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The Influence of Interactive Multimedia Teaching Materials on Cognitive Learning Outcomes of Students in Science Lessons: A Meta-Analysis

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Abstract: Interactive multimedia teaching materials are teaching materials that combine two or more interactive media (audio, text, graphics, images, and video). Interactive multimedia is one of the teaching materials that can be used to support the learning process. The purpose of this study was to see how interactive multimedia influences students' mastery of concepts and cognitive learning outcomes in science learning. This type of research is meta-analysis research. The example used is 25 journals that meet the criteria. The data analysis technique is calculating the effect size of each journal, testing heterogeneity and testing hypotheses. Based on the results of data analysis in this study it can be concluded that in general interactive multimedia influences student learning outcomes. Specifically grouped into several moderator variables, it can be concluded that, first, interactive multimedia influences student learning outcomes, especially in physics and chemistry lessons. Second, interactive multimedia has an influence on the learning outcomes of class X and class XI students. Third, interactive multimedia has an influence on student learning outcomes when combined with cooperative learning models and inquiry learning.

Keywords: Teaching materials, Interactive multimedia, Cognitive learning outcomes

Introduction

Science and technology are continuously developing and have caused many changes in all areas of life, including developments in the world of education (Widiasanti et al., 2023; Yulia et al., 2023). The development of science and technology causes the learning process as a system consisting of several parts, namely objectives, content or material, methods, media and evaluation must be carried out systematically so that it is useful and effective. The quality of education will increase if the learning process carried out both inside and outside the classroom is effective and useful, as can be seen from the expected abilities, knowledge, attitudes and skills. Because in essence the learning process is the core of the entire educational process (Gustini et al., 2023).

21st century student learning is different from previous centuries (Subagja et al., 2023). In the 21st century students must be able to master and be skilled in combining knowledge, attitudes, skills, and mastery of technology (Husniyah & Ramli, 2023). Not only students, but as an educator must also be able to explore new ideas or innovate and increase their creativity in designing information technology-based teaching materials in the learning process so that the ability to increase material understanding, insight and potential that exists in students. Information technology-based teaching materials are very important so that in delivering material in accordance with the needs and backgrounds of students, information and communication technology-based teaching materials should be prepared from various learning sources that refer to digital (Sri Wulandari et al., 2022). Because

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basically teaching materials are one of the components that must exist because teaching materials are something that will be studied, scrutinized, studied, and used as material that will be mastered by students (Ramdoniati et al., 2018).

However, the reality on the ground shows that the use of printed teaching materials dominates learning compared to non-printed teaching materials (Festiyed et al., 2019). The use of printed teaching materials in learning is less able to develop critical thinking skills and students' understanding of abstract physics concepts. In line with this based on the results of observations (Alfiyah & Wahyuni, 2021; Fauzana et al., 2019). shows that the teaching materials used are only in the form of textbooks which only contain material summaries and sample questions, so that students have difficulty connecting learning concepts and learning becomes meaningless.

For this reason, teaching materials need interesting features such as animations, learning videos, and books that can be flipped automatically like real books (Fitriati et al., 2023), namely in the form of interactive multimedia teaching materials. Furthermore (Davince Gulo et al., 2021) also revealed that one of the teaching materials that can be used to increase activity, response and learning of student learning outcomes is interactive multimedia-based teaching materials. So that even though the concepts in learning are abstract, animations and simulations of various phenomena and cases that are close to students' daily lives can make them concrete for students to understand. In addition, video learning materials on interactive multimedia can explain physics concepts that are poorly understood by students, enabling students to study independently (Djamas et al., 2018). Interactive multimedia teaching materials can provide feedback to students so that they can be actively involved in learning activities (Festiyed et al., 2019).

Interactive multimedia is one of the most discussed topics by researchers. This is because interactive multimedia has a great opportunity to be used in learning activities in class, apart from student interest there are also many benefits that students will get in understanding learning material (Utami et al., 2023). Responding to these opportunities, science learning must take a role in developing digital-based learning by utilizing learning multimedia (Natsir et al., 2022). This statement is supported by the opinion (Sukariasih et al., 2019) which reveals that one of the lessons that requires the use of multimedia is learning natural sciences, because science is a science that develops from natural phenomena and the interactions that occur in them. Science is not only about a collection of knowledge in the form of facts, concepts or principles but also a process of discovery. Furthermore, in his research (Yulianci et al., 2021) states that learning outcomes are important things that always want to be improved in the learning process, one of which is by using interactive multimedia. The results of the study (Khoiriah et al., 2016) also show that multimedia teaching materials have a very significant effect on students' cognitive.

There have been many previous researchers who researched related to interactive multimedia teaching materials. However, the limitations of previous research are first, the researcher only conducted research on one variable. Second, researchers only conduct research for one level of education. The three researchers only conducted research for one grade level. Fourth, researchers only conduct research for some physics materials. So that from these limitations there is a need for a meta-analysis study to see the strength of the influence of multimedia teaching materials on each research variable.

Method

This study uses a meta-analysis method. The meta-analysis method is research that is carried out by summarizing, reviewing and analyzing data from several studies with the same problem (Pancaningrum, 2021). The data used is secondary data, where secondary data is data obtained from the results of previous studies without having to conduct research in the field. Data collection in this study was carried out by searching for a number of articles through Google Scholar, with the keywords "interactive multimedia teaching materials" and "cognitive learning outcomes". The results of the article search found 25 articles that match the predetermined criteria.

There is one dependent variable used in this study, namely cognitive learning outcomes. While the moderator variable is based on class, lesson and learning model. The steps taken in this study were (1) choosing the topics to be studied, (2) collecting article data that matched the criteria for the selected topics, (3) determining the effect size of each article and using the random effect model and the fixed effect model. to determine the overall effect size. (4) grouping articles according to predetermined moderator variables, (6) calculating the heterogeneity and homogeneity of each moderator variable, (7) drawing conclusions from the results of data processing.

Result and Discussion

The purpose of this research is to see the effect interactive multimedia teaching materials on students' cognitive learning outcomes by reviewing and analyzing several moderator variable. Data obtained from articles relevant to this study and effect sizes each article can be counted. A total of 25 articles were selected because of them meet certain criteria, namely interactive research multimedia teaching materials implemented in science learning. Effect size calculation results of the 25 articles are then grouped into three parts, namely based on lessons, based on class, and based on the learning model. Code each article can be seen in table 1.

Table 1. General Distribution of Articles

Article Code	Class Level	Learning Model	Lesson	ES	Average ES	Category
A1	XII	-	physics	2.19		
A2	XII	-	physics	0.66		
A3	X	-	physics	0.82		
A4	X	Cooperative	physics	4.84		
A5	XI	Instructional games	physics	0.42		
A6	X	-	physics	0.71		
A7	XI	PBL	chemical	1.85		
A8	X	-	physics	2.8		
A9	X	-	physics	4.1		
A10	XII	-	Biology	0.007		
A11	X	Problem Based Learning	chemical	2.40		
A12	X	Inquiry	physics	1.38		
A13	XI	NHT	chemical	1.25	1.22	Very high
A14	X	-	physics	0.09		
A15	XI	-	physics	-0.41		
A16	XI	-	physics	-0.02		
Al17	XI	Problem Solving	chemical	0.055		
A18	X	Collaborative Creativity	physics	0.001		
A19	XI	Discovery Learning	Biology	0.035		
A20	X	Inquiry	physics	1.62		
A21	X	Inquiry	physics	1.06		
A22	XI	Cooperative	Physics	1.88		
A23	XI	Inquiry	Biology	2.23		
A24	X	Inquiry	physics	0.32		
A25	X	experiential learning model	physics	1.05		

From table 1 it can be seen the effect size of each article about the effect of interactive multimedia teaching materials on students' cognitive learning outcomes. The table contains the journal code, class level, learning model, and the effect size category for each article. Related articles are coded A.

Based on table 1, it can be seen that multimedia teaching materials have a very high effect size on cognitive learning outcomes, namely 1.22. That is, there is a very high difference in learning outcomes between the control class and the experimental class. This happened because in the learning process the experimental class used interactive multimedia teaching materials. This is in accordance with the statement (Anggraeni et al., 2019; Anike Putri & Ardi, 2021; Musdalifa et al., 2021) which states that interactive multimedia can improve student learning outcomes because it helps students to be able to learn independently and makes learning more interesting.

Heterogeneity Testing in General

Based on the results of the heterogeneity test obtained in table 2, learning outcomes and understanding of the concept show Q > df, so the assumption of variance between articles is quite large and heterogeneous. The model that is the random effects model. The heterogeneity value of the article data is 95.127%, thus indicating that there is a population difference between articles of 95.127%.

Table 2. Heterogeneity Testing in General

No	Article Code	Effect Size Yi	Variance Vyi	Weight Wi	Wi^2	WiYi	Wi.Yi^2
1	A1	2.163	4.680	13.58505	184.554	29.3899	63.5822
2	A2	0.649	0.421	10.98414	120.651	7.13069	4.6291
3	A3	0.809	0.655	13.56312	183.958	10.9773	8.8845
4	A4	4.764	22.695	9.881835	97.6507	47.0769	224.273
5	A5	0.948	0.899	14.34158	205.681	13.6007	12.8981
6	A6	0.699	0.488	11.39875	129.931	7.96599	5.56702
7	A7	1.826	3.334	12.90438	166.523	23.5631	43.0255
8	A8	2.682	7.191	4.225316	17.8533	11.331	30.3862
9	A9	4.053	16.429	13.64434	186.168	55.3037	224.159
10	A10	0.007	0.000	15.93145	253.811	0.11017	0.00076
11	A11	2.375	5.639	15.36852	236.191	36.4935	86.6558
12	A12	1.365	1.864	15.78035	249.019	21.5427	29.4093
13	A13	1.235	1.525	14.12415	199.492	17.4408	21.5362
14	A14	0.089	0.008	14.55264	211.779	1.29273	0.11483
15	A15	-0.403	0.162	10.50408	110.336	-4.2311	1.70432
16	A16	-0.020	0.000	17.29199	299.013	-0.342	0.00676
17	A17	0.054	0.003	17.58214	309.132	0.95662	0.05205
18	A18	0.001	0.000	17.2469	297.455	0.01705	1.7E-05
19	A19	0.035	0.001	17.68401	312.724	0.61229	0.0212
20	A20	1.603	2.568	15.61347	243.781	25.0219	40.0995
21	A21	1.044	1.091	11.8232	139.788	12.3474	12.8948
22	A22	1.846	3.409	9.476042	89.7954	17.4949	32.2996
23	A23	2.205	4.863	14.81932	219.612	32.6813	72.0724
24	A24	0.316	0.100	15.95574	254.586	5.0476	1.59681
25	A25	1.035	1.072	12.49789	156.197	12.9397	13.3971
Amount				340.7804	4875.68	385.765	929.266
Q							492.579117
C							326.4730019
df							24
T^2							1.435276774
I^2							95.12768626

Homogeneity Test in General

Table 3. Homogeneity Test in General

Article Code	ES Average	SEM	LLM	ULM	P
A1					
A2					
A3					
A4					
A5					
A6					
A7					
A8					
A9					
A10					
A11	1.22	0.246	0.763	1.728	0.000
A12					
A13					
A14					
A15					
A16					
Al17					
A18					
A19					
A20					
A21					
A22					
A23					
A24					
A25					

Based on the results of the calculations listed in table 1, the total of 25 articles shows that the P value<α, which means H_0 is rejected. So it can be concluded that there is an influence of interactive multimedia on student learning outcomes. This statement is in accordance with research conducted by Andinny & Lestari, (2016) which states that the use of multimedia in the learning process is better than those who do not use multimedia because learning with multimedia can be more enjoyable.

The first moderator variable is seen based on the lesson. The effect size summary value of the effect of interactive multimedia teaching materials on students' cognitive learning outcomes is based on being obtained through the initial stage, namely the heterogeneity test in each lesson. This heterogeneity test can be seen in table 4.

Heterogeneity Testing Based on the Lesson

Based on the heterogeneity test results obtained in table 4, the learning outcomes of physics, chemistry, and biology show Q > df, so the assumption of variance between articles is quite large and heterogeneous. The model that is suitable for use in the 2 studies is the random effect model. heterogeneity of the articles in each subjects, namely in physics lessons the heterogeneity value was 95.787%, chemistry lessons with a heterogeneity value of 95.923%, and biology lessons the heterogeneity value was 92.952%. This heterogeneity value shows that there are population differences between articles at each class level.

Table 4. Heterogeneity Testing Based on The Lesson

Lesson	Code	Q	df	I^2
Physics	A1	379.794	16	95.787
	A3			
	A4			
	A5			
	A6			
	A8			
	A9			
	A12			
	A14			
	A15			
	A16			
	A18			
	A20			
	A21			
	A22			
	A24			
	A25			
Chemical	A1	49.057	2	95.923
	A7			
	A11			
	A13			
	A17			
Biology	A10	56.754	4	92.952
	A19			
	A23			

Homogeneity Testing Based on the Lesson

Based on table 5 we can see that in physics and chemistry lessons the value of P > α, namely 0.0001 for physics and 0.0003 for chemistry. This shows that H0 is rejected, meaning that there is an effect of interactive multimedia on students' physics and chemistry learning outcomes. But in chemistry lessons, the value of P > α, which means H_0 is accepted. This shows that there is no effect of interactive multimedia on students' chemistry learning outcomes. So it can be concluded that this interactive multimedia will be more effective if used in physics and chemistry lessons. This is because the illustrations and visualizations in interactive multimedia can encourage motivation to continue learning, because multimedia in physics learning is used to simplify students' abstractions (imaginations) (Yanti et al., 2017).

Further research results (Dwiningsih et al., 2022; Saselah et al., 2017) which implies that multimedia-assisted chemistry teaching is highly recommended because learning using multimedia can make lessons more interesting and not boring. Apart from creating a pleasant learning atmosphere, the use of multimedia can involve students actively so that interest in learning and student achievement also increases as well (Primamukti & Farozin, 2018).

Interactive multimedia is a type of non-printed teaching materials (Indriyani & Mufit, 2023). The results of the study prove that interactive multimedia is quite capable of providing learning experiences that are appropriate to the level of students' cognitive development (Manurung & Panggabean, 2020). The characteristic of interactive multimedia is that students can learn independently to achieve the expected competencies through various activities in multimedia. That is, multimedia can convey messages and stimulate students' thoughts, feelings, attention and interests which can help the learning process (Liliana et al., 2020).

Table 5. Homogeneity Testing Based on The Lesson

Lesson	Code	Es	SE_M	LL_M	UL_M	P
Physics	A1	0.66	0.326	0.614	1.892	0.0001
	A3	0.82				
	A4	4.84				
	A5	0.42				
	A6	0.71				
	A8	2.8				
	A9	4.1				
	A12	1.38				
	A14	0.09				
	A15	-0.41				
	A16	-0.02				
	A18	0.001				
	A20	1.62				
	A21	1.06				
	A22	1.88				
	A24	0.32				
	A25	1.05				
Chemical	A1	0.007	0.439	0.664	2.388	0.0003
	A7	0.035				
	A11	2.23				
	A13	2.19				
	A17	1.85				
Biology	A10	2.40	0.712	-0.65	2.143	0.1491
	A19	1.25				
	A23	0.055				

Heterogeneity Testing Based on Class

Based on the heterogeneity test results obtained in table 6, class X, XI, and XII showed Q > df, so the assumption of variance between articles was quite large and heterogeneous. The model that is suitable for use in the 2 studies is the random effect model. Heterogeneity of the articles in each class level, namely in class X the heterogeneity value is 96.259%, class XI is 92.244%, and in class XII is 94.299%. This heterogeneity value shows that there are population differences between articles at each class level.

Table 6. Heterogeneity Testing Based on Class

Class	Code	Q	df	I^2
X	A3	320.778	12	96.259
	A4			
	A6			
	A8			
	A9			
	A11			
	A12			
	A14			
	A18			
	A20			
	A21			
	A24			
	A25			
XI	A5	103.148	8	92.244
	A7			
	A13			
	A15			
	A16			
	A17			
	A19			
	A22			
	A23			
XII	A1	35.081	2	94.299
	A2			
	A10			

Homogeneity Testing Based on Class

Based on table 7, it can be seen that in class X and class XI the value of P > α indicates that H_0 is rejected, meaning that there is an influence of interactive multimedia on the learning outcomes of class X and class XI. But in class XII the value of P > α which means H_0 is accepted. So it can be concluded that interactive multimedia is better used for students of class X and class XI only.

In class XII there was no effect because it could be that during the research students were still experiencing difficulties in doing the assignments given, and students were still shy in communicating and expressing opinions so that learning activities were passive. Therefore, to optimize students' cognitive learning outcomes, teachers must present more concepts in the form of story questions, provide contextually related practice questions that require higher-order thinking skills (Malik et al., 2022). For teachers and future researchers, it is better to consider how learning resources in the form of interactive multimedia affect students' abilities. Such as students' mathematical communication skills based on initial mathematical abilities in addition to providing information for teachers and researchers (Angraini & Hardi, 2023).

Actually the use of interactive multimedia in learning can produce an effective communication process between teachers and students while learning, because interactive multimedia is one of the learning media with the ability to display material in audiovisual form and allows interaction to occur between students and the media use (Roemintoyo et al., 2020). Multimedia is media consisting of pictures, tests, animation, sound and video that combines visual and audio aspects so that it can be understood more easily by students with different learning styles (Hadi et al., 2022).

Table 7. Homogeneity Testing Based on Class

Lesson	Code	Es	SE_M	LL_M	UL_M	P
X	A3	0.83	0.396	0.815	2.369	0.000
	A4	4.84				
	A6	0.71				
	A8	2.8				
	A9	4.1				
	A11	2.40				
	A12	1.38				
	A14	0.09				
	A18	0.001				
	A20	1.62				
	A21	1.06				
	A24	0.32				
	A25	1.05				
XI	A5	0.42	0.317	0.231	1.476	0.003
	A7	1.85				
	A13	1.25				
	A15	-0.41				
	A16	-0.02				
	A17	0.055				
	A19	0.035				
	A22	1.88				
	A23	2.23				
XII	A1	2.19	0.661	-0.358	2.236	0.07
	A2	0.66				
	A10	0.007				

Heterogeneity Testing Based on Learning Models

Based on the results obtained in table 8 it is known that only 2 learning models can be tested for heterogeneity, because only 2 learning models have different populations, namely the inquiry learning model and the cooperative learning model. While other learning models cannot be tested for heterogeneity because the population is the same.

Based on the table, the inquiry learning model shows a value of Q > df, so that the estimation of variance is quite large and the data is heterogeneous.

The model that is suitable for calculating the summary effect size of the inquiry learning model is the random effect model. Meanwhile, other learning models use the fixed effect model.

Table 8. Heterogeneity Testing Based on Learning Models

Learning Model	Code	**Q**	df	I^2
Cooperative Type TGT	A4	29.850	4	86.599
	A22			
Inquiry	A12			
	A20			
	A21	41.181	1	97.571
	A23			
	A24			
Experiential Learning Model	A25	-	-	-
Discovery Learning	A19	-	-	-
Collaborative Creativity	A18	-	-	-
NHT	A13	-	-	-
Problem Based Learning Model	A11	-	-	-
PBL	A7	-	-	-
Instructional Game	A5	-	-	-
Problem Solving	A17	-	-	-

Homogeneity Testing Based on Learning Models

Based on table 9, it can be seen that homogeneity only occurs in cooperative learning models and inquiry learning models. Both of these learning models both have a P value < α which indicates that H_0 is rejected, meaning that there is an effect of the use of interactive multimedia with cooperative learning models and inquiry learning models on student learning outcomes. However, when viewed from the average effect size, the cooperative learning model has a greater value than the inquiry model, which is 3.36. This shows that interactive multimedia is more suitable to be combined with cooperative learning models, so that it will be more effective in improving student learning outcomes.

The reason is because the cooperative model groups students in small groups to work together in understanding lessons that do not only come to mastery of the material, but students must be able to think at a higher level during and after discussions and most importantly students are required to be able to explain the material presented, learned from other students (Jumarni et al., 2013). Studying with classmates in groups benefits students because it can lead to quality student outcomes. Students who learn through collaboration build strong concepts and ideas in group discussions and interactions with peers or instructors. Therefore, more resources can be obtained by students and they can access information through collaborative learning and engagement, which ultimately improves their learning outcomes (Qureshi et al., 2023).

Table 9. Homogeneity Testing Based on Learning Models

Learning Model	Code	ES	Average ES	SE_M	LL_M	UL_M	P
Cooperative	A4	4.84	3.36	1.458	0.446	6.165	0.011
	A22	1.88					
Inquiry	A12	1.38	1.32	0.318	0.683	1.930	0.000
	A20	1.62					
	A21	1.06					
	A23	2.23					
	A24	0.32					
Experiential Learning Model	A25	1.05	-	-	-	-	-
Discovery Learning	A19	0.035	-	-	-	-	-
Collaborative Creativity	A18	0.001	-	-	-	-	-
NHT	A13	125	-	-	-	-	-
Problem Based Learning Model	A11	2.40	-	-	-	-	-
PBL	A7	1.85	-	-	-	-	-
Instructional Games	A5	0.42	-	-	-	-	-
Problem Solving	A17	0.055	-	-	-	-	

Conclusion

Based on the results of data analysis in this study it can be concluded that in general interactive multimedia influences student learning outcomes. Specifically grouped into several moderator variables, it can be concluded that first, interactive multimedia influences student learning outcomes, especially in physics and chemistry lessons. Second, interactive multimedia has an influence on the learning outcomes of class X and class XI students. third, interactive multimedia has an influence on student learning outcomes when combined with cooperative learning models and inquiry learning models.

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The author declares there is no conflict of interest in writing this article.

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