Kasuari: Physics Education Journal 7(2) (2024) 342-350
P-ISSN: 2615-2681
E-ISSN: 2615-2673

Kasuari: Physics Education Journal (KPEJ)
Universitas Papua
Web: http://jurnal.unipa.ac.id/index.php/kpej

Enhancing Students Concept Mastery through Integrative Active Learning Models of Momentum and Impulse

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Abstract: *Students' low concept mastery of Momentum and Impulse leads to difficulties applying these concepts in everyday life. Solutions are needed to address these challenges and enhance students' concept masteryof Momentum and Impulse. Integrating phenomena into active learning is crucial for improving students' concept mastery. This research aims to enhance students' understanding of Momentum and Impulse through an integrative active learning model. An experimental study with a one-group pretest-posttest design was conducted on 30 grade 11 students. The results showed that technology-based active-integrative learning effectively increased students' concept mastery of Momentum and Impulse concepts, particularly within the medium category. Students' understanding at higher levels (levels 2 and 3) also saw significant improvement. Therefore, adopting technology-based active-integrative learning is a vital step in this direction.*

Keywords: *concept mastery, high school students, integrative active learning model, momentum and impulse*

Peningkatan Penguasaan Konsep Peserta Didik melalui Model Pembelajaran Aktif Integratif pada Materi Momentum dan Impuls

Abstrak: Penguasaan konsep materi Momentum dan Impuls yang rendah pada siswa menyebabkan kesulitan dalam mengaplikasikan konsep tersebut dalam kehidupan sehari-hari. Diperlukan solusi untuk mengatasi kesulitan siswa dalam membangun pengetahuan yang komprehensif, sehingga penguasaan mereka terhadap konsep Momentum dan Impuls dapat ditingkatkan. Mengintegrasikan fenomena dalam pembelajaran aktif merupakan dasar penting dalam meningkatkan penguasaan konsep siswa. Penelitian ini bertujuan untuk meningkatkan penguasaan konsep siswa pada materi Momentum dan Impuls melalui penerapan model pembelajaran aktif integratif. Penelitian eksperimental dilakukan dengan menggunakan desain *one group pretest-posttest* terhadap 30 peserta didik kelas 11. Pembelajaran aktif-integratif berbasis teknologi terbukti efektif dalam meningkatkan penguasaan konsep Momentum dan Impuls, dengan peningkatan yang signifikan terutama pada kategori sedang. Tingkat pemahaman siswa pada level yang lebih tinggi (level 2 dan 3) juga mengalami peningkatan yang signifikan. Oleh karena itu, adopsi pembelajaran aktif-integratif berbasis teknologi merupakan langkah penting yang perlu dilakukan.

Kata kunci: model pembelajaran aktif integratif, momentum dan impuls, penguasaan konsep, siswa SMA

INTRODUCTION

Momentum and impulse are crucial topics in physics because they relate to everyday phenomena (Eksanita & Diantoro, 2021). However, students often struggle to understand this material, such as having difficulty applying the relationship between force and speed (Saifullah et al., 2017) and answering questions involving new concepts (Xu et al., 2023)Click or tap here to enter text.. Additionally, students find it challenging to apply the relationship between momentum and impulse in calculations, use the law of conservation of momentum to solve everyday problems, and describe different collisions (Trinovitasari et al., 2022). These studies highlight that students need to have an in-depth understanding. Therefore, students must have a deep understanding of momentum and impulse basic concepts (Xu et al., 2023). So, students must have mastery of concepts to solve problems on impulse and momentum.

Concept mastery enables students to identify, analyze, and understand physics concepts deeply, both in theory and practical applications in everyday life (Kumullah et al., 2018). This mastery helps students apply their physics knowledge to real-life situations (Banda & Nzabahimana, 2021). Connecting the concept mastery of physics concepts to real-life scenarios is a learning method that stimulates scientific reasoning in students (Rimadani, 2017). However, the concept mastery of momentum and impulse remains low. Sugiana et al. (2016) revealed that students' concept mastery was relatively low due to difficulties in linking initial and new knowledge and constructing it. Kusumaningrum et al. (2022) indicates that while there has been a moderate increase in concept mastery, students still struggle with interpreting symbols and determining the correct equations to solve momentum and impulse problems. Rahmawati et al. (2019) found that the increase in concept mastery was relatively small because students could not understand the concepts of momentum and impulse based on Newton's Second Law. These findings demonstrate that further efforts are needed to enhance students' concept mastery of momentum and impulse material.

Students' concept mastery can be enhanced through active learning models (Adinia et al., 2022; Banda & Nzabahimana, 2021; Dahlan & Maulidiah, 2024). One such model is inquiry-based learning (Michael, 2006; Michael & Modell, 2003). Inquiry-based learning has been shown to significantly improve academic achievement based on a meta-analysis (Kaçar et al., 2021). Asyhari & Clara (2017) support that inquiry-based learning can improve students' concept mastery. However, some students still struggle to use prior knowledge to recognize and explain scientific phenomena during the learning process independently. Based on these studies, integrating inquiry-based learning with phenomena is necessary to bridge this gap and create integrative active learning. Previous research confirms that incorporating phenomena in active learning can serve as a foundation for building students' knowledge and understanding (fazio, 2020; Funfuengfu, 2022; Suryadi et al., 2021). Integrating problems with real phenomena can make students better able to connect theory with practice, thus improving their understanding of impulse and momentum.

Previous studies have utilized active learning models. Khan et al. (2017) research indicates that active learning significantly impacts junior high school students' academic achievement, including knowledge, understanding, application, problem-solving, observation, and reasoning. That aligns with (Pal, 2024) findings that virtual lab-enabled active learning can enhance the academic achievement of grade 10 students, although this study focused on static electricity. Nun˜ez et al. (2021) found that active learning helps increase students' knowledge levels, resulting in greater concept mastery by the end of the intervention on the topic of force. This research recommends active learning strategies that align with the current curriculum. While previous studies have shown that active learning models can improve concept mastery and other skills, further research is needed to provide a new perspective by enhancing concept mastery through an integrative active learning model that utilizes inquiry-based and phenomenon-based learning on momentum and impulse.

RESEARCH METHOD

This research aims to determine the increase in student's concept mastery through an active-integrative learning model on momentum and impulse material. It is an experimental study using a one-group pretest-posttest design (Creswell, 2015), where the researchers use a single group of subjects with an active-integrative learning model, with test measurements taken before and after the treatment. This data is reinforced by the results of the interview. The research subjects were selected using a cluster sampling technique, resulting in 30 students from class XI-2 at a high school in Malang City. The one-group pretest-posttest research design is illustrated in Figure 1.

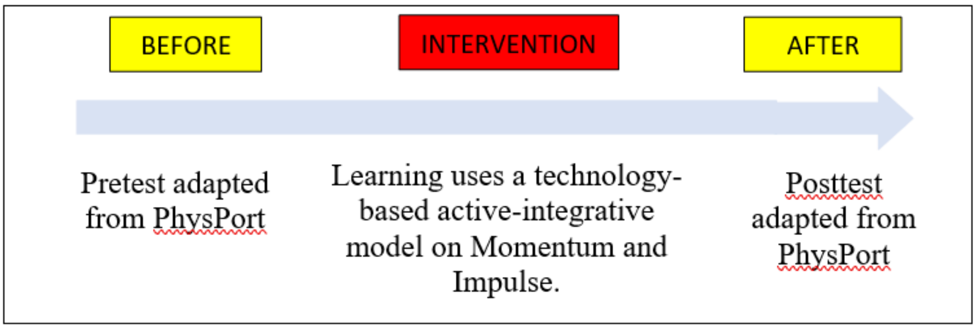

Figure 1. Research Flow Diagram

The research instrument consists of seven questions that assess concept mastery of momentum and impulse, adapted from Physport. The test is categorized into indicators C2 to C5. Data collection began with administering a pre-test to students, followed by three sessions of momentum and impulse learning based on the active-integrative model facilitated by the teacher. After completing the learning sessions, students undergo a post-test to evaluate their concept mastery of momentum and impulse material. The assessment method employs concept mastery scores, following the rubric described in Table 1.

Table 1. Concept Mastery Assessment Rubric

Scale	Concept Mastery Level	Answer Categories
3	Understand the Concept	Answers contain all parts of the concept
2	Partially understand	The answer contains several parts of the concept
1	Misconceptions	The answer contains misconceptions
0	Don't Understand the Concept	Didn't answer or answered unclear

Data analysis involved using descriptive and inferential statistics. Descriptive statistics were employed to present the mean and variability of pre-test and post-test scores obtained by students. Inferential statistics included a normality test, revealing that the data did not follow a normal distribution with a significance value below 5%. Consequently, a non-parametric test, specifically the Wilcoxon test, was conducted to assess the difference in pre-test and post-test scores achieved by students.
The null and alternative hypotheses for this study are as follows:

Ho: There is no significant increase in students' concept mastery before and after technology-based active-integrative learning.

Ha: There is a significant increase in students' concept mastery before and after technology-based active-integrative learning.

Concept mastery improvement was assessed using N-gain (Hake, 1998). Interpretation of the N-gain results is shown in Table 2.

Table 2. Interpretation of N-gain Values

No.	N-gain Values	Categories
1	(<g>) ≥ 0,7	High
2	0,7 > (<g>) ≥ 0,3	Medium
3	(<g>) < 0,3	Low

RESULTS AND DISCUSSION

Hypothesis Testing on Students' Concept Mastery

The active-integrative learning model trains students to develop their concept mastery of momentum and impulse. The research results provided descriptive statistics on students' concept mastery, presented in Table 3 below.

Table 3. Descriptive Statistics of Pre-test and Post-test Scores

	N	Mean	Standard Deviation
Pre-test	30	5,47	3,980
Post-test	30	14,4	2,527

Table 3 illustrates a difference in concept mastery scores between the pre-test and post-test, as indicated by the mean values. The post-test score (M=14.4, SD=2.527) was higher than the pre-test (M=5.47, SD=3.980). That aligns with the Wilcoxon test results, which show a value of (Asymp. Sig. 0.00 < 0.05), indicating that the alternative hypothesis is accepted and there is a significant difference in students' concept mastery after technology-based active-integrative learning. The results of the pretest and posttest can be evidence of an influence on concept mastery (Putra et al., 2020). The pretest measures students' initial understanding before the intervention and the posttest measures understanding after the intervention, the difference in scores between the two tests indicates how effective the intervention is in improving students' concept mastery.

Analysis of Students' Concept Mastery Improvement

N-gain results show an increase of 0.5588, falling into the medium category (Hake, 1998). This improvement indicates that technology-based active-integrative learning is effective in students' concept mastery. Students' concept mastery of momentum and impulse is assessed by focusing on three main areas: 1) Momentum and Impulse, 2) The Law of Conservation of Momentum, and 3) Types of Collisions. This main concept was chosen because students struggled to connect the concepts of momentum and impulse when solving problems and understanding momentum as a vector quantity concerning the conservation law of momentum. These difficulties often led to misconceptions among students (Setiyani et al., 2023). A total of seven essays were used to evaluate the students' concept mastery. The percentage of pre-test and post-test answers, along with the categories of students' concept mastery acquisition, can be found in Table 4.

Table 4. The Improvement of Students' Concept Mastery

Sub Material	Level	Percentage (%)	
		Pre-test	Pos-test
Momentum and Impulse	3	16,67	41,11
	2	11,11	26,67
	1	20,00	30,00
	0	52,22	2,22
The Law of Conservation of Momentum	3	17,78	36,67
	2	12,22	36,67
	1	8,89	25,56
	0	61,11	1,11
Types of Collisions	3	0,00	30,00
	2	0,00	33,33
	1	0,00	36,67
	0	100,00	0,00

Based on Table 4, more than half of the students' pre-test answers regarding impulse and momentum were at level 0 (52.22%), indicating that most students did not adequately grasp the basic concepts. This difficulty stemmed from students struggling to apply momentum and impulse formulas. Students still believe that impulse is influenced by changes in time (Setiyani et al., 2023). After the technology-based active-integrative learning process, the number of students at level 0 decreased drastically to 2.22%, while those at level 2 increased by 26.67% and level 3 by 41.11%. This indicates that students experience an increase in mastery of the concepts of impulse and momentum. These results are also reinforced by the results of interviews with several students who stated that the impulse done on an object is the same as the change in momentum experienced by the object, which is the difference between the final momentum and the initial momentum.

In the sub-chapter on the law of conservation of momentum, the pre-test scores indicate that most students are at level 0 (61.11%), demonstrating low concept mastery. Students believe that the amount of momentum is influenced by mass and speed only. Following technology-based active-integrative learning, students showed a significant increase in concept mastery. It is proven that at level 3 from 17.78% to 36.67%, level 2 from 12.22% to 36.67%, level 1 from 8.89 to 25.56%, and the most significant level 0 from 61.11% to 1.11%. Thus, comprehending momentum as a vector quantity is related to the law of conservation of momentum (Close & Heron, 2011). So, they understand that momentum is a vector quantity with both direction and magnitude.

In the sub-chapter on types of collisions, the pre-test results showed that 100% of students were at level 0, indicating they had not mastered the concept of collision types. This finding is consistent with Trinovitasari et al. (2022), who stated that students could not apply the law of conservation of momentum to solve collision problems. However, after participating in technology-based active-integrative learning, students can apply the law of conservation of momentum to various collisions. This is shown by the increase in percentage at each level of concept mastery, where at level 3 from 0% to 30%, level 2 from 0% to 33.33%, level 1 from 0% to 36.67%, and the most significant is at level 0 from 100% to 0%.

The improvement of concept mastery through integrative active learning is also shown from the results of interviews with several learners who stated that experimental activities and group discussions that utilize technology can help them observe and understand concepts directly. The activity of problem-based experiments can make students more active in learning, thus improving their mastery of concepts (Sumarni et al., 2020). This can be seen from the following excerpt from the learner interview 'Experimental activities, especially with technological support, really help understanding because with experiments I can practice and observe the proof of a theory directly. So, I will understand more quickly if the theory has been explained and can be discussed properly. Technology helps widen accessibility, enrich the learning experience, and make learners' mastery of the concepts of impulse and momentum clearer. On the other hand, group discussions allow them to share their understanding and interpretations, and encourage the exchange of ideas and joint problem-solving, thus strengthening learners' mastery of the concepts.

The implementation of the technology-based active-integrative learning model can improve students' concept mastery. In this approach, students are not merely passive recipients of information; instead, they actively explore concepts through group discussions, virtual lab experiments, and presenting their findings to the class. This approach is supported by research from Khoiriyah et al. (2015), which emphasizes the importance of actively involving students in learning activities to enhance cognitive abilities. Drawing on previous knowledge and experiences helps students achieve a deeper understanding of concepts. A learning process that encourages students to interpret data and design experiments has significant potential to enhance concept mastery of complex concepts (Husnaini & Chen, 2019). This is also supported by Swandi et al. (2021) Integrating learning materials with real phenomena and using technology can help understand concepts better. In a learning process that involves interpreting data and designing experiments, students can significantly improve their understanding of the concepts of impulse and momentum.

CONCLUSION AND RECOMMENDATIONS

Research indicates that technology-based active-integrative learning is effective in enhancing students' concept mastery of momentum and impulse. This effectiveness is evidenced by a notable increase in post-test scores compared to pre-test scores, along with an N-gain of 0.5588, indicating a medium level of improvement. Following the lesson, there was a significant decrease in students at the basic concept mastery level (level 0). There was a considerable increase in students achieving higher levels of mastery (levels 2 and 3). These findings illustrate the effectiveness of technology-based active-integrative learning in assisting students in understanding and applying concepts related to momentum, impulse, the law of conservation of momentum, and various collisions.

Physics teachers can implement Technology-Based Active-Integrative Learning by designing and executing lessons of the integration technology into active learning methods, such as group discussions, simulations, and computer-based experiments. They can leverage interactive online learning platforms and resources to enhance student motivation and engagement. So, schools play a crucial role in ensuring sufficient technological infrastructure, including reliable internet access, appropriate electronic devices, and relevant educational applications. Additionally, schools should provide training and professional development opportunities for teachers to enhance their proficiency in implementing technology-based active-integrative learning strategies.

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