PILLAR OF PHYSICS EDUCATION
Vol. 19 (2), 2026, page. 81-93
ISSN (Print) : 2337-9618
ISSN (Online) : 2684-8880

Effect of Team Games Tournament Learning Model With Experimental Activities on Students' Learning Interest and Critical Thinking Skills in Newton's Laws

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ABSTRACT

Physics education continues to face challenges related to low students' learning interest and insufficient development of critical thinking skills, particularly in abstract topics such as Newton's Laws. This study aims to investigate the effect of the Teams-Games-Tournament (TGT) learning model integrated with experimental activities on students' learning interest and critical thinking skills in Newton's Laws, as well as to examine the profile and relationship between learning interest and critical thinking skills following the implementation of this model. A quasi-experimental method with a pretest–posttest control group design was employed, involving 67 eleventh-grade students from SMA Negeri 1 Prambanan Sleman, consisting of 36 students in the experimental class and 31 students in the control class. The experimental class was taught using the TGT model integrated with experiments, while the control class received conventional instruction. Data were collected using learning interest questionnaires and critical thinking tests and were analyzed through descriptive and inferential statistical methods. The results indicated that the TGT model integrated with experiments has a highly significant effect on students' learning interest, with an N-gain of 0.57 and a Cohen's d effect size of 2.69, as well as on critical thinking skills, with an N-gain of 0.67 and a Cohen's d effect size of 2.12. Additionally, Pearson correlation analysis reveals a significant positive relationship between learning interest and critical thinking skills (r = 0.596, p = 0.001). These findings demonstrate that the TGT learning model integrated with experimental activities is highly effective in enhancing both affective aspects, namely students' learning interest, and cognitive aspects, particularly critical thinking skills, in physics education.

Keywords : Team Games Tournament, experimental activities, learning interest, critical thinking skills, Newton's Laws.

I. INTRODUCTION

Physics education in Indonesia remains predominantly dominated by conventional, teacher-centered instructional approaches, which often results in low student learning interest and suboptimal development of critical thinking skills [1]. Physics, as a branch of natural science, encompasses two inseparable dimensions: physics as a body of knowledge (product) and physics as a scientific process, which includes scientific skills and scientific attitudes [2]. Consequently, physics learning is expected not only to emphasize conceptual understanding but also to foster students' abilities in observation, hypothesis formulation, experimentation, data analysis, and conclusion drawing, all of which are fundamental components of critical thinking [3].

Critical thinking is recognized as a core competency of the 21st century within the 4Cs framework, alongside communication, collaboration, and creativity [4]. In the Indonesian context, the 2013 Curriculum explicitly mandates the development of Higher Order Thinking Skills (HOTS), including critical thinking, through the implementation of a scientific approach in classroom instruction. In addition to cognitive competencies, learning interest constitutes an essential affective factor influencing learning success. Students with high learning interest tend to demonstrate greater diligence, active participation, and responsibility in learning activities [5]. Empirical evidence provided by Taa, Liu, & Kaleka, (2021) reveals that learning interest contributes 37.1% to students' physics learning outcomes, indicating a strong relationship between affective engagement and academic achievement[6].

Despite these curricular expectations, physics education in Indonesia continues to encounter fundamental problems, particularly low student interest and motivation. Many students perceive physics as a difficult, monotonous, and abstract subject that is disconnected from everyday life [7], [8], [9]. These issues are further exacerbated by instructional practices that emphasize verbal explanation and mathematical problem solving, while providing limited opportunities for students to actively construct knowledge through inquiry and interaction[1]. Such approaches tend to position students as passive recipients of information and fail to optimally develop their critical thinking skills [10].

One of the physics topics that exemplifies these challenges is Newton's Laws, which constitute foundational concepts describing the relationship between force and motion. The abstract nature of Newton's Laws, combined with the requirement for mathematical reasoning, often presents significant learning difficulties for students [11]. Consequently, students frequently rely on rote memorization of formulas without a deep understanding of their physical meaning or real-world applications, resulting in limited critical thinking development [12]. Misconceptions related to force and motion are particularly persistent and difficult to remediate without appropriate instructional interventions. Sari, Parno, & Taufiq, (2018) reported that students' average conceptual understanding score on Newton's Laws was only 24.3 out of 100, indicating a low level of mastery. Given the conceptual complexity and importance of this topic, innovative and student-centered learning approaches are required, including cooperative learning models [13].

The Teams-Games-Tournament (TGT) learning model is a cooperative learning strategy that integrates academic competition through structured group activities and tournaments, encouraging students to share knowledge, engage in discussion, and develop social skills within a positive competitive environment[14]. Previous studies have demonstrated the effectiveness of the TGT model in improving learning outcomes. Slavin, E (2010) reported an effect size of 0.38 on academic achievement, accompanied by increased learning motivation, positive attitudes toward learning, and enhanced social interaction skills[15]. Furthermore, Nufus, (2020) found that the Teams Games Tournament (TGT) learning model assisted by game-based media (snakes and ladders) significantly improved students' learning achievement on Newton's Laws, as indicated by a higher post-test mean score (81.74) compared to the conventional model[16]. Maria Ulfah, (2025) emphasized that the effectiveness of the TGT model is enhanced when it is combined with supporting instructional methods, such as experimental activities[17].

Experimental methods in physics education serve as a critical bridge between abstract theoretical concepts and observable physical phenomena. Through experimental activities, students are actively involved in designing experiments, conducting measurements, analyzing data, evaluating sources of error, and drawing evidence-based conclusions, which collectively represent essential science process skills and components of critical thinking [18]. Zacharia & Olympiou, (2011) demonstrated that physics learning integrated with real laboratory experiments significantly improves students' conceptual understanding ($p < 0.05$) with an effect size of 0.68[19]. Similarly, Luthfiyati (2020) reported that the integration of experimental methods within cooperative learning models effectively enhances cognitive learning outcomes and students' cooperative attitudes[20]. Maria Ulfah, (2025) further found that an experiment-based TGT model improved students' problem-solving abilities with an N-gain of 67%[17].

Although previous studies have independently confirmed the benefits of the TGT learning model and experimental methods, research examining the combined implementation of the TGT model integrated with experiments and its simultaneous effect on students' learning interest and critical thinking skills in Newton's Laws remains limited. Therefore, this study aims to investigate the effect of the Team Games Tournament learning model integrated with experimental activities on students' learning interest and critical thinking skills in Newton's Laws, as well as to examine the profile and relationship between learning interest and critical thinking skills following the implementation of this learning model. However, empirical studies examining the combined implementation of the TGT model with experimental activities and its simultaneous effects on both learning interest and critical thinking skills in Newton's Laws remain scarce, particularly in Indonesian secondary physics education.

II. METHOD

1. Research Design

This study employed a quasi-experimental research method using a pretest–posttest control group design, involving an experimental group and a control group [21]. This method was selected to examine the effect of implementing the Teams-Games-Tournament (TGT) learning model integrated with experimental activities on students' learning interest and critical thinking skills in physics.

The research design consisted of two groups, both of which were administered pretests and posttests. However, only the experimental group received instruction using the TGT model integrated with experiments, while the control group was taught using conventional instructional methods. This design was chosen because random assignment of students to groups was not feasible within the school context, as students had already been organized into intact classes. Quasi-experimental designs are widely used in educational research under such conditions, as they allow for meaningful comparison while maintaining ecological validity [22].

2. Research Procedure

The research was conducted chronologically through several instructional stages. In the experimental class, the learning process was implemented using the TGT learning model integrated with experimental activities, following five main stages adapted from [15]:

1) Class Presentation, in which the teacher presented learning objectives and core concepts of Newton's Laws through interactive explanations and contextual examples to build students' initial understanding.

2) Teams, where students were organized into heterogeneous groups consisting of four to five members based on academic ability, gender, and ethnicity. In this stage, students worked collaboratively on student worksheets (LKPD)

3) Games, conducted physics experiments related to Newton's Laws and during which students participated in academic games involving physics questions designed to reinforce conceptual understanding.

4) Tournament, where students competed by representing their respective teams to answer questions and earn points through structured academic competitions.

5) Team Recognition, in which teams achieving the highest scores were given recognition and rewards to enhance motivation and positive learning attitudes.

Meanwhile, the control class received conventional instruction through direct teaching methods. In this class, the teacher explained the material using lectures, assigned textbook-based exercises, and facilitated limited discussions, without incorporating cooperative group work, academic games, or tournament activities.

3. Research Subjects

The research subjects consisted of 67 eleventh-grade students from SMA Negeri 1 Prambanan Sleman during the 2024/2025 academic year. The experimental group comprised 36 students from Class XI MIPA 2, while the control group consisted of 31 students from Class XI MIPA 3.

The selection of research subjects was conducted using a purposive sampling technique, based on considerations of equivalence in terms of the number of students, academic ability, instructional schedule, and the same physics teacher. Both classes had previously received similar physics instruction and demonstrated comparable initial abilities, as indicated by their prior semester physics achievement scores.

4. Data Collection Instruments

The research instruments consisted of two types: a learning interest questionnaire and a critical thinking skills test.

Learning Interest Questionnaire

The learning interest questionnaire employed a four-point Likert scale consisting of 26 statement items designed to measure four indicators of learning interest: feelings of pleasure, student interest, attention in learning, and active student involvement. In this study, the learning interest questionnaire was adopted from an instrument previously developed by [23], which had demonstrated strong psychometric properties, with an Aiken's V validity coefficient of 0.86 and a Cronbach's Alpha reliability coefficient of 0.91, indicating high validity and reliability.

The blueprint of the learning interest questionnaire used in this study is presented in Table 1.

Table 1. Blueprint of the Learning Interest Questionnaire

No	Learning Interest Indicator	Item Numbers
1	Feelings of Pleasure	1, 2, 3, 4, 5, 6, 7
2	Student Interest	8, 9, 10, 11, 12, 13, 14
3	Attention in Learning	15, 16, 17, 18, 19, 20, 21
4	Student Involvement	22, 23, 24, 25, 26
	Total	**26**

Critical Thinking Skills Test

The critical thinking skills test consisted of 10 essay questions designed to measure six critical thinking indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation, based on the Facione, critical thinking framework (2020) [24]. The instrument demonstrated satisfactory psychometric quality, with an Aiken's V validity coefficient of 0.86 and a Cronbach's Alpha reliability coefficient of 0.753, indicating acceptable reliability.

Student responses were assessed using an analytic scoring rubric, with a maximum total score of 40. The instrument was validated through expert judgment involving physics education lecturers and experienced physics teachers and was subsequently pilot-tested on 36 twelfth-grade students who had previously studied Newton's Laws.

The blueprint of the critical thinking skills test is presented in Table 2.

Table 2. Blueprint of the Critical Thinking Skills Test

Topic/Material	Critical Thinking Indicator	Test Indicator	Item Number
Newton's First Law	Interpretation	Explaining inertia phenomena based on Newton's First Law	1
	Analysis	Analyzing differences in coin experiment results based on friction and inertia	4
	Evaluation	Evaluating differences between stationary and moving boat conditions based on Newton's First Law	5
Newton's Second Law	Interpretation	Interpreting force components on an inclined plane to determine an object's motion	2
	Analysis	Analyzing the resultant force and calculating acceleration with friction	3
	Inference	Making inferences about the relationship among mass, force, and acceleration from observational data	7
	Self-Regulation	Identifying experimental errors and designing improvement strategies	10
Newton's Third Law	Evaluation	Evaluating the causes of upward motion based on the action–reaction principle	6

Topic/Material	Critical Thinking Indicator	Test Indicator	Item Number
	Inference	Making inferences about action–reaction forces from a volleyball player phenomenon	8
	Explanation	Explaining differences between rocket and airplane working principles based on action–reaction	9

5. Data Analysis Techniques

Data analysis involved both descriptive and inferential statistical techniques. Descriptive analysis was conducted to determine the mean, standard deviation, and frequency distribution of students' learning interest and critical thinking skills. The improvement in students' performance from pretest to posttest was measured using the normalized gain (N-gain) formula proposed by [25].

To determine the magnitude of the treatment effect, effect size analysis was conducted using Cohen's d. Prior to hypothesis testing, prerequisite assumption tests were performed, including normality testing using the Shapiro–Wilk test and homogeneity testing using Levene's test. Hypothesis testing was conducted using an independent samples t-test to examine differences between the experimental and control groups.

Additionally, Pearson correlation analysis was employed to investigate the relationship between students' learning interest and critical thinking skills. All statistical analyses were performed using SPSS version 25, with a significance level of $\alpha = 0.05$" above.

III. RESULTS AND DISCUSSION

Implementation of the TGT Model Integrated with Experiments

Learning activities in the experimental class were conducted using the Teams Games Tournament (TGT) model integrated with experimental methods on the topic of Newton's Laws. The learning implementation followed the Teaching Module (see Appendix), which consisted of the following stages: class presentation, team formation (Teams), academic games (Games) based on experimental activities, tournaments (Tournament), and team recognition (Team Recognition).

During the first meeting, students completed a pretest, which consisted of a critical thinking skills test (60 minutes) and a learning interest questionnaire (30 minutes). This activity aimed to measure students' initial levels of critical thinking ability and learning interest prior to the implementation of the instructional treatment.

Class Presentation and Teams Study

The teacher presented Newton's First, Second, and Third Laws through an interactive class presentation, accompanied by simple demonstrations to attract students' attention and activate prior knowledge. Following the class presentation, students were divided into heterogeneous groups consisting of six members, based on academic ability levels. Each group received a structured Student Worksheet (LKPD) containing guiding questions designed to stimulate students' critical thinking regarding Newton's Laws concepts. Students engaged in group discussions to understand the material and complete the worksheets under teacher supervision.

(a) (b)

Fig 1. Documentation of (a) Implementation of Class Presentation and (b) Implementation of Team Study

Experimental Activities and Games

At this stage, each group conducted experiments to verify the Newton's Laws concepts that had been studied. The experiments included an inertia experiment using coins and paper, an experiment on the relationship between force, mass, and acceleration using toy cars and weights, an action–reaction experiment using balloons and strings, and a force experiment using inclined planes with smooth and rough surfaces. Students observed phenomena, recorded data, analyzed experimental results, and drew conclusions based on the collected data. After completing the experiments, academic games in the form of short quizzes were conducted collaboratively within groups to assess students' conceptual understanding.

(a) (b) (c) (d)

Fig 2. Documentation of (a) Newton's First Law Experiment, (b) Newton's Second Law Experiment, (c) Newton's Third Law Experiment, (d) Force Experiment

Tournament

Students from different groups competed in an academic tournament. Students answered Newton's Laws questions individually, and the scores obtained contributed to their respective group scores. The tournament was designed to enhance students' motivation and to create a healthy and engaging competitive learning environment.

Fig 3. Documentation of the Implementation Tournament

Team Recognition

The teacher announced the tournament results and provided rewards and verbal appreciation to groups with the highest scores. This recognition aimed to increase students' motivation and learning interest. After the recognition stage, students completed the posttest, which consisted of the critical thinking skills test and the learning interest questionnaire to measure their final conditions after the instructional intervention.

The implementation fidelity of the learning process in the experimental class was observed by two independent observers using a prepared observation sheet. The results of the learning implementation analysis using the Interjudge Agreement (IJA) calculation are presented in Table 3.

Table 3. Analysis of Learning Implementation in the Experimental Class

Meeting	Observer 1 (%)	Observer 2 (%)	Average (%)	Category
1	94.4	100	97.2	Very Good
2	100	100	100	Very Good
3	100	100	100	Very Good
Average	**98.1**	**100**	**99.05**	**Very Good**

Based on Table X, the average IJA score was 99.05%, categorized as very good. This indicates that the TGT model integrated with experiments was implemented with high fidelity in accordance with the designed Teaching Module. High implementation fidelity serves as an important indicator that the treatment was applied consistently, thereby supporting the validity and credibility of the research findings.

Description of Learning Implementation in the Control Class

Learning in the control class employed the Direct Instruction model, which is teacher-centered and consisted of the following stages: teacher explanation, worked examples, guided practice, and independent practice. The teacher explained Newton's First and Second Laws in detail using lecture methods accompanied by demonstrations, followed by worked examples solved on the board. Students listened to the explanation and took notes. Subsequently, students completed worksheets in groups under teacher guidance and continued with individual practice exercises.

Similar to the experimental class, students in the control class completed the pretest (critical thinking skills test and learning interest questionnaire) before instruction and the posttest after instruction. Learning implementation was observed by two independent observers. The results of the IJA analysis are presented in Table 4.

Table 4. Analysis of Learning Implementation in the Control Class

Meeting	Observer 1 (%)	Observer 2 (%)	Average (%)	Category
1	94.1	100	97.05	Very Good
2	87.5	93.75	90.62	Very

Meeting	Observer 1 (%)	Observer 2 (%)	Average (%)	Category
				Good
3	100	100	100	Very Good
Average	**93.8**	**97.91**	**95.89**	**Very Good**

The average IJA score of 95.89% indicates that the Direct Instruction model was also implemented very well according to the Teaching Module. This confirms that the control class treatment was conducted properly, ensuring that comparisons between groups are valid and reliable.

Effect of the TGT Model Integrated with Experiments on Students' Learning Interest

Descriptive analysis showed that the mean learning interest score of the experimental class increased from 71.72 (pretest) to 90.25 (posttest), whereas the control class's score increased from 70.55 to 75.23. The improvement in the experimental class was significantly higher than that in the control class, indicating that the TGT model integrated with experiments had a positive effect on students' learning interest. The posttest standard deviation in the experimental class (6.68) was smaller than the pretest (9.50), suggesting that the intervention reduced variability in students' learning interest and improved it more evenly across students. A more detailed description of students' learning interest results is further elaborated in Table 5

Table 5. Descriptive Statistics of Students' Learning Interest Scores

Statistics	Experimental Class			Control Class		
	Pretest	Posttest	N-Gain	Pretest	Posttest	N-Gain
N	36	36	36	31	31	31
Mean	71,72	90,25	0,57	70,55	75,23	0,14
Median	73	90,5	0,57	70	75	0,08
Mode	68	82	0,80	67	66	0,20
Standard Deviation	9,50	6,68	0,19	10	10,17	0,18
Minimum	52	76	0,29	44	55	−0,20
Maximum	87	103	0,94	89	96	0,72
Range	35	27	0,65	45	41	0,92

Normality testing using the Shapiro–Wilk test indicated that the N-gain data for learning interest in the experimental class were normally distributed ($p = 0.191 > 0.05$), and the control class data were also normally distributed. The Levene's test showed homogeneous variances ($p = 0.367$). Due to partial violations of assumptions, Welch's t-test was applied and confirmed using the Mann–Whitney U test.

Welch's t-test results showed $t = 10.714$, $p < 0.001$, indicating a highly significant difference in learning interest improvement between the experimental and control classes. The average N-gain of the experimental class (0.571, medium category) was significantly higher than that of the control class (0.176, low category). These findings were confirmed by the Mann–Whitney U test ($p < 0.001$).

Wilcoxon test results further supported these findings. In the experimental class, 100% of students (36 students) experienced an increase in learning interest ($Z = -5.237$, $p < 0.001$). In contrast, in the control class, only 81% of students showed improvement, while 16% experienced a decrease and 3% showed no change, with a smaller effect magnitude ($Z = -3.373$).

The increase in learning interest can be attributed to several factors. First, cooperative learning in the TGT model creates positive interdependence, encouraging students to support one another and remain motivated to achieve shared goals, consistent with[15]. Second, the game and tournament components create a fun yet challenging learning atmosphere, increasing student engagement[26]. Third, experimental activities allow students to directly observe and verify physics concepts through hands-on experiences, making abstract concepts more concrete [18], [27]. Fourth, group recognition reinforces students' efforts and enhances intrinsic motivation.

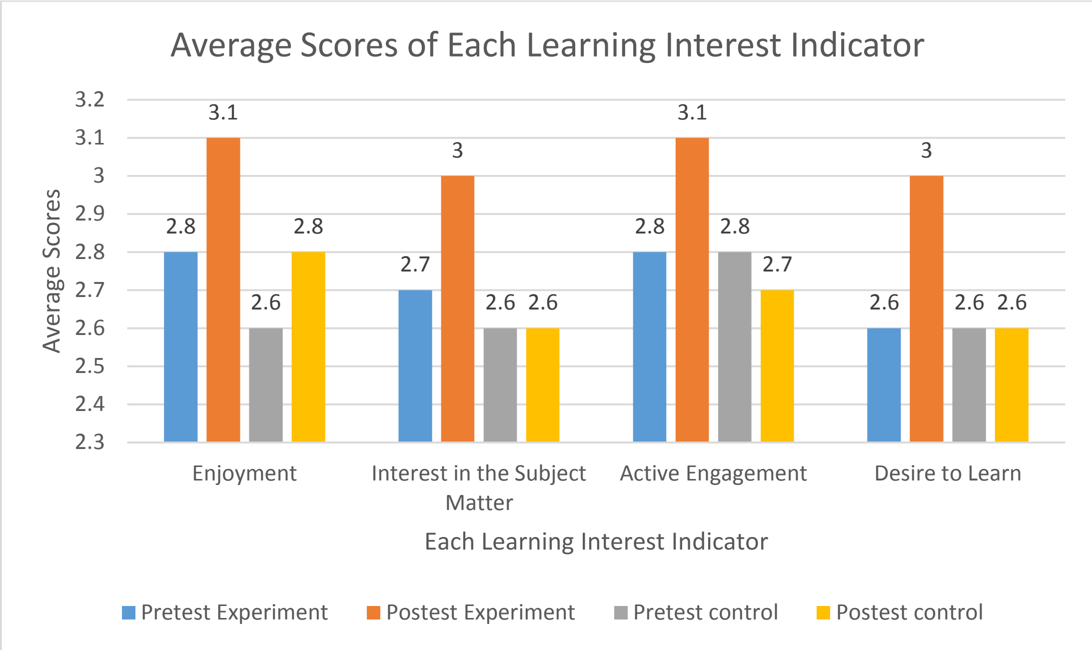

Fig 4. Average scores of each learning interest indicator for the experimental and control groups in the pretest and posttest.

Indicator-based analysis shows that all learning interest indicators improved, with active involvement showing the highest increase (N-gain = 0.62). This finding aligns with Asih, 2018 and international evidence indicating that cooperative-game-based learning significantly enhances student participation [28], [29].

Effect of the TGT Model Integrated with Experiments on Students' Critical Thinking Skills

Descriptive analysis indicates that the mean critical thinking score in the experimental class increased from 14.28 (pretest) to 31.25 (posttest), whereas the control class's score increased from 14.16 to 20.13. The improvement in the experimental class was nearly twice that of the control class. The reduced score range in the experimental class posttest indicates more uniform improvement across ability levels. Detailed analyses of Critical Thinking Ability are presented separately in Table 6

Table 6. Descriptive Statistics of Students' Critical Thinking Ability Scores

Statistics	**Experimental Class**			**Control Class**		
	Pretest	**Posttest**	**N-Gain**	**Pretest**	**Posttest**	**N-Gain**
N	36	36	36	31	31	31
Mean	15,47	32	0,67	16,23	20,97	0,19
Median	15,5	32	0,67	16	22	0,29
Mode	15	30	0,70	16	24	0,43
Standard Deviation	1,93	2,91	0,12	3,16	5,02	0,24
Minimum	12	26	0,36	12	12	−0,28
Maximum	19	38	0,92	24	29	0,54
Range	7	12	0,56	12	17	0,82

Normality tests showed that the N-gain data for critical thinking skills were normally distributed in both groups. However, homogeneity testing indicated non-homogeneous variance ($p = 0.003$). Therefore, Welch's t-test was applied and confirmed using the Mann–Whitney U test.

The results showed $t = 8.628$, $p < 0.001$, indicating a highly significant difference in critical thinking improvement between the experimental and control classes. The experimental class achieved a high N-gain (0.671), while the control class remained in the low category (0.147). Wilcoxon tests revealed that 100% of experimental-class students experienced improvement, compared to 71% in the control class.

These improvements can be explained by several mechanisms grounded in established learning theories. Experimental activities engaged students in authentic scientific inquiry processes observing phenomena, identifying variables, collecting data, and drawing evidence-based conclusions which are fundamental to inquiry-based learning [30], [31]. Group discussions facilitated collaborative knowledge construction and promoted critical thinking through social interaction and peer dialogue, consistent with cooperative learning theory [32], [33].The game and tournament components required rapid decision-making and logical problem-solving, processes shown to enhance critical thinking skills in game-based learning environments [34]. These varied learning activities collectively supported social constructivist learning principles, wherein students actively construct knowledge through social interaction and collaboration within their zone of proximal development [35], [36]. The improvement in students' critical thinking abilities can also be observed across each indicator, as presented in the table below

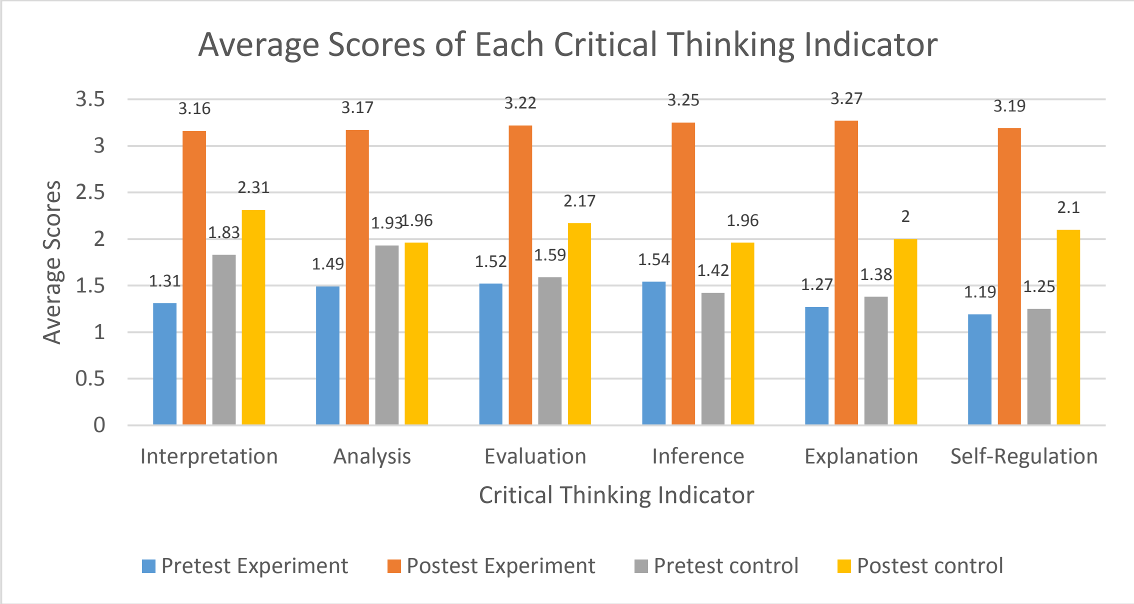

Fig 5. Average scores of each critical thinking indicator for the experimental and control groups in the pretest and posttest

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Indicator analysis shows the highest gains in explanation (0.72) and self-regulation (0.70), followed by interpretation, analysis, evaluation, and inference. These results confirm that the TGT model integrated with experiments develops critical thinking skills holistically, in accordance with Facione 2020 framework[24].

Relationship between Learning Interest and Critical Thinking Skills

Pearson correlation analysis revealed a significant positive relationship between learning interest and critical thinking skills ($r = 0.596$; $p = 0.001$), categorized as a moderate-to-strong correlation. The coefficient of determination ($r^2 = 0.355$) indicates that 35.5% of the variance in critical thinking skills can be explained by learning interest.

These findings align with educational psychology theory, which posits that learning interest constitutes an internal factor that influences students' cognitive processes and facilitates the development of higher-order thinking skills, including critical thinking [37]. Students with high interest tend to demonstrate greater focus, persistence, and motivation to understand material deeply, with research establishing bidirectional relationships between motivational constructs and achievement [38]. Within the context of the Teams-Games-Tournament (TGT) model integrated with experimentation, this interrelation becomes particularly evident as engaging experimental activities enhance students' interest while providing opportunities to exercise critical thinking skills through observation, data analysis, and conclusion drawing [39]. Tournament-based competition and collaborative group discussions further develop critical thinking abilities through processes of problem-solving, argumentation, and idea evaluation[40]. This synergistic approach creates a positive cycle where well-developed critical thinking skills enhance learning interest as students feel more competent and confident, while increased interest motivates deeper engagement with challenging learning tasks .

Within the TGT-with-experiment context, this relationship is clearly evident. Engaging experiments increased interest, which in turn facilitated deeper cognitive processing. Group discussions and tournaments enhanced both interest and critical thinking simultaneously. Individual profile analysis showed that 77.8% of experimental-class students demonstrated proportional improvements in both learning interest and critical thinking skills, confirming the integrative effectiveness of the modeln**.**

IV. CONCLUSION

Based on the research findings and discussion, it can be concluded that the TGT learning model with experiments has a highly significant effect on students' learning interest in Newton's Laws topic with an N-gain of 0.57 (moderate category) and Cohen's d Effect Size of 2.69 (very large category). Additionally, the TGT learning model with experiments significantly influences students' critical thinking skills in Newton's Laws topic with an N-gain of 0.67 (moderate-high category) and Cohen's d Effect Size of 2.12 (very large category). Furthermore, there exists a significant positive relationship between learning interest and critical thinking skills ($r = 0.596$; $p = 0.001$), indicating that higher learning interest contributes to improved critical thinking skills, and vice versa.

These findings demonstrate that the integration of the TGT model with experiments proves effective in holistically enhancing students' learning interest and critical thinking skills. The combination of cooperative learning, academic games, tournaments, and experimental activities creates a pleasant, challenging, and meaningful learning environment for students. It is recommended that physics teachers implement the TGT learning model with experiments for other physics topics, particularly those that are abstract in nature and require empirical verification, with attention to thorough preparation including provision of experimental equipment and materials, structured worksheets, and fair assessment systems. Further research can be conducted using true experimental designs with random sampling to enhance internal validity, as well as longitudinal approaches to examine the long-term effects of this learning model on concept retention and transfer of critical thinking to different contexts.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to SMA Negeri 1 Prambanan Sleman for granting permission and facilitating the implementation of this research. The authors also extend their deepest appreciation to Dr. Tsania Nur Diyana, M.Pd., for her invaluable guidance, constructive feedback, and continuous academic support throughout the research and writing process of this article. Appreciation is further addressed to all students and observers who actively contributed to the successful completion of this study.

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