BUKTI KORESPONDENSI

ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul artikel : Project-Based Learning Via Traditional Game in Physics Learning: Its Impact on Critical Thinking, Creative Thinking, and Collaborative Skills

Jurnal : Jurnal Pendidikan IPA Indonesia Vol. 12 No. 2, pp 286-292

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No.	Perihal	Tanggal
1	Bukti Konfirmasi Submit Artikel dan Artikel yang disubmit	10 Maret 2023
2	Bukti Konfirmasi review dan hasil review pertama dan artikel yang disubmit	16 Mei 2023
3	Bukti Konfirmasi Pembayaran Artikel JPII	24 Mei 2023
4	Bukti Konfirmasi review dan hasil review kedua dan artikel yang disubmit	19 Juni 2023
5	Bukti Konfirmasi review dan hasil review ketiga dan artikel yang disubmit	23 Juni 2023
6	Bukti Konfirmasi Proofreading Artikel	24 Juni 2023
7	Bukti Konfirmasi Letter of Accepted Artikel	11 Juli 2023
8	Bukti Konfirmasi Surat Pernyataan dan deklarasi	11 Juli 2023
9	Bukti Konfirmasi artikel published online dan artikel yang publish	13 Juli 2023

1. Bukti Konfirmasi Submit Artikel dan Artikel yang disubmit

(10 Maret 2023)

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[JPII] Submission Acknowledgement

1 pesan

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

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DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: Creative thinking, critical thinking, traditional games, collaboration, PjBL

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out.

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centered learning to student-centered. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative.

The learning model following the paradigm's demands is the project-based learning model. The project-based learning model is student-centered, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The PjBL model encourages students to work independently in producing a product (Susilawati et al., 2018). Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. On the other hand, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these two skills for students, the effects of PjBL through games on students' critical thinking, creative thinking, and

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collaborative skills will be explained clearly in this paper.

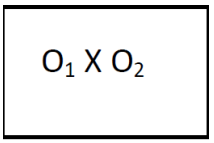
METHODS

The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

Measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:



O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The test was carried out twice before and after the experimental treatment in this design. The test carried out before getting the treatment is called the pre-test. The pre-test was given to the experimental class (O1). After doing the pre-test, the next step is to give the topic of the game the project will make. Next, the final step is to give a post-test.

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1. The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

$$N - gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques, and planning assessments in the form of assessments before being given treatment and assessments after being given treatment.

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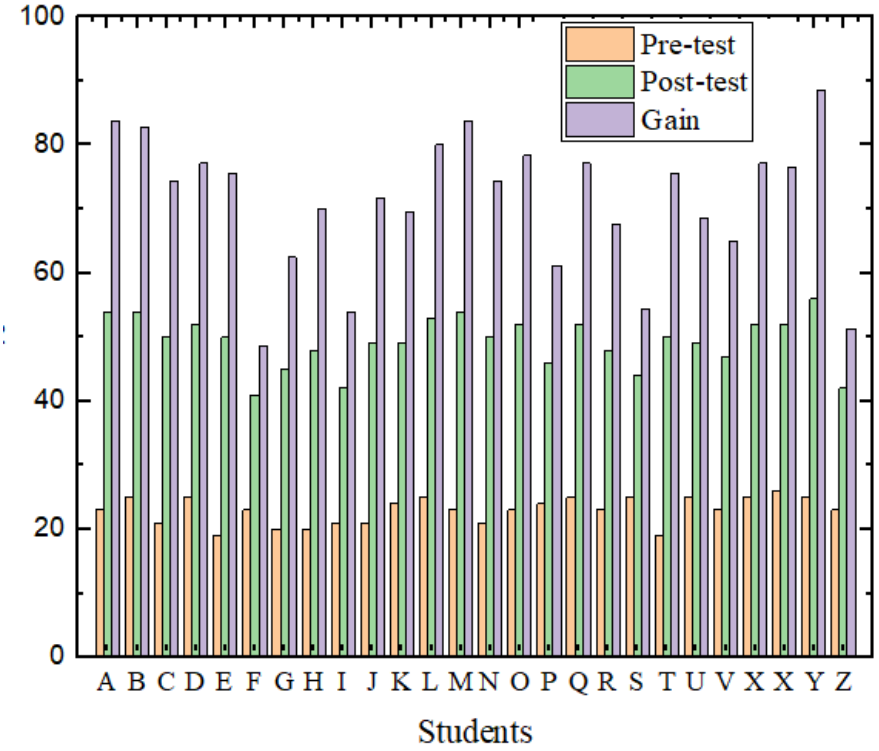

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results.

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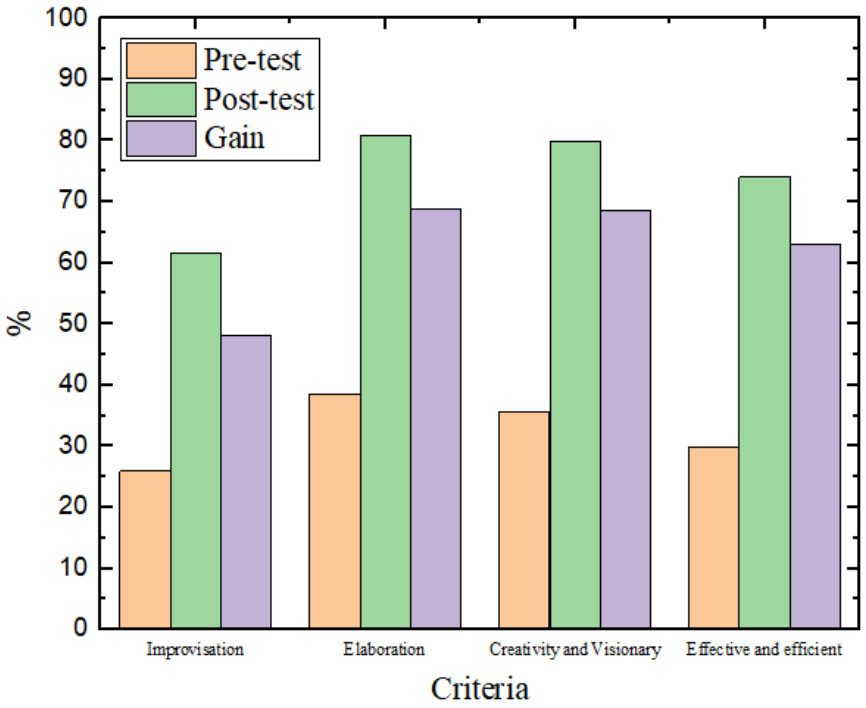

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang. Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills

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Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97.

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. The results of this study indicate that learning using the PjBL model affects students' collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PBJI model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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2. Bukti Konfirmasi review dan hasil review pertama dan artikel yang disubmit

(11 September 2021)

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Update: Manuscript Review

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Nationally Accredited based on the Decree of the Minister of Research, Technology and Higher Education, Number 2/E/KPT/2015

Jurnal Pendidikan IPA Indonesia (Indonesian Journal of Science Education) [p-ISSN 2339-1286 | e-ISSN 2089-4392] published a scientific paper on the results of the study and review of the literature in the sphere of natural science education in primary education, secondary education and higher education. This journal in collaborate with ***Perkumpulan Pendidik IPA Indonesia (PPII)*** / **Indonesian Society for Science Educators**

This journal has been indexed in Google Scholar, DOAJ, EBSCO, **SCOPUS**

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Kepada: Jurnal Pendidikan IPA Indonesia <jpii@mail.unnes.ac.id>

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: Creative thinking, critical thinking, traditional games, collaboration, PjBL

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out.

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centered learning to student-centered. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative.

The learning model following the paradigm's demands is the project-based learning model. The project-based learning model is student-centered, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The PjBL model encourages students to work independently in producing a product (Susilawati et al., 2018). Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. On the other hand, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these two skills for students, the effects of PjBL through games on students' critical thinking, creative thinking, and

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GAP ANALYSIS refers to articles published in various internationally reputable journals to emphasize the novelty of research.
• clear limitation of research objectives

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collaborative skills will be explained clearly in this paper.

METHODS

The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

Measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:

O_1 X O_2

O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The test was carried out twice before and after the experimental treatment in this design. The test carried out before getting the treatment is called the pre-test. The pre-test was given to the experimental class (O1). After doing the pre-test, the next step is to give the topic of the game the project will make. Next, the final step is to give a post-test.

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1. The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques, and planning assessments in the form of assessments before being given treatment and assessments after being given treatment.

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• Each stage is explained and analyzed by what method
• Data analysis must be with clear references
• The research instruments used were elaborated to the data analysis technique
• It is hoped that there will be a modification in the stages of research from sources referred by the researcher

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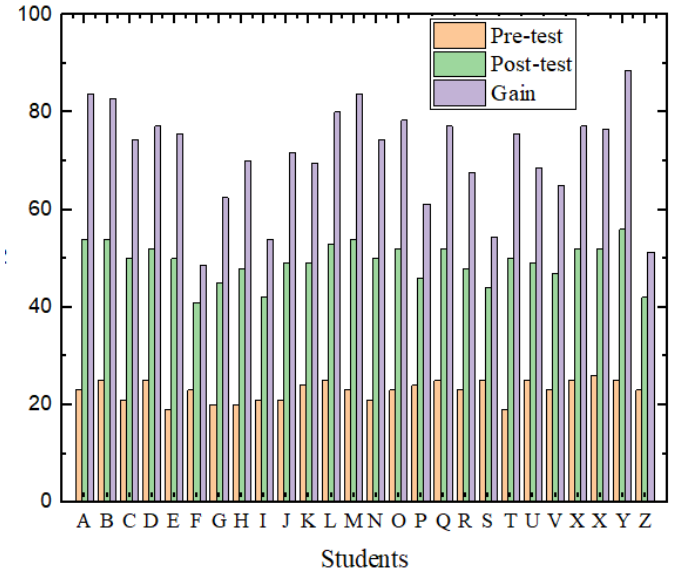

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results.

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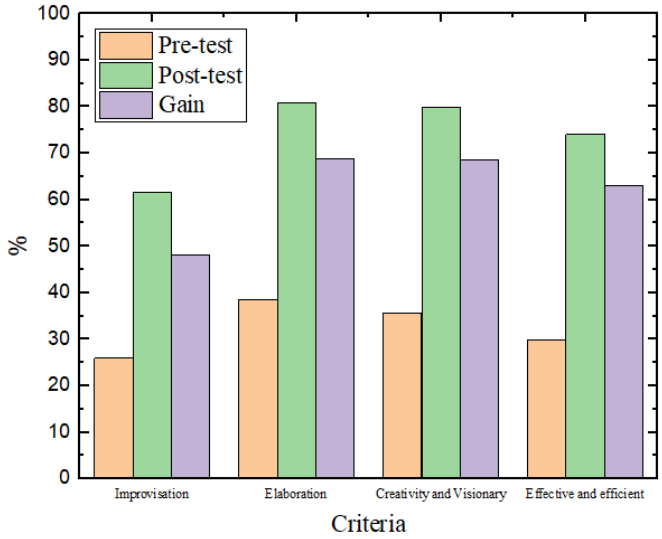

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang. Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

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2. The pictures/tables must not be consecutive.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills

Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97.

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. The results of this study indicate that learning using the PjBL model affects students' collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PBJI model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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	• Does the rationale of the study clearly explained using relevant literature?		√			
	• Is the "aim" of the manuscript clear and understandable?	√				
Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)		√			
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√			
	• Are the validity and reliability of data collection tools established? (only for empirical studies)					
	• Are the data collection tools suitable for the methodology of the study? (only for empirical studies)		√			
Results & Discussio n	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√			
	• Do the data analysis and the interpretation appropriate to the problem and answer the objectives?		√			
	• Does the "discussion" section of the manuscript adequately relate to the current and relevant litarature?		√			
	• Are the findings discussed adequately considering the research question(s), sub-question(s) or hypothesis?		√			
Conclusio n	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
	• Isn't the conclusion a summary and consistent between problems, objectives and conclusion?		√			
Reference s	• Do the references and citations match?		√			
	• Are the writing of references correct?		√			
Quality Criteria	• Do the title, problem, objectives, methods and conclusion are in line? Is it well organized?		√			
	• The quality of the language is satisfactory		√			
	• The work relevant and novel		√			
	• Are there strong consistencies among the parts of the manuscript? (introduction,		√			

	methods, results and discussion, and conclusion)					

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: Creative thinking, critical thinking, traditional games, collaboration, PjBL

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). In order to succeed in 21st-century learning, students need to be capable to think critically and creatively (OECD, 2017; Triyatma, Ratmawati Y, Ridwan, Budiningsih, Suryani, Nurliatani, 2017; Bybee, 2020; Pramasdyahsari, Farida, Irkham, Lilik, 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, the creative and critical thinking ability of students in Indonesia remains low (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centred learning to student-centred. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could be fostering these important skills for the 21st learning century.

Developing learning strategies is a method to help students critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students the opportunity to organize their own learning activities, complete group projects, and create original works (Wang, Teng, & Lin, 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo, S., & Yang, Y. (2012). The project-based learning model is student-centred, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The Project Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). It is crucial for students to be computer and tool knowledgeable in order to learn. Information and communication technology has an impact on every aspect of society, including education (Kong, 2014). Additionally, using multimedia in the classroom contributes to developing critical

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• contain urgency (importance) to research
• contain a carrying capacity in the form of supporting data and facts
• contain a preliminary study as a basis for the importance of the research conducted
• contain a GAP ANALYSIS Departing from the preliminary study, analysis of published articles formulated in the Gap analysis
GAP ANALYSIS refers to articles published in various internationally reputable journals to emphasize the novelty of research.
• clear limitation of research objectives

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thinking abilities and concept understanding (Rosida, Fadiawati, & Jalmo, 2017).

Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. There is a limitation in research that particularly focuses on implementing PjBL using games.

In fact, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these skills for students; therefore, this study intends to explore the effects of PjBL through games on students' critical thinking, creative thinking, and collaborative skills. It will be explained clearly in this paper.

METHODS

The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

The research procedures began by conducting the test before implementing the treatment which is called the pre-test. It was given to the experimental class (O1). After completing the pre-test, then the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The results from the pretest and posttests were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests. The measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:

O_1 X O_2

O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1. The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques, and planning assessments in the form of

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• contain detailed research stages
• Each stage is explained and analyzed by what method
• Data analysis must be with clear references
• The research instruments used were elaborated to the data analysis technique
• It is hoped that there will be a modification in the stages of research from sources referred by the researcher

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2. Each step has been elaborated on and explained how to analyze it.
3. The data analysis has provided clear references.
4. The research instrument has been added and highlighted
5. Even though there is no modification in the stage however it involves more comprehensive variables which consist of creative and critical thinking skills.

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•Tables or graphs (one selected) must represent different results
•The results of data analysis must be strong in answering the analysis gap
•Display of results other than those narrated in table-graph-image-modeling
•The research novelty has not been clear enough
•It is recommended not to repeat the references in the introduction, using previous research findings.
•References used should be taken from reputable journals.
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assessments before being given treatment and assessments after being given treatment.

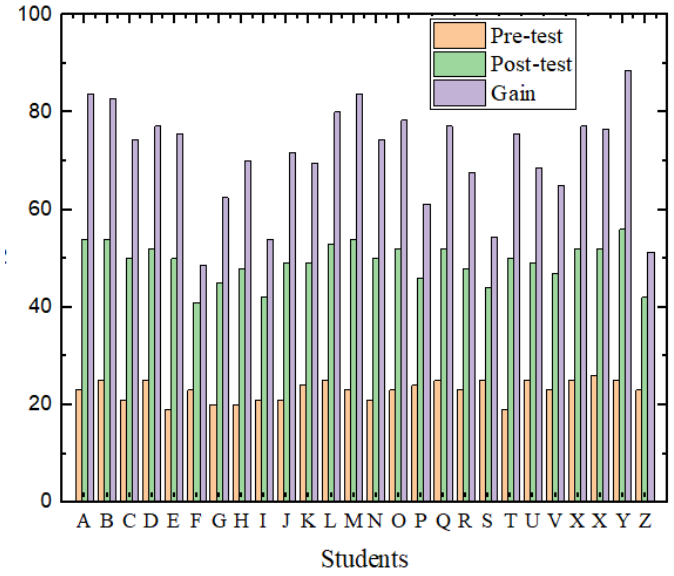

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results.

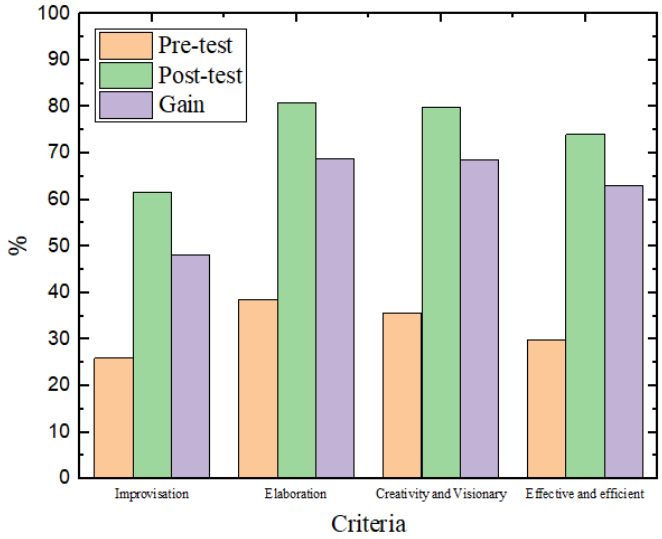

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang. Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

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Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to using the conventional model. This is in line with Pramasdyahsari et.al (2023) that students' collaboration skills and communication abilities improve while the STEM-PjBL was implemented.

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Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. The results of this study indicate that learning using the PjBL model affects students' collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PBJI model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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3. All of the listed references must be cited in the body of the article, and vice versa.

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Paper Title: **PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS**

Parts of review	Guidelines	Yes	Partly	No	Reviewer's note for improvement	Author's responds (highlight of revision)
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Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√			
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Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
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PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

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DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

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Keywords: Creative thinking, critical thinking, traditional games, collaboration, PjBL

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). In order to succeed in 21st-century learning, students need to be capable to think critically and creatively (OECD, 2017; Triyatma, Ratmawati Y, Ridwan, Budiningsih, Suryani, Nurliatani, 2017; Bybee, 2020; Pramasdyahsari, Farida, Irkham, Lilik, 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, the creative and critical thinking ability of students in Indonesia remains low (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centred learning to student-centred. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could be fostering these important skills for the 21st learning century.

Developing learning strategies is a method to help students critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students the opportunity to organize their own learning activities, complete group projects, and create original works (Wang, Teng, & Lin, 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo, S., & Yang, Y. (2012). The project-based learning model is student-centred, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The Project Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). It is crucial for students to be computer and tool knowledgeable in order to learn. Information and communication technology has an impact on every aspect of society, including education (Kong, 2014). Additionally, using multimedia in the classroom contributes to developing critical

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thinking abilities and concept understanding (Rosida, Fadiawati, & Jalmo, 2017).

Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. There is a limitation in research that particularly focuses on implementing PjBL using games.

In fact, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these skills for students; therefore, this study intends to explore the effects of PjBL through games on students' critical thinking, creative thinking, and collaborative skills. It will be explained clearly in this paper.

METHODS

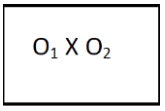
The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

The research procedures began by conducting the test before implementing the treatment which is called the pre-test. It was given to the experimental class (O1). After completing the pre-test, then the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The results from the pretest and posttests were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests. The measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:



O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1. The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques, and planning assessments in the form of

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assessments before being given treatment and assessments after being given treatment.

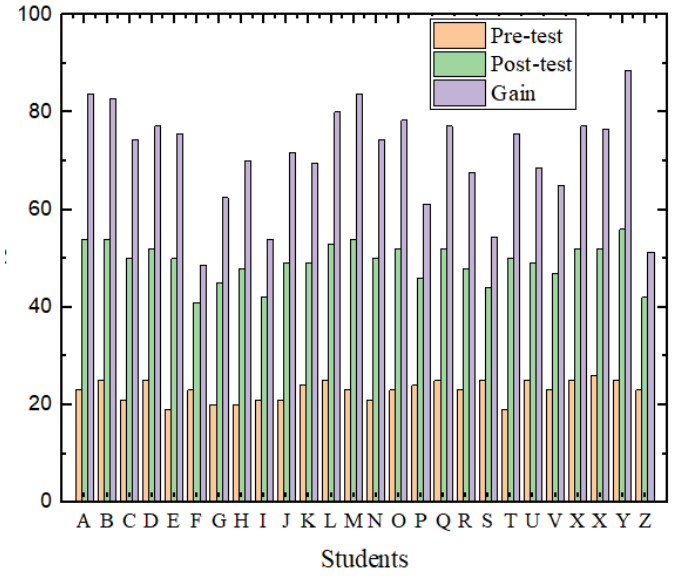

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

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Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results.

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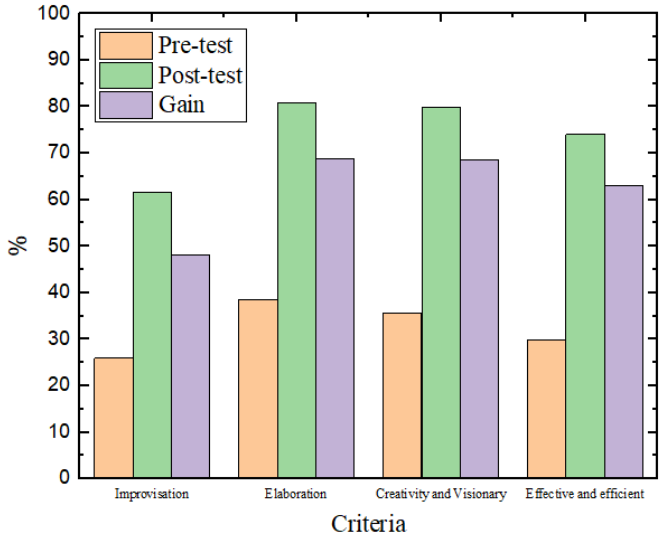

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang. Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to using the conventional model. This is in line with Pramasdyahsari et.al (2023) that students' collaboration skills and communication abilities improve while the STEM-PjBL was implemented.

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Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. The results of this study indicate that learning using the PjBL model affects students' collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PBJI model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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Paper Title: **PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS**

Parts of review	Guidelines	Yes	Partly	No	Reviewer's note for improvement	Author's responds (highlight of revision)
Title	• Does the subject matter fit within the scope of journal?	√				
	• Does the title clearly and sufficiently reflect its contents?	√				
Abstract	• Does the abstract contain informative, including Background, Methods, Results and Conclusion?	√				
Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√			
	• Is research question of the study clear and understandable?		√			
	• Does the rationale of the study clearly explained using relevant literature?		√			
	• Is the "aim" of the manuscript clear and understandable?	√				
Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)		√			
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√			
	• Are the validity and reliability of data collection tools established? (only for empirical studies)					
	• Are the data collection tools suitable for the methodology of the study? (only for empirical studies)		√			
Results & Discussio n	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√			
	• Do the data analysis and the interpretation appropriate to the problem and answer the objectives?		√			
	• Does the "discussion" section of the manuscript adequately relate to the current and relevant litarature?		√			
	• Are the findings discussed adequately considering the research question(s), sub-question(s) or hypothesis?		√			
Conclusio n	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
	• Isn't the conclusion a summary and consistent between problems, objectives and conclusion?		√			
Reference s	• Do the references and citations match?		√			
	• Are the writing of references correct?		√			
Quality Criteria	• Do the title, problem, objectives, methods and conclusion are in line? Is it well organized?		√			
	• The quality of the language is satisfactory		√			
	• The work relevant and novel		√			
	• Are there strong consistencies among the parts of the manuscript? (introduction,		√			

	methods, results and discussion, and conclusion)					

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

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Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research for measuring the effectiveness of implementing project-based learning. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

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Keywords: Creative thinking, critical thinking, collaboration, PjBL, traditional games,

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). In order to succeed in 21st-century learning, students need to be capable to think critically and creatively (OECD, 2017; Triyatma, Ratmawati Y, Ridwan, Budiningsih, Suryani, Nurliatani, 2017; Bybee, 2020; Pramasdyahsari, Farida, Irkham, Lilik, 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, the creative and critical thinking ability of students in Indonesia remains low (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centred learning to student-centred. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could be fostering these important skills for the 21st learning century.

Developing learning strategies is a method to help students critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students the opportunity to organize their own learning activities, complete group projects, and create original works (Wang, Teng, & Lin, 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo, S., & Yang, Y. (2012). The project-based learning model is student-centred, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The Project Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). It is crucial for students to be computer and tool knowledgeable in order to learn. Information and communication technology has an impact on every aspect of society, including education (Kong, 2014). Additionally, using multimedia in the classroom contributes to developing critical

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thinking abilities and concept understanding (Rosida, Fadiawati, & Jalmo, 2017).

Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. There is a limitation in research that particularly focuses on implementing PjBL using games.

In fact, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these skills for students; therefore, this study intends to explore how the PjBL-assisted traditional games could impact students' critical thinking, creative thinking, and collaborative skills which are important in the 21st learning.

METHODS

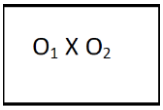
The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

The research procedures began by conducting the test before implementing the treatment which is called the pre-test. It was given to the experimental class (O1). After completing the pre-test, then the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The results from the pretest and posttests were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests instrument. The measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:



O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1. The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques, and planning assessments in the form of assessments before and after treatment.

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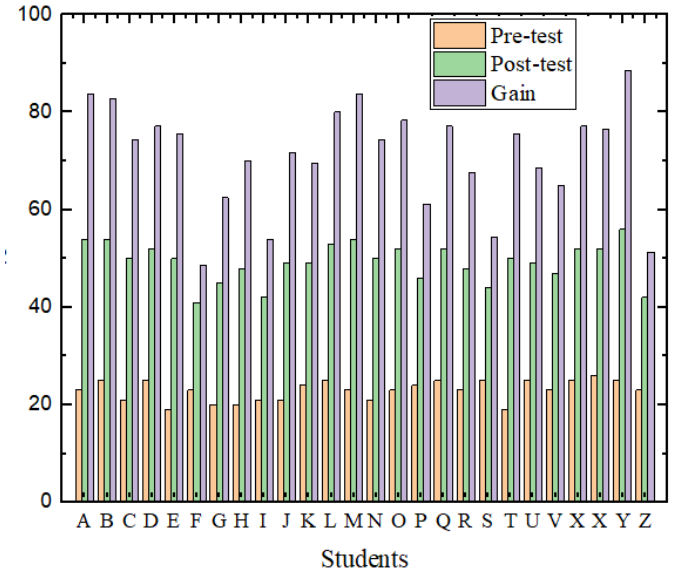

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results.

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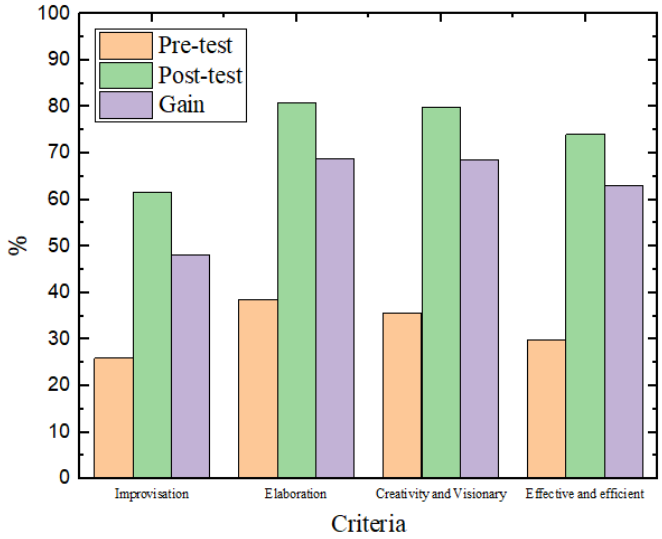

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang. Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to using the conventional model. This is in line with Pramasdyahsari et.al (2023) that students' collaboration skills and communication abilities improve while the STEM-PjBL was implemented.

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Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. Considering this result, it shows that the score is representing the impact of PjBL-assisted traditional games that could positively affect collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PjBL model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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Paper Title: **PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS**

Parts of review	Guidelines	Yes	Partly	No	Reviewer's note for improvement	Author's responds (highlight of revision)
Title	• Does the subject matter fit within the scope of journal?	√				
	• Does the title clearly and sufficiently reflect its contents?	√				
Abstract	• Does the abstract contain informative, including Background, Methods, Results and Conclusion?	√				
Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√			
	• Is research question of the study clear and understandable?		√			
	• Does the rationale of the study clearly explained using relevant literature?		√			
	• Is the "aim" of the manuscript clear and understandable?	√				
Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)		√			
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√			
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Results & Discussio n	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√			
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	• Are the findings discussed adequately considering the research question(s), sub-question(s) or hypothesis?		√			
Conclusio n	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
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Quality Criteria	• Do the title, problem, objectives, methods and conclusion are in line? Is it well organized?		√			
	• The quality of the language is satisfactory		√			
	• The work relevant and novel		√			
	• Are there strong consistencies among the parts of the manuscript? (introduction,		√			

	methods, results and discussion, and conclusion)					

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(23 Juni 2023)

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Best regard,
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PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research for measuring the effectiveness of implementing project-based learning. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: Creative thinking, critical thinking, collaboration, PjBL, traditional games

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). In order to succeed in 21st-century learning, students need to be capable to think critically and creatively (OECD, 2017; Triyatma, Ratmawati Y, Ridwan, Budiningsih, Suryani, Nurliatani, 2017; Bybee, 2020; Pramasdyahsari, Farida, Irkham, Lilik, 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, the creative and critical thinking ability of students in Indonesia remains low (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centred learning to student-centred. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could be fostering these important skills for the 21st learning century.

Developing learning strategies is a method to help students critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students the opportunity to organize their own learning activities, complete group projects, and create original works (Wang, Teng, & Lin, 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo, S., & Yang, Y. (2012). The project-based learning model is student-centred, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The Project Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). It is crucial for students to be computer and tool knowledgeable in order to learn. Information and communication technology has an impact on every aspect of society, including education (Kong, 2014). Additionally, using multimedia in the classroom contributes to developing critical

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thinking abilities and concept understanding (Rosida, Fadiawati, & Jalmo, 2017).

Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. There is a limitation in research that particularly focuses on implementing PjBL using games.

In fact, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these skills for students; therefore, this study intends to explore how the PjBL-assisted traditional games could impact students' critical thinking, creative thinking, and collaborative skills which are important in the 21st learning.

METHODS

The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

The research procedures began by conducting the test before implementing the treatment which is called the pre-test. It was given to the experimental class (O1). After completing the pre-test, then the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The results from the pretest and posttests were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests instrument. The measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:

O_1 X O_2

O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1. The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques, and planning assessments in the form of assessments before and after treatment.

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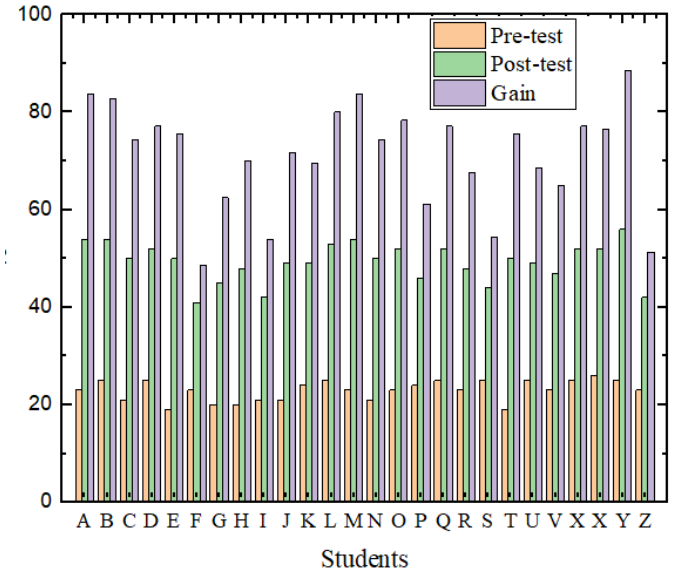

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

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Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results.

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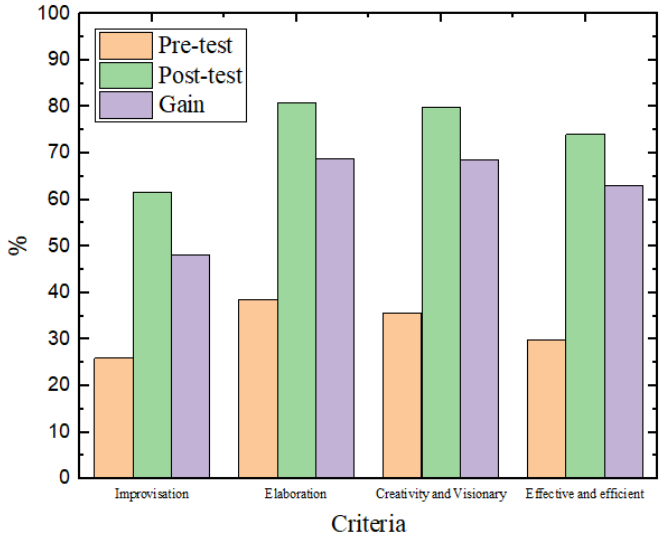

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

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Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang. Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to using the conventional model. This is in line with Pramasdyahsari et.al (2023) that students' collaboration skills and communication abilities improve while the STEM-PjBL was implemented.

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Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. Considering this result, it shows that the score is representing the impact of PjBL-assisted traditional games that could positively affect collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PjBL model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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Paper Title: **PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS**

Parts of review	Guidelines	Yes	Partly	No	Reviewer's note for improvement	Author's responds (highlight of revision)
Title	• Does the subject matter fit within the scope of journal?	√				
	• Does the title clearly and sufficiently reflect its contents?	√				
Abstract	• Does the abstract contain informative, including Background, Methods, Results and Conclusion?	√				
Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√			
	• Is research question of the study clear and understandable?		√			
	• Does the rationale of the study clearly explained using relevant literature?		√			
	• Is the "aim" of the manuscript clear and understandable?	√				
Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)		√			
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√			
	• Are the validity and reliability of data collection tools established? (only for empirical studies)					
	• Are the data collection tools suitable for the methodology of the study? (only for empirical studies)		√			
Results & Discussio n	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√			
	• Do the data analysis and the interpretation appropriate to the problem and answer the objectives?		√			
	• Does the "discussion" section of the manuscript adequately relate to the current and relevant litarature?		√			
	• Are the findings discussed adequately considering the research question(s), sub-question(s) or hypothesis?		√			
Conclusio n	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
	• Isn't the conclusion a summary and consistent between problems, objectives and conclusion?		√			
Reference s	• Do the references and citations match?		√			
	• Are the writing of references correct?		√			
Quality Criteria	• Do the title, problem, objectives, methods and conclusion are in line? Is it well organized?		√			
	• The quality of the language is satisfactory		√			
	• The work relevant and novel		√			
	• Are there strong consistencies among the parts of the manuscript? (introduction,		√			

	methods, results and discussion, and conclusion)					

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME IN PHYSICS LEARNING: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to measure the effectiveness of increasing creative thinking skills in applying the game-assisted PjBL model. The research sample is a local school in Semarang, concerning the direction and objectives of this research for measuring the effectiveness of implementing project-based learning. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. This one-group pretest-posttest design consisted of one predetermined group. After doing the pre-test, the next step was to give the topic of the game that the project would make. The research results show that applying the PbJL model through game techniques is 61.53% with high criteria and 38.64% with medium criteria. The study results also show an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that learning using the PjBL model affects students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: creative thinking, critical thinking, collaboration, PjBL, traditional games

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). Creative thinking and critical thinking skills are critical for students to make decisions when faced with several choices (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). In order to succeed in 21st-century learning, students need to be capable to think critically and creatively (OECD, 2017; Triyatma et al., 2017; Bybee, 2020; Pramasdyahsari et al., 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, the creative and critical thinking ability of students in Indonesia remains low (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. However, based on the current curriculum, it is necessary to change the learning approach from teacher-centric to student-centric. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). Kurniawati and Diantoro (2014) state that the process of learning physics should emphasize direct experience to develop students' conceptual skills so that students can better understand various natural phenomena around them scientifically. In addition, according to Kemendikbud (2016), the learning process should be held interactively, inspiring, fun, and challenging, motivating students to participate actively and providing space for developing students' creativity. In line with this, it can be concluded that students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centred learning to student-centred. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could be fostering these important skills for the 21st learning century.

Developing learning strategies is a method to help students critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students the opportunity to organize their own learning activities, complete group projects, and create original works (Wang et al., 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo & Yang (2012). The project-based learning model is student-centred, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The Project Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). It is crucial for students to be computer and tool knowledgeable in order to learn. Information and communication technology has an impact on every aspect of society, including education (Kong, 2014). Additionally, using multimedia in the classroom contributes to developing critical thinking abilities and concept understanding (Rosida et al., 2017).

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Another method that can focus on students' learning and attract students to the center of learning through dynamic learning activities is the learning while playing method. The use of games in learning that involve the basics of life positively impacts the development of creative abilities and collaborative skills while making meaningful learning fun.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Learning activities through games can increase students' success and facilitate learning (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this fun activity occurs and can be implemented in a learning environment that considers students' characteristics, it can help them gain success in fields such as physics, where students tend to fear and suspect that physics is complex. However, the effect of PjBL through this game on the development of students' creative and critical thinking skills was not well reported. There is a limitation in research that particularly focuses on implementing PjBL using games.

In fact, PjBL, through games, can provide good teaching practices to improve students' creative and critical thinking skills and collaborative skills. Due to the importance of these skills for students; therefore, this study intends to explore how the PjBL-assisted traditional games could impact students' critical thinking, creative thinking, and collaborative skills which are important in the 21st learning.

METHODS

The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014).

This one-group pretest-posttest design consists of one predetermined group. In this design, the test was carried out twice: before treatment (pre-test) and after treatment (post-test).

The research procedures began by conducting the test before implementing the treatment which is called the pre-test. It was given to the experimental class (O1). After completing the pre-test, then the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The results from the pretest and posttests were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests instrument. The measurement of students' creative and critical thinking skills was carried out using the test method. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. Open questions also refer to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

The research pattern of the one-group pretest-posttest design method, according to Sugiyono (2013), is as follows:

O_1 X O_2

O_1 = pre-test score (before treatment)
O_2 = post-test score (after treatment)
X = project-based learning model

The increase in students' critical thinking skills (indicated by the N-gain score) is calculated using Equation 1.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model through Game Techniques

The design of applying the PjBL model through game techniques begins with good goal setting, planning learning through lesson plans using the PjBL method through game techniques,

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and planning assessments in the form of assessments before and after treatment.

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of each class as illustrated as below.

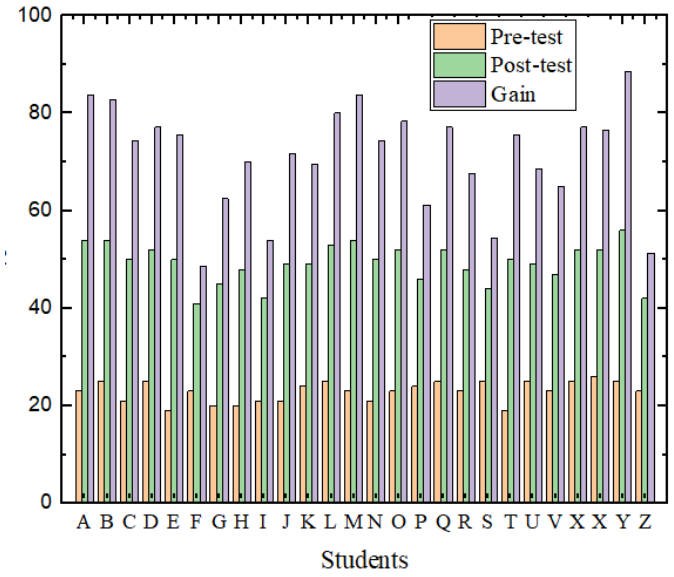

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

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Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 class X MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that the criteria for students' creative thinking skills in applying the PjBL model through game techniques are for 16 students (61.53%) with high criteria and ten people with medium criteria (38.46%). This study's results differ from the research conducted by Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Sumarni and Kadarwati (2020) research to improve creative thinking skills with Ethno-STEM Project-Based Learning for high school students. This study shows increased creative thinking skills, as indicated by the N-Gain value. There are 27.4% of students in the high category, 47.4% in the medium category, and 25.2% in the low category. Meanwhile, research conducted by Apriwanda and Hanri (2022) shows that the creative thinking level of prospective chemistry teachers is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of class X MAN 2 Semarang. Sumarni and Kadarwati's (2020) research used a sample of 230 students from 7 high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results. Figure 2 shows the percentage of pre-test, post-test, and N-gain scores for each indicator of creative thinking skills in the tenth grade of MAN 2 Semarang.

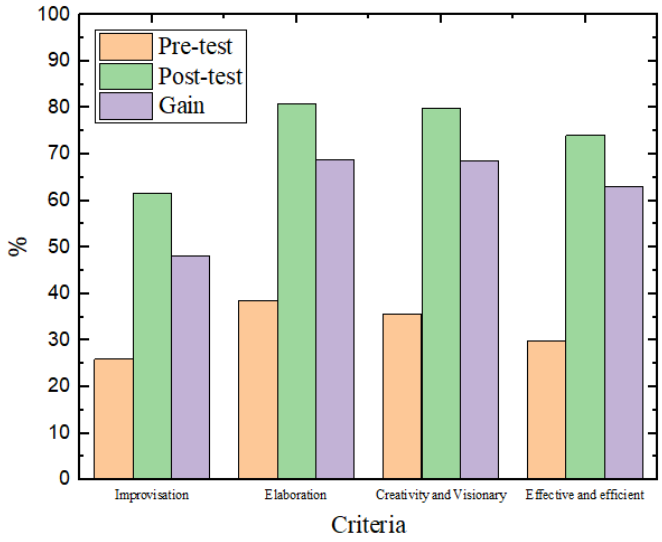

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

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Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. Using the PjBL model with game techniques effectively increases students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building basic skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques (shown in the post-test results in Figure 2) are higher than those who do not use the PjBL model with game techniques (shown in the pre-test results in Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to using the conventional model. This is in line with Pramasdyahsari et.al (2023) that students' collaboration skills and communication abilities improve while the STEM-PjBL was implemented.

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Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. Considering this result, it shows that the score is representing the impact of PjBL-assisted traditional games that could positively affect collaboration skills. It is supported by research by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. The results of Christwardana et al.'s (2022) research also show an increase in chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Research conducted by Sjöberg and Brooks (2022) explains that school students can develop digital game designs through smart mobile technology by collaborating in problem-solving activities. In addition, research conducted by Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students through collaborative game design.

According to Albar and Southcott (2023), creativity is not limited to a particular discipline or activity. However, most of the research on creativity in Australia is related to art, dance, and music education. Research linking curricular areas and creativity is rare in international and Australian arenas. The results of research by Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

The results of this study indicate that applying the PjBL model through traditional games has an impact on increasing students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and has an effect on students' collaboration skills. The "improvised" criterion shows the lowest result. Some of the impacts of Project-Based Learning through traditional games in this study are highlighted. Research shows that continuous implementation of critical and creative thinking strategies and collaborative skills can be further developed.

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Paper Title: **PROJECT-BASED LEARNING VIA TRADITIONAL GAME: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS**

Parts of review	Guidelines	Yes	Partly	No	Reviewer's note for improvement	Author's responds (highlight of revision)
Title	• Does the subject matter fit within the scope of journal?	√				
	• Does the title clearly and sufficiently reflect its contents?	√				
Abstract	• Does the abstract contain informative, including Background, Methods, Results and Conclusion?	√				
Back-ground	• Is the background informative and sufficient (include the background problem and objectives)?		√			
	• Is research question of the study clear and understandable?		√			
	• Does the rationale of the study clearly explained using relevant literature?		√			
	• Is the "aim" of the manuscript clear and understandable?	√				
Methods	• Is the methodology chosen suitable to the nature of the topic studied?	√				
	• Is the methodology of the research described clearly?(including study design, location, subjects, data collection, data analysis)		√			
	• Is there adequate information about the data collection tools used? (only for empirical studies)		√			
	• Are the validity and reliability of data collection tools established? (only for empirical studies)					
	• Are the data collection tools suitable for the methodology of the study? (only for empirical studies)		√			
Results & Discussio n	• Are the tables, graphs and pictures understandable, well presented and numbered consecutively?		√			
	• Do the data analysis and the interpretation appropriate to the problem and answer the objectives?		√			
	• Does the "discussion" section of the manuscript adequately relate to the current and relevant litarature?		√			
	• Are the findings discussed adequately considering the research question(s), sub-question(s) or hypothesis?		√			
Conclusio n	• Is the conclusion clear and in the form of a narration instead of pointers?		√			
	• Isn't the conclusion a summary and consistent between problems, objectives and conclusion?		√			
Reference s	• Do the references and citations match?		√			
	• Are the writing of references correct?		√			
Quality Criteria	• Do the title, problem, objectives, methods and conclusion are in line? Is it well organized?		√			
	• The quality of the language is satisfactory		√			
	• The work relevant and novel		√			
	• Are there strong consistencies among the parts of the manuscript? (introduction,		√			

	methods, results and discussion, and conclusion)					

6. Bukti Konfirmasi Proofreading Artikel

(24 Juni 2023)

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME IN PHYSICS LEARNING: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

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Submission date: 26-Jun-2023 05:18PM (UTC+0700)
Submission ID: 2122899645
File name: PROOFREAD_NUR_KHOIRI.docx (162.35K)
Word count: 4194
Character count: 25236

Jurnal Pendidikan IPA Indonesia

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME IN PHYSICS LEARNING: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

DOI:

Accepted:... .Approved: ... . Published: ...

This study aims to investigate how PjBL via traditional games impact students' critical thinking, creative thinking, and collaborative skills. The research sample is a local school in Semarang. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. There is only one predetermined group in this design. The theme of the game that the project will create was revealed following the pre-test. The research results show students' creative thinking skills in applying the PjBL model via game techniques are 61.53% in high criteria and 38.46% in medium criteria. The study results also show a fair increase in the N-Gain value for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that the PjBL model impacts students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: creative thinking, critical thinking, collaboration, PjBL, traditional games

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INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Apriwanda & Hanri, 2022; Gu et al., 2019). For students to make decisions when presented with a variety of options, they need to possess both creative and critical thinking skills (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). To succeed in 21st-century learning, students must think critically and creatively (OECD, 2017; Triyatma et al., 2017; Bybee, 2020; Pramasdyahsari et al., 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, Indonesian students still lack creative and critical thinking skills (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. But given the existing curriculum, it is essential to switch from a teacher-centric to a student-centric learning strategy. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati et al., 2014; Bereczki & Kárpáti, 2021; Calavia et al., 2023; Chen et al., 2023; Gu et al., 2019; Apriwanda & Hanri, 2022; Sumarni & Kadarwati, 2020). According to Kurniawati and Diantoro (2014), the process of learning physics should emphasize direct experience to develop students' conceptual skills and enable them to better scientifically comprehend a variety of natural phenomena in their immediate environment. In addition, Kemendikbud (2016) states that students should be encouraged to actively participate in the learning process and that there should be room for them to develop their creativity in an interactive, fun, and challenging environment. In line with this, students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centric learning to student-centric. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dada et al., 2023; Dunbar & Yadav, 2022). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could foster these crucial skills for the 21st century.

Developing learning strategies is a method to help students develop critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students to organize their learning activities, complete group projects, and create original works (Wang et al., 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo & Yang (2012). The project-based learning model is student-centric, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Eroğlu & Bektaş, 2022; Stolz et al., 2022). The Project-Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). Students must be knowledgeable about computers and tools in order to learn. Information and communication technology impacts every aspect of society, including education (Kong, 2014). Additionally, multimedia in the classroom contributes to developing critical thinking abilities and concept understanding (Rosida et al., 2017).

The learning while playing method is another approach that places an emphasis on learning and draws students into the learning

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center through dynamic activities. The development of creative and collaborative skills is positively impacted when games are used in learning that involves the fundamentals of life. It also makes a fun and meaningful learning.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Students' success be improved and learning made easier through the use of games (Bottino et al., 2007; Lee et al., 2022; Brezovszky et al., 2019). If this engaging activity is carried out in a setting that takes into account the characteristics of the students, it may assist them in achieving success in subjects like physics where students are more likely to be intimidated and suspicious of their complexity. However, not much was said about how this game of PjBL helped students develop their creative and critical thinking skills. There is a limitation in research that mainly focuses on implementing PjBL using games.

Students can improve their critical thinking, creative thinking, and collaborative thinking skills with PjBL via games. This study aims to investigate how PjBL via traditional games might impact students' critical thinking, creative thinking, and collaborative skills, which are essential for 21st-century learning..

METHODS

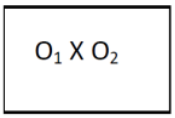
The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014).

There is only one predetermined group in this one-group pretest-posttest design. The test was administered twice in this design: once before the treatment (pre-test) and once after the treatment (post-test).

The research procedures began by conducting the test before implementing the treatment, called the pre-test. It was given to the experimental class (O1). After completing the pre-test, the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The test results were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests instrument. The test method was used to measure students' creative and critical thinking skills. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2020). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. The test items refer to the developed measurement of creative and critical thinking skills by Yoon (2017), Sumarni et al. (2018), Gelerstein et al. (2016), and Sumarni et al. (2020).

Sugiyono (2013) describes the one-group pretest-posttest design research pattern as follows:



O_1 = pre-test score
O_2 = post-test score
X = project-based learning model

Equation 1 is used to determine the rise in students' critical thinking skills under their N-gain score.

$$N - gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\% \qquad (1)$$

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain≤ 100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

RESULTS AND DISCUSSION

Description of Activities in Applying the Project-Based Learning Model via Game

The design of applying the PjBL model via game begins with good goal setting, planning learning through lesson plans using the PjBL method via game, and planning assessments in the form of assessments before and after treatment.

Figure 1 shows the percentage of each class's pre-test, post-test, and N-gain scores.

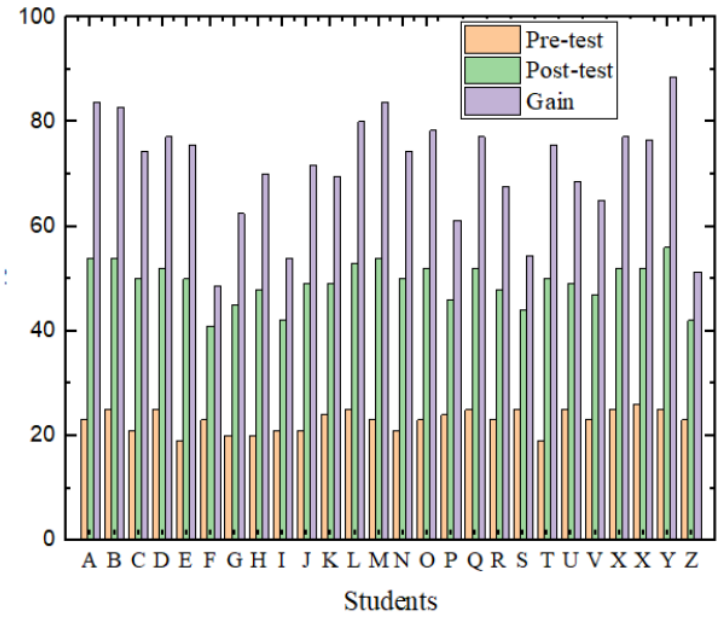


Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019).

Figure 1 shows the percentage of the pre-test, post-test, and N-gain scores of 26 tenth-grade MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that students' creative thinking skills in applying the PjBL model via game are 16 students in high criteria (61.53%) and ten people in medium criteria (38.46%). This result differs from Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Ethno-STEM Project-Based Learning for high school students improved creative thinking skills, according to Sumarni and Kadarwati (2020). The N-Gain value indicates that this study improves creative thinking skills. 27.3 percent of students fall into the high category, 47.4 percent into the medium category, and 25.2 percent into the low category. Meanwhile, Apriwanda and Hanri (2022) show that prospective chemistry teachers' creative thinking level is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of tenth grade in MAN 2 Semarang. Sumarni and Kadarwati (2020) used a sample of 230 students from seven high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results. The percentage of pre-, post-, and N-gain scores for each creative thinking skill indicator is shown in Figure 2.

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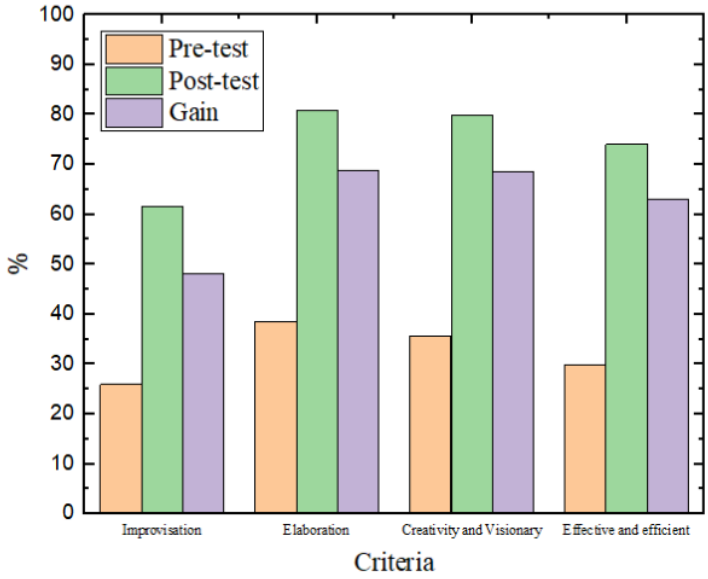

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. The PjBL model via game effectively impacts students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building essential skills.

In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques are higher than those who do not use the PjBL model with game techniques (Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks

	Learning model	N	Mean Rank	Sum of Ranks
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to the conventional model, which aligns with Pramasdyahsari et al. (2023) that students' collaboration and communication abilities improved while the STEM-PjBL was implemented.

Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics

	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. This result shows that the score represents the impact of PjBL-assisted traditional games that could positively affect collaboration skills. It is supported by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. Christwardana et al. (2022) also show increased chemical engineering students' competence through collaboration and PjBL.

The field of game design also shows a similar trend. Sjöberg and Brooks (2022) explains that school students can develop digital game designs via smart mobile technology by collaborating in problem-solving activities. In addition, Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students via collaborative game design.

Albar and Southcott (2023) assert that creativity transcends any one field or activity. However, most Australian research on creativity focuses on art, dance, and music education. In both the international and Australian contexts, there is scant research linking creative endeavors to curriculum areas. Albar and Southcott (2023) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

This study indicates that the PjBL model via traditional game impacts the increase of students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and impacts students' collaboration skills. The "improvised" criterion shows the lowest result. In this research, some of the impacts of Project-Based Learning via traditional games are emphasized. This study demonstrates how collaborative skills and critical and creative thinking strategies can be continuously developed.

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Nomor AHU-0015885.A.H.01.04.Tahun 2019

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Jurnal Pendidikan IPA Indonesia <jpii@mail.unnes.ac.id> 11 Juli 2023 pukul 07.43
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authors : 1. Nur Khoiri
2. Sigit Ristanto
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JPII 12 (2) (2023) 286-292

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PROJECT-BASED LEARNING VIA TRADITIONAL GAME IN PHYSICS LEARNING: ITS IMPACT ON CRITICAL THINKING, CREATIVE THINKING, AND COLLABORATIVE SKILLS

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DOI: 10.15294/jpii.v12i2.43198

Accepted: March 10th, 2023. Approved: June 26th, 2023. Published: June 27th, 2023

ABSTRACT

This study aims to investigate how PjBL via traditional games impact students' critical thinking, creative thinking, and collaborative skills. The research sample is a local school in Semarang. The research design was a quantitative study using the pre-experimental design type one group pretest-posttest method. There is only one predetermined group in this design. The theme of the game that the project will create was revealed following the pre-test. The research results show students' creative thinking skills in applying the PjBL model via game techniques are 61.53% in high criteria and 38.46% in medium criteria. The study results also show a fair increase in the N-Gain value for the four indicators of creative thinking skills: improvisation, elaboration, creativity, vision, effectiveness, and efficiency. The results show it is effective for six students (25%), fairly effective for 13 students (54.16%), and less effective for five students (20.83%). The study's results also show that the Mann-Whitney U statistical test is 69. It means that the PjBL model impacts students' collaborative skills. This research has a big impact on increasing students' creative thinking skills and collaboration.

Keywords: creative thinking; critical thinking; collaboration; PjBL; traditional games

INTRODUCTION

Physics is a part of science that explains natural phenomena and how these natural phenomena can occur. The purpose of learning physics in schools is to improve creative thinking, critical thinking, and collaboration skills so that students are capable and skilled in the cognitive field. To face challenges in the 21st century requires creative thinking skills (Gu et al., 2019; Apriwanda & Hanri, 2022). For students to make decisions when presented with a variety of options, they need to possess both creative and critical thinking skills (Fields & Bisschoff, 2014; Sumarni & Kadarwati, 2020). To succeed in 21st-century learning, students must think critically and creatively (OECD, 2017; Triyatma et al., 2017; Bybee, 2020; Pramasdyahsari et al., 2021). Physics learning will provide optimal results if students can build knowledge and find answers to a problem through the learning process that is carried out. However, Indonesian students still lack creative and critical thinking skills (OECD, 2017).

The current physics learning process often uses a teacher-centric learning approach. But given the existing curriculum, it is essential to switch from a teacher-centric to a student-centric learning strategy. Teacher-centric learning significantly reduces students' responsibility in carrying out learning tasks. Teacher-centric learning does not improve but reduces students' learning abilities. The use of suboptimal learning models is

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one of the problems in the physics learning process. Learning models that do not match the characteristics of students create a monotonous and boring learning atmosphere. It can limit students' abilities to discover and try new things and cannot hone communication skills.

Many studies have been conducted to answer the previous questions (Kurniawati & Diantoro, 2014; Gu et al., 2019; Sumarni & Kadarwati, 2020; Bereczki & Kárpáti, 2021; Apriwanda & Hanri, 2022; Calavia et al., 2023; Chen et al., 2023). According to Kurniawati and Diantoro (2014), the process of learning physics should emphasize direct experience to develop students' conceptual skills and enable them to better scientifically comprehend a variety of natural phenomena in their immediate environment. In addition, Kemendikbud (2016) states that students should be encouraged to actively participate in the learning process and that there should be room for them to develop their creativity in an interactive, fun, and challenging environment. In line with this, students are more successful when directly involved in class because they can actively build ideas and connect physics concepts with everyday life. With these activities, students are expected to understand the facts.

Changes in demands on people's lives have changed the paradigm of learning physics from a result-oriented to a process-oriented one. According to Longworth and Davies (1996), we need to change our focus from looking for what needs to be learned and how to learn it. Learning how to learn something becomes more important than looking for the results of the facts and concepts learned. Badan Standar Nasional Pendidikan (2010) reports that the characterization of a shift in the learning paradigm is the view of teacher-centric learning to student-centric. Learning following this paradigm is learning that can create a sense of responsibility for learning in students, while the teacher is responsible for creating situations that encourage students' motivation, creativity, and responsibility for learning (Listyani, 2007; Dunbar & Yadav, 2022; Dada et al., 2023). In line with that, one of the efforts that the teacher can make is to plan and use a learning model that can make students active and creative. However, there is a limitation in employing the learning model that could foster these crucial skills for the 21st century.

Developing learning strategies is a method to help students develop critical and creative thinking abilities. The project-based learning (PjBL) approach to education allows students to organize their learning activities, complete group projects, and create original works (Wang et al., 2015). In the PjBL paradigm, which employs a contextual approach, students actively participate in problem-solving, decision-making, research, and presentation (Guo & Yang (2012). The project-based learning model is student-centric, allowing students to learn and try new things. This project-based learning model emphasizes the creativity and skills of students to work in teams to solve problems (Pradita et al., 2015; Gomez-del Rio & Rodriguez, 2022; Ero**ğ**lu & Bekta**ş**, 2022; Stolz et al., 2022). The Project-Based Learning (PjBL) model encourages students to work independently in producing a product (Susilawati et al., 2018).

Digital literacy is equally crucial for learning in the twenty-first century (OECD, 2017). Students must be knowledgeable about computers and tools in order to learn. Information and communication technology impacts every aspect of society, including education (Kong, 2014). Additionally, multimedia in the classroom contributes to developing critical thinking abilities and concept understanding (Rosida et al., 2017).

The learning while playing method is another approach that places an emphasis on learning and draws students into the learning center through dynamic activities. The development of creative and collaborative skills is positively impacted when games are used in learning that involves the fundamentals of life. It also makes a fun and meaningful learning.

The game is very interesting, especially for children. Students are generally more enthusiastic about participating in the learning process that involves games. Students' success be improved and learning made easier through the use of games (Bottino et al., 2007; Brezovszky et al., 2019; Lee et al., 2022). If this engaging activity is carried out in a setting that takes into account the characteristics of the students, it may assist them in achieving success in subjects like physics where students are more likely to be intimidated and suspicious of their complexity. However, not much was said about how this game of PjBL helped students develop their creative and critical thinking skills. There is a limitation in research that mainly focuses on implementing PjBL using games.

Students can improve their critical thinking, creative thinking, and collaborative thinking skills with PjBL via games. This study aims to investigate how PjBL via traditional games might impact students' critical thinking, creative thinking, and collaborative skills, which are essential for 21st-century learning..

METHODS

The study sample was a local school in Semarang which was selected based on the direction and objectives of this research. This quantitative research uses the pre-experimental design type one group pretest-posttest method (Arikunto, 2010; Sugiyono, 2013; Creswell, 2014). There is only one predetermined group in this one-group pretest-posttest design. The test was administered twice in this design: once before the treatment (pre-test) and once after the treatment (post-test).

The research procedures began by conducting the test before implementing the treatment, called the pre-test. It was given to the experimental class (O1). After completing the pre-test, the next step is implementing project-based learning by creating the game. The last stage was carried out the post-test. The test results were analyzed to know the impact of the treatment by seeing the gain number as the indicator of effectiveness.

The research instruments consist of the creative and critical thinking skills tests instrument. The test method was used to measure students' creative and critical thinking skills. The test items are open-ended questions focusing on metacognitive aspects and the question content (Sumarni et al., 2018). Coşkun (2018) states that metacognitive can lead to higher-order thinking skills. The test items refer to the developed measurement of creative and critical thinking skills by Yoon (2017), Sumarni et al. (2018), and Gelerstein et al. (2016).

Sugiyono (2013) describes the one-group pretest-posttest design research pattern as follows:

O_1 X O_2

O_1 = pre-test score
O_2 = post-test score
X = project-based learning model

Equation 1 is used to determine the rise in students' critical thinking skills under their N-gain score.

$$N-gain\ (\%) = \frac{score\ of\ post\ test - score\ pre\ test}{maximum\ score - score\ of\ pre\ test} x\ 100\%$$

The N-gain score obtained by each student and per each skill criterion is categorized using the criteria presented in Table 1.

Table 1. Students' Critical Thinking Skill Criteria (Sumarni & Kadarwati, 2020)

Percentage of N-Gain (%)	Students' Critical Thinking Skill Criteria
70 <N-Gain100	High
29 <N-Gain≤ 70	Medium
N-Gain ≤ 29	Low

RESULTS AND DISCUSSION

The design of applying the PjBL model via game begins with good goal setting, planning learning through lesson plans using the PjBL method via game, and planning assessments in the form of assessments before and after treatment.

Figure 1 shows the percentage of each class's pre-test, post-test, and N-gain scores.

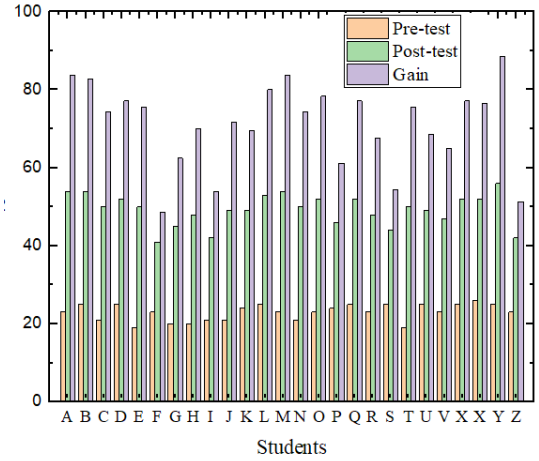

Figure 1. Percentage of Pre-test Scores, Post-test Scores, Gain of Each Class

Various studies have been conducted in the last five years on increasing students' creativity. In these studies, there are many treatments to increase students' creativity. These treatments include reading and writing in cooperative learning classes (Marcos et al., 2020), playful design jams (Tang et al., 2020), English language course design for junior high school students (Bağ & Gürsoy, 2021), through mathematics and music (Azaryahu et al., 2023), STEM (Yalçın & Erden, 2021; Eroğlu & Bektaş, 2022), mathematical games based on the learning environment (Brezovszky et al., 2019), entrepreneurial skills (Durnali et al., 2023), 5-I training program (Gu et al., 2019). Figure 1 shows the percentage of

the pre-test, post-test, and N-gain scores of 26 tenth-grade MAN 2 Semarang students. The data in Figure 1 and Table 1 shows that students' creative thinking skills in applying the PjBL model via game are 16 students in high criteria (61.53%) and ten people in medium criteria (38.46%). This result differs from Sumarni and Kadarwati (2020) and Apriwanda and Hanri (2022). Ethno-STEM Project-Based Learning for high school students improved creative thinking skills, according to Sumarni and Kadarwati (2020). The N-Gain value indicates that this study improves creative thinking skills. 27.3 percent of students fall into the high category, 47.4 percent into the medium category, and 25.2 percent into the low category. Meanwhile, Apriwanda and Hanri (2022) show that prospective chemistry teachers' creative thinking level is at a medium level (35.43%).

Different samples cause the difference. The research sample used a sample of 26 students of tenth grade in MAN 2 Semarang. Sumarni and Kadarwati (2020) used a sample of 230 students from seven high schools in Central Java. The research sample by Apriwanda and Hanri (2022) was 92 prospective chemistry teachers in Pekanbaru, Sumatra, Indonesia. The sample quantity, heterogeneity and homogeneity, geographic location, and research method greatly influence the results. The percentage of pre-, post-, and N-gain scores for each creative thinking skill indicator is shown in Figure 2.

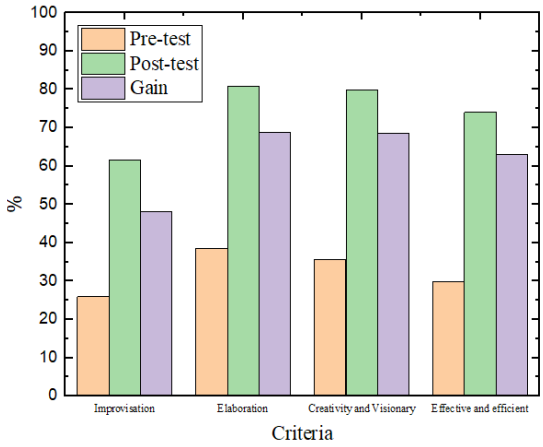

Figure 2. Percentage of Pre-test and Post-test Scores, N-Gain of Each Indicator of Creative Thinking Skills

Figure 2 also shows an increase in the N-Gain value with medium criteria for the four indicators of creative thinking skills: improvisation, elaboration, creativity and vision, effectiveness, and efficiency. The PjBL model via game effectively impacts students' creative thinking skills on four indicators. Using the PjBL model with game techniques makes students happy and enjoy learning, increasing students' creativity significantly in four indicators. The results of this study are slightly different from the research conducted by Sumarni and Kadarwati (2020) and Han et al. (2016). The two studies show that students achieve N-gain in the medium category on two indicators: simple explanations and building essential skills. In comparison, N-gains in the low criteria are achieved by making inferences and advanced explanations. This study shows that the scores achieved by students when using the PjBL model with game techniques are higher than those who do not use the PjBL model with game techniques (Figure 2). Sumarni and Kadarwati (2020) and Han et al. (2016) also show the same trend. Both studies state that higher scores are achieved by students when STEM PjBL is used compared to non-STEM PjBL.

Table 2. Mean Rank Student Collaboration Skills of the PjBL Model and the Conventional Model

Ranks				
	Learning model	**N**	**Mean Rank**	**Sum of Ranks**
Collaboration skills	PjBL model	26	45.85	1192.00
	Conventional model	35	19.97	699.00
	Total	61		

Table 2 compares the mean rank of students' collaboration skills. The first group consisted of 26 students. The learning model used by the first group is the PjBL learning model using traditional games. The second group of 35 students uses a conventional learning model. The mean rank of the first group is 45.85, while the mean rank of the second group is 19.97. It shows that the PjBL model could improve collaboration skills compared to the conventional model, which aligns with Pramasdyahsari et al. (2023) that students' collaboration and communication abilities improved while the STEM-PjBL was implemented.

Table 3. Mann-Whitney U Test Results for Students' Collaboration Skills

Test Statistics	
	Collaboration skills
Mann-Whitney U	69.000
Wilcoxon W	699.000
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: learning model

Table 3 shows the result of students' collaboration skills using a statistical test using the Mann-Whitney U is 69. This result shows that the score represents the impact of PjBL-assisted traditional games that could positively affect collaboration skills. It is supported by Rojas et al. (2021), showing that the proposed instrument effectively measures students' collaborative problem-solving skills in the age range of 10-13 years. Christwardana et al. (2022) also show increased chemical engineering students' competence through collaboration and PjBL. The field of game design also shows a similar trend. Sjöberg and Brooks (2022) explains that school students can develop digital game designs via smart mobile technology by collaborating in problem-solving activities. In addition, Laakso et al. (2021) also demonstrates an increase in the digital competence of elementary and middle school students via collaborative game design.

Albar and Southcott (2021) assert that creativity transcends any one field or activity. However, most Australian research on creativity focuses on art, dance, and music education. In both the international and Australian contexts, there is scant research linking creative endeavors to curriculum areas. Albar and Southcott (2021) reveal that problem-based learning strategies (PBL) and projects (PjBL) used in learning have an impact on arousing children's creative processes. PjBL also has an impact on increasing creativity (fluency, flexibility, originality, and elaboration) and learning motivation in social sciences (history) for high school students (Pan et al., 2023).

CONCLUSION

This study indicates that the PjBL model via traditional game impacts the increase of students' creative and critical thinking skills on all criteria in various categories (low, medium, high) and impacts students' collaboration skills. The "improvised" criterion shows the lowest result. In this research, some of the impacts of Project-Based Learning via traditional games are emphasized. This study demonstrates how collaborative skills and critical and creative thinking strategies can be continuously developed.

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