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Development of a Web-Based Interactive Multimedia Course with Feedback for Conceptual Understanding of Equilibrium and Rotational Dynamics

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Abstract

This study aims to determine the effectiveness of using web-based interactive multimedia with feedback on conceptual understanding of rotational equilibrium and dynamics. The data collection method used a quasi-experimental design with a pretest-posttest control group design. The sample used in this study were 30 students in the control class and 30 students in the experimental class, who had studied rotational equilibrium and dynamics. Data analysis techniques used descriptive statistics calculations, independent-sample t-tests, effect size, and N-Gain. The results of the independent-sample t-test obtained p = 0.000 <α = 0.05, indicating a difference in conceptual understanding between the control and experimental groups. The effect size value of d = 0.85 is categorized as high, meaning that the score of the group using web-based interactive multimedia significantly influenced students' conceptual understanding compared to the score of the group that did not use web-based interactive multimedia. Meanwhile, the N-Gain value of 0.31021 indicates that the increase in pretest and posttest scores is in the moderate to upper range. This indicates that the effectiveness of using web-based interactive multimedia programs with formative feedback can improve students' conceptual understanding.

Keywords: Conceptual Understanding, Formative Feedback, Interactive Multimedia, Web Enhanced Course, Equilibrium and Rotational Dynamics, Physics Education.

INTRODUCTION

The objectives of physics subjects are achieved if the ability to understand concepts is also achieved (Eliza et al., 2022). This ability is useful for developing students' knowledge and skills when making decisions logically, critically, intelligently, honestly, and effectively (Arifin & Aprisal, 2020; Safari, 2024; Son et al., 2020). One of the physics materials that is considered difficult is equilibrium and rotational dynamics (Nikmahi, 2020; Isyafiani et al, 2023; Syahrial, 2022; Roja, 2020). These difficulties arise due to several causes, such as students using formulas without understanding the important meaning of the formula (Nasution et al 2025; Syahrial, 2022).

One of the students' conceptual deficiencies is in the topic of torque as a vector quantity defined as the cross product between the quantities **r** and **F**. Students still solve torque problems by multiplying the magnitude of **r** by **F**. They do not realize that torque is a vector product between force and position and depends on the point where the force acts and the direction of the force. Students assume that torque and force are the same concept (Zulfa & Tandililing, 2019).

Several studies have conducted similar developments, such as the development of REACT with a virtual laboratory for conceptual understanding (Sari et al., 2020) and the development of Charta Free Body Diagrams to improve multi-representational skills (Aji et al., 2017). This study still has several shortcomings. Not all physics topics can be learned with virtual laboratories, there is no

feedback in virtual laboratories (Sari., (2020), while in interactive multimedia there is formative feedback on physics material that helps students improve their understanding of concepts. The Charta Free Body Diagram developed by Aji et al., (2017) also does not provide feedback. And it can only be done during learning and it is difficult to make students focus and concentrate (Tebabal & Kahssay, 2011). Media development in this study can be done during learning and outside of learning, so it can adjust to student conditions, it also affects their concentration and focus.

There is a need for tools that can stimulate students' interest in learning physics and enable them to visualize these concepts (Rahmansyah, 2020). The use of interactive multimedia has been shown to improve students' absorption and retention, as well as their desire to learn (Wu & Tai, 2016). The acquired understanding needs to be refined or strengthened to align with physics concepts. One way to do this is through formative assessment. Formative feedback is a key element in formative assessment, typically defined as information about how successfully something has been or is being done (Sadler, 1989).

Formative feedback contains information to be communicated to students intended to change their thinking or behavior to improve learning (Morris, 2021; Sofianto et al., 2016). According to Wisniewski (2020), formative feedback is one of the main influences in learning. Research by Rahmawati, I. L., Hartono, H., & Nugroho, S. E. (2015) shows that integrating feedback into formative tests can improve learning outcomes by up to 28% compared to conventional summative tests. Formative feedback should be provided as soon as possible after students answer a test. One way to display formative feedback directly is through web-based interactive multimedia. This is in line with a comprehensive study conducted by (Kania et al, 2023) which identified that feedback provided within a period of less than 48 hours after the assessment had a significant impact on improving student understanding, with an effectiveness level reaching 45% higher than delayed feedback.

Therefore, this study aims to develop and explain the effectiveness of a multimedia website-based interactive course accompanied by formative feedback in improving understanding of concepts related to rigid body equilibrium and rotational dynamics.

METHODS

This research is Research & Development. The research model is ADDIE (Analysis, Design, Development, Implementation, and Evaluation) proposed by Curry et al., 2021. The analysis stage examines the feasibility and need for developing formative feedback. This analysis phase involves literature review and fieldwork. This stage yields comparisons of formative feedback types developed from various sources and identifies several difficulties encountered by students in understanding the concept of equilibrium, which will later serve as a reference for media development in this study. The design phase consists of designing a product development draft by preparing a product development storyboard, preparing learning indicators, preparing two-level questions for concept mastery, and determining formative feedback. This development phase is a follow-up to the product draft, followed by product validation by a team of experts, and product revision I. The implementation phase consists of limited trials, product revision II, and product trials.

The design used was a pretest-posttest control group design with a quasi-experimental research method. The pretest and posttest were administered with identical questions, aiming to exclude differences in question quality that could affect conceptual understanding. The experimental class implemented a website-based interactive multimedia program reinforced by coursework and formative feedback, while the control class used manual formative feedback. Differences in the quality of students' conceptual understanding are a comparison between the control and experimental groups. At the end of the study, students were given a posttest as

final data to compare conceptual mastery between the two samples. The research design used can be seen in Table 1.

Table 1 Pretest Posttest Control Group Research Design

Pretest	Treatment	Posttest
O_1	X	O_2
O_1	Y	O_2

(Adapted from Shofiah 2024)

Note:
X : Treatment of the experimental class
Y : Treatment of the control class
O_1 : Pretest before treatment
O_2 : Posttest after treatment

The feasibility of the program, using Shofiah's (2024) opinion, is determined by increasing the final score of the assessment questionnaire items, the total score divided by the number of respondents who answered.

Validation indicators for conceptual understanding questions presented in the media are: (1) The test items are in accordance with the context, (2) The test items are in accordance with the feedback and objectives, (3) The images and descriptions in the questions are presented clearly, (4) The question formulation does not provide clues to the correct answer, (5) The choices really function as distractors, (6) The question formulation does not use words/sentences that give rise to multiple interpretations, (7) The answer key is correct, (8) The test items are able to form conceptual understanding. Meanwhile, the validation indicators for the media developed are: (1) The selection of video and animation images is attractive, (2) The selection of video and animation images is appropriate, (3) The selection of colors is attractive, (4) The selection of colors is appropriate, (5) The selection of text forms is appropriate, (6) The selection of text colors is appropriate

The feasibility criteria for the average analysis can be seen in Table 2.

Table 2 Feasibility Criteria for Analysis of Average Values of Validation Results and Limited Trials

Average	Aligibility
3,26 – 4,00	Worthy
2,51 – 3,25	Fairly Worthy
1,76 – 2,50	Less Worthy
1,00 – 1,75	Unworthy

(Adapted from Shofiah 2024)

The practicality test was conducted on 60 students from Bahauddin Mudhary University, Madura. The sample selected was 30 students from MGK24 as the experimental class and 30 students from MGJ24 as the control class. The researcher used a probability sampling technique, namely simple random sampling. This sampling was done randomly, but each member of the population had a fair and equal chance of being selected. The selected sample consisted of those who had received the topics of rigid body equilibrium and rotational dynamics. The practicality criteria can be seen in Table 3.

Table 3 Limited Trial Practicality Criteria

Practicality	Level of Practicality	Description
76%-100%	Very Practical	Can be used without repair
51%-75%	Practical	Can be used with minor repairs
26%-50%	Less Practical	Not recommended for use due to need for major repairs
0%-25%	Impractical	Not suitable for use

(Adapted from Shofiah 2024)

The validation conducted included pretest and posttest questions, as well as the guidebook. Validation was conducted by submitting a questionnaire to the validators (two expert lecturers and two media experts). The data collection instruments for the trial of this web-based interactive multimedia product, along with formative feedback, were in the form of a questionnaire and a questionnaire. The questionnaire sheets were given to the validators and students to assess the product. The content validation questionnaire consisted of two parts: the first part was an assessment

questionnaire and the second part was a comment and suggestion section. The assessment results were explained using appropriate data analysis techniques.

The data collection instrument used was the concept mastery test. The data analysis technique used was obtained from the pretest, posttest, and N-gain scores. A independent sample t-test is used to determine whether there were differences in the students' mastery of concepts before and after the use of the web-based assessment. A independent sample t-test was performed on the average pretest and posttest scores. To find out how much increase between pretest and posttest scores due to treatment using the effect size. To be able to interpret the value of the effect size that has been obtained, whether it is small, medium, or large. It can be seen in Table 4.

Table 4 Guidelines for Interpreting Effect Size Values

Coefficient Interval	Relationship Level
d ≥ 0,8	High
0,5 ≤ d < 0,8	Medium
d < 0,5	Low

(Sutopo & Waldrip, 2014)

To determine the increase in pretest and posttest scores, an N-gain analysis was conducted. The N-gain criteria can be seen in Table 5.

Table 5 N-gain Criterion

Coefficient Interval	Relationship Level
(g) < 0,25	Low
0,25 ≤ (g) < 0,45	Lower Medium
0,45 < (g) < 0,65	Upper Medium
(g) ≥ 0,65	High

(Sutopo & Waldrip, 2014)

RESULTS AND DISCUSSION

Reviewing the existing program equipped with formative feedback and studies on understanding problems, it is necessary to develop an interactive multimedia program based on an enhanced course website accompanied by formative feedback with the following draft: (1) explaining the topic of rigid body equilibrium and rotational dynamics according to the concept; (2) fulfilling the formative feedback needed both in learning and outside of learning; (3) using HTML markup and Python language as a backend equipped with a MySQL database system and online so that it requires a network; (4) questions in the form of 2-tier where formative feedback is in accordance with the concept of the material presented by providing opportunities for improvement and direct tutorials at each level of difficulty of the student's concept; (5) containing questions, tier-1 and tier-2 answer choices, feedback on rigid body equilibrium and rotational dynamics material, self-assessment, and scores; (6) Questions and feedback are presented in the form of videos, animations, texts and/or images; (7) Each question must be answered correctly first, so that you can proceed to the next question and complete the entire test; (8) Every time they finish working on a question, students will be asked to do a self-assessment regarding the difficulties they faced when completing the question. Here is an example of a 2-tier.

The equilibrium lab tool is made of a perforated board that is hung on a stand with an axle as shown in the picture so that the board can move freely without disturbing. Initially, a lump of clay is attached to the initial position and the board is in a stationary state. If the lump of clay is moved to the final position (just below the initial position), what will happen to the board?

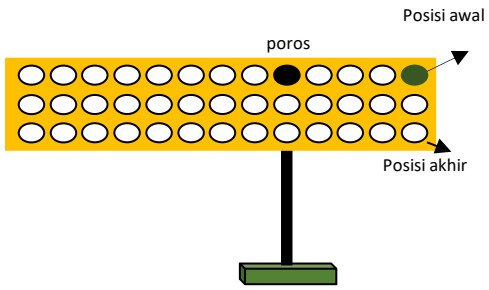


Figure 1. Figure for Question Number 3

Tier-1

a. The board remains stationary
b. The board rotates clockwise

Tier-2

a. There is no change in the magnitude of the torque

b. There is a change in the magnitude of the torque

Here's an example of how formative feedback can address student misunderstandings. Given a problem involving a rigid object rotating on a fixed axis, each point on the rigid object should traverse the same angle in a given time interval or have the same angular velocity.

Based on the pretest results, 20 students (33.3%) chose the correct answer B, arguing that the angular velocity at each point on a rigid object rotating on a fixed axis is the same. Furthermore, 13 students chose the incorrect answer A, 12 students C, and 15 students D.

The majority of students' responses were directed toward answer A. They argued that the farther the object is from the center, the greater its angular velocity. Conversely, students who chose answer C argued that $\omega = \frac{v}{R}$ dan $R_{Ahmad} = 2R_{Samsul}$ maka $\omega_{Ahmad} = \frac{1}{2}\omega_{Samsul}$.. Students with this type of thinking perceive two people, Ahmad and Samsul, as moving at the same linear velocity (Ünsal, 2011). They do not view Ahmad and Samsul as parts of a rigid body, like a merry-go-round rotating on its axis.

During the posttest, the number of students choosing the correct answer increased to 40 (66.6%). These 40 students consisted of 9 who chose A, 10 who chose C, and 10 who chose D. Ten of the 13 who chose answer A in the pretest shifted to the correct answer B in the posttest.

The arguments presented by these students align with the concept of rotational kinematics of rigid bodies. The feedback provided in this program successfully improved students' conceptions and was applied to solving problems in different contexts, resulting in a shift in answers from incorrect answers in the pretest to correct answers in the posttest.

The storyboard resulting from the initial design of interactive multimedia-based formative feedback can be seen in Table 6, while the results of creating product navigation can be seen in Figure 2.

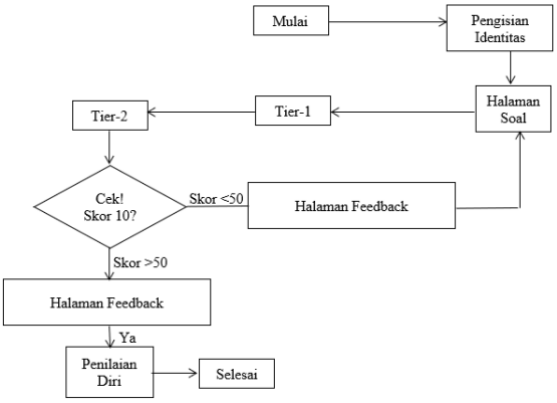
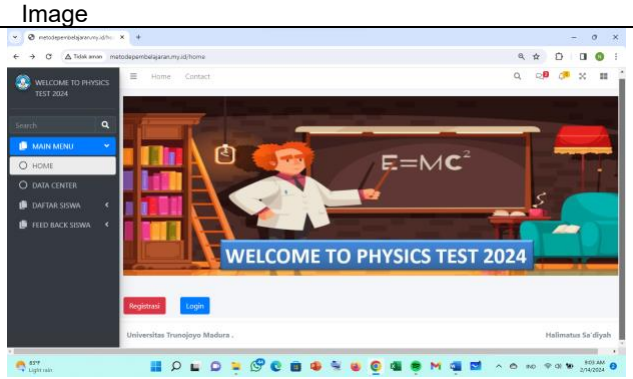
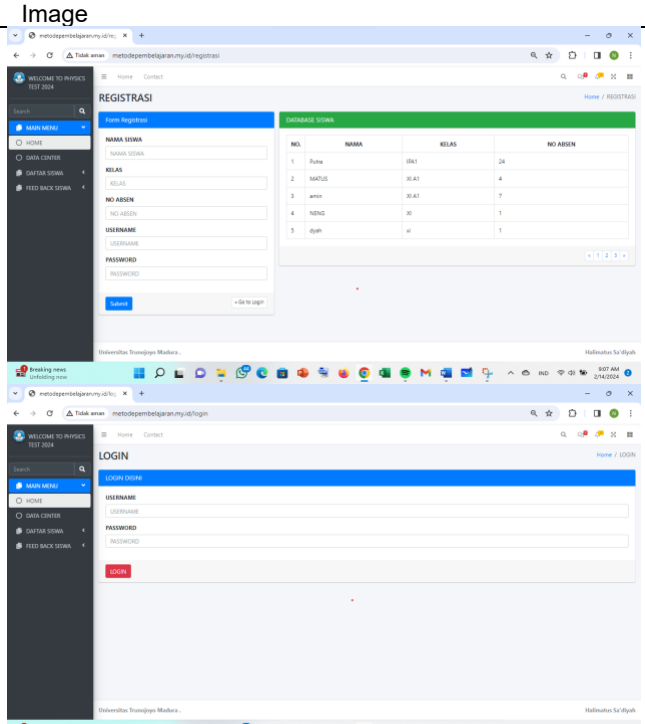
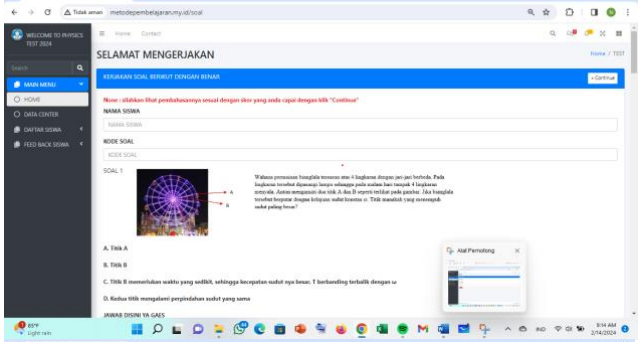
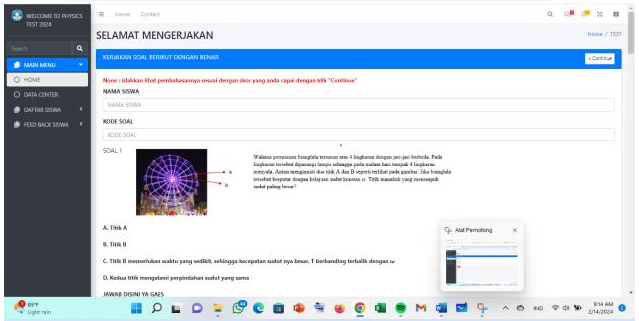
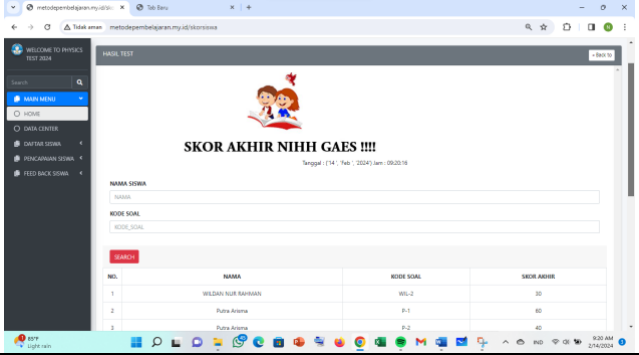


Figure 2. Product Navigation

Table 6 Storyboard is an Initial Design of a Product Development.

Page	Image	Caption
Start		This page contains the product title and buttons for registering and logging in.

Page	Image	Caption
Register and login		This page contains a registration section to create a username and password in the form of personal data and a login section after having a username and password.
Tier – 1 question page		This page contains first level questions and answer choices.
Tier – 2 question page		This page contains second level questions and answer choices.
Score		This page contains student scores from the first and second level answer choices, also includes a summary of scores for all students using the program.

(Sutopo & Waldrip, 2014)

The results of the posttest were analyzed to determine whether there were differences in results between the two samples and indicators of product effectiveness. The normality test conducted in this study used the Shapiro-Wilk test, which showed a significance value of 0.604 for the experimental class, while the control class had a significance value of 0.630, exceeding 0.05. Therefore, it was concluded that the data distribution for both the experimental and control classes was normally distributed. The normality test yielded results as shown in Table 7.

Table 7 Posttest Data Normality Test

Class	N	$\bar{x}$	P-Value
Experiment	30	75,70	0,604
Control	30	66,73	0,630

Tests of Normality

Kelas		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Posttest	Eksperimen	.110	30	0.200*	.972	30	0.604
	Kontrol	.105	30	0.200*	.973	30	0.630

The homogeneity test found that the significance of the experimental and control classes was 0.242, exceeding 0.05. Therefore, it was concluded that the conceptual understanding of both the experimental and control classes was homogeneous. The homogeneity test data can be seen in Table 8.

Table 8 Posttest Data Homogeneity Test

Class	N	$\bar{x}$	P-Value
Experiment	30	75,70	0,242
Control	30	66,73	

Levene Statistic	df1	df2	Sig.
1.397	1	58	0.242

The independent sample t-test results obtained p = 0.000 <α = 0.05, indicating that H_0 was rejected, indicating a difference in conceptual understanding between the control and experimental groups. This means that the developed program was effective in improving students' conceptual understanding. The data can seen in Table 9

Table 9. Independent Samples Test

		Independent Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PRE TEST - POSTTEST	-1.44578	1.11807	.12272	-1.68992	-1.20165	-11.781	59	.000

After determining whether there was a significant difference between the pretest and posttest scores, an effect size was required to determine the extent of the relationship between the pretest and posttest scores due to the treatment. The standard deviation using an independent-samples t-test is 33,17. The pre-test mean was found to be 47.5, while the post-test mean was found to be 75.7. Thus, the d-effect size value (d = 0,85) falls into the very large category. Statistically, the scores of the group using the interactive multimedia-based enhanced course with formative feedback significantly impacted students' conceptual understanding compared to the scores of the group not using the interactive multimedia-based enhanced course with formative feedback.

Meanwhile, the calculated g value was 0.31021, while the calculated $\bar{g}$ value was 0.31023, indicating that the increase between the pretest and posttest scores was quite high or in the upper medium range. This demonstrates that the effectiveness of using an interactive multimedia program based on a website-enhanced course accompanied by formative feedback can improve students' conceptual understanding. The N-gain value data for each test item is shown in Table 10.

Table 10 N-gain of Each Question Item

Question Number	N-Gain	Question Number	N-Gain
1*	0.565	7	0.111
2	0.225	8*	0.488
3	0.094	9*	0.477
4	-0.045	10	0.109
5	0.174	11	0.182
6	0.273		

*Questions that achieve upper medium N-gain

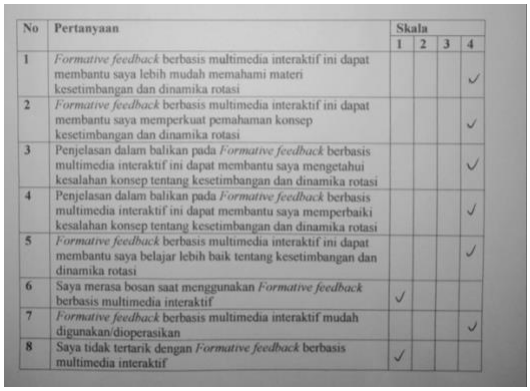
Based on the table, the items with the lowest percentage in the posttest are question number 4. Students' low conceptual understanding was the cause of the low percentage in the posttest. Question number 4 in the conceptual understanding test accesses students' understanding of the concept of rotational kinematics. Students are asked to determine the magnitude and direction of the angular acceleration of the pendulum relative to the plane of the image. They argue that the pendulum is always moving so that over time its acceleration decreases. In addition, because the direction of the swing is opposite, students assume it will cause a large difference in the angular acceleration. Meanwhile, the direction of the angular acceleration follows the direction of the pendulum's motion, which is in the plane of motion.

The practicality test results yielded an average percentage of 91.3%. Overall, this can be interpreted as highly practical. The highest percentage, 94.2%, indicates that the website-based interactive multimedia enhanced course with formative feedback is easy to use/operate. The lowest percentage, 88.3%, indicates that 11.7% still found the website-based interactive multimedia enhanced course with formative feedback boring. The results for each indicator indicate that the website-based interactive multimedia course, accompanied by formative feedback, is feasible and practical for implementation with students. The indicators for each practicality test item assessed and their results can be seen in Table 11.

Table 11. Practicality Test Results

Aspencts Assessed	Percentage
This website-based interactive multimedia enhanced course, accompanied by formative feedback, helped me understand the material on equilibrium and rotational dynamics more easily	88,3 %
This website-based interactive multimedia enhanced course, accompanied by formative feedback, helped me strengthen my understanding of the concepts of equilibrium and rotational dynamics.	92,5 %
The explanations in the feedback in this website-based interactive multimedia enhanced course, accompanied by formative feedback, helped me identify misconceptions about equilibrium and rotational dynamics.	91,7 %
The explanations in the feedback in this website-based interactive multimedia enhanced course, accompanied by formative feedback, helped me correct misconceptions about equilibrium and rotational dynamics.	89,2 %
This website-based interactive multimedia enhanced course, accompanied by formative feedback, helped me learn more about equilibrium and rotational dynamics.	89,2 %
I didn't get bored when using this website-based interactive multimedia enhanced course, accompanied by formative feedback.	88,3 %
This website-based interactive multimedia enhanced course, accompanied by formative feedback, was easy to use/operate.	94,2 %
I was interested in this website-based interactive multimedia enhanced course, accompanied by formative feedback.	93,3 %
The conceptual questions presented in this website-based interactive multimedia enhanced course, accompanied by formative feedback, were presented. It wasn't too difficult for me.	93,3 %
Self-assessment helped me identify where I didn't understand the material.	93,3 %

Based on the data presented, including t-test results, pretest/posttest results, effect sizes, N gain, and student response shifts, it is concluded that the website-based interactive multimedia program, an enhanced course, with formative feedback, has been found to have advantages over previous research. These advantages include (1) helping students improve their understanding of the concepts of rigid body equilibrium and rotational dynamics; (2) being time-unrelated; (3) making it easier for educators to provide evaluation and formative feedback, and measure learning achievement when implemented at the end of the lesson; (4) being student-friendly because it uses laptops or mobile phones; (5) being conducted online; and (6) not limited by a large number of students. The following is evidence from student self-reports of learning effectiveness.



No	Pertanyaan	Skala			
		1	2	3	4
1	*Formative feedback* berbasis multimedia interaktif ini dapat membantu saya lebih mudah memahami materi kesetimbangan dan dinamika rotasi				✓
2	*Formative feedback* berbasis multimedia interaktif ini dapat membantu saya memperkuat pemahaman konsep kesetimbangan dan dinamika rotasi				✓
3	Penjelasan dalam balikan pada *Formative feedback* berbasis multimedia interaktif ini dapat membantu saya mengetahui kesalahan konsep tentang kesetimbangan dan dinamika rotasi				✓
4	Penjelasan dalam balikan pada *Formative feedback* berbasis multimedia interaktif ini dapat membantu saya memperbaiki kesalahan konsep tentang kesetimbangan dan dinamika rotasi				✓
5	*Formative feedback* berbasis multimedia interaktif ini dapat membantu saya belajar lebih baik tentang kesetimbangan dan dinamika rotasi				✓
6	Saya merasa bosan saat menggunakan *Formative feedback* berbasis multimedia interaktif	✓			
7	*Formative feedback* berbasis multimedia interaktif mudah digunakan/dioperasikan				✓
8	Saya tidak tertarik dengan *Formative feedback* berbasis multimedia interaktif	✓			

Figure 2. Student Responses to Effectiveness Media

The interactive multimedia program based on the website, enhanced course, with formative feedback, also has shortcomings. Based on the obstacles in the research, these are: (1) the interactive multimedia product based on the website, enhanced course, with formative feedback, is limited to the given sub-questions; (2) students perform calculations or analysis outside the program and only draw conclusions using the program; (3) students cannot ask questions directly if the formative feedback in the program is unclear because only one problem-solving approach is used.

Considering the advantages and disadvantages of the website-based interactive multimedia program, the enhanced course, with formative feedback, concludes that the program is suitable for application or implementation with students, with several improvements for future research development. Therefore, recommendations for further research that need to be developed are: (1) an enhanced website-based interactive multimedia course accompanied by formative feedback provided using tutorials with a diverse material approach; (2) conducting more experiments to demonstrate the effectiveness of the enhanced website-based interactive multimedia program accompanied by formative feedback; (3) implementing the enhanced website-based interactive multimedia program accompanied by formative feedback integrated into every classroom learning session.

CONCLUSION

The development of web-based interactive multimedia accompanied by formative feedback has successfully improved students' conceptual mastery. This result can be seen in the pre-test and post-test scores. There was a significant difference between the pre-test and post-test scores. The improvement from pre-test to post-test was in the moderate to low category. Furthermore, this improved web-based interactive multimedia, accompanied by the developed formative feedback, effectively facilitated conceptual mastery for all students. Both students with high and low pre-test scores experienced similar improvements. However, this program has several areas for improvement: a more diverse approach to the material; integration into each classroom learning session; and the ability to be used for larger samples.

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