RESEARCH ARTICLE

Video animation in coordination system to improve students' cognitive ability

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Abstract: The biological concept has a broad scope and requires the visualisation of bioprocesses to provide complex understanding. Learning media can help visualise bioprocesses to enhance students' cognitive abilities. The study aimed to develop, test the practicality, and test the effectiveness of video animation in improving grade XI high school students' und erstanding of the coordination system. This study involved 66 high school students in grade XI of the science department at State Senior High School 2 Malang, Indonesia. This research used the Lee & Owens Multimedia-Based Instructional Design method, which consisted of analysis, design, development, implementation, and evaluation stages. In the evaluation stage, we conducted face validity by media experts and content validity by material experts, successively getting results of 97% and 100%. Then, the concurrent validity test was obtained from student assessments of the media interface with a result of 97%, the user-friendly with a result of 100%, and the appropriateness of the material with a result of 95%. In the final stage, construct validity was carried out through an effectiveness test using a quasi-experimental design with a pretest-posttest control group design. Data analysis was performed using the Independent T-test, with the results showing a significance of 0.006 < 0.05, which showed a significant difference in the average post-test between the control and experimental classes. The average score in the experimental class increased from 76.32 to 89.03, but the control class increased from 76.38 to 84.56. The results showed that the video animation media effectively improved students' abilities. Therefore, this learning media can be a recommendation in the learning coordination system.

Keywords: animation; coordination system; cognitive ability

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Introduction

The biological concept has a broad scope, including various branches of science, such as botany, zoology, microbiology, genetics, ecology, and biotechnology (Amrullah et al., 2021). Some biological topics require a deep understanding of the coordination system (Ratan, 2020). The coordination system comprises nerves, sensory, and hormonal systems (Yang et al., 2020). The coordination system explains the signalling pathway and biochemical processes (Scott-Solomon et al., 2021).

Many students encounter difficulties when exploring topics with complex characteristics, especially when understanding the basic concepts and mechanisms of the coordination system (Xu et al., 2019; Fiani et al., 2021). It is also crucial to connect the concept of a coordination system with examples from everyday life (Damopolii et al., 2023). Students' lack of understanding of the biological topic can cause a decrease in their cognitive abilities (Hammer, 2020; Schröter & Bar-Kochva, 2019). A high cognitive ability can be one of the indicators of successful learning (Peng & Kievit, 2020).

Students with difficulty learning tend to have lower cognitive learning outcomes (Rezeki et al, 2023). Students' difficulties in learning can be solved by using learning media (Virijai & Asrizal, 2023). Preliminary study data was collected in October 2023 using observation and interview methods, showing teacher efforts in facilitating learning media through practicum of the five senses and making posters at State Senior High School 2 Malang. However, teachers find it challenging to visualise bioprocesses that occur in the body on nerve impulse transport material. The other difficulty teachers experienced was providing a bridge between text material and their implementations in daily activities.

The difficulty of delivering material to students can be overcome by using visual-based learning media (Sari et al., 2023). Several learning media have also been proven to improve students' cognitive abilities (Bouali et al., 2022; Deaton et al., 2013; Teixeira et al., 2013; Ghofur & Zubaidah, 2023). For example, the research on the media game about the integration of synapses, muscle contractions, and nerves enhanced students' understanding of nervous system signalling (Cardozo et al., 2020). Learning media for a video animation of nerve impulse transmission, uploaded on social media, provides good visualisation for students so that understanding improves (Leksono et al., 2021). One of the learning media that can provide visualisation of daily activities and can be integrated with existing theories in biology is the animation media (Siregar & Harahap, 2022). The animation can illustrate biochemical processes in growing humans which can not be observed directly (Dorfman et al., 2019). Animation media has shown significant success in learning, but few have integrated it into daily activities. The advantages of video animation are that the visuals can be adjusted to the requirements, feature engaging moving visuals, can facilitate biochemical processes in the body that are micro and can present visualisations of daily human activities (Susanto, et al., 2024; Firdaus et al., 2022; Setiawan, et al., 2023). The learning concept based on daily activities can make it easier for students to relate subject matter to real-world situations (Min et al., 2022). Existing research on animated videos in biology focuses on bioprocesses and is not linked to daily activies (Stadlinger, et al 2021). There is a need to create animated videos that present bioprocesses and are integrated with daily activities to make learning more meaningful.

The demand for media and teaching materials is adapted to the needs of users (Persada et al., 2019). In this case, the coordination system learning media users are high school students and the broader community. High school students, an average age of 15-16 years old, who belong to Generation Z, tend to like interactive things (Saadah et al., 2022; Marshall & Wolanskyj-Spinner, 2020). The approach to education in the era of the Industrial Revolution 4.0 emphasised the generation of Gen Z to increase technological knowledge and innovative use of information (Zubaidah, 2018). The advancement of technology has an impact on changing mindsets and ways of learning in Generation Z (Szymkowiak et al., 2021; Loseñara, et al., 2023). Generation Z has habits like self-learning, is open to technology, is creative, has many ideas, and likes visual and interactive learning styles (Mosca et al., 2019). This context-based learning animation video is considered appropriate as one of the learning media that facilitates coordination system material. The purpose of the research was to develop, test the practicality, and test the effectiveness of the animated video in improving the understanding of grade XI high school students on coordination system.

Method

Research Framework

Media development and practicality testing were conducted using the Multimedia-Base Instructional Design method (Lee & Owens 2004), which consisted of analysis, design, development, implementation, and evaluation (Figure 1). The explanation of the research and development procedure of the video animation in the Lee & Owens model is described in Figure 2.

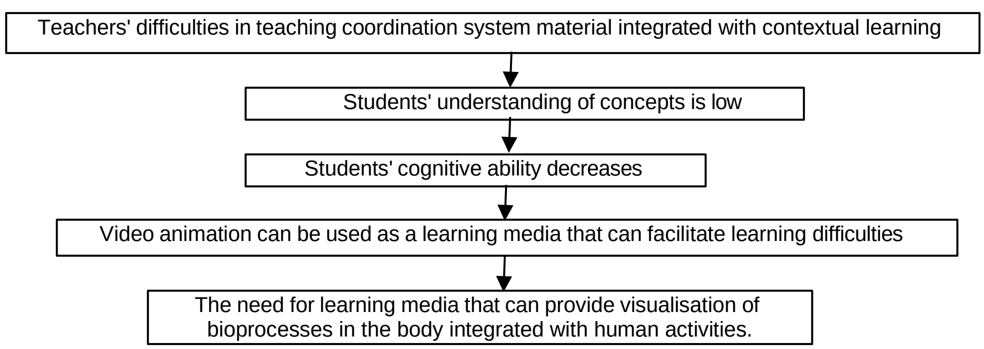

Figure 1. Research Framework

The analysis stage consisted of two stages: the needs analysis and the front-end analysis. The needs analysis was used to ascertain the objectives. The front-end analysis aimed to identify gaps between actual field conditions and anticipated conditions and formulate solutions to overcome these problems. Interviewing teachers and distributing needs analysis questionnaires to students were conducted. The results of the student needs questionnaire showed the student's intention to use interactive and interesting learning media.

The design stage consisted of designing the material, which conceptualised the materials to be made in the video and the design of the storyboard of the video animation. The concept of the material was correlated with daily life based on the learning outcomes of the coordination system material in grade XI. The video storyboard design was created as a preliminary sketch equipped with dialogue to present the visualisation of the coordination system.

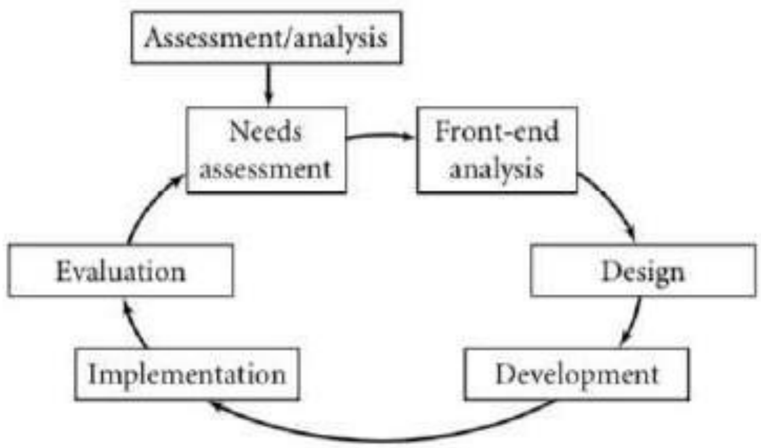

Figure 2. Chart of Research and Development Procedure Model

The development and implementation stage was performed through the preproduction, production, postproduction and quality review stages. Created media assets using Adobe Illustrator and developed video animation products using Adobe Premier and Adobe After Effects software. Quality review consisted of standards review, editorial review, and functional review.

The evaluation stage consisted of reaction, knowledge, performance, and impact. The evaluation was used to see the feasibility of the media. The media was evaluated through face validity by media experts, content validity by material experts, concurrent validity by ten students in each class as a practicality test, and construct validity in the control and experimental classes through a quasi-experimental design with a pretest-posttest control group design. Both groups were given treatment, pretest, and post-test to see the difference in treatment results.

Research Sample

This research has been approved by the school, teachers, and students. The participants in the study were 66 students of grade XI of science major at State Senior High School 2 Malang, Indonesia, who were studying coordination system topics. The learning design is illustrated in Figure 3. Sampling was conducted using a random sampling technique divided into two groups. Each group consisted of 33 students.

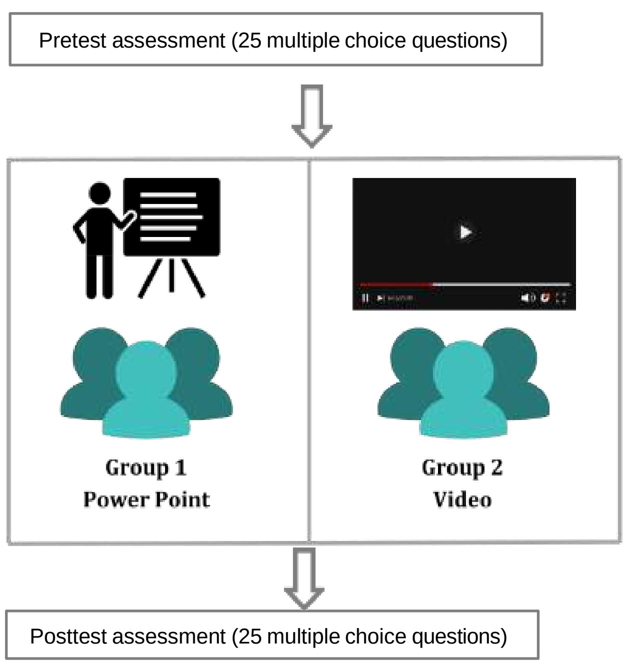

Figure 3. Summary of the research design applied in the two distinct groups.

Group 1 represented the control class that used PowerPoint media. Group 2 represented the experimental class using the animated video. The first assessment stage was a pretest using 25 multiple-choice questions based on Bloom's Taxonomy Level 1 to measure students' memory level and Bloom's Taxonomy Level 2 to measure students' comprehension level. Bloom levels 3 and 4 to measure students' level of analytical understanding.

Research Material

In this study, the researcher created learning resources and media to improve the understanding of the coordination system. These learning resources and media included six episodes of video animations, an assessment of achievement to measure learning outcomes, and a student assessment of the video animations.

a) Video animation
   Video animation was developed based on a coordination system, including nerves, hormones and senses, integrated with contextual learning.
b) Evaluations of academic progress
   The researcher evaluated the achievement of cognitive abilities consisting of 25 pretest and 25 post-test items. The questions were arranged in order of difficulty level C1 to C4 of Bloom's taxonomy.
c) Questionnaire for evaluating video animation acceptance
   Data analysis of students' responses to the use of video animation in biology learning was calculated using the Formula 1. Description: P: Percentage; ∑X: Total score; ∑Xi: Maximum score.

$$P = \frac{\sum X}{\sum Xi} \times 100\% \quad (1)$$

The mean score will be compared with the student response criteria in Table 1. Two experts in the field evaluated all the assessments. The questionnaires were calculated using the percentage formula and scored using a Likert scale. The Pearson correlation coefficient (r) of the questionnaire was between 0.77 and 0.8, which can be acceptable. Open-ended questions were easy to answer once respondents had understood the content. The questionnaire was not changed after the validity and reliability tests. The reliability of the questionnaire was analysed using Cronbach α. The Cronbach α coefficient was 0.84. A Cronbach α value between 0.73 and 0.92 indicated high reliability.

Table 1. Student Response Criteria

Percentage of Student Response	Criteria
80% ≤ Score < 100%	Strongly positive
60% ≤ Score < 80%	Positive
40% ≤ Score < 60%	Moderately positive
20% ≤ Score < 40%	Less positive Score
< 20%	Strongly less positive

Adapted from Arikunto (2014)

Data Analysis

The reliability and validity of the questionnaire were tested using Cronbach α and Pearson Correlation. The validity and reliability of the questionnaire were analysed using IBM SPSS 20 software. The one-way ANOVA (ANOVA, p = 0.05) analysis was conducted to see the equality of the two classes. To see the effectiveness of using animated videos on students' understanding, the one-way ANOVA test was conducted on students' pretest, and an unpaired T-test on students' post-test scores to see the difference in students' post-test means using the Excel software.

Results and Discussion

Animation Video Development

The analysis stage was conducted on teachers and students through interviews and questionnaires regarding students' needs. The results of the interview with the biology teacher of Senior High School 2 Malang, Indonesia, showed that the teacher found it challenging to provide visualisation of the bioprocess of the coordination system in the body. The teacher provides an overview of the bioprocess of the coordination system to students through general videos on social media. The result of the analysis through the student needs questionnaire was that students had difficulty understanding the material of the coordination system because it was difficult to relate to events or daily life. Students tend to memorize the material without knowing where the bioprocess occurs and the consequences of the process.

The design stage produced materials on the coordination system consisting of the human nervous system, nerve impulses, conscious movement, reflex movement, nerve impulse delivery mechanism, endocrine system, and sensory system. The materials that have been selected were made into a sequence of stories that were integrated with everyday stories. The story was made into a series of storyboards. Meanwhile, the design of animated video assets was made using Adobe Illustrator. The 2D asset results were prepared to create a moving animation video using Adobe Effects. Effective design can support the delivery of material in an interactive and interesting manner. An integrated and consistent design also minimizes cognitive load, allowing greater focus on the material being presented, while appropriate visual elements such as character postures and characteristics as well as backgrounds that are relevant to the story, increase reader comfort and engagement.

The development stage consisted of preproduction, production, postproduction and quality review. The preproduction stage began with creating a story script presented in Figure 4, video assets presented in Figure 5, and voice dubbing. The preproduction stage was developed from the storyboard created at the design stage.

Creating a video script based on a story that relates to the material of the coordination system

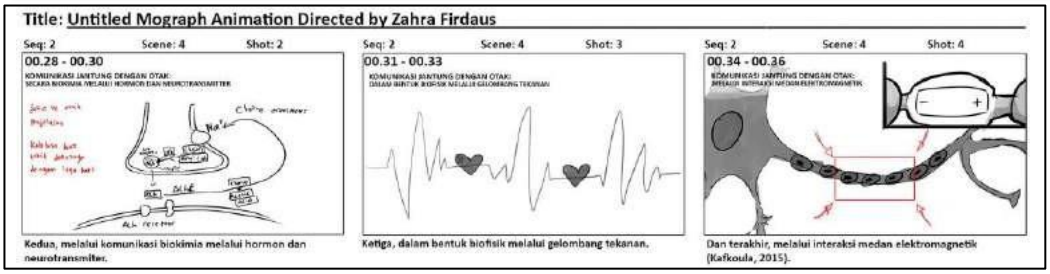

Figure 4. Script Video

Figure 5. Video Asset Creation

The production stage of development resulted in six animated videos being uploaded to the "Innovation Smart Solution" YouTube channel. Creating video assets was a 2D design of each part of the video. Asset design was made using Adobe Illustrator following the appearance of interest to users using cartoon style. The results of the video animation development consist of six episodes, as shown in Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11. Video animation presents biochemical processes in the body and provides an overview of how these biochemical processes can affect human daily activities. The video animation raised several daily activities to be more easily understood and interpreted by students.

Animated videos package daily phenomena in a witty video and with cute character illustrations, strengthening visual engagement and ensuring that users are not only entertained but also gain true and in-depth knowledge of the material presented. Effective animation helps explain difficult or abstract concepts, as well as logically illustrate processes or events, which makes it easier for users to follow and understand the material better (Barut Tugtekin & Dursun, 2022).

Figure 6. Episode 1: “Why do our eyes start to glaze over?”

Episode 1 explores how the eyes glaze over in direct sunlight. This video discusses the nerve impulse transmission of the pupil reflex movement and how it processes in the body to cause the eyes to glaze. The video animation explained the bioprocesses that occur in the body and the response of the body. The video can be accessed on the YouTube link: https://www.youtube.com/watch?v=mFifiMEH6oQ.

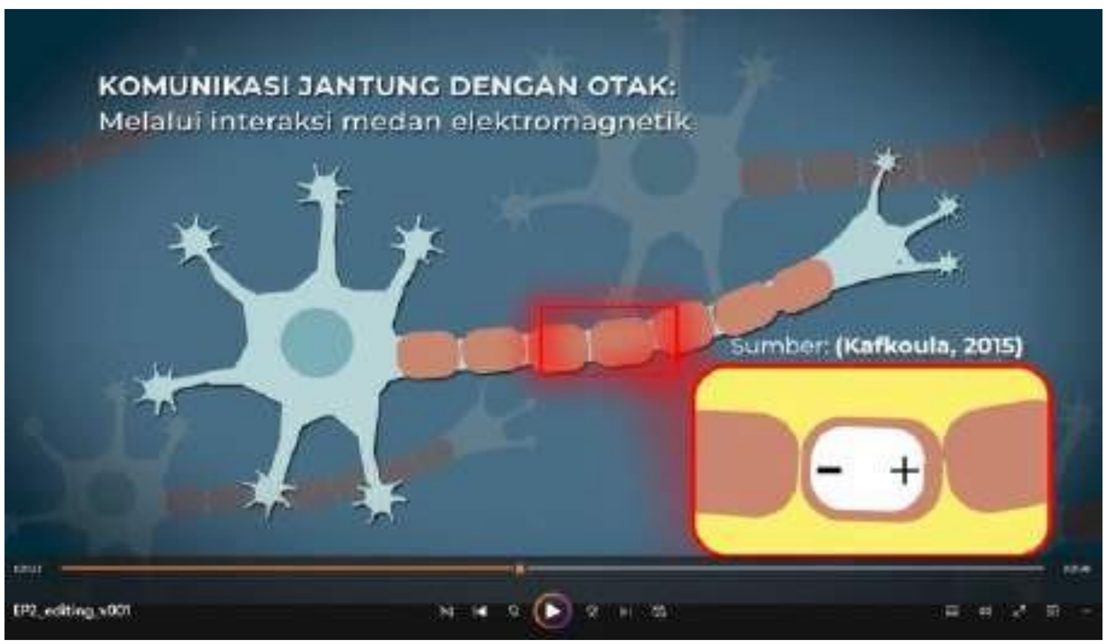

Figure 7. Episode 2: “How does the nervous process occur?”

Episode 2 talked about the process of getting nervous. When we get nervous, our heart beats faster. Some people experience excessive sweat production, and in some circumstances, it can lead to panic attacks. The video explains the bioprocess of getting nervous and its effects. The video can be accessed at www.youtube.com/watch?v=gNdF2CObSOw.

Figure 8. Episode 3 “What is the process of dreaming?”

Episode 3 told how dreaming occurs during sleep and the coordination system’s role in the dreaming process. The video animation showed the phases of dreaming and the hormonal processes that occur during dreaming. The video visualises how the coordination system affects the hormonal balance that influences the existence of dreams and the phases of dreaming. The video can be accessed on the YouTube link: https://youtu.be/-mGRHSH-21Y.

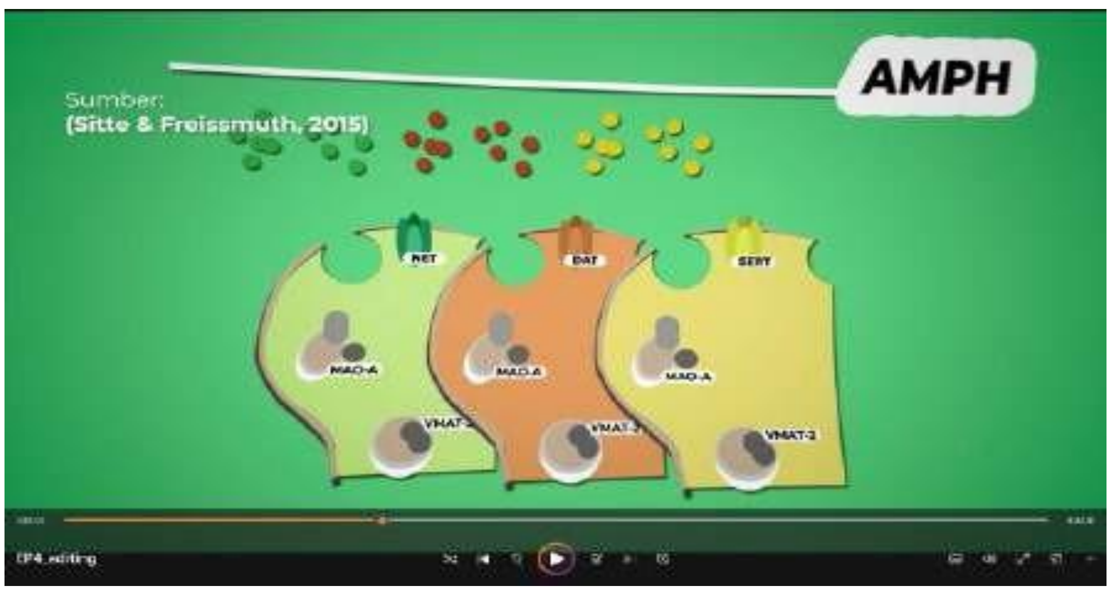

Figure 9. Episode 4 “How drugs work in the body?”

Episode 4 talked about how drugs affect the coordination system in the body. The video explained the biochemical processes that occur in the body when users take drugs and the effects they have on the body. The video visualises the process of drug substances affecting performance in the body and daily activities. The video can be accessed at the YouTube link: https://youtu.be/FRwY6HohyWQ.

Figure 10. Episode 5: “What are the dangers and adverse effects of drug consumption?”

Episode 5 talked about how drugs adversely affect the bioprocesses in the body and cause various disorders in the body. The video animation explained the dangers of drugs to the human body. The video illustrates the risks the drugs pose, from mild to severe. The video can be accessed at https://youtu.be/ODanvrli4O4.

Figure 11. Episode 6 “Stay healthy and drug-free”

Episode 6 talked about managing drug users, healthy living, and avoiding drugs. This video aimed to socialise ways to avoid the dangers of drugs through various examples of positive activities that the student can do. The material delivered in the video was relaxed and persuasive so that students could understand it. The video can be accessed on the YouTube link: https://youtu.be/cwA7WAMXKgw.
The final stage of development was postproduction and quality review. The final results of the video animation media can present material following the concepts in the coordination system, and the animation can play well without bugs, with clear sound, clear graphics, and dubbing with clear articulation. Video animations that have passed this stage will be evaluated and tested. The evaluation stage consisted of level 1: reaction, level 2: knowledge, level 3: performance, and level 4: impact. However, in this study, the evaluation was conducted at level 1 and level 2. In the initial stage, the media was evaluated through face validity by media experts with a result of 97%, with a note

of improvement in the video given subtitles to make it easier for users and content validity by material experts with a result of 100%.

Level 1: reaction was conducted through a concurrent validity test by ten students in the control and experimental classes. Students were requested to provide an assessment of the animated video using a questionnaire sheet distributed after students tried the animated video media. The concurrent validity test experiment selected 10 participants with high, middle, and low cognitive scores. The questionnaire results in the concurrent validity experiment were that the appearance of the media was 90%, the user-friendly was 100%, and the suitability of the material was 90%. There were suggestions for revision in the appearance section, such as adding a title at the beginning of the video and simplifying the visualisation of biochemical processes. The material was good but needed to be aligned with the material in the student handbook. Concurrent validity validation is very important to ensure that the learning media used can be operated practically by students (Garbett, dkk., 2022). This process involves evaluating and testing learning media to ensure that all aspects, from appearance, ease of use, to understanding the material, meet high practical standards (Darmayanti, et al., 2022). The very valid validation results indicate that the media is not only effective but also efficient and easily accessible to students with various levels of cognitive abilities. The detailed concurrent validity test results are presented in Figure 12.

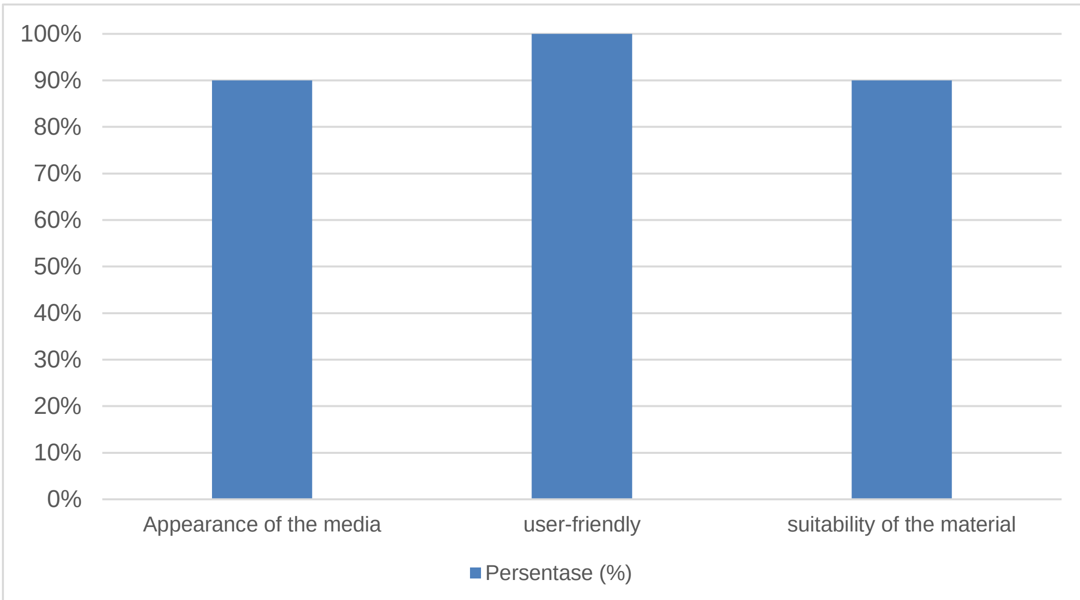

Figure 12**.** Results of the Concurrent Validity Test

Level 2: knowledge was performed through a construct validity test as a media effectiveness test with a quasi-experimental design using control and experimental classes. The data collected were pretest-posttest and student response questionnaires. The results of the student response questionnaire to the media appearance showed that 97% of students were interested in the animation display because it was interesting and easier to understand. User-friendly was 100%. The video has been uploaded to the YouTube channel “Inovasiin Smart Solution,” making it easier for users to access. The suitability of the material results in 95%; the materials have been adjusted to the learning outcomes of high school grade XI students. Based on the results of the implementation and student response questionnaire, the media can consider that the response meets the very positive category so that it can be used in learning. Animated videos are a learning media that is rich in visualization and interactivity, helping students understand scientific concepts more deeply through simulations and interesting stories. Animated representations in videos must be clear and easy to understand, including depictions of phenomena, storylines and stories that are relevant to the target audience (Pandaleke, dkk., 2020). Student feedback collected through the questionnaire sheet on the animated video is summarised in Figure 13.

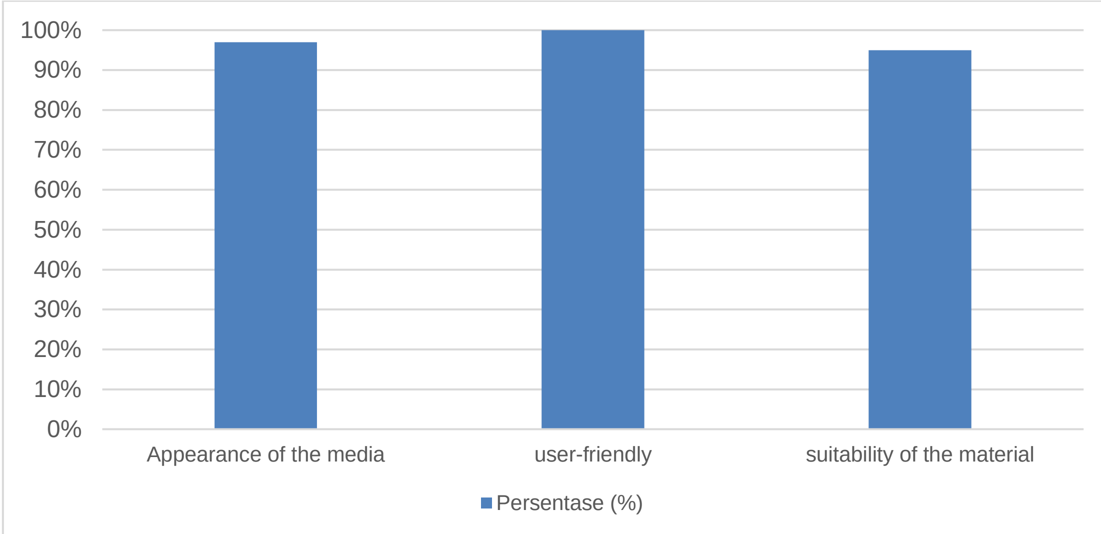

Figure 13. Student response results

The one-way ANOVA test was tested before implementation to determine the difference in pretest means between the two groups. Implementation was conducted using the quasi-experiment research with a pretest-posttest control group design. This was used to see the starting point of whether the pretest results of the two classes had the same average. Before the one-way ANOVA test, normality and homogeneity tests were performed as prerequisite tests. The results of the normality test of the pretest of both groups are presented in Table 2. The normality test results have a significance level of 0.526 > 0.05 in pretest data and 0.407 > 0.05 in post-test data, which means the data is normally distributed. The detailed homogeneity test results are in Table 3. The homogeneity test results obtained a significance value of 0.591 > 0.05. Thus, it can be concluded that the data is homogenous. The data is declared normal and homogeneous so that the one-way ANOVA test can be proceeded.

Table 2. Normality Test of Pretest Data of Control and Experimental Classes

Class		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest	Control	0.104	32	0.200*	0.971	32	0.526
	Experiment	0.119	31	0.200*	0.966	31	0.407

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

Table 3. Homogeneity Test of Pretest

Levene Statistic	df1	df2	Sig.
0.292	1	61	0.591

The one-way ANOVA test was conducted on the pretest scores. The results of the significance value obtained a value of 0.979 > 0.05, so it can be concluded that the pretest averages of the two classes were not significantly different or the same. The one-way ANOVA test data is presented in Table 4. It can be concluded that the starting point, the pretest value, was not different between the control and experimental classes, so the difference in post-test averages can be used as a benchmark for the difference in value significance.

Table 4. One-way ANOVA test of Pretest

	Some of	df	Mean Square	F	Sig.
Between Groups	0.043	1	0.043	0.001	0.979
Within Groups	3956.274	61	64.857		
Total	3956.317	62			

The significance value of the post-test between the control and experimental groups was determined using an independent T-test. Before the independent T-test, the data should be tested for normality and homogeneity as a prerequisite test. The results of the post-test data normality test obtained a significance value of 0.105 > 0.05 and 0.275 > 0.05, so it can be concluded that the data was normally distributed. The results of the post-test data normality test are in Table 5. The results of the post-test data homogeneity test obtained a significance value of 0.591 > 0.05, so it can be concluded that the data was homogeneous. The post-test data was normally distributed and homogeneous, so the independent T-test could have proceeded.

Table 5. Normality Test of Post-test Score of Control and Experimental Classes

	Kelas	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Post-test	Control	0.173	32	0.016	0.945	32	0.105
	Experiment	0.136	31	0.146	0.959	31	0.275

The effectiveness of using video animation in improving students' cognitive abilities was tested using the Independent T-test. Data was taken using quasi-experiment research with pretest-posttest control group design. The Independent T-test results obtained a significance of 0.006 < 0.05, so it can be concluded that there was a significant difference in the average post-test between the two classes. Video animation media was effective in improving students' cognitive abilities. The detailed independent T-test results are presented in Table 6.

Table 6. Independent T-test results

		Levene's Test for Equality of Variance		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal variances assumed	3.120	0.082	-2.822	61	0.006	-4.469	1.58	-7.63	-1.30
	Equal variances not assumed			-2.836	56.826	0.006	-4.469	1.57	-7.62	-1.31

The use of learning videos in learning coordination system material has a significant effect, as seen from the difference in pretest and post-test scores of the control class and experimental class. The control class had an average increase from 76.38 to 84.56, with a difference of 8.19 points. The experimental class had an average increase from 76.32 to 89.03, with a difference of 12.71. The significance of this value can be interpreted as an increase in cognitive abilities in learning in the experimental class.

Effectiveness of using animated videos to improve students' cognitive ability

The enhancement of cognitive ability is caused by the main determining factor, which is the effectiveness of the learning media (Syakur et al., 2020). Video animation learning media can simultaneously deliver knowledge through combined visual and audio elements (Knapp et al., 2022). Audio-visual delivery can facilitate students' understanding of abstract concepts (Kadarisman et al., 2023). Video animation can capture students' attention and increase their learning drive (Rissanen & Costello, 2023). Video animation can also optimally facilitate audio and visual students' learning styles (Zardecki et al., 2022). Video animation can allow students to acquire knowledge that suits their individual learning preferences (Dorfman et al., 2019). Research findings showed that incorporating animated learning videos into teaching coordination system materials greatly improved students' cognitive abilities (Bloch et al., 2015; Deaton et al., 2013).

The coordination system is composed of the process of cooperation of various organs and tissues, which is a crucial factor in understanding the various functions of systems in the body (Hadiprayitno et al., 2019). Many students find it challenging to understand the content and concepts of the coordination system (Susanto et al., 2022). This challenge is aggravated by some abstract ideas, such as how nerves and hormones work, which are complex and difficult to visualise (Damopolii et al., 2023). The dynamism of the coordination system in response to changes in the internal and external environment adds to the complexity of understanding (Hadiprayitno et al., 2019).

Video animation overcomes difficulties in the coordination system in the context of learning (Lepito, 2018). Video animation provides the ability to convey information visually, facilitating students' understanding of abstract ideas in the coordination system (Sumida & Jefcoat, 2018). The nature of video animation enhanced its ability to provide information dynamically, thus facilitating a more comprehensive understanding of the process of coordination system function. The interactive aspect of video animation can increase students' enthusiasm for learning and actively engage them in the learning process (Rissanen & Costello, 2023).

Using video animation to study the coordination system has many benefits, such as improving students' understanding of abstract ideas and operational principles (Muhamedyev et al., 2014; Anwar, et al., 2023). Video animation also increases students' motivation and cultivates their active participation in the learning process (Raman et al., 2015). Interactive learning that involves students will improve students' understanding (Pangestuti et al., 2015).

Using video animation in teaching the coordination system significantly improved learning outcomes, as students using this media showed superior learning outcomes. However, data collection in the research was undoubtedly problematic as it was conducted during the last class hour and daytime learning. It was difficult for students to focus because it was near dismissal time. Therefore, the teacher needs to act in activating students' enthusiasm in the classroom. In addition, the material in the video animation is limited to the coordination system of grade XI, so it is expected to make video animations on different topics.

Conclusion

Research and development of video animation on coordination systems showed valid, practical, and effective. The product can be accessible on the YouTube channel "Inovasiin Smart Solution". The results of media development obtained a media validation score of 97% and material validation of 100%. Learning media has been tested practical and effective in enhancing students' cognitive abilities through various advantages of video animation media, so it can become one of the recommendations for learning media in teaching coordination systems. The suggestion for further research should be to implement with more prepared students to minimise external factors affecting the results. In addition, the application of video animation should be studied in various topics at higher education levels to make the effectiveness results more accurate.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

Z. Firdaus: writing original draft preparation, methodology, analysis; **S. Zubaidah:** responsible, review and editing; **M. Munzil:** review.

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