Faculty of Natural and Applied Sciences Journal of Mathematics and Science Education
Print ISSN: 2814-0885 e-ISSN: 2814-0931
www.fnasjournals.com
Volume 6; Issue 2; March 2025; Page No. 49-56.

Effect of Mayer's Modality Principle of Multimedia Design on Secondary School Students' Performance in Biology in Rivers State

Agbarakwe, H.A., & Ossai-Chidi, A.G.
Department of Curriculum Studies and Educational Technology, University of Port Harcourt, Nigeria

*Corresponding author email: haret.agbarakwe@uniport.edu.ng

Abstract
This study examined the effect of Mayer's modality principle of multimedia design on secondary school students' performance in Biology in Rivers State, Nigeria. The Modality principle suggests that students learn better when information is presented in both visual and auditory formats, rather than relying solely on text-based information. Three objectives and three research questions guided the study. A pre-test, post-test quasi-experimental design was adopted for the study. A sample size of 100 secondary school students participated in the study, divided into an experimental group (52 students) that received multimedia instruction based on the Modality principle, and a control group (48 students) that received traditional text-based instruction. Mean and standard deviation were used to answer research questions, while ANCOVA was used to test the hypothesis at a significance level of 0.5. The findings show that students who learned with multimedia designs aligned with the Modality principle had a higher mean performance score compared to those taught with the text-based principle. The study concludes that applying Mayer's Modality principle in multimedia design can enhance students' academic performance in secondary school, Rivers State. It was recommended amongst others that teachers should receive training on Mayer's Modality principle to effectively design lessons that reduce cognitive overload and improve engagement.

Keywords: Modality Principle, Multimedia Design, Learning Outcomes

Introduction

Mayer's Cognitive Theory of Multimedia Learning (CTML) is based on the idea that when information is provided in both visual and aural modalities, rather than just text, learners understand and retain it better. According to Mayer (2014), multimedia learning is more effective because it engages the dual-channel cognitive system, utilising both the auditory and visual channels, hence increasing information processing capacity. The hypothesis is consistent with cognitive load theory, which states that there is a limit to how much information an individual can process at any given time in working memory. Multimedia learning improves learning efficiency by balancing cognitive load across both visual and aural channels (Sweller, 2019). One of the basic ideas of CTML is the Modality principle, which states that learners benefit from obtaining information in both aural and visual modes rather than depending solely on text (Mayer, 2014). This theory is based on the assumption that the human brain has distinct channels for processing auditory and visual information. When information is presented simultaneously via both channels, learners can digest it more efficiently and prevent cognitive overload. Plass et al. (2019) found that multimedia presentations with both visual and aural components boost learning results, especially when the topic is difficult. The Modality principle, then, offers a technique to improve learning by engaging both channels, allowing for more efficient processing and lowering the burden on working memory. The Modality principle has been found to lessen cognitive load, an important aspect in effective learning. Sweller (1988) proposed cognitive load theory, which states that when instructional materials surpass the capacity of working memory, learning suffers. The Modality principle addresses this issue by distributing cognitive processing between the auditory and visual channels, preventing one channel from becoming overloaded. This enables students to interact with more complicated content without becoming cognitively overloaded. For example, providing visual aids such as diagrams and animations in addition to auditory explanations can give students numerous ways to understand abstract topics, making them more accessible and memorable (Mayer & Fiorella, 2014). In the context of secondary school education in Rivers State, Nigeria, where digital tools are increasingly becoming a part of the learning environment, the use of

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multimedia learning principles, such as the Modality principle, has enormous potential. With the increased usage of e-learning platforms and digital materials in the classroom, there is a chance to improve students' learning experiences by implementing multimedia learning concepts. Subjects like physics and mathematics, which frequently offer complicated and abstract concepts, might benefit greatly from multimedia training. For example, while studying chemical reactions or the laws of motion, students who engage with multimedia tools that mix animations, diagrams, and vocal explanations may have a better understanding of the ideas than those who rely just on traditional text-based resources. (Fletcher & Tobias, 2018; Digital Learning Institute, 2025).

The Modality principle can have a significant impact on secondary education in Rivers State, where the quality of teaching resources varies and class numbers are often considerable. Multimedia resources can be an effective addition to traditional instructional techniques by providing students with alternate learning opportunities. Students who struggle with reading-intensive texts, for example, can benefit from audio explanations that reinforce essential concepts, whereas visual aids can assist students who learn best through drawings and diagrams. This multimodal method is especially useful in locations with limited educational resources because it provides a dynamic and engaging manner for students to obtain information (Clark & Mayer, 2016). Furthermore, research has indicated that students who engage with multimedia information that corresponds to the modality principle tend to have better levels of engagement and motivation, both of which are necessary for active learning. For example, when students actively participate in the learning process rather than passively reading text, they are more likely to stay engaged and retain information. This is especially crucial in secondary education, as student participation is essential for academic performance (Moreno & Mayer, 2020). The use of multimedia that includes both aural and visual features can help students stay interested and motivated by allowing them to interact with the subject in a variety of interesting ways. Rivers State, where many schools are introducing digital technology into their classrooms, offers a unique chance to use multimedia learning principles, such as the Modality principle, to improve educational outcomes. For example, in topics such as biology or physics, where comprehending complicated processes is critical, multimedia classes that incorporate animations, simulations, and voiceover explanations may help students learn difficult concepts more effectively. This technique not only improves comprehension but also creates a more inclusive learning environment that accommodates different learning styles (Plass et al., 2019). Furthermore, multimedia learning can help students who struggle in traditional classrooms, such as those with reading disabilities, by providing alternative ways of content delivery that suit varied learning styles. However, the efficiency of multimedia learning is determined by how it is designed. Simply adding multimedia features without considering cognitive load risks overwhelming pupils and detracting from learning outcomes. As a result, instructional designers must carefully employ principles like the Modality principle to ensure that the visual and aural components complement rather than compete for cognitive resources (Mayer & Fiorella, 2014). Properly designed multimedia materials that adhere to Mayer's principles can dramatically increase learning experiences, comprehension, and prevent cognitive overload.

Mayer's Multimedia Learning Theory

The multimedia theory of learning was invented by Richard Mayer in 2001. This theory provided the basis and principles guiding the design, development and implementation of multimedia packages for and during instructions, and as such, it has become a perfect companion to all instructional designers, course developers and eLearning content creators.

This theory is based on three assumptions;

- People have two separate channels for processing visual and auditory information, known as – channel.
- Individuals have a limited span to absorb information, hence can be regarded as limited carrying capacity.
- People should be actively engaged in the learning process to achieve meaningful learning or effective communication.

From the above assumptions, Mayer developed 12 principles of Multimedia Learning, which are: Multimedia Principle

i. ICoherence principle
ii. Signaling principle
iii. Redundancy principle
iv. Spatial principle
v. Temporal contiguity principle
vi. Segmenting principle

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vii. Pre-training principle
viii. Modality principle
ix. Voice principle
x. Personalization principle
xi. Image principle

Out of these 12 principles, this study is anchored on the Modality principle of Mayer's Multimedia Learning. This is because the use of multimedia learning in education has grown in popularity due to its ability to improve student learning outcomes. Mayer's Cognitive Theory of Multimedia Learning (CTML) is fundamental to the design of effective multimedia learning because it posits that people learn more efficiently when information is presented in both words and pictures rather than just words. This idea Mayer uses to emphasise the human brain's dual-channel processing system, which includes different channels for processing visual and auditory information. The Modality principle, one of Mayer's core principles, suggests that learners benefit from receiving information in both auditory and visual formats, such as narrated animations or images accompanied by spoken explanations, rather than purely visual or purely text-based presentations (Mayer, 2014).

Cognitive Theory and the Modality Principle

According to Mayer's Cognitive Theory of Multimedia Learning, humans process information through two cognitive channels: one for visual input and one for auditory input, each with a limited capacity for processing information at any given time. This dual-channel structure forms the foundation of the modality principle, which posits that learning is enhanced when information is presented in both auditory and visual formats, rather than relying solely on text. By distributing the cognitive load between these two channels, learners experience reduced cognitive overload, thereby improving their ability to process, retain, and comprehend information (Sweller, 2019).

The Modality principle emphasizes the importance of balancing cognitive demand across these channels. When a single channel becomes oversaturated, such as relying exclusively on text for instruction, the likelihood of cognitive overload increases, hindering learning outcomes. Research supports the idea that integrating both modalities, visual and auditory, into multimedia instruction enhances cognitive processing. For example, instructional approaches that combine visuals (e.g., animations) with auditory narrations are significantly more effective than those using only text and static images (Mayer & Moreno, 2003). This is because providing auditory input, such as narrations or voiceovers, leverages an independent cognitive channel, allowing learners to engage with complex material more effectively. Mayer and Moreno demonstrated that multimedia instruction employing this principle not only enhances comprehension but also facilitates the understanding of challenging concepts. Recent studies continue to validate the Modality principle in educational contexts. For instance, Moreno and Mayer (2020) found that students who engaged with multimedia resources containing both auditory and visual elements outperformed those who were exposed to the same material in text-based formats. These findings are particularly significant in disciplines like science and mathematics, where students often encounter complex and abstract ideas. Dynamic visual representations, coupled with auditory explanations, provide the scaffolding necessary to make such concepts more accessible and comprehensible. The Modality principle underscores the value of thoughtfully designed multimedia learning experiences, which cater to the human cognitive needs and optimize learning outcomes.

Multimedia Learning in Secondary Education

Multimedia learning is gaining popularity in secondary education as an effective way to engage students and improve learning outcomes. The use of multimedia resources such as movies, animations, and simulations has proven especially useful in topics involving abstract concepts, such as mathematics and science, where visual representations are required for a deeper comprehension. In secondary schools, implementing the modality principle can assist in lessening the cognitive burden associated with traditional text-based learning approaches, resulting in enhanced retention and comprehension. In Rivers State, Nigeria, where digital technology is being rapidly integrated into classrooms, there is a rising opportunity to use multimedia technologies to improve student learning. Clark and Mayer (2016) found that teaching strategies that use multimedia learning principles, such as the Modality principle, are more likely to result in better student performance in topics requiring complex reasoning. Secondary students in science and mathematics, in particular, might benefit from multimedia resources that incorporate images and audio explanations, as these formats can better attract students' attention, clarify difficult topics, and foster deeper involvement. While multimedia learning is becoming more popular, obstacles remain in its implementation, particularly in

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impoverished places such as Rivers State. Despite increased access to technology, many schools continue to encounter infrastructure difficulties, such as insufficient computer and internet connections.

Furthermore, teachers may lack the essential skills to create and conduct multimedia classes that are consistent with Mayer's concepts. Without sufficient instructional design training, multimedia tools may overwhelm students rather than enrich their learning experience, resulting in unsatisfactory learning results (Plass et al., 2019). Nonetheless, multimedia resources, when used well, may adapt to a variety of learning styles and preferences, making them especially useful in secondary school, where students frequently have unique needs. Teachers can improve motivation and achievement by including visual and audio aspects in their lessons. According to Moreno and Mayer (2020), multimedia learning not only helps students process information more effectively but also leads to higher engagement, which in turn improves motivation and academic performance. This is especially relevant in secondary schools in Rivers State, where students may face challenges in staying engaged in traditional, lecture-based classrooms.

The Role of Technology in Secondary Schools in Rivers State

The rise of digital technology has created both opportunities and challenges for secondary education in Rivers State. As schools increasingly embrace multimedia learning resources, recognising the Modality principle becomes critical to ensuring that these tools are used to their greatest potential. While multimedia techniques like interactive whiteboards, video courses, and educational applications have been proven to improve learning experiences in industrialised countries, Rivers State provides its own set of opportunities and challenges. Many Rivers State schools continue to suffer with limited access to high-quality multimedia materials, as well as a lack of appropriate infrastructure to support them (Clark & Mayer, 2016). However, research has shown that using multimedia tools in the classroom can considerably benefit pupils, especially in science and mathematics instruction, which necessitates a combination of visualisation and complicated concepts. Plass et al. (2019) found that secondary school students who were taught using multimedia materials such as animations and interactive simulations fared higher on problem-solving and critical thinking assessments. This shows that multimedia tools, particularly those that adhere to the Modality principle, might improve not only students' cognition but also their capacity to apply knowledge in practical circumstances. In Rivers State, employing multimedia to teach complicated concepts has the potential to significantly improve learning results. Using the Modality principle, instructors can create classes that avoid cognitive overload while increasing students' ability to remember and apply information. Furthermore, as students interact with multimedia resources, they are more likely to become active participants in their education, resulting in enhanced motivation and academic success.

Challenges in Implementing Multimedia Learning

Despite the obvious benefits, integrating multimedia learning methodologies in secondary schools in Rivers State presents various hurdles. One important difficulty is that teachers do not receive adequate professional development in multimedia instructional design. According to research, teachers must be educated to use multimedia resources efficiently to maximise learning while reducing cognitive overload (Sweller, 2019). Furthermore, infrastructure problems such as limited access to computers, projectors, and internet connectivity impede the successful adoption of multimedia learning. According to Moreno and Mayer's (2020) research, multimedia learning must be intelligently designed, ensuring that visual and aural aspects are blended in ways that increase learning without overwhelming pupils. Furthermore, students in Rivers State may have difficulty understanding the content of multimedia tools, particularly if they lack the essential background knowledge if the materials are poorly constructed. To ensure that multimedia learning benefits students' cognitive growth, instructional designers must follow principles such as the Modality principle, which ensures that multimedia pieces complement one another and help to reduce cognitive load. The Modality principle of Mayer's Cognitive Theory of Multimedia Learning sheds light on how to design multimedia instruction that can dramatically improve learning results, especially in complicated topics like science and mathematics. When used properly, the Modality principle minimises cognitive load while improving comprehension and retention by activating both aural and visual channels.

The purpose of this study is to investigate the Modality principle's impact on secondary school students' performance in Rivers State, namely in Biology. With the increased usage of multimedia resources in the classroom, it is critical to understand how to appropriately use these resources to optimise student learning outcomes. This study aims to contribute to the body of knowledge on multimedia learning in Nigerian secondary

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schools by investigating the impacts of multimedia education developed using the Modality principle, as well as to provide evidence-based recommendations for improving instructional methods.

Statement of the Problem

Despite the growing usage of digital technology in Rivers State, Nigeria, there is paucity of data to support the usefulness of multimedia learning principles, particularly Mayer's modality principle, in improving secondary school students' academic performance The Modality principle implies that learners gain more from information delivered in both aural and visual modes than from text alone. However, its impact on student achievement, particularly in areas such as Biology, has received little attention. The purpose of this study is to look into how the modality principle affects secondary school students' learning outcomes in Rivers State, with a particular emphasis on enhancing knowledge and retention of complex subjects such as Biology.

Aim and Objectives of the Study

This study aims to investigate the effect of Mayer's modality principle of multimedia design on secondary school students' Performance in Rivers State, specifically, it sought to:

1. To determine the effect of multimedia instruction based on Mayer's modality principle on the performance of secondary school students in Biology
2. To. Examine the effect of multimedia instruction based on Mayer's modality principle on the performance of male and female secondary school students in Biology

Research Questions

1. What is the effect of multimedia instruction based on Mayer's modality principle on the Performance of secondary school students in Biology?
2. What is the effect of multimedia instruction based on Mayer's modality principle on the performance of male and female secondary school students in Biology

Hypotheses

1. There is no significant different between the mean performance scores of students taught using Mayer's modality principle and those tauhght with out mayers modality principle.
2. There is no significant difference between the mean performance scores of male and female students taught using Mayer's modality principle

Methodology

A pre-test post-test quasi-experimental design was adopted for the study; one hundred secondary school students from two Rivers State schools took part in the study. The experimental group (52 students) and the control group (48 students) were the two groups to which the students were randomly assigned. The students aged 15 to 17 were from Senior Secondary School Two (SS1). Using teaching resources that followed Mayer's modality principle, the experimental group got multimedia science lessons with a biology focus. Visual aids like animations and graphs, as well as audio explanations like voiceover narrations, were incorporated into these resources. The same lessons in the same subjects were given to the control group, but they were only text-based and lacked any audio or visual assistance other than the typical pictures seen in textbooks. Before the experiment, a pre-test was administered to both the control and experimental groups to assess the students' baseline knowledge. Both groups received instruction over two weeks. Upon completion of the instructional sessions, a post-test was given to both groups to evaluate their performance. The mean and standard deviation were used to address the research questions, while ANCOVA was employed to test the hypothesis at a 0.05 level of significance.

Results

Research Question 1: What is the effect of multimedia instruction based on Mayer's modality principle on the Performance of secondary school students in Biology?

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Table 1: Effect of multimedia instruction based on Mayer's modality principle on the Performance of secondary school students in Biology

	Pre-Test			Post-Test	
Strategy	N	Mean	SD	Mean	SD
Modality principle	52	24.6	12.1	67.5	17.5
Text-base principle	48	21.2	10.7	58.9	15.7

Table 1 presents pre-test and post-test results for two instructional strategies: modality and text-based principle. For each strategy, the number of participants (N), mean scores (X), and standard deviations (SD) are reported for both the pre-test and the post-test. Both the modality group and the text-based group resulted in substantial improvements in mean scores from pre-test to post-test. The students taught with the modality principle had a pre-test mean of 24.6, which increased to 67.5 in the post-test. The students taught using text-based principles had a lower pre-test mean of 21.6, which increased to 58.9 in the post-test. The standard deviations for both groups increased from pre-test to post-test, indicating a broader spread of scores in the post-test results.

Research Question 2: What is the effect of multimedia instruction based on Mayer's modality principle on the performance of male and female secondary school students in Biology

Table 2: Effect of multimedia instruction based on Mayer's modality principle on the performance of male and female secondary school students in Biology

	Post-Test		
Gender	**N**	**Mean**	**SD**
Male	25	67.5	17.5
Female	27	67.4	15.6

Table 2 displays the post-test results for male and female students taught using the modality the number of participants (N), mean scores (X), and standard deviations (SD) are reported for both male and female students. The male has a mean value of 67.5 while the female has a mean value of 67.4.

HO_1: There is no significant difference between the mean performance scores of students taught using Mayer's modality principle and those taught without Mayer's modality principle.

Table 3: Statistical difference between the mean performance scores of students taught using Mayer's modality principle and those taught without mayers modality principle.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2400.022[a]	2	1200.011	4.426	.015	.100
Intercept	79301.490	1	79301.490	292.470	.000	.785
Prescore	743.084	1	743.084	2.741	.102	.033
Teaching strategy	2364.858	1	2364.858	8.722	.004	.098
Error	21691.520	80	271.144			
Total	352134.000	83				
Corrected Total	24091.542	82				

P=0.04, hence reject the null hypothesis.

HO_2: There is no significant different between the mean performance scores of male and female students taught using Mayers modality principle.

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Table 4: Statistical difference between the mean performance scores of male and female students taught using Mayer's modality principle.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	660.994[a]	2	330.497	1.065	.350	.027
Intercept	83446.891	1	83446.891	268.925	.000	.780
Prescore	660.913	1	660.913	2.130	.149	.027
Teaching strategy	12.023	1	12.023	.039	.844	.001
Error	23582.677	76	310.298			
Total	384525.000	79				
Corrected Total	24243.671	78				

a. R Squared = .027 (Adjusted R Squared = .002)

P=0.8, hence accept the null hypothesis

Discussion

Findings from the study on the effect of Mayer's modality principle of multimedia design on secondary school students' performance in Biology in Rivers State revealed that students taught using the modality principle has a higher mean performance score when compared to the students taught using the text-based principle. Further investigation using ANCOVA revealed that the difference between students taught with the modality principle and those taught using the text-based principle is statistically significant, while the difference between male and female students taught using modality principle was found to be not statistically significant. g According to the principle, students who were exposed to multimedia materials that had both visual and auditory features had considerably better mean performance scores than their peers who received traditional text-based training. This lends credence to the claim that dispersing cognitive strain across dual channels (visual and auditory) improves information processing and engagement. Prior research, such as Moreno and Mayer (2020), has shown that students who are exposed with multimedia content that includes dynamic graphics and narrations outperform those who are supplied with static text-based materials. Similarly, Mayer and Moreno (2020) emphasised the effectiveness of multimedia training in minimizing cognitive overload and boosting understanding, especially in complicated areas. The findings of this study confirm that the Modality principle is both a theoretical framework and a practical strategy for designing effective instructional materials in secondary education settings, where students frequently encounter challenging and abstract concepts that benefit from multimodal representation. The experimental group's higher mean performance scores are consistent with the concepts of dual-channel information processing articulated in Mayer's Modality principle. By utilizing both the aural and visual channels, multimedia instruction significantly improved cognitive processing and understanding. This finding is consistent with previous research, such as that of Moreno and Mayer (2020), which showed that dual-channel presentations reduce cognitive overload and improve learners' capacity to absorb complicated topics.

Conclusion

The study concludes that Mayer's Modality principle improves secondary school students' performance in Biology in Rivers State. Multimedia training, which includes both visual and auditory elements, improves learning, retention, and engagement when compared to traditional text-only instruction.

Recommendations

1. Schools in Rivers State should incorporate multimedia tools, such as videos and animations, into subjects like Biology to enhance students' understanding and retention.
2. Teachers should receive training on Mayer's Modality Principle to effectively design lessons that reduce cognitive overload and improve student engagement.
3. Schools should invest in technology infrastructure, including computers and reliable internet, to support multimedia learning and ensure smooth implementation of these tools.
4. Regular assessments of multimedia instruction's effectiveness should be carried out to evaluate its impact and guide improvements in teaching strategies.
5. Active learning should be promoted through student-centered activities that utilize multimedia tools, fostering deeper engagement and better learning outcomes.

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