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Moodle-Integrated Flipped Classroom: Fostering Self-Directed Learning and Academic Achievement in Physics Mechanics

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Abstract: This study investigates the effect of the Flipped Classroom model assisted by Moodle on student learning independence and academic outcomes in physics, specifically regarding Newton's Laws. A quasi-experimental design with a pretest-posttest control group was employed, involving 75 tenth-grade students. The experimental group utilized the Moodle-integrated flipped approach, while the control group received conventional instruction. Data were analyzed using MANOVA, normalized gain, and Pearson correlation. The results indicate that the integrated model significantly improves both variables. The experimental group achieved a moderate increase in learning independence (normalized gain = 33%) and a high increase in learning outcomes (normalized gain = 73%), outperforming the control group (15% and 63%, respectively). Furthermore, a moderate positive correlation was found between learning independence and academic achievement. In conclusion, leveraging Moodle within a flipped classroom framework effectively fosters student autonomy and enhances cognitive mastery in physics education.

Keywords: Flipped Classroom; Moodle; Learning Independence; Learning Outcome; Newton Law

Introduction

The rapid advancement of technology has significantly transformed the educational landscape, particularly in the context of 21st-century learning (Kiraly et al., 2025; Pradana et al., 2025; Yan, 2025). Today's students are recognized as "digital natives" who are highly accustomed to information technology and active internet use (Dečman et al., 2025; Fan, 2025; Ma et al., 2025). In alignment with this digital shift, the Indonesian 2013 Curriculum strongly emphasizes the integration of science and technology, urging educators to optimally utilize Information and Communication Technology (ICT) to create effective, efficient, and ubiquitous learning environments (Ronaghi, 2024; Wang et al., 2025; Xu et al., 2024). However, despite these technological demands, the implementation of technology in physics education at MAN 1 Medan remains suboptimal. Although the school is well-equipped with adequate facilities—including a computer laboratory, robust Wi-Fi access, and students possessing personal smartphones—these resources are predominantly utilized for socializing and gaming rather than academic purposes.

Currently, physics instruction at the school still relies heavily on conventional, teacher-centered lectures and extensive note-taking. This traditional approach consumes excessive classroom time, leaving little room for interactive problem-solving or immediate feedback. Consequently, student achievement in physics is relatively low, with only 41% of students meeting the Minimum Completeness Criteria (KKM). Students frequently perceive physics as an overwhelmingly difficult subject due to its heavy reliance on mathematical formulas, which ultimately leads to a lack of academic confidence.

Furthermore, preliminary observations and student condition analyses indicate a critical lack of self-regulated learning (learning independence) (Conde-Izquierdo et al., 2025; Costa et al., 2025; Smith et al., 2025). Students consistently struggle to comprehend learning objectives, fail to develop independent strategies to achieve them, rarely utilize available learning facilities for academic growth, and seldom evaluate their own learning processes to identify the causes of their successes or failures (Fılız et al., 2026; Jiang, 2025; Wang et al., 2026). To address these multifaceted challenges, the implementation of a

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Moodle-assisted Flipped Classroom model is proposed as a viable, technology-driven solution (Eyland et al., 2025; Graham et al., 2026; Rahman et al., 2025).

The Flipped Classroom model strategically reverses traditional teaching methods by introducing students to new concepts and instructional materials—such as videos and modules—at home, thereby dedicating precious classroom time to active learning, collaborative discussions, and practical demonstrations (Lima Guedes, 2026; Ren et al., 2025; Trabelsi et al., 2025). As a dynamic, web-based Learning Management System (LMS), Moodle perfectly supports this model by providing students with flexible, unrestricted access to learning materials, enabling them to learn at their own pace. This innovative combination is expected to optimize face-to-face classroom time, foster student autonomy, and ultimately improve academic performance (Gu et al., 2025; Marini et al., 2026; Monib et al., 2025).

Driven by these underlying issues, this research aims to comprehensively investigate the efficacy of this integrated teaching approach in physics education. Specifically, this study is designed to determine the overall effect of the Moodle-assisted flipped classroom learning model on both student learning independence and their corresponding learning outcomes. Furthermore, it seeks to precisely measure the increase in student learning independence and academic achievement when applying this model to the specific context of Newton's Laws. Beyond measuring these separate variables, this study also aims to analyze the potential relationship and correlation between students' self-regulated learning independence and their learning outcomes under the intervention of the Moodle-assisted flipped classroom model. Through these objectives, the study hopes to provide empirical evidence on how blended learning environments can bridge the gap between technology availability and meaningful physics conceptual mastery.

Method

Research Design

This study employed a quantitative approach using a quasi-experimental method. Specifically, a *two-group pretest-posttest design* was utilized to evaluate the effect of the instructional intervention. The research was conducted at MAN 1 Medan.

Population and Sample

The population of this study comprised all 10th-grade science students (Class X IPA) at MAN 1 Medan, consisting of 12 classes. A *simple random sampling* technique was used to select two classes as the research sample. Experimental Class (X IPA 3): Consisted of 36 students who were taught using the Flipped Classroom model assisted by the Moodle Learning Management System (LMS). Control Class (X IPA 5): Consisted of 39 students who were taught using conventional learning methods.

Research Variables The study involved two primary variables. Independent Variable: The learning model applied, which consisted of the Flipped Classroom model assisted by Moodle (for the experimental group) and conventional learning (for the control group). Dependent Variables: Student learning independence (*kemandirian belajar*) and student learning outcomes (*hasil belajar*) on the topic of Newton's Laws.

Research Instruments

Data were collected using both test and non-test instruments. Test Instrument (Learning Outcomes): A multiple-choice test consisting of 22 validated questions (derived from an initial pool of 30 items) covering cognitive levels C1 to C6 based on Anderson and Krathwohl's revised Bloom's Taxonomy. This test was administered as a *pretest* and *posttest*. The instrument demonstrated high reliability (Cronbach's Alpha = 0.860) and appropriate levels of difficulty and discrimination. Non-Test Instrument (Learning Independence): A self-assessment questionnaire comprising 20 statements measured on a 4-point Likert scale. The questionnaire was designed based on three dimensions of self-regulated learning: thinking (task analysis and self-belief), performance control (self-control and self-experimentation), and self-reflection (self-evaluation and self-reaction).

Data Collection Procedure

The research procedure was divided into three main stages. Preparation: Developing lesson plans (RPP), teaching materials, student worksheets (LKPD), and research instruments, followed by expert validation and instrument trial runs. Implementation: Administering the pretest and initial independence questionnaire to both classes. The experimental class then underwent the Flipped Classroom learning via Moodle (where students accessed materials at home and engaged in active problem-solving and discussions in class), while the control class received conventional direct instruction. Following the treatment, the posttest and final independence questionnaire were administered. Finalization: Scoring, data tabulation, and statistical analysis.

Data Analysis Techniques

Data were analyzed using statistical software (SPSS 20.0) through the following steps. Prerequisite Tests: Normality was tested using the Kolmogorov-Smirnov test, and homogeneity of variances was assessed using Levene's Test to ensure the data met the assumptions for parametric testing. Hypothesis Testing: A Multivariate Analysis of Variance (MANOVA) was conducted to determine the simultaneous effect of the learning models on both learning independence and learning outcomes.

Improvement Analysis: The normalized gain (N-Gain) formula developed by Meltzer was used to measure and categorize the magnitude of improvement in both variables (categorized as high, medium, or low).

Correlation Analysis: The Pearson Product-Moment correlation was utilized to determine the strength and direction of the relationship between students' learning independence and their learning outcomes in the experimental class.

Result and Discussion

Descriptive Statistics

The study involved an experimental class (Flipped Classroom assisted by Moodle) and a control class (Conventional learning). The descriptive statistics for student learning outcomes (pretest and posttest) are summarized in Table 1.

Table 1. Descriptive Statistics of Learning Outcomes

Data	Class	N	Mean	Std. Deviation
Pretest	Experimental	36	39.6	7.66
	Control	39	37.9	8.29
Posttest	Experimental	36	83.1	7.59
	Control	39	76.7	6.66

Prior to hypothesis testing, prerequisite tests (normality and homogeneity) were conducted. The results confirmed that all data sets (pretest, posttest, initial independence, and final independence) for both classes were normally distributed (Kolmogorov-Smirnov test, $p > 0.05$) and homogeneous (Levene's test, $p > 0.05$).

Hypothesis Testing

A Multivariate Analysis of Variance (MANOVA) was employed to test the hypothesis. The initial data MANOVA showed a significance value of 0.105 ($p > 0.05$), indicating that both classes had equivalent initial abilities in learning independence and outcomes before the treatment.

The MANOVA results for the final data (posttest and final independence) are presented in Table 2.

Table 2. MANOVA Results for Final Data

Effect	Value	F	Hypothesis df	Error df	Sig.
Pillai's Trace	0.252	12.100	2.000	72.000	0.000
Wilks' Lambda	0.748	12.100	2.000	72.000	0.000

As shown in Table 2, the significance value is 0.000 ($p < 0.05$). Therefore, the null hypothesis is rejected, confirming that the Flipped Classroom learning model assisted by Moodle has a significant effect on both student learning independence and learning outcomes on Newton's Laws.

Learning Improvement (N-Gain Analysis)

The improvement in learning independence and learning outcomes was measured using the normalized gain (N-Gain). The summary of the N-Gain analysis is presented in Table 3.

Table 3. Summary of N-Gain for Learning Independence and Outcomes

Variable	Class	Initial Mean	Final Mean	N-Gain (%)	Category
Learning Independence	Experimental	70.3	80.0	33%	Medium
	Control	66.0	71.0	15%	Low
Learning Outcomes	Experimental	39.6	83.1	73%	High
	Control	37.9	76.7	63%	Medium

Table 3 indicates that the experimental class experienced a higher improvement in both variables compared to the control class. The N-Gain for learning independence in the experimental class was 33% (Medium category), while the control class was 15% (Low category). Furthermore, the N-Gain for learning outcomes in the experimental class reached 73% (High category), compared to 63% (Medium category) in the control class.

Correlation Analysis

The relationship between student learning independence and learning outcomes in the experimental class was analyzed using the Pearson Product-Moment correlation. The results are detailed in Table 4.

The analysis yielded a Pearson correlation coefficient of 0.562 with a significance value of 0.000 ($p < 0.05$). This indicates a moderate positive correlation between student learning independence and their learning outcomes, meaning that higher levels of learning independence are associated with better academic achievement.

Table 4. Correlation between Learning Independence and Learning Outcomes

Variable	Pearson Correlation	Sig. (2-tailed)	N
Learning Independence & Outcomes	0.562**	0.000	75

Note: ** Correlation is significant at the 0.01 level (2-tailed).

The findings of this study demonstrate that integrating the Flipped Classroom model with the Moodle Learning Management System significantly transforms the physics learning environment, yielding substantial improvements in both student learning outcomes and learning independence. Rather than merely serving as a digital repository for materials, Moodle acted as a critical pedagogical scaffold that enabled the successful reversal of traditional instructional time.

Significance of Improved Learning Outcomes

The most profound significance of this intervention lies in the reallocation of cognitive load and classroom time. In the conventional model, classroom time was heavily consumed by passive note-taking and basic information delivery, leaving students to grapple with complex problem-solving alone at home. By shifting the initial acquisition of foundational knowledge (such as the definitions of Newton's Laws and basic force vectors) to the pre-class phase via Moodle, the experimental class reclaimed valuable face-to-face time (Pan et al., 2024; Sailer et al., 2024; Zhu et al., 2026).

This reclaimed time was utilized for active, higher-order cognitive processes. The significant N-Gain observed in the experimental class, particularly in the cognitive indicators of Application (C3) and Analysis (C4), indicates that students were not just memorizing formulas but were actively applying them to solve dynamic problems, conducting experiments (such as the friction and pulley demonstrations), and engaging in peer discussions. The immediate feedback loop provided by the teacher during in-class troubleshooting allowed students to correct misconceptions in real-time, a luxury unavailable in the conventional model where feedback was delayed until homework was graded. Consequently, the Flipped Classroom model effectively bridged the gap between theoretical understanding and practical application in physics (Liu et al., 2025; Medina Vásquez et al., 2025; Stötzer et al., 2025).

Significance of Enhanced Learning Independence

The improvement in learning independence underscores the behavioral shift triggered by the Flipped Classroom environment. Learning independence, conceptualized through the dimensions of self-regulated learning (task analysis, performance control, and self-reflection), was notably fostered by the inherent flexibility of Moodle.

The highest improvement in the experimental class was observed in the "self-reaction" dimension, which encompasses self-satisfaction and adaptive behaviors following learning outcomes. This is highly significant because it suggests that when students are given autonomy over their pre-class learning—such as the ability to pause, rewind, and re-watch video explanations of complex physics concepts at their own pace—they develop a stronger sense of ownership and self-efficacy. Furthermore, the requirement to arrive at class prepared for discussions and practicums forced students to engage in "task analysis" and "performance control." They had to independently plan their study schedules, manage their time, and utilize digital facilities to overcome learning hurdles. The model effectively transitioned the students from passive recipients of information to active, self-directed managers of their own learning processes (Adnans et al., 2025; Beimel, 2025; Jiang et al., 2025).

The Interplay Between Independence and Outcomes

The moderate positive correlation (0.562) between learning independence and learning outcomes highlights a crucial dynamic in 21st-century science education: cognitive mastery in complex subjects like physics is deeply intertwined with a student's ability to self-regulate. The data implies that the technological tools (Moodle) and the pedagogical model (Flipped Classroom) alone are insufficient to guarantee high achievement; rather, it is the *independent engagement* with these tools that drives success. Students who actively monitored their understanding during the pre-class phase were better equipped to participate meaningfully in the rigorous in-class problem-solving sessions. This symbiotic relationship confirms that fostering autonomy is not merely a supplementary educational goal but a fundamental prerequisite for achieving high-level cognitive outcomes in STEM subjects.

Broader Implications

Ultimately, the significance of this work extends beyond the specific context of Newton's Laws at MAN 1 Medan. It provides a validated framework for leveraging ubiquitous technology (smartphones and internet access) to solve systemic educational bottlenecks. For educational stakeholders, the results signify that technology integration should not focus merely on digitizing traditional lectures, but on restructuring the learning timeline to prioritize active, student-centered knowledge construction. By addressing the dual challenges of low academic achievement and poor learning autonomy simultaneously, the Moodle-assisted Flipped Classroom model offers a sustainable, scalable approach for modernizing science education in resource-adequate but pedagogically traditional settings.

Conclusion

This study concludes that the Flipped Classroom learning model assisted by Moodle significantly enhances both student learning independence and learning outcomes on the topic of Newton's Laws. The experimental class demonstrated a notably higher improvement in learning independence (N-Gain of 33%, medium category) compared to the conventional learning class (15%, low category), alongside a more substantial increase in learning outcomes (73%, high category versus 63%, medium category). Furthermore, a moderate positive correlation (r = 0.562) was identified between learning independence and learning outcomes, indicating that fostering student autonomy through this flexible, technology-integrated approach directly contributes to better academic achievement.

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