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The Impact of Video and Simulation Based Learning on Cognitive Development of Secondary School Students (Biology)

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ABSTRACT

This research study explores how, technology integrated learning, using videos and simulations, influence the Cognitive development of secondary school science students in Biology Class. It distinct3 main area of Cognitive development, first, memory retention, second is critical thinking, while third one is problem- solving skills. The purpose of this study is to recognize whether using simulation and subject related videos in Science Classroom (Biology) enhances student understanding and learning outcomes as compared to traditional methodologies. A mixed method approach was used, combining both quantitative (pre-and posttests) and qualitative (students feedback) data to better understand the learning outcomes. A quasi-experimental research design was used involving both control and experimental group. Two groups were selected for this research. One group was taught traditional teaching methodologies and other group through video and simulation, pre and posttest Classroom observation, combining assessment, and student related surveys. The population was consisting of government secondary school students, through purposive sampling, a sample of 60 students were selected, 30 in the experimental group and 30 in the control group. A questionnaire was used to evaluate student's perception and their cognitive outcomes. It was found through results that students who learned by technology_ integrated methodologies accomplished better in tasks specifically in (Cognitive) recalling information, solving Biology based difficulties and improved critical thoughts related to scientific concepts. This research finding supports provide significance perception for teachers, school leaders and curriculum developers to integrate and use technological enhanced tools to improved students learning outcomes.

Introduction

Education plays an important part in molding cognitive and social development of individual and societies. Pakistan's educational system, especially at secondary school level, is continuously facing challenges like in curriculum delivery, teaching strategies and student engagement particularly in science subjects. Per Pakistan Education Statistics(2021-22), underdeveloped regions as Balochistan is suffering from insufficient framework, untrained teachers, and lack of pedagogical innovative tools. All this adversely affecting students' skills to understand complex scientific concepts which require inquiry based learning strategies. In Pakistan, learning outcomes are stagnant due to outdated teaching methods, teacher shortages, and lack of resources and poor engagement of students (UNESCO, 2022). These matters are more apparent in science education where students need to understand and learn complex concepts without proper knowledge or critical thinking (Rehman et al. 2021).

As Balochistan is most destitute province of Pakistan struggles with little access to contemporary educational tools and practices. Mostly secondary schools follow traditional teacher centered approach, which stresses rote memorization over skill development. According to the Pakistan Education statistics (AEPAM, 2021), in the region secondary school students frequently experience unsatisfactory performance due to conventional instruction and limited use of interactive learning materials. This resulted in a growing apprehension related to students' cognitive development, especially in science subjects, which need sound understanding and application-based learning.

With the increasing of technological enhanced strategies educational system all over the world has been significantly shifted. Pedagogical tools like videos simulations and interactive modules have been manifested to increase learning outcomes by motivated and engaging students improving critical thinking and help them to keep knowledge more effectively (Mayer 2014; khan et al., 2020). Though, in Pakistan, especially in Baluchistan, the amalgams of technologies in classroom strategies are very limited and under-researched.

As cognitive development which comprises critical thinking, memory retention and problem-solving is pivotal for secondary school students. Conventional teaching methodologies fail to support these skills which lead to poor learning outcomes and less practical applications.

On the contrary (TEL) Technology enhanced learning provides possible solutions by generating an engaging and interactive learning environment that assist deeper learning processes (Krik wood & Price 214). Yet, empirical research study is needed in the context of Pakistan on how TEL impacts the cognitive development of students at the secondary level specifically in science subject.

This research highlights the gap by inspecting the impact of technology enhanced learning particularly through simulations and videos on cognitive development of secondary school students in Balochistan. Despite internationally proven benefits, TEL remain underutilize in Pakistan. In the present case, there is an imperative need to explore and find out the impact of TEL on cognitive growth in local settings. The purpose of this study is to find out whether technology enhanced learning can notably improve students memory, critical thinking and problem solving abilities compared to traditional methods.

Problem Statement

Across many secondary schools, conventional teaching methods remain the dominant style of instruction, particularly in science subjects like biology. These techniques often depend on rote

memorization and very limited student engagement, along with textbook-based learning. As an effect, the learner wrestles to acquire basic cognitive skills, specifically problem-solving, memory retention, and critical thinking. Nowadays, in the digital era, where students are living in a tech-driven world, the gap between their learning needs and the teaching methodologies incorporated in classrooms is broadening.

Though previous studies have focused on the benefits of using instructional technologies, there is little empirical evidence. Specifically in developing areas, on how tools like simulation and videos impact students' cognitive development in an actual classroom. This literature gap creates unpredictability for policymakers, curriculum developers, and educators who want to improve learning outcomes through student-centered approaches. Despite international progress in educational technology, still in Balochistan the classrooms depend on traditional methods. Due to lack of learning resources students struggle to understand complex scientific concepts. This raises concerns related to students' cognitive skills development

As many international research studies have highlighted and discussed the benefits' of technology enhanced learning hardly any have addressed its impact on cognitive development of students in circumstances of underdeveloped regions like Balochistan. The existing literature lacks localized evidence to evaluate the impact of TEL on students learning.

Therefore, the purpose of this study is to highlight this problem by probing the influence of technology-enhanced learning (specifically through videos and simulations) on the cognitive development of secondary school students. It assesses whether such interventions can enhance students ' memory retention, critical thinking, and problem-solving skills compared to traditional teaching methods. The study aims to bridge this gap.

Research Objectives

The objectives of the study are;

1. To evaluate the impact of technology enhanced learning on students' memory retention, critical thinking, and problem solving skills in the biology at the secondary school level.
2. To compare cognitive development between traditional taught students and those taught using technology enhanced tools.
3. To explore the practical application of learning and multimedia theories in improving cognitive function through TEL in the context of Balochistan.

Research Questions

Following are the research questions to guide the studies;

1. How technology enhanced learning can impact on secondary school students critical thinking, memory retention and problem-solving skills in biology?
2. What will be the significant difference in cognitive development between students using traditional methods and those taught using technology enhanced tools?
3. How so cognitive development in multimedia learning theories support the use of technology enhanced tools in improving learning outcomes in Balochistan secondary science classrooms?

Literature Review

Technology- Enhanced Learning in Education

(TEL) Technology-enhanced learning means the utilization of digital tools, like simulations, videos, and online platforms, to assist in the teaching and learning process. According to Mayer (2009), learning through multimedia, especially employing subject related videos and animations, supports students to understand difficult and complex content easily and effectively because it attracts both auditory and visual learning pathways. In science subjects, particularly in biology, these digital tools help students to learn at best through visualizing abstract concepts and topics like blood circulation or photosynthesis (Zhang et al., 2006).

Numerous studies have highlighted that the use of technology enhances students' learning, their engagement, and motivation increases (Yilmaz & Bayraktar, 2014)

Simulations let learners explore, experiment, and envision complex concepts, making learning more interactive. On the other hand, videos assist step wise processes that are difficult to understand through text alone.

Cognitive Development and Learning

Cognitive development consists of mental processes such as reasoning, problem-solving memory, and attention. The cognitive development theory of Piaget indicates that learners pass through different stages of learning as they grow and need more advanced thinking strategies (Piaget, 1972).

Students begin to develop formal operational thinking at the secondary school level, which makes learners analyze, solve problems, and reason more efficiently.

Primary or working memory plays an important role in the learning process. In 1988, Sweller's cognitive load theory proposed that too much information at once can affect students and decrease learning. With the help of videos and simulations, this cognitive load can be reduced by providing information in a much clearer way and making students motivated by engaging format and attractive visuals, helping students to understand and retain knowledge better.

Memory Retention

In academic success, memory retention is pivotal, particularly in lengthy theoretical subjects like biology. According to Moreno and Mayer (2000), students retain information much better if it is introduced with both visuals and narration. Technological tools like animated videos are helpful in reinforcing memory by recur renting the concepts and providing students to see it again and reflect.

Critical Thinking and Problem - Solving

The ability to ask questions, analyze, and take out conclusions is called critical thinking. Problem-solving is the ability to use knowledge in new situations. Studies indicate that simulation improves both skills (Rutten et al., 2012). Students engage in a simulated laboratory. They should notice, forecast, and assess ideas. It helps to build higher order thinking skills, as explained in Bloom taxonomy.

Gap in Research

Though many studies have highlighted the benefits of technological advancements in education, hardly any focused on biology subject at secondary school level and its impact on critical thinking, memory retention and Problem solving abilities, limited research exist in the context of developing countries like Pakistan, particularly in under-resourced region such as Balochistan. Mostly, local studies emphasize on general academic performance. This study fills the gap by giving an understandable proof that simulations and videos impact the cognitive development of students in biology classrooms

Theoretical Framework

This study is based on three well established educational theories that brace the utilization of technology-integrated learning to enhance students' cognitive skills.

Cognitive Theory of multimedia learning (Richard Mayer, 2001)

This theory describes the learning process as better and effective when knowledge is imparted through both words and visuals rather than through text alone.

Different multimedia tools like simulations and videos attract both auditory and visual channels, assist students learning, organize, and store more knowledge successfully. This theory provides ground to use both videos and simulations impacts the learning process for longer memory retention, critical thinking skills and strong problem solving abilities in biology.

Piaget's Cognitive Development Theory (Jean Piaget, 1972)

In 1972, Piaget suggested that secondary school students are in formal operational stage of cognitive development. This is the stage when learners start thinking abstractly, reason logically, and take out solutions of difficult tasks.

This theory supports the learning task designs in this research, which need learners to critically observe, analyze, react, and answer to video content and simulations in biology.

Cognitive Load Theory (John Sweller, 1988)

The focus of this theory is on the limits of working memory. Sweller's theory suggests that effective instructional methodologies reduce unrequited mental load. Therefore, learners can give more attention to understanding and learning main concepts. Simulations and subject related video content decrease extra cognitive load by creating abstract biology concepts to stronger and easier to keep on.

This study provides ground that the benefits of technological tools in the teaching learning process can make complex topics easier and more interesting, like photosynthesis.

Research Methodology

This research study is conducted to evaluate "**The Impact of Videos and Simulations Based Learning on Cognitive Development of Secondary School Students",** of Govt. Girls High School Quetta, Balochistan.

Research Design

This research adopts a mixed method approach, combining both quantitative and qualitative techniques to give a complete analysis of how TEL particularly videos and simulations impacts secondary school students' cognitive development in biology. A quasi research design was used, by comparing both pre-test and post-test between a controlled group (traditional teaching) and an experimental group (TEL).

Population and Sample

The population consisted of (grade 9) from Govt. Girls High school in Quetta, Balochistan, aged between 14 and 15 years secondary school science students. Students were randomly divided in 2 equal groups of 30 students each with basic knowledge of using computers and had prior exposure to general science subjects.

Sample Size: 60 students were selected (30 in experimental group and 30 in a control group.

Sampling Technique: Purposive Sampling: Purposive sampling was used for selections the school that had multimedia facilities and were willing to participate.

Instruments and Tools

Cognitive Assessment Tool (CAT): A researcher-designer test consisting of:

- Memory retention questions (re-call based).
- A test was designed to calculate students' understanding of biology topics before and after the intervention.
- Critical thinking questions (application and analysis). The test included multiple choice questions and short answer questions.
- Problem-solving scenarios (real-life biology tasks).
- It focused on memory recall, critical thinking and problem solving skills related to biology.

Videos and Simulations Content

The experimental group was taught by using interactive simulations and educational videos on topics like; cell structure and human digestive system.

Trusted Educational Websites like; Khan Academy, PhET interactive simulations were selected for learning materials.

Observation Checklist

A checklist was used by teachers to observe student behavior, participation, questioning and engagements during lessons.

This helped to measure any change in critical thinking, attention span and classroom involvement.

Student Feedback Questionnaire: A simple survey with questions, Likert-scale tool was used to assess and collect students' perception of learning with or without videos and simulations.

Interview Guide: Few students were selected from both groups for short interviews to collect qualitative insights on engagement and understanding.

Validity and Reliability

- **Content Validity:** The validity was ensured by the expert review from related fields.
- **Internal Consistency:** The consistency was measured by using Cronbach's Alpha:
- **CAT: a = 0.81**
- **Student questionnaire; a = 0.78**

Procedure

1. Both groups were administered by pre-test.
2. Traditional methodology was used to taught the control group (textbooks and lectures only)
3. Videos and simulations related with the biology syllabus were used to teach the experimental group for duration of four weeks.
4. Following the intervention, student feedback questionnaires and post-tests were conducted.
5. After interviews conduction with five students from the experimental group.

Data Collection

Data was collected by the researcher herself. The questionnaire was distributed among the students of both groups. Moreover, interviews were conducted from selected participants.

Data Analysis

SPSS is used to analyze numerical data statistically.

Quantitative Analysis

Q1. How technology enhanced learning can impact on secondary school students critical thinking, memory retention and problem-solving skills in biology?

Table 1:

Impact on Memory Retention

Group	Pre-Test Mean	Post-Test Mean	Gain Score
Control	54.2	58.7	+4.5
Experimental	53.8	71.3	+17.5

Interpretation: Significant improvement was seen in memory retention of experimental group as compared to the control group

Impact on Critical Thinking

Group	Pre-Test Mean	Post-Test Mean	Gain Score
Control	50.1	54.9	+4.8
Experimental	49.5	67.5	+18.0

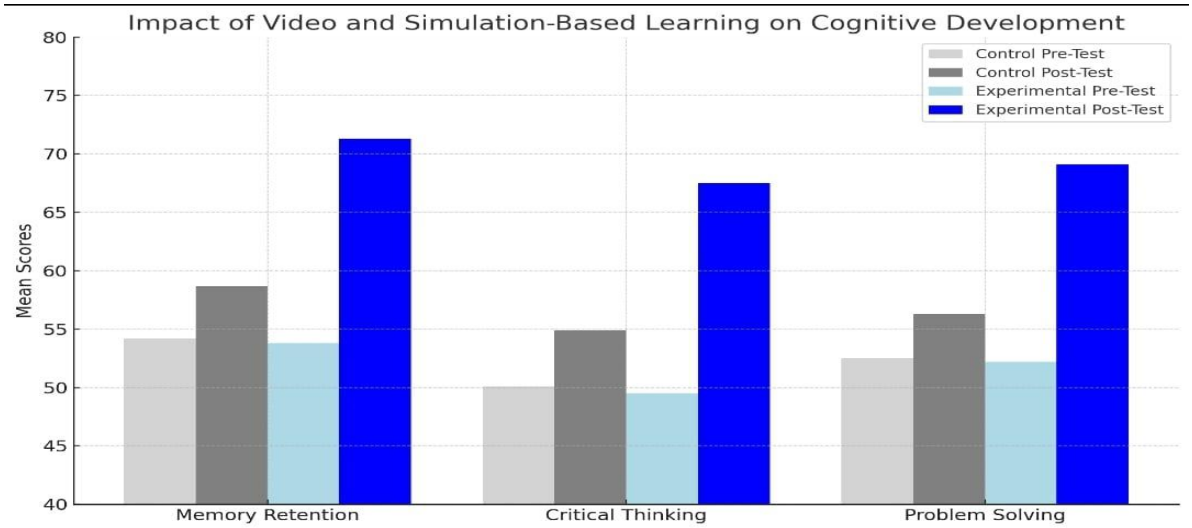
Interpretation: Those students who were exposed to technology enhance learning showed higher critical thinking.

Impact on Problem Solving

Group	Pre-Test Mean	Post-Test Mean	Gain Score
Control	52.5	56.3	+3.8
Experimental	52.2	69.1	+16.9

Interpretation: Technology integrated learning remarkably increased students skills to solve real world biology tasks.

Figure 1:



Key Background

- This graph shows that experimental group persistently showed remarkably higher post test mean score as compared to the control group across all areas.
- Acquired scores shows positive improvement in the experimental group, confirming increased effect of multimedia based learning on students.

Q2. What will be the significant difference in cognitive development between students using traditional methods and those taught using technology enhanced tools?

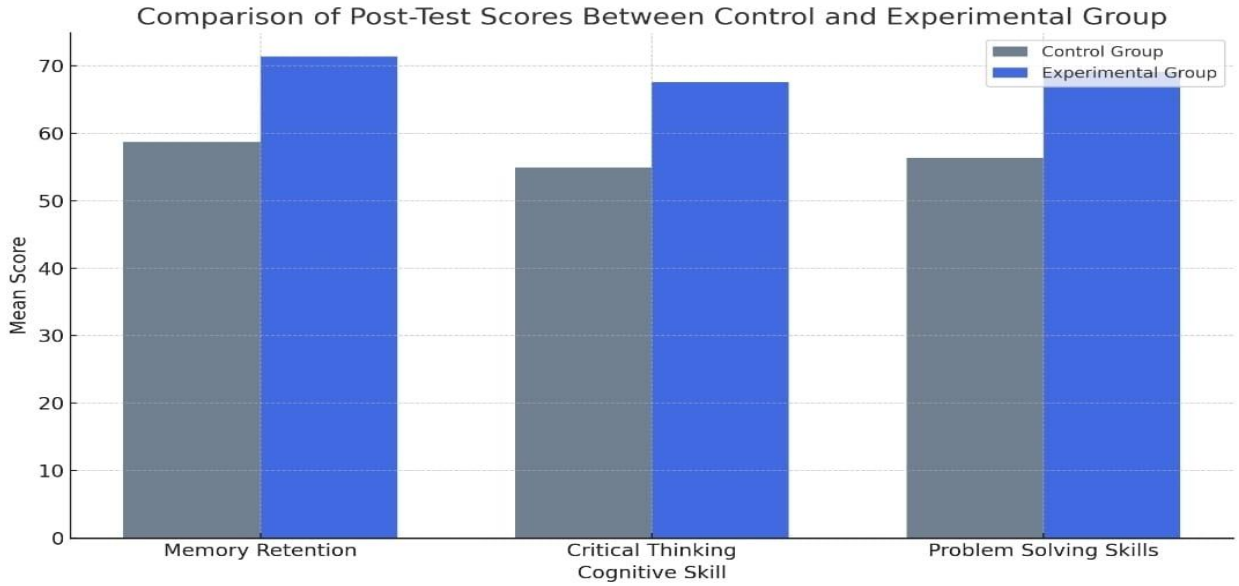
Table 2: Comparison of Post-Test Scores Between Control and Experimental Group

Cognitive Skill	Control Group Mean	Experimental Group Mean	Mean Difference	Interpretation
Memory Retention	58.7	71.3	+12.6	Significant improvement with TEL
Critical Thinking	54.9	67.5	+12.6	Higher-Order thinking enhanced by TEL
Problem Solving Skills	56.3	69.1	+12.8	TEL helps apply knowledge in real-life contexts

Explanation

- Significantly improvement is observed by the experimental groups in all 3 cognitive domains as compared to domain group.
- Across the domain, the mean differences were constantly above +12 points manifesting a visible advantage of using technology enhance methods.

Figure 2:



The following graph shows that the experimental group performed better than control group in all three skills.

Q3. How so cognitive development in multimedia learning theories support the use of technology enhanced tools in improving learning outcomes in Balochistan secondary science classrooms?

Table 3: Themes from Student Feedback and Their Link to Learning Theories

Theme from Student Responses	Example	Linked Theory	Explanation
Learning with peer discussions during video pauses	Students paused the videos and discussed	Vygotsky's Social Constructivism	Peer interaction and inquiry based learning enhanced students' knowledge
Active engagement	They felt more focused in video class than in a normal lecture	Piaget's Active Learning Theory	Students' active interaction with multimedia improved deep learning
Better problem-solving simulations	The virtual lab helped them what would happened in case of any change	Mayer's Experiential Learning Theory	Students were able to experiment and analyze outcomes with the help of simulations.

Interpretation

- Following qualitative findings show that students' experiences directly reflect basic principles of educational learning theories.
- Technology enhanced learning tools developed positive learning environment that supports interaction, visualization, collaboration and cognitive challenges.

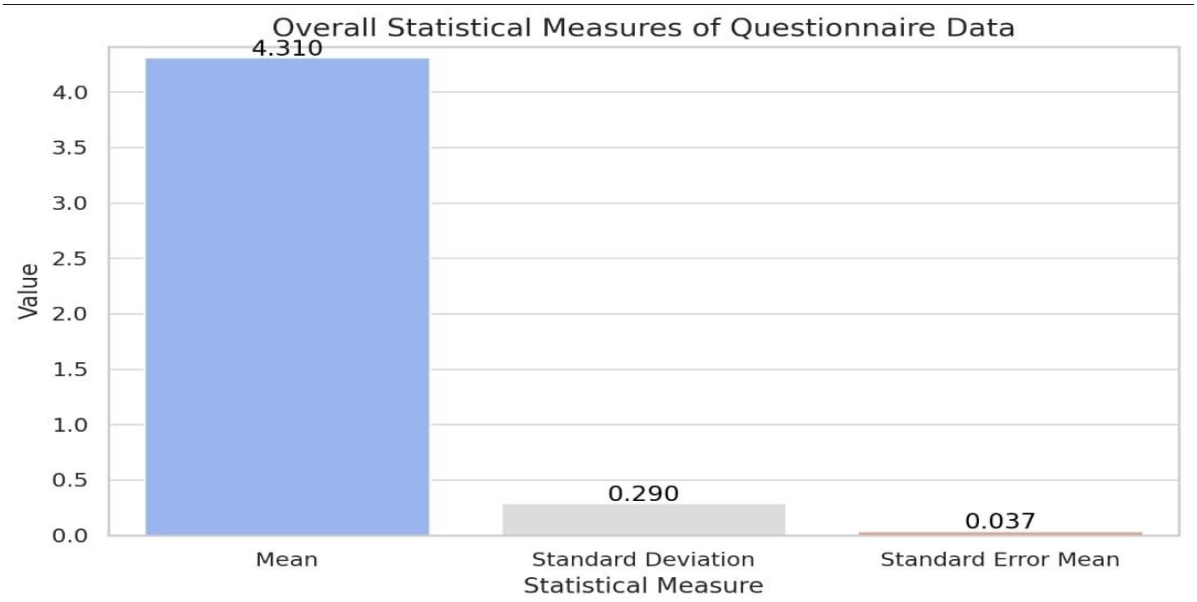
Analysis of the Questionnaires

Comprehensive analysis of the questionnaire responses of 60 students

Table 4: Overall Statistical Results

Statistical Measure	Value
Overall Mean	4.31
Overall Standard Deviation	0.29
Overall Standard Error Mean	0.037

Figure 3:



Interpretation

- Overall Mean (4.31): It shows that average, students agreed to strongly agreed that the technology enhanced learning categorically influenced their memory retention critical thinking and problem solving skills in biology.
- Standard Deviation (0.29): The following less standard deviation shows that mostly students' responses were close to the mean, which shows persistence certainty across different questions.
- Standard Error Mean (0.037): Low SEM indicates the reliability of the sample mean is high, showing the average result is satisfactory evaluation of the overall student population view.

Interview Analysis

Interview analysis based on responses from students of the both groups. The purpose of the interview is to find out students' perception and experiences about Memory Retention, Critical Thinking and Problem-Solving.

Table 5: Themes and Responses: Experimental vs. Control Group

Theme	Experimental Group	Control Group	Interpretation
1. Improved Memory Retention	The videos helped the students to revise easily before tests.	Students forgot different points from the textbooks after few days.	The following visual content in the experimental group increased memory retention unlike the control group lacked in reinforcement.
2. Enhanced Understanding	The animations made difficult Biology concepts easy to understand.	They found it hard to imagine hard to imagine the process from the book.	Simulations supported deep understanding while the control group found hard with abstract concepts.
3. Increased Interest	It makes biology more fun and easy to learn.	Students felt bored in the class.	Technology enhanced learning made the lessons more interesting, and develop intrinsic motivation.
4. Critical Thinking	The activities made the students think about different processes in biology.	They just memorize the notes.	Students from the experimental group developed critical thinking, unlike the rote based learning of the control group.
5. Better Problem Solving	Students could solve the diagrams and case studies after watching the videos.	Students found case studies hard.	Simulations helped the students to strongly transfer the knowledge to new situations.
6. Collaborative Learning	Students discussed the videos in group and shared ideas.	Mostly students studied alone.	Interactive and peer supported learning was promoted in the experimental group.

Discussion

The findings of this study visibly indicates that technology enhanced learning particularly through videos and simulations, positively improves students' cognitive development in biology at the secondary school level. As the result of experiment showed higher gain in memory retention, problem-solving and critical thinking as compared to control group. The following outcomes

support Mayer's (2009) Cognitive Theory of Multimedia Learning, which suggests that the learning can be improved when content is delivered with both visual and verbal formats. The findings of posttest described considerable improvement in the experimental group, particularly in using knowledge to new situation, showing the efficacy of simulation based instruction. However, positive feedback through questionnaire and interviews also support Vygotsky's (1978) Theory that learning is increased and improves by social interaction and cooperative environment.

The findings are relevant especially in the context of Balochistan, where education in science usually affected due to shortage of resources, traditional teaching methodologies, and poor student engagement. This study layout evidence that the integration of simulations in videos in teaching of science can control some of these limitations by creating content more interesting, accessible and interactive. The following identical results have been reported in other studies (Kay et al., 2016; Joda et al., 2020), shows that those students who use digital content improve better in analytical and problem-solving skills. The given findings underline the significance of using and adopting innovative, student-centered instructional tools to improve science education in under developed regions like Balochistan.

Conclusion

According to this analysis, it is proved that by using videos and simulations in teaching biology to secondary school students has a remarkable impact on their cognitive development. These tools assisted students to engage better, deep understanding, and perform more positively in problem solving and critical tasks. The triangulation of findings showed significantly higher improvement in all cognitive domains. The data from the experiment, questionnaire and interview proves the positive impact of the technology enhanced learning supporting the relevance of Multimedia Learning Theories and Cognitive Development Theories in the context of secondary science education in Balochistan.

Recommendation

On the basis of the result of this study, it is recommended that in Balochistan and similar under developed regions should integrate technology enhanced learning tools in secondary schools, into their science curriculum, especially for subjects like biology which consists of complex concepts. It is important that the teachers should be trained so that they can efficiently introduce multimedia content into their lessons to improve student cognitive development. In addition to this, policy makers should give importance to the provision of digital infrastructure and resources to support this innovational shift, the result of this study indicates that such pedagogical tools effectively increase all three cognitive domains. This approach can overcome the learning gaps and increase quality of science education in the region.

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