THE EFFECTIVENESS OF PASSIVE AND ACTIVE VISUAL AID IN TEACHING COMPLEX SCIENCE TOPICS

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ABSTRACT: *This study investigated the effectiveness of passive and active visual aids in teaching complex science topics among Grade 7 students using a mixed-methods research design. Two intact sections were selected through cluster sampling and divided into two experimental groups, where one was taught using passive visual aids and the other using active visual aids. A pretest and posttest were administered to both experimental groups to assess learning gains, while observations were used to provide qualitative insights into student engagement.*

Results showed that both experimental groups significantly improved in their posttest scores (p < .001), proving that visual aids are effective tools for enhancing science learning. However, the passive group showed slightly higher posttest scores. In contrast, qualitative data indicated that students exposed to active visual aids were more engaged and motivated during the lessons. These findings suggest that while passive visual aid supports better short-term retention, active visual aid also contributes positively to students' interest and interaction.

The study concluded that a blended approach utilising both passive and active visual aids can maximise student learning outcomes. It recommends developing instructional materials that can balance clarity and interactivity, especially in resource-limited classrooms. This study contributes to evidence-based science instruction strategies and provides practical outputs such as lesson plans and evaluation tools.

Keywords: Science education, visual aid, passive visual aid, active visual aid, student engagement, instructional strategies, junior high school

1. INTRODUCTION

Science is both a body of knowledge and a process. It is a way of discovering what is in the universe and how those things work in the future based on empirical evidence [1]. It involves complex processes, abstract concepts, and specific vocabulary that often constitute challenges not just for learners but also for educators. These complexities make science one of the most challenging subjects for students to grasp, especially in the early and middle stages of formal education. A multitude of students find it difficult to connect with scientific content, particularly when it is delivered through traditional lecture-based approaches, where complex topics such as cellular respiration, climate change, or geological processes remain abstract and hard to visualise.

In recent years, the shift toward a student-centred approach has opened up new opportunities to address these challenges. One approach involves the integration of visual aids into teaching methodologies. Visual aids are any devices that can be used to make the learning experience more real, more accurate and more active [2, 11]. It serves as a tool to support both verbal and visual information with either graphic or interactive elements; in that way, it makes the abstract ideas more concrete and easier to grasp. In science education, visual aids have been an important part for both students and educators since they help them to translate theoretical concepts into observable and relatable forms. The use of visual aids has demonstrated a positive impact on student motivation and academic achievement, suggesting that visual engagement plays an important role in comprehension and retention [3].

Visual aids are not monolithic, however, they can be categorised into two: passive and active. Passive visual aids are those that present information in a static format, sometimes for observation rather than interaction. Examples include diagrams, infographics, photographs, charts, and pre-recorded animations. This type of visual aid generally focuses on delivering information in a clear, concise manner. On the other hand, active visual aid invites student interaction and exploration. Tools in this type of visual aid include virtual labs, augmented reality (AR), virtual reality (VR), simulations, and manipulable 3D models. Such aid fosters active learning that allows students to engage with content dynamically, which in turn deepens their conceptual understanding [4].

The effectiveness of these visual aids has been the centre of growing interest in educational research. [5]. A study emphasised that active visual aids, especially simulations and interactive graphics, improve students' problem-solving skills and understanding of complex topics. Meanwhile, passive visual aids, though less interactive, have proven valuable in clarifying challenging vocabulary and organising information logically [6].

The increase in demand for innovative and effective science instruction comes with the pressing need to determine which type of visual aid–passive or active– is more effective in enhancing students' understanding, engagement, and retention of complex science topics. This question becomes more crucial in 21st-century education, where digital tools are becoming increasingly accessible and student needs are evolving fast.

Many studies have been conducted on teaching pedagogies [7, 8, 9, 10, 11, 12], student preferences and readiness [13, 14], student motivation and attitude [15, 16, 17, 18], teachers skills, competencies, and challenges [19, 20, 21], assessment techniques and tools [22, 23, 24, 25] and other related factors [26, 27, 28, 29, 30, 31, 32] to enhance students learning outcome but little was done on investigating passive and active visual aids on teaching complex science topics.

This research aims to bridge the gap between examining the effectiveness of passive and active visual aids in teaching complex science topics. The study is inspired by the need to develop instructional strategies that are not only evidence-based but also applicable in various learning environments, including classrooms that are resource-limited.

A handful of complex science topics present significant challenges in secondary education. These include, but are not limited to, cellular respiration and photosynthesis, climate change, genetics, and geological processes such as plate tectonics and earthquakes. Each of these topics contains elements that are difficult to grasp without proper visualisation. For example, understanding the movement of plate tectonics that results in seismic activities can be confusing for students who simply rely on textbooks. The use of animations or interactive simulations can help students visualise these processes in real-time, enhancing their understanding and memory retention.

Moreover, student engagement in science education is important for fostering inquiry, curiosity, and lifelong learning. Research [8] states that the use of immersive virtual reality (IVR) is suitable for learning environments that prioritise active learner engagement and practical application. Student engagement increases significantly when lessons include visual elements that require manipulation or exploration. Students become more active participants in their learning process rather than passive recipients of information. Active visual aids are specifically beneficial in this regard, offering immersive learning experiences that resonate with digital-native learners.

Nevertheless, it is also important to acknowledge the role of passive visual aids in supporting foundational learning. These tools often serve as the first step in building scientific literacy, helping students to identify key concepts, follow logical structures, and make basic connections between ideas. Passive visual aid helps decrease cognitive load by simplifying complex information into something easier to understand.

Thus, a balanced approach that considers the strengths and limitations of both passive and active visual aids may be the most beneficial. The central question becomes not just which is more effective, but how and when each type should be used to enhance learning outcomes. The present study takes this comprehensive view by exploring both types in real classroom settings, analysing their impact on comprehension, engagement, and retention.

In doing so, this research also seeks to produce tangible outputs that educators can use. These include lesson plans that incorporate appropriate visual aids based on how complex the topic is; teacher guides that explain how to implement and assess visual tools, and evaluation instruments that measure student outcomes efficiently. Such resources aim to support educators in developing their teaching practices with visual aids, whether they are working in technologically advanced schools or resource-limited classrooms.

The study's objectives are thus multi-faceted. Mainly, it seeks to compare the impact of passive and active visual aids on students' understanding of complex science topics. Secondly, it evaluates how these tools affect student engagement and participation during science lessons. Thirdly, it explores the long-term effects on student retention of scientific knowledge. Lastly, it uses these findings to develop instructional resources that reflect best practices in visual aid integration.

The research questions guiding this study are as follows:

1. What is the difference in student comprehension when using passive vs. active visual aids in teaching complex science?
2. Do passive and active visual aids affect student engagement and participation in science lessons?
3. Which type of visual aids leads to better knowledge retention among students?
4. How can the findings of this study be used to develop instructional materials and teaching strategies for science education?

The hypotheses to be tested include:

Null hypothesis (H0): There is no significant difference in student comprehension, engagement, and retention between passive and active visual aids in teaching complex science topics.

Alternative hypothesis (H1): There is a significant difference in student comprehension, engagement, and retention between passive and active visual aids in teaching complex science topics, with one type being more effective than the other.

As education continues to change due to technological advancements and pedagogical research, understanding the importance of instructional tools. By examining the effectiveness of passive and active visual aids in science education, this study contributes not only to academic knowledge but also to classroom practice. The findings will provide valuable insights for teachers, curriculum developers, and policymakers aiming to enhance science learning in diverse educational settings.

As this study will show, the strategic use of passive and active visual aids has the ability to significantly improve how science is taught and learned, paving the way for more engaging, inclusive, and effective science education for all learners.

2. RESEARCH METHODOLOGY

This study employed a quasi-experimental design utilising a pretest and posttest approach to evaluate the effectiveness of passive and active visual aids in teaching complex science topics among junior high school students. A mixed-methods research design was adopted to obtain both quantitative and qualitative insights. The quantitative approach was used to analyse pretest and posttest scores. The qualitative approach focused on student observation and semi-structured interviews to better understand learner experiences and interaction with the visual aid. This combination of methods allowed a comprehensive evaluation of how passive and active visual aids influence comprehension, engagement, and retention of complex scientific topics.

The study aimed to identify not only which type of visual aid was more effective, but also to examine how students interacted with these aids and what impact they had on the learning process. It is expected that this methodological framework would yield insights for science educators and curriculum developers who wish to enhance instructional strategies

2.1. Participants

Participants were selected using cluster sampling, where two intact sections of Grade 7 were chosen. Each section included a balanced representation of male and female students. This sampling ensured that natural classroom groupings were maintained while allowing for a fair comparison between the groups.

The participants were divided into two groups: **Experimental Group 1** (Active Visual Aid): This group received instruction using hands-on 3D models and simulations. These tools are encouraged to actively engage and interact with the content.

Experimental Group 2 (Passive Visual Aid): This group received instruction using visual aids such as diagrams, charts, infographics, and illustrations. These tools were used to visually simplify complex science topics without requiring interaction from the students.

Each group consisted of at least 15 students, ensuring a sufficient sample size to derive statistically meaningful conclusions. The grouping also accounted for variations in academic performance to ensure balance and eliminate bias.

2.2. Research Instrument

This study utilised two instruments to capture both quantitative and qualitative data. Primarily, a Pre-Test and Post-Test consists of 30 multiple-choice items, text-based on plate tectonics, administered before and after the instructional intervention. The tests were identical for both groups to enable direct comparison. Secondly, an observation checklist where classroom observations were conducted by the researcher using a structured checklist. This included indicators such as student attentiveness, participation, and interaction with visual aids.

2.3. Data Gathering Procedure

The research was conducted over a period of three months, beginning with an orientation session where students were informed about the purpose and nature of the study. There were no consent forms given to the participants since it was considered part of the regular instructional delivery during the 4th quarter of the school year.

Initially, a pretest was administered to evaluate the students' baseline knowledge about Plate Tectonics. Following this, the instructional intervention took place over two weeks. Students in Experimental Group 1 were taught using active visual aids like hands-on 3D models and simulations, while Experimental Group 2 received instruction using passive visual aid, such as infographics, diagrams, and charts. Both groups followed the same lesson plans and covered the same topic, such as plate tectonics, types of plate boundaries, and how earthquakes occur.

During the lessons, the researcher conducted classroom observations to monitor student engagement and participation. After the instructional phase, a posttest was administered to both groups to measure changes in understanding.

All data collected from the tests were analysed using statistical methods, such as the Kolmogorov-Smirnov Test to determine the normality of both pretest and posttest scores. Then, after concluding the normality, the researchers used a Paired Sample T-test to determine the significance of differences between the two groups.

3. RESULT AND DISCUSSION

1.1. Normality Testing

To determine the suitable parametric statistical test, the researchers utilised the Kolmogorov-Smirnov test for normality. It was conducted on the pretest and posttest scores of both experimental groups. Results indicated that all data sets followed a **normal distribution,** having a p-value greater than .05. Thus, parametric statistical tests such as the paired samples t-test were deemed appropriate for subsequent analysis.

1.2. Comparison of Pretest Performance: Passive vs. Active Group

A paired sample t-test was conducted to compare the pretest performance of Experimental Group 1 (active visual aid) and Experimental Group 2 (passive visual aid). The results indicated a statistically significant difference, **$t(14) = 5.71$, $p < .001$,** with the **passive group ($M = 17.67$, $SD = 3.063$)** outperformed the **active group ($M = 15.07$, $SD = 3.262$).**

This difference may suggest that students in the passive group had slightly better initial understanding of prior knowledge of the topic before the intervention. Pre-instructional cognitive structures may influence how students absorb new scientific content, regardless of the mode of instruction [4].

1.3. Comparison of Posttest Performance: Passive vs. Active Group

After the implementation of the instructional interventions, a significant difference in posttest performance was also observed between the two groups. The Experimental Group 2 performed better than the active group, **$t(14) = 4.68$, $p < .001$,** with a mean score of **$M = 26.07$ ($SD = 2.43$)** for the passive group compared to **$M = 23.93$ ($SD = 3.90$)** for the active group. While both groups showed improvement, these findings go against studies elsewhere [9], which found that interactive visual tools like simulations and VR tend to boost learner engagement and enhance conceptual understanding more effectively than static visuals. However, the current study's result may reflect that passive visual aid allowed more focused, less cognitively demanding content processing, supporting the cognitive theory of multimedia learning, which suggests that overly complex visuals can overwhelm students' working memory [36].

3.4 Pretest vs. Posttest: Passive Group

To determine the effectiveness of passive visual aid within the same group, a paired sample t-test was used to compare pretest and posttest scores. A significant increase in performance was observed, **$t(14)=-29.02$, $p < .001$,** indicating that students learned significantly from the intervention. From **$M = 17.67$ to $M = 26.07$** shows a large improvement, which suggests that passive visual aids, such as diagrams and charts, were effective in clarifying complex science concepts.

This result aligns with a study [3] that emphasised the role of static visual representations in improving learners' retention of content. Additionally, it is noted that passive visual aids help reduce cognitive overload by simplifying information, thus supporting deeper understanding when used properly [8].

3.5 Pretest vs. Posttest: Active Group

Similarly, a significant improvement was found in the active group between pretest and posttest scores **t(14) = -12.74, p < .001.** The active visual aids also positively influenced conceptual understanding, although to a slightly lesser extent than passive aids in this study. This supports prior findings [5] that interactive simulations and VR tools promote higher-order thinking and engagement. Also, it was found that active visual aids foster inquiry-based learning and problem-solving skills, especially when students are given enough guidance during exploration [6].

Figure 1. Paired Sample Test

Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest_passive - Pretest_active	2.600	1.765	.456	1.623	3.577	5.706	14	.000
Pair 2	Posttest_passive - Posttest_active	2.133	1.767	.456	1.155	3.112	4.675	14	.000
Pair 3	Pretest_passive - Posttest_passive	-8.400	1.121	.289	-9.021	-7.779	-29.016	14	.000
Pair 4	Pretest_active - Posttest_active	-8.867	2.696	.696	-10.359	-7.374	-12.739	14	.000

All four paired comparisons yielded statistically significant **(p < .001),** leading to the rejection of the null hypothesis in all cases. These findings suggest that both passive and active visual aids are effective instructional strategies for teaching complex science topics, with passive aids slightly outperforming active ones in this study. This supports the study that while technology may increase engagement, it does not necessarily lead to better learning outcomes [40].

The result emphasises the pedagogical value of visual representations in science education. As supported [37], visual aid–whether static or interactive - still helps to bridge the gap between abstract scientific theories and concrete understanding by making unseen processes visible.

4. CONCLUSIONS

The study starts with the problem and the conclusions drawn from the results of the study.

1. **Both passive and active visual aids are effective in enhancing science learning outcomes.** The study showed that both experimental groups showed statistically significant improvements in their posttest performance compared to their pretest performance. The passive group improved from a mean score of 17.67 to 26.07, while the active group improved from 15.07 to 23.93. This indicates that visual aids, regardless of active or passive, can positively contribute to student comprehension of complex scientific concepts. These results are supported by existing studies, which suggest that the use of visual aids makes abstract science content more solid and easier to understand. The fact that both methods yielded significant gains supports the integration of visual aids as a foundational component in science teaching, especially for topics that involve advanced lessons, processes, or multi-step reasoning.
2. **Passive visual aid was slightly more effective than an active visual aid in this study.** While both groups improved, students who were taught using passive visual aids outperformed the active group in both pretest and posttest. The statistical difference was significant (p <.001), which suggests that passive visual aids were more effective for the given sample and instructional setting. This can be explained by assuming that passive visual aids, such as diagrams and infographics, allow students to process the concepts at their own pace without the cognitive load associated with navigating interactive simulations. This aligns with the cognitive theory of multimedia learning, which posits that simple, yet well-structured visual inputs are often more effective than overly complex media. Also, passive visual aids are more accessible to both students and educators, even in resource-limited classrooms where technological fluency varies.
3. **Active visual aid fosters student engagement and motivation despite lower test scores.** Although students in the active group scored slightly lower on the posttest compared to the passive group, based on observations, it revealed that these students were generally more engaged and enthusiastic during lessons. They participated more during class discussions, expressed curiosity, and asked questions, especially during the use of simulations. This aligns with studies [5, 35] which suggest that visual tools tend to promote higher-order thinking and engagement, even if they do not immediately translate into higher test scores. Therefore, while passive visual aids may be better for content retention in the short term, active visual aids are invaluable for stimulating interest, inquiry, and deeper cognitive engagement over time.

Overall, the study underscores the importance of integrating both types of visual aids into teaching complex science topics. Educators are encouraged to adopt a blended approach that grasps the strengths of both passive and active visual aids–using diagrams and charts to build baseline knowledge, while integrating simulations and 3D models to promote engagement and deeper exploration. With the right balance, visual aids can transform traditional science education into a more dynamic, inclusive, and effective learning experience for all students.

5. RECOMMENDATION

The recommendations drawn from this study were based on the significance of the study, along with the results of this study.

1. To Curriculum Planners: Curriculum designers are encouraged to integrate both passive and active visual aids into the official curriculum for science subjects, especially in the junior high school levels. As the study found that passive visual aids led to higher and easier comprehension, these should be systematically included in lesson plans and textbooks to support the teaching of complex science topics such as climate change, plate tectonics and even energy systems. On the other hand, active visual aids such as simulations and models should be included to serve as enrichment tools to develop the students' higher-order thinking skills and engagement.

2. School Administrators: School administrators are encouraged to provide both technological and pedagogical support for educators using visual aids in science education. This includes allocating a budget for projectors, televisions or access to educational simulation platforms. Additionally, administrators should offer training workshops focused on the effective use of passive or active visual aids in classrooms. Educators must also be supported in conducting formative and summative assessments to evaluate not only the retention of the topic, but also to evaluate the student engagement and understanding of the conducted visual strategies.

3. Science Teachers: Teachers should make use of both passive and active visual aids depending on how complex the topics are. For building the foundational knowledge, teachers can use diagrams, charts, and static visuals that can help students understand the information effectively. On the other hand, 3D models and simulations, and for more schools with access, VR can be utilised for teaching more complex topics, which can deepen the students' understanding and raise curiosity. Teachers are also encouraged to assess students' engagement and learning outcomes using activities, quizzes, or group tasks.

4. Students: Students are highly encouraged to actively explore both types of visual aids provided by their teachers. They should take initiative in interacting with the visual resources offered by their teachers. As part of learning, regardless of what visual aid is utilised, students must ask questions and participate in group work or in manipulating simulations. Students are also encouraged to develop study habits that are best suited to them, where teachers can meet them halfway. Taking responsibility for one's learning by exploring different learning styles at different grade levels. Researchers might also explore the impact or effectiveness of utilising both types of visual aid in the classroom.

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