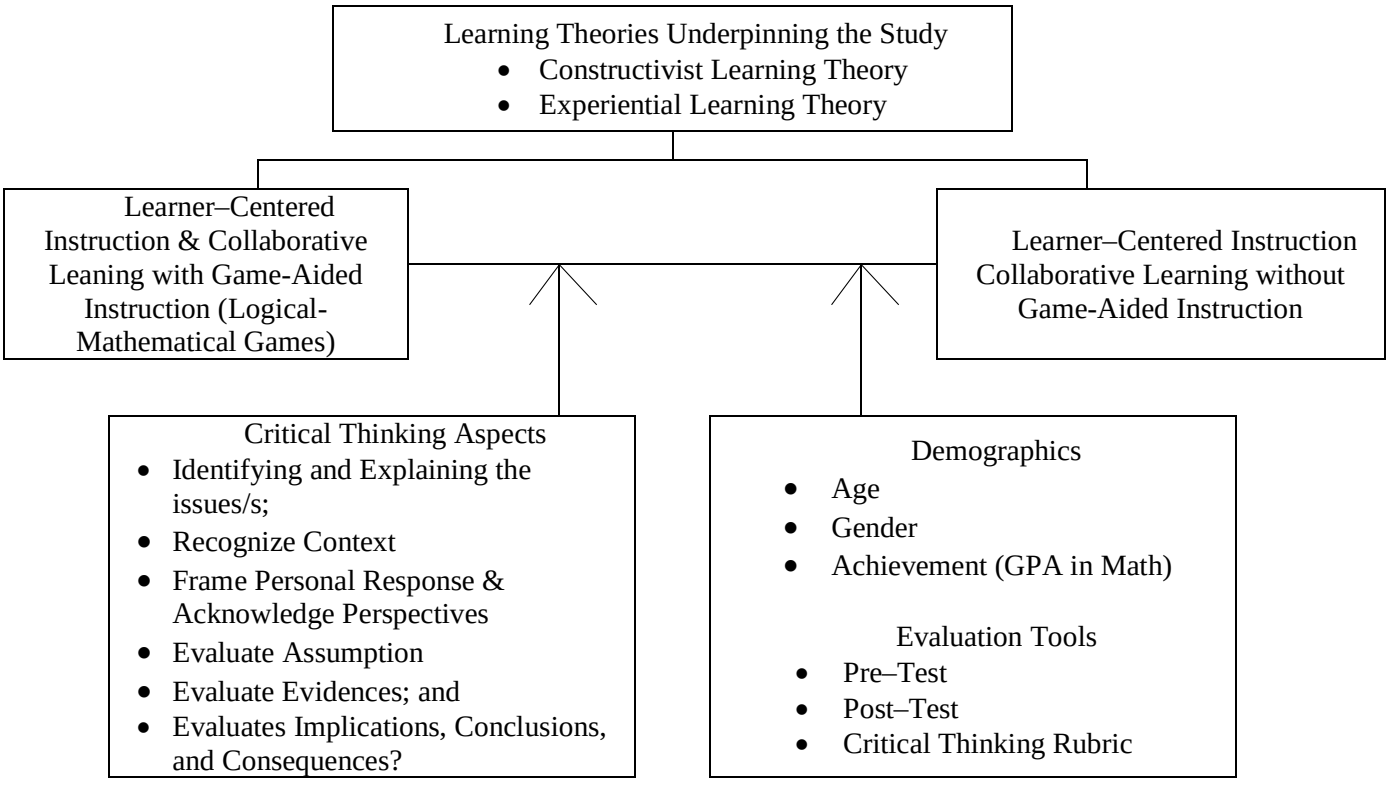

Figure 1. Conceptual framework of the study

and expresses to their ideas to other players. The constructive theory states that knowledge is something that is constructed actively, and games offer this platform that assists students in acquiring new information and adding it to their already existing reservoir of knowledge. It allows enabling of appropriate modifications that would accommodate it to the problem presented in the games (McLeod, 2019). Figure 1 illustrates the conceptual framework of the study.

The study further believes in the theory that when learning incorporates some game elements as playful learning which focuses on the activity or task by the learner it becomes a playful endeavor (Playmeo, n.d.). To be proficient in games, an individual must obtain experience and use that experience on a similar problem. This constant gathering of information (through experience) and testing of concepts would help build knowledge. Games provide this cycle of information gathering, but do not necessarily begin with observation; some students observe first then build on this knowledge before they try it for themselves. Hence, games adhere to the concept that knowledge is the result of combining the gathered experience and the transformation of experience (Cherry, 2019).

Some aspect of Critical Thinking includes: a) Identifying and explaining the issue/s. As an individual is presented with a possible problem, they are primarily obligated to analyze the problem encountered and to define the problem an individual has to be able to clearly identify and summarize the primary issue or problem and be able to explain the reasons why and how it is a problem. b) Recognizes context. A problem is not only words combined together but is has in depth thoughts and theories towards it. As a critical thinker, one must be able to identify the empirical and theoretical context relevant to the possible solution to the problem. c) Frames personal response and acknowledge perspectives. In deciding for a possible solution, a critical thinker does not just solely rely on his/her own verdict but rather tries to incorporate the thought (either they are agreement or objection to their thought) of others as well. d) Evaluates assumption. As part of the decision-making process, the individual has to identify and evaluate their own assumptions as well as others assumptions. But they are not also only limited to the ones that are presented to them but also be able to identify hidden and abstract ones; e) Evaluates evidence. Critical thinking is not just about the accepting everything that seems true, but rather, they also question and analyzes the evidences presented. They can also provide new possible information or data to also be considered. f) Evaluates implications, conclusions, and consequences. An aspect of critical thinking is not just seeking for the possible answer or solution to the problem, but also thinks ahead and evaluates the possible outcomes of the decisions that would be made. Considering and evaluating all the probable solutions and identifying their pros and cons to the end result of the problem.

This research involved two groups of respondents; both groups experienced the learner-centered instruction and collaborative learning approach. However, one group has game-aided instruction. The group that undertook the game aided instruction played the logical-mathematical games. The evaluation was through an unstructured interview and rubric point system. Both groups took the pre-test and the post-test. A critical thinking rubric served as its evaluation tool. The data were statistically treated and interpreted based on the results.

STATEMENT OF THE PROBLEM

This study assessed the use of Logical-Mathematical games in enhancing the critical thinking skill of the first-year students in a mathematics class. It answered the following problems:

1. Do the following factors affect the rating of the students in Critical Thinking:
   - 1.1 gender;
   - 1.2 age; and
   - 1.3 GPA in mathematics?
2. Is there a significant difference between the scores of the students exposed to game-aided instruction and learner-centered instruction?
3. Is there a correlation between their rating in the Logical-Mathematical Games and the rating in Critical thinking?
4. What observations on the critical thinking ability are manifested when using Game-Aided Instruction considering the following;
   - 4.1 Identifying and explaining the issue/s;
   - 4.2 Recognizes context;
   - 4.3 Frames personal response and acknowledge perspectives;
   - 4.4 Evaluates assumption;
   - 4.5 Evaluates evidences; and
   - 4.6 Evaluates implications, conclusions, and consequences?

RESEARCH DESIGN

The study used the parsimonious embedded design in assessing the game – aided instruction in enhancing the learners' critical thinking. The researcher administered a pretest on the students to gather the quantitative data on their current capacity for critical thinking. The researcher monitored the respondents' progress via interview and using the NEIU's Critical Thinking Rubric to assess the critical thinking of the respondents. The critical thinking rubric consists of six dimensions. After the 5 – month duration of the study, the researcher administered the post-test to the students.

The respondents of the study were gathered through multistage sampling. The primary step is to assign the respondent by grouping them according to their sections thus making a cluster, there were a total of ten sections at the end of the grouping. The researcher then used the lottery random sampling to select four sections for the experimental group and four sections for the controlled group. The four sections in the experimental group had a total of one hundred twenty–one students and the four sections in the controlled group had a total of one hundred two students having a total of two hundred twenty–three students. The researcher instructed the eight sections to group themselves with five or six members; the experimental group was then subjected to a random sampling which was the source of the data for the unstructured interview. There were a total of five groups for interviewed during the implementation of the study where at least one group was selected in each cluster.

RESULTS

Comparison of Critical Thinking Skills Considering Gender and Age

Gender

The gender of the students was taken into consideration when assessing their critical thinking. Table 1 shows the comparison of the critical thinking ability of the students when grouped according to gender.

Table 1. Comparison of the critical thinking ability of students when grouped by gender.

Gender	N	Mean	SD	*t*	*p*
Male	64	81.380	12.084	0.764	0.446
Female	57	79.751	11.258	0.767	0.444

The result contradicts the study of Shubina and Kulakli (2019) stating that gender affects critical thinking, especially in males. A similar observation in the studies of Bagheri and Ghanizadeh (2016) and Halpern (2003) suggest that gender has no role to play when thinking critically and further supports that gender has nothing to do with critical thinking.

The performance of male students and female students regarding their critical thinking skills is closely similar. But considering their means, it is contrary to the study of Shubina and Kulakli (2019) that males have a lower ability in critical thinking when in fact the data suggests that male students have better performance than the female students.

Age

The age of the students was taken into consideration when assessing their critical thinking. Table 2 shows the comparison of the critical thinking ability of the students when grouped by age.

Table 2. Comparison of the critical thinking ability of students when grouped by age.

Gender	N	Mean	SD	*f*	*p*
18 or Younger	17	82.351 **a**	12.104	1.690	0.143
19	35	80.714 **a**	12.422		
20	24	74.827 **a**	13.542		
21	15	83.335 **a**	6.289		
22	12	81.945 **a**	11.839		
23 or older	18	93.333 **a**	8.924		

The result of the study of Dwyer and Walsh (n.d.) supports the claim that the age of the students does not play a part in their critical thinking. Though there is no significant difference in their performance, taking into consideration their means, the students aged 21 years old performed the best among the groups and the students of age 20 years old performed the least. The result shows that there is a homogenous performance among the different ages.

Comparison of Post-Test Scores Between Students Exposed to Game-Aided Instruction and Learner-Centered Instruction

Table 3. Comparison of the post–test scores of the experimental and controlled group.

Group	N	Mean	SD	*t*	*p*
Controlled	102	26.003	12.012	21.666	0.000**
Experimental	121	74.369	20.777	20.761	

** $p < 0.01$

Table 3 shows the difference in the post-test scores of the students who were exposed to game-aided instruction when compared to the students who were exposed to learner-centered instruction.

Based on the result of the statistical analysis, the group exposed to game aided instruction performed better when compared to the group exposed to learner-centered instruction. The studies of Turan & Meral (2018); Mavridis & Tsiatsos (2016); Ku et al. (2014); Wang (2015); and Chang et al. (2012) support the result that a higher level of achievement on the learning of the students when coupled with games compared to non-game-based instruction or traditional instruction. Hence, the idea of Turgut & Temur (2017) suggested that games have a positive effect on the academic achievement of the students. The result shows that using game-based instruction in the class is more effective than using a learner-centered approach.

Comparison of The Scores of the Students Post Intervention

Academic Achievement.

Table 4 shows the comparison of the scores of the student exposed to game-aided instruction pre-implementation and post-implementation.

Table 4. Comparison of the test scores of the experimental group.

Scores	Mean	SD	*t*	*p*
Pre–test	27.076	9.599	– 24.854	0.000**
Post–test	74.369	20.777		

** $p < 0.01$

Based on the statistical result, the academic performance of the students has highly improved since the pre-implementation. The researches of Turgut and Temur (2017); Yilmaz (2014); and Özgenç (2010) came up with a similar result suggesting that games have a positive effect on the learning of the students. This result shows that there are still underperforming students though, within the span of five months, the significant improvement of the students' test scores is very good. But the students computed means still did not reach the 75% mark, entailing improvement on the part of the implementation of the games and facilitation on the learning of the students.

Critical Thinking.

The critical thinking was monitored with the use of the NEIU critical thinking rubric and the comparison between the pre-implementation rating and post-implementation rating as shown in Table 5.

Based on the statistical result, the critical thinking of the students has highly improved since the pre-implementation. The studies conducted by Duncan (2018); Russo T. (2018), Buchheister et al. (2017), and Bragg (2012b) supports the improvement of the students critical thinking claiming that the games enhance the students' retention skill-developing them to remember the experience and use those experience in future scenarios. The study of Rutherford (2015) also supports this development as games motivate students to be self-directed in their learning.

Table 5. Comparison of the pre–implementation and post–implementation Critical Thinking rating.

Rating	Mean	SD	*t*	*p*
Pre–implementation	34.711	7.838	– 58.791	0.000**
Post–implementation	80.613	11.682		

** $p < 0.01$

The result is very significant as the rating of the students exceeds that 75% mark. Ankucic (2018) and Duncan (2018) affirmed that considering students as critical thinkers in their own right as this development is more on the students' willingness to improve on the aspect. The claims of Hafni (2018) and Russo J. et al. (2018) also support the result that students can apply their learning in real-world scenarios or even just in the classroom.

Logical–Mathematical Games and Critical Thinking Correlation

Table 6. Result of Person r on the extent of the association between the scores of Logical-Mathematical games and the rating on Critical Thinking

Score	Mean	*r*	Extent of Relationship
Critical Thinking	80.613	0.905	Very High Relationship
Logical-Mathematical Games	84.421		

To ascertain the association of the scores of the students in playing Logical-Mathematical Games and with their rating in Critical thinking, the Product Moment Correlation was computed and presented in Table 6 showing a coefficient correlation of 0.905.

The finding is indicative of how the scores of the students in their Logical-Mathematical games have a strong correlation to their rating in critical thinking. The result of the studies of Buchheister et al. (2017); Bay-Williams & Kling (2014); and Amr (2012) further supported that games have a positive effect on not only their academic performance but the students critical thinking as well.

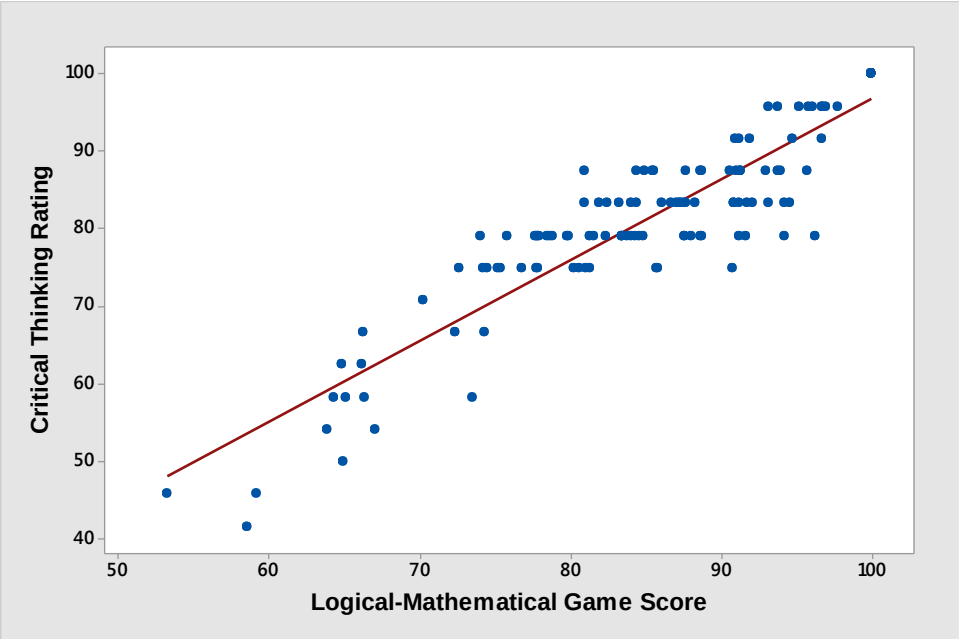

Figure 2. Scatter plot of the relation of the association between the score of Logical-Mathematical games and the rating on Critical Thinking

The scatter plot depicts a strong correlation on the score of Logical-Mathematical games and rating on Critical Thinking with a coefficient value of 0.905

and has a very high relationship. Games as stated by Duncan (2018) and August (2016) have a considerable impact on the academic learning of students and when using games, the teacher must planned-out and relate it to the lesson to maximize its output.

The result of the correlation and the scatter plot presented also reveals that some students did not improve. An observation in the scatter plot showed that some students who have high scores in the game but do not correlate to their critical thinking rating and the same are true the other way around. But still, a very strong correlation exists between games and critical thinking.

Observation on the Critical Thinking Ability when using Game-Aided Instruction

Identify and Explain Issues.

The obligation of the student is to primarily analyze the problem encountered and to define the problem. The learner has to identify and summarize the primary issue or problem and be able to explain the reasons why and how it is a problem. The progress of the learners' critical thinking ability to identify and explain issues is observed from pre-implementation (1) to post-implementation (6) that is presented in Table 7.

Table 7. Observation on the Critical Thinking ability to identify and explain issues

Observation	Mean	SD	*f*	*p*
1	1.34 **a**	0.475	186.051	0.000**
2	1.74 **b**	0.509		
3	2.06 **c**	0.537		
4	2.46 **d**	0.592		
5	2.69 **e**	0.563		
6	3.24 **f**	0.619		

** $p < 0.01$

Based on the result of the statistical analysis, there is a steady improvement of the students' critical thinking ability to identify and explain issues. According to the concept presented in the works of Ankucic (2018); Hilliard & Kargbo (2017); and Stathakis (2013) that the active processes presented in games have a significant influence on their ability to focus on the task since they are actively engaged. Alkharusi et al. (2019) stated that this active process establishes a ground for students to understand and evaluate information that is presented to them or they have encountered. It is evident in Table 7 that the learners have improved when the means of the pre-implementation is compared to the post-implementation. A presentation on the progress of the students shown in an interval plot found in Figure 3 that records the first observation (pre-

implementation) to the last observation (post-implementation).

Based on Table 7, the observation conducted during the pre-implementation (1) had a mean of 1.34 which is interpreted as students possess a limited proficiency in identifying and evaluating issues. This implies that students fail to identify, summarize, or explain the main problem or question or the students represent the issues inaccurately or inappropriately (CTL, 2005).

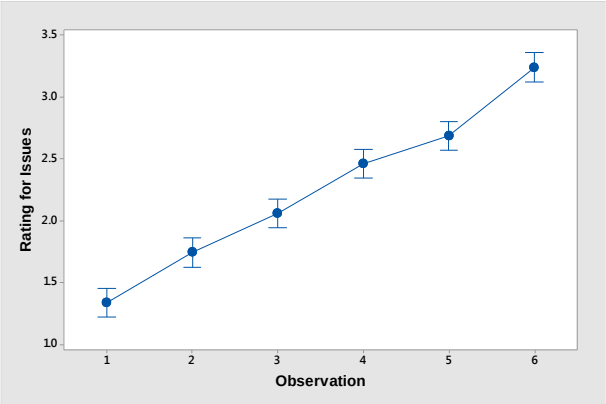

Figure 3. Interval plot of the progress of the students' critical thinking ability to identify and evaluate issues

During the in initial observations, the responses of the students are very evident that they lack the skill to analyze and evaluate the problem presented to them. Nfon (2018) suggested that this could stem from their negative experiences of students in mathematics making them doubt their ideas or question their thought. The responses of the students show that they were helping each other to identify the problem or issue. The studies of Doyle (2019), Nfon (2018), Hilliard & Kargbo (20170, August (2016), and Özgenç (2010) support this idea as games foster the teamwork and interaction within its players to evaluate or understand a problem.

During the final observations, the response of the students depicts that they can already identify the problem but they still cannot quite explain why it is a problem. Alkharusi et al. (2019) and Stathakis (2013) explained that this is due to the level of understanding of the students. They can identify the problem but do not have the complete faculties to understand why it is a problem. August (2016) and Prisner (2014) stated that rules of the game may also contribute to their lack of explanation for the problem as rules bound them to the specifics and may distract them from the overall problem. The transition of the students from limited proficiency to proficiency is a very good improvement and it is evident using the Tukey HSD test and observing Figure 3, there is an improvement in the students' quality in their ability to identify and explain issues.

Recognize Stakeholders and Context.

A problem is not only words combined but is has in-depth thoughts and theories towards it. As a critical thinker, one must be able to identify the empirical and theoretical context relevant to the possible solution to the problem. The progress of the learners' critical thinking ability to recognize stakeholders and context observed from pre-implementation (1) to post-implementation (6) that is presented in Table 8.

Table 8. Observation on the Critical Thinking ability to recognize stakeholders and context.

Observation	Mean	SD	*f*	*p*
1	1.36 **a**	0.481	174.953	0.000**
2	1.85 **b**	0.628		
3	2.21 **c**	0.618		
4	2.63 **d**	0.565		
5	2.74 **d**	0.475		
6	3.26 **e**	0.616		

** $p < 0.01$

Based on the result of the statistical analysis, it can be inferred that a steady improvement of the students' critical thinking ability to recognize stakeholders and context. The active engagement of the students toward the games helps them recognize valuable information that could aid them in solving their problem as supported by the studies of White & McCoy (2019), Russo J. et al. (2018), Hilliard & Kargbo (2017), August (2016), and Boaler (2016). Alkharusi et al. (2019) justify that games establish the grounds that allow the player to evaluate and

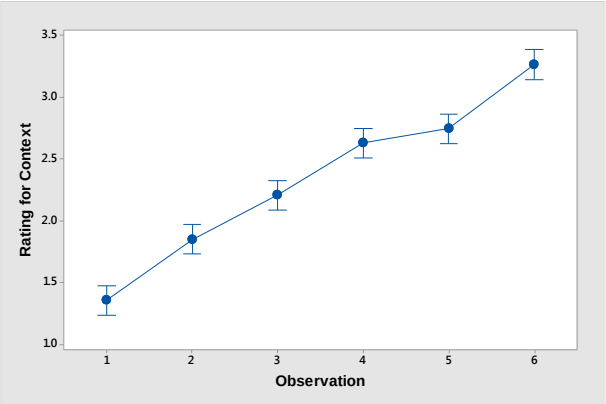

Figure 4. Interval plot of the progress of the students' critical thinking ability to recognize stakeholders and context

understand information as they encounter them. It is evident in Table 8 that the learners have improved when the means of the pre-implementation (1) is compared to the post-

implementation (6).

The progress of the students is presented in an interval plot found in Figure 4 that records the first observation (pre-implementation) to the last observation (post-implementation). Based on Table 8, the observation conducted during the pre-implementation had a mean of 1.3 which is interpreted as students possess a limited proficiency in recognizing stakeholders and context. The result implies that students fail to accurately identify and explain any empirical of theoretical contexts from the problem or the students' present problems as having a connection to the conditions or contexts (CTL, 2005).

The doubtful tone presented by the students is clearly stating that they do not know what the problem is telling or conveying. Nfon (2018) suggests that this is could stem from the lack of exposure to similar problems during their primary or secondary education, which could present a problem in their performance.

The response of the students shows that they tried to explore the problem to develop an understanding and synthesized their idea to have a clearer understanding. The study of Russo J. et al. (2018) and Stathakis (2013) and an article on Teach Starter (2017) expressed that games are more than just playing a game. Games encourage players to explore and experiment on their ideas to come up with a better understanding of the problem of the game as a whole. The response of the student shows that they enjoyed their experience in their group discussions and found a way to easily understand the implication of the problem. The notion presented by Ankucic (2018), Russo J. et al. (2018), Hilliard & Kargbo (2017), Bragg (2012a), and Clarke & Roche (2010) gave an impression that games are fun in the most part and when students are enjoying themselves it is easier for them to understand a topic or are more eager to continue to learn.

The post-implementation supports this improvement that the students are more engaged within their groups. The study of Nfon (2018), Hilliard & Kargbo (2017), and Özgenç (2010) explained that the interaction between the individual can help them develop their thought and share their ideas and further supported by an article on Teach Starter (2017) implying that the more they interact and share their ideas the more it will develop their ability to understand and analyze context. The transition of the students from limited proficiency to high proficiency is a very good improvement and it is evident using the Tukey HSD test and can be observed in Figure 4 that there is an improvement on the students' quality in their ability to recognize stakeholders and context.

Frame Personal Responses and Acknowledge Other Perspective.

When students are deciding for a possible solution, a critical thinker does not just solely rely on his/her verdict but rather tries to incorporate the thought (either they are agreement or objection to their thought) of others as well. The progress of the learners' critical thinking ability to frame personal responses and acknowledge others' perspectives is observed from pre-implementation (1) to post-implementation (6) presented in Table 9.

Table 9. Observation on the Critical Thinking ability to frame personal responses and acknowledge others' perspective.

Observation	Mean	SD	*f*	*p*
1	1.43 **a**	0.497	138.940	0.000**
2	1.88 **b**	0.503		
3	2.18 **c**	0.632		
4	2.48 **d**	0.593		
5	2.69 **d**	0.533		
6	3.17 **e**	0.650		

** $p < 0.01$

Based on the result of the statistical analysis, it is observed that there is a steady improvement of the students' critical thinking ability to frame personal responses and acknowledge other perspectives. Stathakis (2013) emphasized the different perspectives being considered is an influential aspect of gameplay as is builds on the idea of others to come up with a solid argument or grounded idea. It is evident in Table 9 that the learners have improved when the means of the pre-implementation (1) is compared to the post-implementation (6). The progress of the students presented in an interval plot found in Figure 5 that recorded the first observation (pre-implementation) to the last observation (post-implementation).

Based on Table 9, the observation conducted during the pre-implementation had a mean of 1.43 and interpreted as students possess a limited proficiency in framing personal responses and acknowledge other perspectives. This means that

students fail to formulate and clearly express their point of view or anticipate objections to their point of view or to consider other perspectives and positions (CTL, 2005). The responses of the students show that they have some form of understanding of the problem but are not confident with their stand or perspective. This study of Alkharusi et al. (2019) detailed the urge for students to understand a problem is the root of any problem-solving strategy and displaying any form of understanding is a good step in itself.

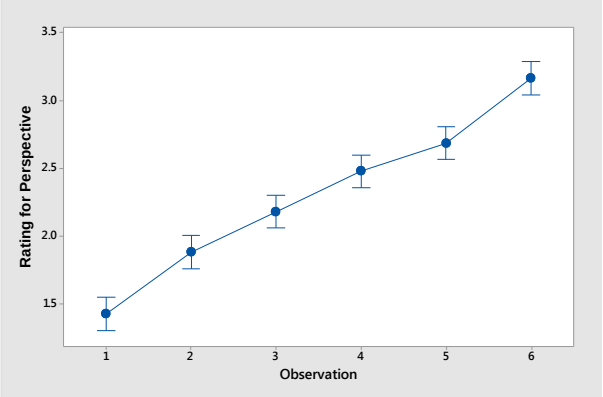

Figure 5. Interval plot of the progress of the students' critical thinking ability to frame personal responses and acknowledge others' perspectives

The response of the students' states that they engage in group discussions for everyone to have an idea of the problem, sharing their ideas and building upon those ideas. An article on Happy Neuron (2019) implied that student shares their ideas while at the same time explaining why that is their ideas. The study of Craven (2013) supplemented the idea on the article that student gives their reasons for others to also understand the though and engage in a discussion to either confirm or debunk the idea. The article presented on Teach Starter (2017) explained that the discussion conducted by the students is one way for them to formulate a good perspective on the topic or problem. The study of Russo J. et al. (2018) and Stathakis (2013) expanded further the idea presented that the arguments the learners will delve on will build on their idea and structure their thought

The response of the student states that they have retained some information from previous games or problems and that they applied those concepts as they progress. Russo T. (2018), Buchheister (2017) and Bragg (2012b) emphasized that some interrelated concepts are present in games that help develop the retention of students and apply those concepts later on. When comparing the first and sixth observation, there is a 1.74 mean difference, which is a highly significant improvement. The transition of the students from limited proficiency to proficiency is a very good improvement and it is evident using the Tukey HSD test and observing Figure 5, there is an improvement on the students' quality in their ability to frame personal responses and acknowledge other perspectives.

Evaluate Assumptions

It is a part of the decision-making process to identify and evaluate their assumptions as well as other assumptions. But they are not also only limited to the ones that are presented to them but also be able to identify hidden and abstract ones. The progress of the learners' critical thinking ability to evaluate assumptions observed from pre-implementation (1) to post-implementation (6) that is presented in Table 10.

Table 10. Observation on the Critical Thinking ability to evaluate assumptions.

Observation	Mean	SD	*f*	*p*
1	1.36 **a**	0.483	148.926	0.000**
2	1.76 **b**	0.578		
3	2.22 **c**	0.612		
4	2.56 **d**	0.590		
5	2.71 **d**	0.539		
6	3.11 **e**	0.656		

** $p < 0.01$

Based on the result of the statistical analysis, there is a steady improvement on the students' critical thinking ability to evaluate assumptions. As stated by White & McCoy (2019) and Boaler (2016) the evaluation of the assumptions formulated and or acquired is one way of finding a solution to a problem. It is evident in Table 10 that the learners have improved when the means of the pre-implementation (1) compared to the post-implementation (6). The progress of the students' presented in an interval plot found in Figure 6 that records the first observation (pre-implementation) to the last observation (post-implementation).

Based on Table 10, the observation conducted during the pre-implementation (1) had a mean of 1.34 which interpreted as students possess a limited proficiency in evaluating assumptions. The result implies that students fail to identify and evaluate the important assumptions behind the claims and recommendations made (CTL, 2005).

The responses of the students have some confusion and doubt and it is understandable since common word problems have to be dissected to fully understand the gist of the problem. The study

conducted by Magnussen et al. (2014) stated that Mathematics is a subject that is feared or even loathed by many students and their assumptions may be affected due to the subject. The study of Nfon (2018) further supported that this could also stem from their negative experiences in mathematics making them have second thought and confusion on the problem that is presented to them.

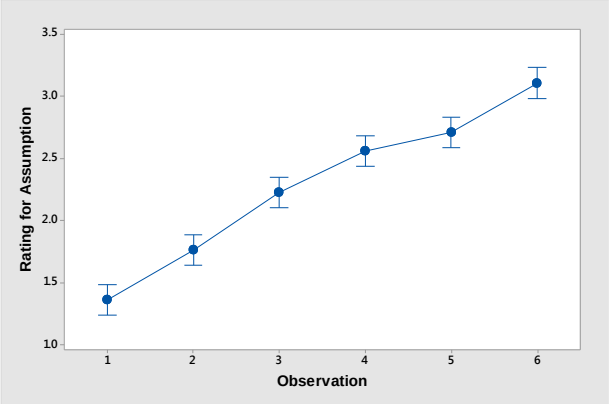

Figure 6. Interval plot of the progress of the students' critical thinking ability to evaluate assumptions

The response of the students' stated that they are experimenting on their assumptions to get a possible solution. The study of Stathakis (2013) explained experimentation in games is common as those trials may lead to a good outcome. The principle presented in the study of Russo J. et al. (2018) emphasized that winning a game is a matter of chance, so trial and error is an approach that may have a positive result or negative, this approach is a matter of luck. The response of the student shows an out-of-the-box thinking demonstrating that they do not solely focus on the problem but associates it to other subjects or topics. The study of Stathakis (2013) and Hilliard & Kargbo (2017) gave meaning to the interrelatedness of games adheres to relating the concept being faced to concepts from other games and gradually understanding the problem and coming up with a solution.

When comparing the first and sixth observation, there is a 1.74 mean difference, which is a highly significant improvement. The transition of the students from limited proficiency to proficiency is a very good improvement and it is evident using the Tukey HSD test and observing Figure 6, there is an improvement in the students' quality in their ability to evaluate assumptions.

Evaluate Evidences

Critical thinking is not just about accepting everything that seems true, but rather, they also question and analyze the evidence presented. They can also provide new possible information or data to also be considered. The progress of the learners' critical thinking ability to evaluate evidence is observed from pre-implementation (1) to post-implementation (6) that is presented in Table 11.

Table 11. Observation on the Critical Thinking ability to evaluate evidence.

Observation	Mean	SD	*f*	*p*
1	1.45 **a**	0.499	145.271	0.000**
2	1.91 **b**	0.577		
3	2.21 **c**	0.580		
4	2.53 **d**	0.578		
5	2.73 **d**	0.500		
6	3.21	0.657		

** $p < 0.01$

Based on the result of the statistical analysis, there is a steady improvement of the students' critical thinking ability to evaluate evidence. The study of Hafni (2018) and Stathakis (2013) discussed that analyzing the assumptions to prove a claim is an aspect of games that encourages the players to experiment and gather evidence to support and prove their claims. It is evident in Table 11 that the learners have improved when the means of the pre-implementation (1) is compared to the post-implementation (6). The progress of the students' presented in an interval plot found in Figure 7 that records the first observation (pre-implementation) to the last observation (post-implementation).

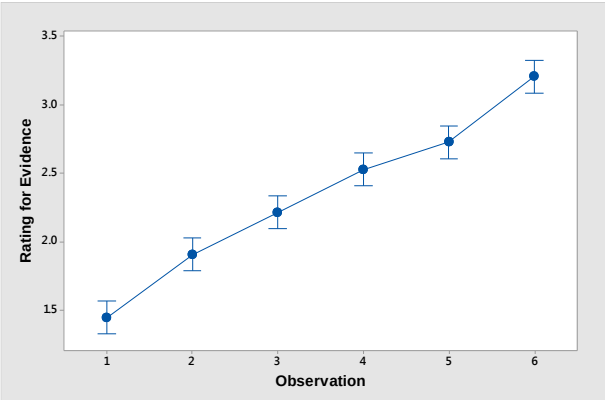

Figure 7. Interval plot of the progress of the students' critical thinking ability to evaluate evidence

Based on Table 11, the observation conducted during the pre-implementation had a mean of 1.45 and interpreted as students possess a limited

proficiency in evaluating evidence. The result indicates that students fail to identify data and information that counts as evidence for truth-claims and fails to evaluate its credibility (CTL, 2005). The responses of the students are some of the basic steps in problem-solving, but are only at the surface level. The students still lack the skill in identifying and supporting their evidence as supported by the study of White & McCoy (2019) and Boaler (2016).

The response indicates the drive of the students to understand and discover the answer to the problem is a sign that they are motivated to continue the rigorous process in problem-solving. Since the motivational contribution of games is a factor that support the players to engage in the game or continue to play even if it seems difficult. The studies of Ankucic (2018), Duncan (2018), Nfon (2018), and Magnussen et al. (2014) attributed this difficulty encountered by the student as a motivation for them to find the answer to the problem. The response of the student shows that they occasionally encounter problems with their members with their tomfoolery and competitiveness. The competitive nature of games is a good aspect as it helps students to work harder to win the game as long as it is a healthy competition. The study of August (2016) and Friehs (2016) stipulated that sometimes this competition becomes rivalry that derails the learning goal and diverts to the competition instead.

When comparing the first and sixth observation, there is a 1.76 mean difference, which is a highly significant improvement. The transition of the students from limited proficiency to proficiency is a very good improvement and it is evident using the Tukey HSD test and observing Figure 7, there is an improvement on the students' quality in their ability to evaluate evidence.

Evaluate The Implications, Conclusions, and Consequences

An aspect of critical thinking is not just seeking the possible answer or solution to the problem, but also thinks ahead and evaluates the possible outcomes of the decisions that would be made. Considering and evaluating all the probable solutions and identifying their pros and cons to the end result of the problem. The progress of the learners' critical thinking ability to evaluate implications, conclusions, and consequences are observed from pre-implementation (1) to post-implementation (6) that is presented in Table 12.

Table 12. Observation on the Critical Thinking ability to evaluate the implications, conclusions, and consequences.

Observation	Mean	SD	*f*	*p*
1	1.40 **a**	0.491	196.837	0.000**
2	1.85 **b**	0.543		
3	2.21 **c**	0.580		
4	2.64 **d**	0.541		
5	2.79 **d**	0.503		
6	3.35 **e**	0.642		

** $p < 0.01$

Based on the result of the statistical analysis, there is a steady improvement of the students' critical thinking ability to evaluate the implications, conclusions, and consequences. The studies of White & McCoy (2019), Russo J. et al. (2018), Hilliard & Kargbo (2017), August (2016), and Boaler (2016) imply that the active engagement of the students toward the games helps them come up with answers or solutions to a problem. It is evident in Table 12 that the learners have improved when the means of the pre-implementation (1) is compared to the post-implementation (6). The progress of the students is presented in an interval plot found in Figure 8 that records the first observation (pre-implementation) to the last observation (post-implementation).

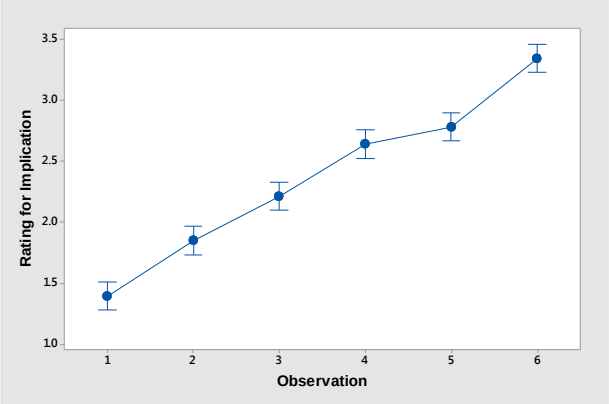

Figure 8. Interval plot of the progress of the students' critical thinking ability to evaluate implications, conclusions, and consequences

Based on Table 12, the observation conducted during the pre-implementation had a mean of 1.40 which is interpreted as students possess a limited proficiency in evaluating implications, conclusions, and consequences. This means that students fail to identify implications, conclusions and consequences of the issue or the key relationship between the other elements of the problem, such as context, assumptions, or data and evidence (CTL, 2005). The responses of the students contain some valid points

but it has weak arguments when it comes to their answer. According to the study of Nfon (2018), the problem may not be solely the student fault but could stem from their training in elementary and high school, which could be a factor in their answering process.

The response of the students demonstrates their retention of information during their discussion and use that information to formulate a possible solution to the problem. Games stimulate the memory of a player to recall past actions or moves that were done to either continue to move in a similar path or review the error made in committing such move. There is a similar claim in the study of Duncan (2018), Russo T. (2018), Buchheister et al. (2017), and Bragg (2012b) that the analysis of moves or decisions made is a crucial part of any gameplay as it will help a player correct move errors or strategies further to attain victory. The response of the student depicts their confidence in their answer and it is clear that they have applied the previous concepts about the problem. The studies of Reed & Young (2018), Rutherford (2015), Prisner (2014), and Craven (2013) explained that the problems presented in games help the students develop their problem-solving skills and enhance their reasoning skills.

When comparing the first and sixth observation, there is a 1.95 mean difference, which is a highly significant improvement. The transition of the students from limited proficiency to high proficiency is a very good improvement and it is evident using the Tukey HSD test and observing Figure 8, there is an improvement on the students' quality in their ability to evaluate the implications, conclusions, and consequences.

SUMMARY

This study investigated the use of game-aided instruction on the critical thinking skill of college students at San Isidro College during the academic year 2019 – 2020. A total of one-hundred twenty-one students are in the experimental group and a total of one hundred two students are in the controlled group giving a total of two hundred twenty-three students who were enrolled in Mathematics in the Modern World. The selection of these students followed the multi-stage sampling procedure and the experimental group experienced the intervention. The researcher utilized the parsimonious research design in the study, applying both quantitative and qualitative descriptions. The study delved into the factors affecting critical thinking, the difference of pure learner-centered teaching and game aided instruction to critical thinking and the correlation between games and critical thinking. The research also examined the individual improvements of the students in critical thinking, referring to the criterion for critical thinking developed by NEUI.

CONCLUSION

Based from the findings of the study drew the following conclusions:

1. Gender does not play a part in the students' critical thinking ability. Age is to be considered but does not affect the capacity to think critically.
2. Game-Aided Instruction has a more significant impact on the students learning when compared to a pure learner-centered teaching approach. Game-Aided instruction has a more positive impact on the students learning as it can address multiple concepts within a short amount of time.
3. Due to the active nature of games, Game-Aided Instruction offers a teaching strategy that promotes active learning, interaction, out of the box thinking, and at the same time engaging and enjoyable for the learners.
4. Using Game-Aided Instruction can improve students' academic achievement and enhance their critical thinking ability, provided that the games are structure and is aligned with the lesson
5. Using Logical-Mathematical Games can enhance the students' ability to think critically, with the guidance and feedback from the teacher.

REFERENCES

Alkharusi, H.A., Sulaimani, H.A., & Neisler, O. (2019). Predicting Critical Thinking Ability of Sultan Qaboos University Students. *International Journal of Instruction*, 12(2), 491-504. https://doi.org/10.29333/iji.2019.12231a.

Amr, K. (2012). Learning through Games: Essential Features of an Educational Game. Syracuse University, Syracuse, NY, United States. Instructional Design, Development and Evaluation – (Published Dissertations) 56. Retrieved from https://surface.syr.edu/idde_etd/56

Ankucic, M. (2019). The Value of Mathematics Games. Mathletics. Retrieved from https://www.mathletics.com/blog/using-mathletics/value-of-games-in-mathematics/

August, S. (2016). Pros & Cons of Game-based Learning. Retrieved from https://saraaugust.wordpress.com/2016/05/08/pros-cons-of-game-based-learning/

Bagheri, F. & Ghanizadeh, A. (2016). Critical Thinking and Gender Differences in Academic Self-regulation in Higher Education. Journal of Applied Linguistics and Language Research. 3(3):133 – 145

Bay-Williams, J. M. and Kling, G. (2014). Enriching Addition and Subtraction Fact Mastery Through Games. *Teaching Children Mathematics*, 21(4), 238-247.

Boaler, J. (2016). Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching. New York, NY: Jossey-Bass

Bragg, L. A. (2012a). The Effect of Mathematical Games on On-Task Behaviours in the primary classroom. *Mathematics Education Research Journal*, 24(4), 385–401. DOI:10.1007/s13394-012-0045-4.

Bragg, L. A. (2012b). Testing the Effectiveness of Mathematical Games as a Pedagogical Fool for Children's Learning. *International Journal of Science and Mathematics Education*, 10(6), 1445–1467. https://doi.org/10.1007/s10763-012-9349-9

Buchheister, K., Jackson, C., and Taylor, C. (2017) Math Games: A Universal Design Approach to Mathematical Reasoning. Australian Primary Mathematics Classroom, 22(4), 7–12.

Chang, K.E., Wu, L.J. Weng, S.E., Sung, Y.T. (2012). Embedding Game-Based Problem-Solving Phase into Problem-Posing System for Mathematics Learning. *Computers & Education*, 58(2), 775–786.

Cherry, K. (2019). The Experiential Learning Theory of David Kolb. Retrieved from https://www.verywellmind.com/experiential-learning-2795154

Center for Teaching and Learning (2005). Critical Thinking Rubric. CTL Bulletin. Retrieved from https://web.uri.edu/assessment/files/CriticalThinkingRubric_NEIU.pdf

Cicchino, M.I. (2015). Using game-based learning to foster critical thinking in student discourse. *Interdisciplinary Journal of Problem Based Learning*, 9(2). DOI:10.7771/1541-5015.1481.

Clarke, D.M. & Roche, A. (2010) The Power of a Single Game to Address a Range of Important Ideas in Fraction Learning. *Australian Primary Mathematics Classroom*, 15(3), 18–23.

Craven, J.D., (2013). How are LSAT logic games relevant to law school? Retrieved from https://lawschooli.com/how-are-lsat-logic-games-relevant-to-law-school/.

Doyle, A. (2019). Critical Thinking Definition, Skills, and Examples. The balance careers. Retrieved from https://www.thebalancecareers.com/critical-thinking-definition-with-examples-2063745

Duncan, S. (2018). 4 Reasons to Promote Math Success through Games. Retrieved from https://blog.mindresearch.org/blog/game-based-learning-tips-math

Dwyer, C.P. & Walsh, A. (n.d). A quantitative case study of critical thinking development through adult distance learning. Retrieved from https://www.psychologytoday.com/us/blog/thoughts-thinking/201708/age-and-critical-thinking

Education World. (2013). Five Reasons to Use Games in the Classroom. Retrieved from https://www.educationworld.com/a_curr/reasons-to-play-games-in-the-classroom.shtml.

Figliuolo, M. (2016). The Importance of Critical Thinking. Retrieved from https://www.lynda.com/Business-Skills-tutorials/importance-critical-thinking/424116/500485-4.html

Friehs, B. (2016). Games in Adult Foreign Language Teaching. In Proceedings of 3rd International Conference on Language, Innovation, Culture and Education, 51–61. Singapore: Interdisciplinary Circle of Science, Arts and Innovation.

Hafni, R.N. (2018). 21st Century Learner: Be a Critical Thinker. Retrieved from https://www.researchgate.net/publication/324209643_21st_Century_Learner_Be_a_Critical_Thinker

Halpern, D. F. (2003). The "how" and "why" of critical thinking assessment. Critical thinking and reasoning: Current research, theory, and practice, pp 355 – 366. Cresskill, NJ: Hampton Press.

Happy Neuron, (2019). Logic Games: Sharpen your reasoning skills! Retrieved from http://www.happy-neuron.com/logic-games.

Hilliard, A. & Kargbo, H.F. (2017). Educationally Game-Based Learning Encourages Learners to Be Actively Engaged in Their Own Learning. *International Journal of Education and Practice*. Vol. 5, No. 4, 45-60, DOI: 10.18488/journal.61.2017.54.45.60

Ku, O., Chen, S. Y. Wu, D. H., Lao, A. C. C., & Chan, T.-W. (2014). The Effects of Game-Based Learning on Mathematical Confidence and Performance: High Ability vs. Low Ability. *Journal of Educational Technology & Society*. 17(3), 65 – 78. Retrieved from www.jstor.org/stable/jeductechsoci.17.3.65

Kurfiss, J.G. (1988), "critical thinking theory, research, practice, and possibilities". ERIC document reproduction service No. ED 304-041 in n. *International Journal of Lifelong Education*, Vol 10, pp.287-303, No.4, 1991. DOI: 10.1080/0260137910100403.

Magnussen, R., Hansen, S.D. Planke, T., and Sherson, J.F., (2014). "Games as a Platform for Student Participation in Authentic Scientific Research. *The Electronic Journal of e-Learning* Volume 12 Issue 3 2014, pp259-270. Retrieved from www.ejel.org

Mavridis, A. and Tsiatsos, T. (2016). Game-Based Assessment: Investigating the Impact on Test Anxiety and Exam Performance. *Journal of Computer Assisted Learning*, 33(2), 1–14

McLeod, S. (2019). Constructivism as a theory for teaching and learning. Retrieved from https://www.simplypsychology.org/constructivism.html

Nfon, N.F. (2018). The Use of Mathematical Games and Secondary School Students' Achievement in Mathematics in Fako Division, South West Region of Cameroon. *Journal of Education & Entrepreneurship*. Vol. 5, N0.1, 21-32. https://doi.org/10.26762/jee.2018.40000009

Nicholoson, B. (2019). Why It's Alarming That Students Aren't Learning to Think Critically and why critical thinking is so important. Retrieved from https://medium.com/publishous/why-its-alarming-that-students-aren-t-learning-to-think-critically-2aeae831ac5a

Özgenç, N. (2010). Oyun temelli matematik etkinlikleriyle yürütülen öğrenme ortamlarından yansımalar (Unpublished master's thesis). Karadeniz Teknik University, Trabzon.

Patel, D. (2018). 16 Characteristics of Critical Thinkers. Entrepreneur – Asia Pacific. Retrieved from https://www.entrepreneur.com/article/321660

Plass, J.L., Homer, B.D., & Kinzer, C.K. (2015). Foundations of Game-Based Learning. Educational Psychologist, 50(4), 258-283. DOI:10.1080/00461520.2015.1122533.

Plass, J.L., Perlin, K. & Nordlinger, J. (2010). The games for learning institute: Research on design patterns for effective educational games. Paper presented at the Games Developers Conference, San Francisco, CA.

Playmeo, (n.d.). Critical thinking: Group games are ideal for developing critical-thinking skills. Retrieved from https://www.playmeo.com/theme/critical-thinking/.

Prisner, E. (2014). What's a Game? Game Theory through Examples (pp.1-2). Washington, DC: The Mathematical Association of America.

Reed, K.E. & Young, J.M. (2018). Math Games to Excite Young Minds: Why Math Games? Retrieved from https://dreme.stanford.edu/news/math-games-excite-young-minds.

Russo, J., Russo, T., and Bragg, L.A. (2018). Five Principles of Educationally Rich Mathematical Games. *Australian Primary Mathematics Classroom.* 23(3) pp 30 – 34.

Russo, T. (2018). The Cat in the Hat mathematical investigation. *Australian Primary Mathematics Classroom*, 22(2), 13–16.

Rutherford, K. (2015). Why Play Math Games? National Council of Teachers of Mathematics. Retrieved from https://www.nctm.org/publications/teaching-children-mathematics/blog/why-play-math-games_/

Shaffer, D.W., Halverson, R., Squire, K.R., & Gee, J.P. (2005). Video games and the future of learning (WCER working paper No.2005-4). Madison: University of Wisconsin-Madison, Wisconsin Center for Education Research (NJ1)

Shubina, I. & Kulakli, A. (2019). Critical Thinking, Creativity and Gender Differences for Knowledge Generation in Education. *Literacy Information and Computer Education Journal* (LICEJ), 10(1) pp. 3086 – 3093. DOI: 10.20533/licej.2040.2589.2019.0405

Stathakis, R., (2013). Five Reasons to Use Games in the Classroom. Retrieved from https://www.educationworld.com/a_curr/reasons-to-play-games-in-the-classroom.shtml.

Teach Starter (2017). 10 Benefits to Playing Games in the Classroom. Retrieved from https://www.teachstarter.com/us/blog/10-benefits-playing-games-classroom-us/

Tips for Teachers (2013). Critical Thinking in Elementary Mathematics: What? Why? When? And How? Retrieved from http://www.tc2.ca.

Turan, Z. & Meral, E. (2018). Game-Based Versus to Non-Game-Based: The Impact of Student Response

Systems on Students' Achievements, Engagements and Test Anxieties. *Informatics in Education*. Vol. 17, No. 1, 105–116. DOI: 10.15388/infedu.2018.07

Turgut, S. & Temur, Ö.D. (2017). The Effect of Game-Assisted Mathematics Education on Academic Achievement in Turkey: A Meta-Analysis Study. International Electronic *Journal of Elementary Education*. Volume 10, Issue 2, pp 195 – 206. DOI: 10.26822/iejee.2017236115

Turocy, T. & von Stengel, B. (2001). Definition of games. Game Theory (pp.2-6). Cambridge, Massachusetts: Academic Press.

Wang, A.I. (2015). The Wear Out Effect of a Game-Based Student Response System. *Computers & Education*, 82, 217–227.

White, K. & McCoy, L.P. (2019). Effects of Game-Based Learning on Attitude and Achievement in Elementary Mathematics. *Networks: An Online Journal for Teacher Research*: 21(1) pp. 1 – 19.https://doi.org/10.4148/2470-6353.1259

Yılmaz, D. (2014). Ortaokul 5. sınıf matematik dersi geometrik cisimler öğretiminde, matematik oyunları kullanımının öğrenci başarısı ve tutumuna etkisi (Unpublished master's thesis). Gazi University, Ankara.