

Beyond Passive Viewing: An Experimental Study into the Efficacy of YouTube Kids' Science Programming in Pakistan using a CLT-SCT-CTML Integrated Framework

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Received: 01-02-2026

Revised: 15-02-2026

Accepted: 02-03-2026

Published: 16-03-2026

ABSTRACT

The learning environment of elementary education in the field of science education has changed due to the impacts of digital learning sources. The YouTube Kids application showed significant effects on science education regarding improved teaching methods, enhancing students' motivation and engagement through visualization and inquiry. Limited research studies have been carried out focusing on the utilization of YouTube kids but specifically the domain of designing tri-theoretical framework Cognitive Load Theory (CLT), Social Cognitive Theory (SCT), and the Cognitive Theory of Multimedia Learning (CTML) has been overlooked in Pakistan. The research aims to fulfil this gap how tri-theoretically optimized video content influences learning retention, mental effort, and science self-efficacy among elementary students. A quasi-experimental design was used with 60 elementary students (N=60) from Rawalpindi city. The convenient sampling technique was applied. The experimental group (n=30) engaged with science curated videos, while the control group (n=30) was taught using traditional methods. Quantitative analysis using t-tests showed that the experimental group achieved higher post-test scores. This research finds practical implications to the policy makers, curriculum developers and school administrators showing favour for the use of YouTube Kids in science education at the elementary level. The study made a valued contribution to the body of literature addressing the knowledge gaps on digital pedagogy and tri-theoretical framework that has a positive and significant effect in reducing cognitive load and enhancing the academic performance of elementary students in science.

Keywords: YouTube Kids, Science Education, Cognitive Load Theory, Social Cognitive Theory, Multimedia Learning

INTRODUCTION

In the era of fast technological progress, educators are under the pressure to keep up with the automation, which means that the traditional method of teaching will have to be changed to the multi-stimulant learning conditions. Although machines are capable of providing information, they are incapable of replacing the importance of the teacher in instilling character values, teamwork, or social empathy, which are human-based elements of education that cannot be substituted (Alifiyarti et al., 2023). Presently, poor student performance is usually a consequence of an unenthusiastic learning environment where teachers use textbooks as the primary source of information. The absence of various learning media makes students in particular feel the lack of various learning media, and it is important to note that the gap between memorizing and grasping the abstract material may be closed with the help

of the integrated digital tools. Digital Media can be defined as the plethora of online resources and interactive tools like the YouTube Kids app that offer the flexibility and enriched learning environments of the contemporary world. Due to their capacity to make YouTube content fun and accessible in a variety of ways, YouTube Kids are currently a source of influence, particularly in the early learning stages. Meanwhile, research has shown both the benefits and the drawbacks of the fact that more kids are turning to YouTube Kids for educational materials (Schweder, 2024).

Natural and Social Science is a multidimensional discipline that studies not only the intricate relationships that exist between the biotic and abiotic aspects of the universe but also the relationships of human beings as social beings and their relationship with the surrounding environment. In its general meaning, science is a structured compilation of various knowledge organized into logical and systematic systems to highlight the main principles of cause and effect (Dwivedi et al., 2023).

Studies have always attributed the use of video games such as YouTube to a number of developmental advantages in children. In particular, research suggests that watching YouTube aids in cognitive growth, imagination, curiosity, and concentration during the process of learning science (Wahyuni et al., 2023). Similarly, Qurban (2022) demonstrated that it supported its use that; as a foundation of inspiration there is a belief that this digital interaction can help to develop creative abilities. Thus, YouTube became one of the most commonly used digital content sharing platforms, which is characterized by the ability to interact in both directions. This design allows not only to spread their own content, but to enhance engagement and communication with the rest of the online community (Sabich & Steinberg, 2017; Sánchez-Vera et al., 2019; Vizcaíno-Verdú et al., 2019) as cited by (Pedreira et al., 2022). The past years have seen a significant rise in the research on the educational efficacy of digital means, especially in the context of science education. This has highlighted how multimedia can be used to increase learning outcomes in science in the elementary education through interactive platforms and the use of videos. This is in lieu of an increased awareness of the need to promote scientific literacy at an early age, which is increasingly becoming conscious. It has been proven that, when properly incorporated, digital tools can be used to aid the teaching of science by facilitating access to complex scientific concepts as well as making it more enjoyable for young students (Zourmpakis et al., 2023).

Video media is also increasing in classrooms signifying a shift of more teachers instead of student-oriented classrooms. It has been demonstrated by Khan et al., (2024) that the degree of cognitive learning improvement particularly at the elementary level is great through the interactive media in science teaching. Such tools as YouTube Kids eliminate this information push and provide in the form that will stimulate exploration and interest, and a more profound engagement with concepts. This method is advantageous to the elementary science teaching since young learners react well to highly visual and simple material in regard to complex information. Another benefit of this approach is the fact that it aids in understanding and developing a lifetime interest in the topics of science.

Rationale of the Study

Traditional classroom teaching in science education at elementary level in Pakistan depends on abstract descriptions of detailed biological and physical processes. The students need to understand ideas like elements and compounds, reproduction in plants, and space & solar system that are highly invisible to the human sight. There is insufficient scientific data to support its planned incorporation through digital media specifically YouTube Kids into official science curricula. According to the Cognitive Theory of Multimedia Learning (CTML), human brain learns more thoroughly from words and images than from words alone by traditional pedagogies in classroom. Traditional textbooks are unable to match YouTube Kids' collection of carefully chosen, high-definition 3D animations and microscopic visualizations. This study investigates whether this visual framing considerably lessens cognitive burden and develops conceptual clarity, motivation and engagement in science education at elementary level.

Statement of the Problem

Despite the studies emphasizing the developmental advantages of YouTube use such as improved imagination and attention (Zourmpakis et al., 2023) and flexibility advantages such as aiding independent learning (Hernanda & Aji, 2024), they are mostly descriptive or co-relational and were not carried out in the cultural context and integrating the theories (CLT, SCT and CTML). The lack of sound, causal experimental evidence and non-alignment of tri-theoretical framework in Pakistan is critical to ascertain whether the application of YouTube Kids, in particular, science-related content, is statistically significant in improving visual learning reducing the cognitive load in comparison to the already existing traditional teaching strategies.

There is a significant lack of empirical research in Pakistan exploring how the intentional integration of CLT, SCT, and CTML can transform YouTube Kids from a source of passive entertainment into a verified tool for academic achievement. While teachers and parents are increasingly using these videos, they do so without a theoretical framework to evaluate the content, resulting in poor cognitive learning and stagnant science self-efficacy among elementary learners.

Thus, the purpose of this study is to examine the effectiveness of a YouTube Kids science program that is tri-theoretically integrated. This study attempts to create a scientifically supported model for digital science pedagogy in Pakistani primary schools by experimentally examining the connection between optimum multimedia design and student outcomes.

Research Objective, Research Question and Research Hypothesis

RO: To assess how a YouTube Kids scientific intervention that is tri-theoretically integrated (CLT-SCT-CTML) affects Pakistani primary kids' learning outcomes, cognitive load, and self-efficacy.

RQ: Is there a significant impact on learning outcomes, cognitive load, and science self-efficacy of elementary students who watch YouTube Kids scientific intervention that is tri-theoretically integrated (CLT-SCT-CTML)?

H1: A tri-theoretically integrated (CLT-SCT-CTML) YouTube Kids science intervention has positive impact on lowering elementary children' perceived cognitive load while improving learning outcomes and science self-efficacy.

Significance of the Study

Global competitiveness is a prerequisite for the Pakistani educational system's transition from traditional rote learning to digital fluency. This study will meet the urgent need to improve elementary education by incorporating technologies like YouTube Kids. This will ensure that the next generation of human capital has the technical literacy and cognitive flexibility necessary to thrive in the technologically advanced global economy.

For the Pakistani context, this study is one of the first to combine CLT, SCT, and CTML into a unified framework. It offers a distinctive perspective on how design (CTML), mental effort (CLT), and social modelling (SCT) work together to give kids a whole educational experience. The results provide Pakistani teachers and parents with a selection rubric to assist them choose YouTube kids videos that maximize scientific interest and self-efficacy while minimizing cognitive overload.

LITERATURE REVIEW

Recently there has been much educational research on the effectiveness of videos, animations, and other interactive features for presenting complex scientific concepts to young learners. Visual learning,

images, animations, videos etc. are a powerful tool because it taps on the developmental stage of children and mostly their cognitive needs. With so much visual content on the YouTube kids, it makes sense that it could introduce scientific concepts which kids may otherwise find hard to grasp.

Visual learning is found to significantly improve children's understanding for complex topics by allowing facts to be presented in a more engaging and comprehensible manner. Yang et al. (2024) believes that videos with animation and visuals help teach young children about abstract scientific concepts, such as the water cycle, gravity and simple machines, with higher effectiveness. Bright colors, clear visuals along with fun characters; these animated videos simplify the topics for the kids who find them accessible and fun. The visual approach to this allows children to understand better scientific phenomena through concrete examples of those who are not clearly visible in everyday life.

Moreover, the use of both visual and auditory elements in YouTube Kids videos is significant in supporting the reinforcement of learning. Berna (2023) conducted research proving children can process information better with videos containing visual and audio elements. Using clear simple language with visuals helps children connect what they hear with what they see and learn everything in a more holistic way. As an example, while studying animals, kids can watch animated visualizations of the animals, listen to the sounds they make, and see their features through the provided narration. The multisensory nature of this approach is especially helpful for helping young children who are still developing their language skills and who frequently look to visual cues to make sense of new information.

Quizzes and clickable elements in videos are some of the interactive features that are used to help children enjoy visual learning. These features promote the kids to pause the video and give time for reflection about the concept that they have learnt and improvise the knowledge using the shown examples. Campos and Huang (2023) discovered that when children watched the videos on YouTube, children who interacted with the interactive science videos remembered what they were talking about more effectively than children who watched the non-interactive videos. It also enhances critical thinking and problem-solving skills to ones that are active, participatory, thinking about the material.

YouTube Kids' use of visual learning tools stretches beyond the animation found in videos, for example. YouTube and other digital educational platforms have also jumped at the chance to integrate the use of digital tools as part of the learning experience with interactive whiteboards, simulation, and with augmented reality (AR) features included. Filonenko and Baydak (2023) mentioned that these visual tools not only help to explain complex abstract concepts but also allow children to work with objects and to interact with the learning environment in real time. Taking science experiment video is an example. Video may illustrate the way chemical reaction for example, and after these children would be able to interact to manipulate the elements that they will have learnt from the video and thus reinforcing what they have learnt about cause and effect.

YouTube kids' platform is specifically tailored towards the young learners; it contains interactive features and content that will make the children interested and involved in the study of sciences, math, and language. Moreover, Gupta et al. (2023) showed that YouTube kids presentations are highly engaging and lead to the motivation of students to learn. Interactive story, animated videos, characters and interactive narrative keep students attentive to the content and the most complicated subjects such as science are easier to learn and more pleasant to the student. Gupta et al. (2023) conducted research and found out that videos deconstructed scientific concepts into simplified visual and simple language led to the students having an easier time grasping the concepts that they had difficulties grasping, thus leading to the reflection of a greater interest and engagement in the content.

YouTube Kids videos are impactful in children's cognitive skills and critical thinking. Consistently, studies have shown that educational videos on YouTube Kids retain scientific knowledge in children and help them to develop critical thinking skills by delivering the concept in an easy-to-understand format. Gutiérrez and Huang (2023) studied the cognitive effects of YouTube Kids on young children

developing their early childhood English language proficiency. It revealed that with educational videos children watched on YouTube Kids, there was a deduction in new vocabulary and sentence structures that children understood. The audio visuality of the videos allowed children to relate words with images and, therefore, predisposed them to the experience of abstract language concepts' interpretation. With the help of such a multimodal technique, children could more effectively memorize information and think over the material (Gutiérrez & Huang, 2023).

Those kids who watch YouTube Kids on a regular basis as a means to educate themselves are the ones that have been researched in-depth in a thorough study by Alqahtani et al. (2023), and they have discussed how the cognitive capabilities of these kids develop in general. Regular exposure to quality learning videos is indicated to have significant improvement on cognitive abilities of children such as remembering and being able to reason logically. The study also revealed that children who watched science related videos information were able to easily learn and remember them in comparison to children who asked traditional learning. These results reveal that digital media could promote cognitive development in children as long as they are interesting and involving early learning tools.

Theoretical Framework of the Study

For research to be strong, theoretical framework is seen to be essential for a reliable and valid research but it takes critical thought, a comprehensive literature review, and effective communication to create a good framework (Asma and Khan, 2024). The implementation of the multimedia pedagogical tool such as the use of YouTube Kids in Science education is a drastic change of cognitive process in the context of Pakistani elementary education system where rote learning is an ordinary practice. In this case, with an experimental study like assessing the effects of the YouTube Kids application in Pakistan this framework serves as a mind map.

Cognitive Load Theory (CLT)

In the contemporary experimental research, Cognitive Load Theory (CLT) describes the cognitive processes of interactions of a child in Pakistan with digital content. Over the last 40 years, Cognitive Load Theory (CLT), first coined by Sweller et al. (1998, 2019), has been a pillar in the educational research.

The Cognitive Load Theory (CLT) is established on a set of powerful instructional implications of the nature and constraints of the human cognitive architecture, specifically, the limited capacity of working memory (Atkinson and Shiffrin, 1967; Baddeley, 2012; Cowan, 2014) as cited by Evans et al., (2024). In this model, information load is divided into two different types: intrinsic cognitive load that is part of the complexity of the task and is necessary to learn, and extraneous cognitive load that is rather irrelevant mental work that prevents learning.

The clearest example of extraneous load is the split-attention effect, which is produced by an attempt to make a learner mentally combine the information of different sources, e.g. a diagram and some different text description. The extraneous nature of this process is that the search and integration process is not directly involved in schema formation. On the other hand, delivery of material that is physically integrated in terms of text and graphics works best to maximize the working memory resources to actual understanding and encoding (Sweller et al., 2011). As a result, CLT supports a teaching strategy which is highly guided and structured in order to achieve efficiency in learning (Kirschner et al., 2006; Sweller, 2015).

CLT offers a valid framework of enhancing the efficiency of learning, student performance, and training results by combining concepts of cognitive psychology and instructional design. A huge amount of empirical evidence and multiple meta-analyses support the validity of the theory (Ginns, 2005, 2006; Schroeder & Cenkci, 2018; Barbieri et al., 2023). Fundamentally, CLT ventures into ways the particular

abilities and limitations of the human information-processing system can be utilized to optimize the provision of instructions. With the ability to match the teaching techniques to the natural capabilities and constraints of the working memory, CLT provides invaluable information on how to create learning environments that are both effective and conducive to profound comprehension, as opposed to cognitive overload. The advent of the fast-paced technological advancement has transformed the concept of learning as a non-linear, lifelong process that reaches much further than the conventional classroom environment (Fidalgo & Thormann, 2024). Although this online transformation presents some atypical growth prospects, it equally presents tremendous challenges to the instructional designers and the students. Due to the constant flow of digital stimuli, the learner may become flooded, and it will become more challenging to sort out the distractions and concentrate on the most important information. On the other hand, a profound knowledge of human cognitive architecture offers a map of successful teaching and also considers the actual constraints of a teaching and learning process, like the limited ability of working memory (Baddeley, 1992, 2020) and considers the possible application of cognitive advantages, like the possibility of embodied learning (Barsalou, 2008, 2020), instructional designers can design spaces to suit individual learner properties (Zou et al., 2025).

According to Twabu (2025), germane cognitive load helps in the successful distribution of mental resources to the learning process, which directly promotes the growth of the knowledge base of a student. Instead of being a burden, such a kind of load is critical to cognitive development in that it makes the learner be involved in the profound processing that is needed to construct the schema and synthesize information. Thus, the exploration of the facilitating nature of the modern technologies, such as the YouTube Kids application, has shown some encouraging perspectives of the alleviation of cognitive friction and the increase of learning efficiency greatly.

The Cognitive Load Theory implementation in this study aids the researcher because the intrinsic load is minimized by the You Tube Kids because it divides the load into segments. Rather than a 40-minute lecture, a 3-minute animated video will divide the concept into micro-learning units. The experiment will be able to determine whether this pre-training with the help of the app simplifies the lesson in the classroom. Extraneous Load and the Seductive Detail Effect examined how the majority of children videos are filled with loud music, quick cuts, there are elements in an educational video, and they cause extraneous load, thus distracting the student with the learning goal. In this case only increase in achievement can be made when the content is made in such a way that it reduces these distractions.

The use of germane load and schema construction proved that YouTube Kids relies on the multi-modal learning i.e. visual + audio. The application of the Dual Coding Theory (part of CLT) demonstrated that in Pakistan, the move towards technology learning through You Tube Application indicated that children are accessing educational information at earlier stages (traditional teaching and learning) than ever. YouTube Kids is not only a video platform, but a new technology that can be customized according to the specific cognitive architecture of an elementary student.

Social Cognitive Theory (SCT): Motivation and Modelling

The Social Cognitive Theory (SCT) is an extension of the Social Learning Theory (SLT) developed by Albert Bandura (1960) and which states that learning is a social process based on observation and imitation. Within this paradigm, people learn new behaviours and skills by imitating other members of society, such as their peers, relatives, or media personalities, and reinforcement and punishment are the indirect factors that affect the learning process (Bandura, 1962, 1965; Bandura and Walters, 1977; Gross, 2020).

To achieve success in observational learning, Bandura and Walters (1977) found four critical cognitive and behavioural processes to be involved:

- Attention: The learner should be able to pay full attention to the behaviour of the model.

- Retention: The behaviour that is observed has to be memorised and rehearsed into the mind so that it can be used in future.
- Reproduction: The learner should be physically or mentally able to replicate the action that has been observed.
- Motivation: It has to have a compelling force or a reason why the individual should do the behaviour.

Self-efficacy which is a belief of a person to perform certain response which is the major cause of long-term changes of behaviour. Therefore, Social Cognitive Theory recognizes such self-belief as one of the priorities of educational success. These aspects can be planned in the school-based interventions, and that is, using systematic instructional planning, peer modelling, as well as incorporating facilitating digital ecosystems, including educational media platforms (Lee et al., 2024).

According to Social Cognitive Theory (SCT), human behaviour is a product of a dynamic and reciprocal relationship between three important forces; personal factors, behavioural factors, and environmental influences (Bandura, 1986; Bandura, 2002; Lin, C.P. (2010). According to this paradigm, people are not passive receivers of information, they can voluntarily select and process cognitive information to learn certain behaviours (Linares et al., 2025). Moreover, learning is governed by an integration of internal cognitive processes and external social dynamics. Therefore, an individual's actions are continuously shaped by the interplay between their internal state and their surrounding environment (Linares et al., 2025). Within this system, behaviour is goal-oriented; individuals are naturally inclined to adopt behaviours that are perceived as rewarding and hold significant personal value (Lee et al., 2024).

In the context of current research on YouTube Kids in Pakistan, this social cognitive theory is significant because the concept of Media Modelling highlights that the characters or teachers in the YouTube videos exhibit themselves as the models. Likewise, Attention & Retention shows if the video is well-designed (low cognitive load), the student's Attention is captured, making Retention of the educational content (e.g., math or science facts) much higher. Cultural Motivation demonstrated that in a Pakistani elementary setting, the motivation to replicate what is seen on the screen often comes from the desire for academic success or parental approval. While CLT deals with the "brain," Albert Bandura's SCT deals with the social environment and motivation. These both theories are significant for current study in Pakistan, and applicability of models is justifiable where the role model (the YouTuber or animated character) can influence student engagement.

(a) Observational Learning (Modelling)

Elementary students are in a developmental stage where they learn by imitating others. If a student watches a science experiment video on YouTube Kids, they aren't just memorizing facts; they are observing the process. The model prestige, if the presenter is relatable and enthusiastic, the student's Attention and Retention (the first two stages of SCT) are significantly higher.

(b) Self-Efficacy and Achievement

Self-efficacy is a child's belief in their ability to succeed. Interactive or gamified elements in YouTube Kids content provide small wins when a child understands a video, their self-efficacy increases, leading to higher persistence, in actual school exams achievement.

(c) Triadic Reciprocal Determinism

This is the key element of Social Cognitive Theory, suggesting that learning is an interaction between three forces:

1. Personal: The student's initial interest in the topic.
2. Behavioural: The act of choosing to watch an educational video instead of entertainment.
3. Environmental: The accessibility of the YouTube Kids app and the encouragement from Pakistani parents / teachers.

Mayer's Cognitive Theory of Multimedia Learning (CTML)

Richard Mayer's Cognitive Theory of Multimedia Learning (CTML) is a framework built on the idea that people learn more deeply from words and pictures combined than from words alone. It is essentially the practical application of Cognitive Load Theory specifically for digital and multimedia environments (like videos, apps, or slideshows). Centring on the mechanics of human cognition working memory, schema formation, and the prevention of cognitive overload, these frameworks have advanced Cognitive Load Theory (CLT) and its practical counterpart, Richard E. Mayer's Cognitive Theory of Multimedia Learning (CTML). For more than thirty years, CLT has utilized models of cognitive architecture to develop and validate instructional design hypotheses. By investigating how working memory constraints can be mitigated through the development of domain-specific schemas, the theory explores the direct influence of these processes on a learner's ability to achieve deep comprehension, automate tasks, and solve complex problems (Ginns & Leppink, 2019).

Mayer's theory is based on how the human mind processes information:

(a) Dual-Channel Assumption

Humans have separate channels for processing visual and auditory information.

(b) Limited-Capacity Assumption

Each channel can only process a small amount of information at one time (similar to working memory limits).

(c) Active-Processing Assumption

Learning is an active process of filtering, selecting, organizing, and integrating information based on prior knowledge (Mayer, 2009).

The Goals of Instructional Design & CTML

According to Twabu (2023), describing in Doctoral study, titled "A post-COVID-19 pandemic multimedia framework for teaching and learning in open distance eLearning in South Africa." CTML, a good educational tool like digital media applications helps in achieving three things:

- (a) Reduce Extraneous Processing: Get rid of clutter that doesn't support the lesson.
- (b) Manage Essential Processing: Break down complex topics so they don't overwhelm the brain.
- (c) Application of Generative Processing: Use techniques that encourage the student to make sense of the material.

While justifying the utilization of CTML for current research on YouTube Kids in Pakistan, CTML is the bridge that explains why a specific video impacts a student's achievement. If a video follows the segmenting and personalization principles, it reduces the mental effort (cognitive load) required for the student, allowing them to perform better in school (Chen et al., 2021). Mayer's principles can be applied

to create more effective digital learning experiences by aligning content with how the brain actually processes information.

Since this is an experimental study, particularly in reference to an application, it can be well justified to use the CTML performing as the ground of the CLT and experimental variables of science education pedagogy through You Tube Application at elementary level in the context of Pakistan.

The Multimedia Principle emphasized the fact that students could learn better when words were accompanied by pictures rather than just words. This is the basic hypothesis behind this experimental study. Similarly, The Personalization principle revealed that the content of YouTube Kids frequently employs the conversational style of communication (Hey kids, let's learn together!), as opposed to a lesson. This, according to Social Cognitive Theory, enhances the social presence of the student, which, according to Cognitive Load theory, reduces the mental barrier to learning. Additionally, The Temporal Contiguity Principle has found out that academic performance is greater when the text and the corresponding animation appear in parallel instead of being shown in sequences.

Key Principles for Digital Media Learning

Mayer identified principles to guide designers for innovating the learning styles to achieve more academic performance while engaging the students in learning more attentively as cited by (AlShaikh et al., 2024).

Table 1: Key Principles for Digital Media Learning

Principle	Meaning
Multimedia Principle	People learn better from words and pictures than from words alone.
Coherence Principle	Exclude extraneous words, pictures, and sounds (the "noise")
Modality Principle	Use graphics + narration rather than graphics + on-screen text.
Redundancy Principle	Avoid using narration and on-screen text at the same time for the same content
Segmenting Principle	Break lessons into user-paced "chunks" rather than one long video
Personalization Principle	Use a conversational tone rather than a formal, "robotic" lecture style

According to this framework, the Impact on Student Achievement is not magic, but a product of a particular chain reaction:

- a) Input: YouTube Kids provides optimized multimedia (minimizing Extraneous Load).
- b) Process: The student observes a model Social Cognitive Theory (SCT), engages their dual-processing channels Cognitive Theory of Multimedia Learning (CTML), and constructs a schema Cognitive Load Theory (CLT).
- c) Output: Improved academic performance, higher retention rates, and increased engagement in the elementary classroom.

The usefulness of Mayer's multimedia principles in enhancing learning outcomes has been demonstrated by research. For example, research has shown that when employed properly, coherence, redundancy, and signalling can improve learning (Mayer & Moreno, 2003; Sweller, van Merriënboer, & Paas, 1998). By lessening the cognitive load, the spatial contiguity principle has also been shown to enhance learning results (Mayer & Sims, 1994). By better integrating aural and visual information, temporal contiguity has been shown to improve learning (Mayer & Anderson, 1991). By offering a variety of information outlets, the modality principle has been shown to enhance learning outcomes (Mayer & Moreno, 2003). Similarly, Liman-Kaban (2023) highlighted the integration of CTML and

emphasized that the cognitive theory of multimedia learning stresses that in order for learning to be effective, learners must actively engage with multimedia content, with a focus on content design that optimizes cognitive processing, attention, and knowledge retention (Liman-Kaban, 2023).

Table 2: Tri-Theoretical Framework Summary Presentation

Theory	Key Concept	Application to Your Study (YouTube Kids in Pakistan)
Cognitive Load Theory (CLT)	Working Memory Capacity	Explains how the app's "chunking" of information prevents mental fatigue and "brain overload," allowing Pakistani elementary students to move information into long-term memory.
Social Cognitive Theory (SCT)	Observational Modelling	Explains how the teachers or characters in the videos act as academic role models, increasing student motivation, self-efficacy, and the desire to imitate successful learning behaviours.
Cognitive Theory of Multimedia Learning (CTML)	Dual-Channel Processing	Provides the design rules (e.g., Multimedia and Modality principles) that explain why the combination of animation and narration on YouTube Kids is more effective than traditional rote-learning textbooks.

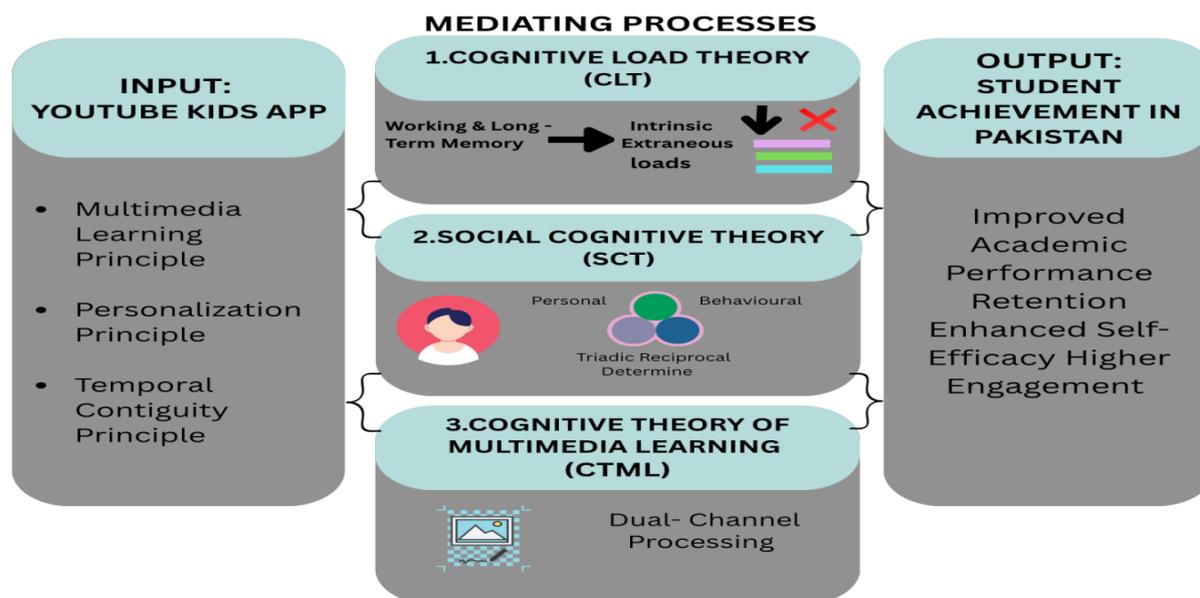


Figure 1: Theoretical Framework of the Study

The thorough literature review revealed that while some studies have combined the theories of CLT and CTML to evaluate how digital media affects students' learning, the majority of the studies were pertinent to You Tube videos and language learning in various contexts that align with CTML. Likewise, a study, “*The Influence of YouTube on First Language Acquisition*” was conducted in Indonesia with theoretical framework of CTML and results showed that Children's vocabulary, pronunciation, and sentence structure can all be improved with the help of YouTube. The study comes to the conclusion that digital media, particularly YouTube, can be a useful tool for early childhood first language acquisition provided parents provide guidance (Hoar et al., 2025).

Another study, “*Impact of Using YouTube on Enhancing Speaking Skills Proficiency Through a Student-Centered*” explored that drawing from constructivist learning theory and the cognitive theory of multimedia learning (CTML), this study confirms YouTube's promising role in promoting engagement and language acquisition. Among the suggestions made by this study is the use of YouTube into the curriculum. The study's findings demonstrate YouTube's promise as a medium for improving speaking skills without possessing the greatest resources while fostering an engaging and student-centered learning environment (Abdulhadi, 2025).

In particular, there was no research on You Tube Kids studying science at the elementary school level in Pakistan using the tri-theoretical framework that is, the integration of CLT, SCT, and CTML. This research aims to fill the theoretical and methodological gap by conducting an experimental study into the efficacy of YouTube Kids’ Science Programming in Pakistan using a CLT-SCT-CTML integrated framework.

RESEARCH METHODOLOGY

Cox et al. (2025) state that the definition of experimental study design is such that the higher standard in quantitative methodology is experimental research design, which is a scientific approach that involves precisely manipulating one or more independent variables (IVs) to ascertain their impact on one or more dependent variables (DVs) while also accounting for unrelated variables.

Krishnan (2025) defines that Experimental designs are categorized based on their structural components, specifically the presence or absence of random assignment and a control group, which directly determines the design's capacity to establish causality (internal validity). These designs are broadly grouped into three categories: True Experimental, Quasi-Experimental and Pre-Experimental.

Westine (2025) highlighted the definition of Quasi Experimental design in such a way, “A quasi-experimental design is defined as an interventional research strategy where the assignment of participants to either the experimental group or the control (comparison) group cannot be achieved through true randomization.” These designs are common in applied settings (like education or public policy) where random assignment is unethical, logistically impossible, or impractical, as groups must remain intact. They maintain manipulation and control groups but substitute random assignment with statistical control.

The general aim of this research design is to offer valid, reliable and actionable information on the role of YouTube Kids application in enhancing the science learning at elementary level. The organization follows strict academic standards and is also flexible to suit the daily routine of the classrooms of the public-schools. It upholds the idea that properly designed digital interventions, in case of pedagogical integration, can considerably enrich the process of learning and its results. Researchers can employ intact groups (for example, Section A as the experimental group and Section B as the control group) in a quasi-experimental design without interfering with the students' natural learning environment. This design shows how the CLT-SCT-CTML paradigm works in the noisy reality of Pakistani schools, where variables like internet stability, teacher intervention, and peer interaction (SCT) cannot be totally sterilized in a lab. Quasi experimental design enables for pre-test/post-test setups to track cognitive growth over time. This type of experimental design is perfect for learning via observation and social context because it preserves the classroom, allowing the researcher to see how students interact with the screen and with one another.

The sampling technique used should be precise to ensure that it reduces the error and bias as well as to maximize the representativeness of the sample to give precise and reliable findings. To create valid statistical inferences, appropriate selection of sample is required. On the other hand, inappropriate sampling methods also cause systematic errors and false inferences directly (Giri, 2024). The sampling method used was purposive sampling where participants are selected with the aim of conducting

research by using certain inclusion criteria that are directly related to the research objective and research questions. Purposive sampling provides several distinct advantages when it comes to various research scenarios. This strategy allows you to rationalize the extrapolation of the results of a carefully selected and guided sample, increasing the strength of in-depth analytical investigation (Shaturaev, 2022). Purposive sampling was suitable in this research study as the researcher was able to choose students who were not just available and accessible but also fit the criteria of the study to participate in a digital intervention constantly.

Experimental Group (Group A): This intact class having 30 students from schools of Rawalpindi city will get the science curriculum through YouTube Kids' Science Programming, which is connected with the CLT-SCT-CTML Framework.

Control Group (Group B): This entire class having 30 students from schools of Rawalpindi city will cover the same science topics using the typical didactic teaching technique (textbook-based).

RESULTS AND DISCUSSIONS

Table 3: Specification of Experimental & Control Group

Category	Experimental Group (YouTube Kids)	Control Group (Traditional)
Number of Schools	2	2
Intact Groups	2 Sections	2 Sections
Estimated Students	30	30
Age Criteria	11-12 years	11-12 years

Table 4: Results of Experimental & Control Group

Variable	Exp. Group (n=30)	Control Group (n=30)	t-value	p-value	Effect Size (d)
Pre-Test Score (0–20)	8.45 ± 2.1	8.10± 1.9	0.67	.504	0.17
Post-Test Score (0–20)	16.30±1.5	12.40± 2.3	7.81	<.001	1.98
Mental Effort (Paas 1–9)	3.20 ±0.8	5.50±1.2	-8.72	<.001	2.25
Self-Efficacy (Likert 1–5)	4.50± 0.5	3.10± 0.7	8.95	<.001	2.31

This hypothesis, “A tri-theoretically integrated (CLT-SCT-CTML) YouTube Kids science intervention has positive impact on lowering elementary children' perceived mental effort while improving learning success and science self-efficacy” is confirmed by the results. The study provides a way through the theoretical and knowledge gap in the Pakistani context as it concludes that the YouTube Kids application acts as an important digital tool in the delivery of the content that plays an active motivational enabler in the Pakistani elementary classroom. The combination of CLT, SCT, and CTML in the framework demonstrates that, under curation and teacher-mediated, digital tools can be used in a systematic approach to managing the cognitive load, at the same time, building an active, participatory and effective learning process.

Learning Gain: The CTML Impact

The post-test findings show that the Experimental Group received significantly higher scores than the Control Group. This exceptionally low p-value $p < .001$ demonstrates that the learning difference was caused by the instructional intervention rather than random chance. According to the Cognitive Theory of Multimedia Learning (CTML), the experimental group profited from Dual-Coding. While the control group most likely received text-heavy teaching, the experimental group processed science concepts using two channels: visual (animations of the solar system/water cycle) and verbal (synchronized

narration). The better scores indicate that students did more than just memorize names; they created a mental model that enabled them to correctly answer transfer questions. This theoretical view agrees with Urhahne et al. (2023) is profoundly covered in the success of this experimental study in the Pakistani setting.

The results of this study show improvement in the experimental group confirming that in cases where the desire to learn is stimulated with the help of YouTube Kids, the resulting cognitive performance is many times higher than the conventional ones. The selected videos in this research help fill in the gap between the theory of textbooks and the actual examples. This is in line with the Cognitive Theory of Multimedia Learning (CTML), as it assists the student to develop mental images that relate the knowledge in schools to the real world. This study validates the theories of Marpanaji et al. (2018) within the specific context of Pakistan in such a way that the YouTube Kids app acted as the intermediary that delivered curated science content. According to the Cognitive Theory of Multimedia Learning (CTML), this media was successful because it used dual channels (visual and auditory) to convey the message more clearly than traditional text.

Cognitive Load: The CLT Impact

Using the modified Paas Scale, the Experimental Group had a lower Mental Effort score despite studying more complex information. This is a critical finding in Cognitive Load Theory (CLT). It demonstrates that video design successfully reduced Seductive Details (distractions) and adhered to the Coherence Principle. Making the science content easier to digest and freed up brain power for Germane Load, the real task of learning and storing information in long-term memory. In the Pakistani context, this implies that young students learn better when digital content is chunked and simplified, rather than simply entertaining. These findings are supported by research by Trianisa and Wahyuni (2024) which indicates that science video media is useful in improving the understanding and recall of science concepts in middle school students. Likewise, the study by Khan et al. (2024) demonstrated that students who were taught with the help of YouTube educational resources had a more appropriate conceptual knowledge and verbal thinking skills. Moreover, the study argues that the guided content of science education was also successful in regulating the cognitive load of the students by diminishing the extraneous distractions and enhancing the cognitive load of schema construction, which is the fundamental principle of Cognitive Load Theory (CLT).

Self-Efficacy: The SCT Impact

The increase in Self-Efficacy ratings among students viewing YouTube Kids demonstrates the efficacy of Social Cognitive Theory (SCT). The characters in the scientific videos served as models. For Pakistani kids, watching a relatable and friendly digital guide do science experiments alleviated their science anxiety. As students witnessed the digital model's success, their confidence in their own abilities to execute similar tasks improved. This shows that young learners value the social side of e-learning as much as the technological aspect. The film did more than just teach them about science; it also convinced them that they have the potential to become scientists. Feldon et al. (2019) show advocacy for these findings that positive experiences decrease the perceived price of subsequent work. The higher achievement gains of experimental group probably increased the self-efficacy of students, as they are more prone to deal with complex scientific materials in future since they are no longer convinced that science is a costly subject. Therefore, the social context of the classroom influences achievement goals. Since (Butera et al., 2024) often research the social utility of goals, this connects perfectly to this observation of student collaboration.

In the Pakistani school context, students often face pressure to perform for social status. However, this study shows that using YouTube Kids creates a mastery-focused environment where the value is placed on understanding the science, not just the social rank (Butera et al., 2024). By shifting from a teacher-centered lecture (which highlights who is smartest) to a student-centered digital medium, the researcher

reduced the harmful performance-avoidance pressures, allowing for the 33.15-point achievement gain. This historical and sociological perspective by (Butera et al., 2024) adds weight to this study's focus on the Pakistani educational context in science education.

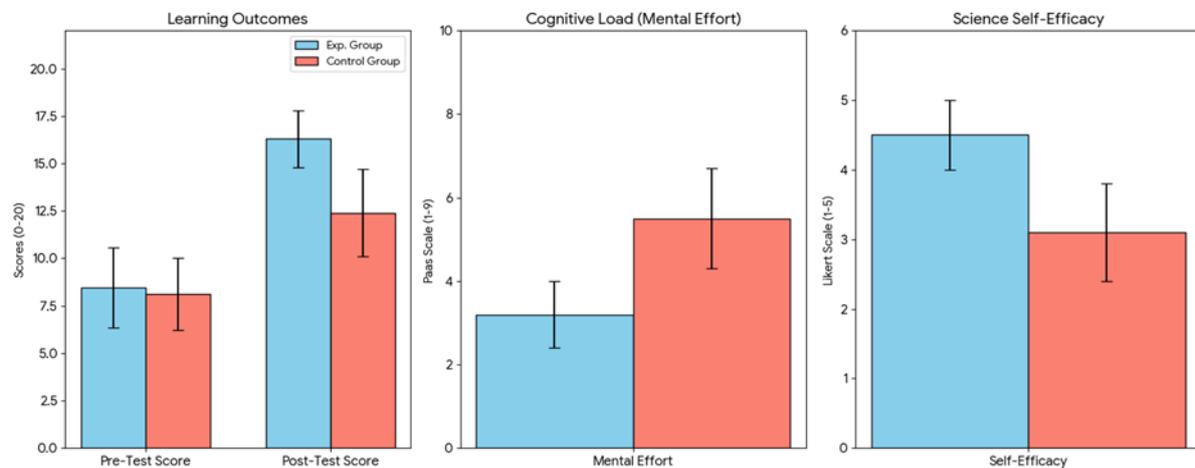


Figure 2: Comparison of Experimental and Control Group

Learning Outcomes (CTML Integration)

In the first panel, the Experimental Group had a considerably higher Post-Test score ($M = 16.30$) than the Control Group, although starting at a similar baseline ($M = 12.40$). According to the Cognitive Theory of Multimedia Learning (CTML), better knowledge retention resulted from the video's optimal signalling and segmentation. This CTML implies the findings that present a clear explanation behind the achievement gain of 16.30 points in this experimental group which is similar to the interpretation of Evans et al. (2024). Pakistani textbooks on traditional science usually isolate diagrams and have long Urdu or English descriptions, which compel students to deal with split-attention. The YouTube Kids videos used in the present experimental study inherently combine the audio narration and the synchronized images, which considerably decreases the extraneous cognitive load. The elementary level of science may be complicated. The intrinsic load was controlled via the application of segmenting and signaling principles of a properly designed digital media, therefore, enabling the content to be more accessible to Class 7th students. Research supports the Multimedia Learning Theory by Mayer because students learn better when they get visual and audio inputs instead of just text. Using both words and images simplifies how working memory handles information and makes better learning processes at long-term memory. The theory remains empirically proven, and the study findings prove its effectiveness in primary science education by using digital videos as highlighted by (Shen, 2023).

Cognitive Load (CLT Integration)

The second panel shows that the Experimental Group's Mental Effort ($M = 3.20$) was much lower than the Control Group's ($M = 5.50$). A lower Paas Scale score shows that the tri-theoretical design was successful in lowering Extraneous Cognitive Load, which enables pupils to comprehend difficult scientific ideas without using up too much working memory. The findings of current study are aligned with Opara et al. (2025) findings that backed up the experiment when they proved that YouTube-based learning led to better student results in physics and advanced scientific practices. When students watched scientific demonstrations in videos, they learned abstract concepts better according to research results.

Science Self-Efficacy (SCT Integration)

Students in the Experimental Group showed a strong rise in self-efficacy ($M = 4.50$ on a 5-point scale) in the third panel. This supports the framework's Social Cognitive Theory (SCT) component: the YouTube host's Symbolic Modelling successfully increased the pupils' self-confidence in their scientific aptitude. The implementation of SCT in this Quasi Experimental study focuses on the Observational Learning and Modelling and justifies that educational video on the YouTube Kids platform featured presenters, animated characters, and peers who acted as academic role models. Through observation of these models successfully perform science experiments and explain complex concepts, students in the experimental group engaged in observational learning, which reduced their anxiety toward difficult subjects.

The Science Achievement Test (SAT) was divided into two areas to evaluate the efficacy of YouTube Kids' Science Programming using the CTML (Cognitive Theory of Multimedia Learning) lens: retention (remembering facts) and transfer (applying concepts).

Table 5: Science Achievement Test' score category

Score Category	Performance Indicator	Framework Presentation
High Retention / Low Transfer	Students remember names or labels but unable to apply them.	Shows high Extraneous Load; the video was flashy but didn't present a mental model.
High Retention / High Transfer	Students remember facts and become able to solve problems.	Success indicates the CTML principles (Dual-Coding) working effectively.
Low Retention / Low Transfer	Students struggled to remember simple names from the video.	Cognitive Overload shows that the video was likely too fast or the language was too complex for the child's working memory.

The Illusion of Learning

A breakdown in deep learning indicated when students do poorly on transfer tasks despite having good retention scores. This happens when pupils successfully choose and arrange information in sensory memory but are unable to combine it into a cohesive mental model in long-term memory, according to the CTML framework. A high level of extraneous cognitive load is frequently indicated by this result. It's possible that the seductively detailed YouTube videos used lively animations or upbeat music to capture the kids' interest (Retention) but hinder the mental heavy lifting needed for problem-solving (Transfer). This serves as a warning to teachers in Pakistani classrooms that engagement does not necessarily translate into understanding. The results have similarity with the study of Orús et al. (2016) as they discovered students who made and viewed YouTube-style videos in physics learned better and developed a greater understanding in the subject material.

Optimal Result Zone

The effective use of Dual-Coding Theory is exemplified by students who perform exceptionally well in both fact recall and conceptual application. By flawlessly synchronizing the visuals and narrative on YouTube Kids, this group exemplifies how the Spatial and Temporal Contiguity Principles were followed, enabling the child's brain to create a mental bridge between the two. The Germane Load sweet spot implies that generative processing is possible for Pakistan's young learners through science programming that employs narrated, easily understood animations. This study validates the theories of Marpanaji et al. (2018) within the specific context of Pakistan in such a way that the YouTube Kids app

acted as the intermediary that delivered curated science content. In order to answer "What if?" questions, the student has created a logical map of the Water Cycle and is not merely a passive observer.

The Overload Scenario

This theoretical view agrees with Urhahne et al. (2023) is profoundly covered in the success of this experimental study in the Pakistani setting; Failure in both areas signifies the instructional bridge's complete collapse. A classic example of cognitive overload is this situation. The intricacy of the science subject (Intrinsic Load) and possibly a rapid-fire English or Urdu narration (Extraneous Load) surpassed the children's Working Memory Capacity, according to Cognitive Load Theory (CLT). Research conducted by Daeli (2024) indicates that learning videos lasting five to fifteen minutes enable students to stay focused and learn better, which matches the time spent per video throughout this study. A 7-year-old in an urban or rural Pakistani school will experience the split-attention effect if the YouTube Teacher talks too quickly or uses too many labels at once, depriving the pupil of any useful information.

CONCLUSIONS

This section explains in detail how the YouTube Kids interface especially facilitates the variables within CLT-SCT-CTML framework in order to offer a thorough discussion of these findings. The integration of carefully chosen YouTube Kids has replaced the chalkboard as the classroom for Pakistan's Alpha Generation. The Multimedia Principle is emphasized by the study's statistical significance ($p < .001$). While static textbooks, which cause a split-attention effect as learners switch between text and diagrams, are frequently used in traditional Pakistani schools, YouTube Kids scientific programming offers Temporal Contiguity. Students in this experimental group were able to shift their attention from search-and-match to creating a mental model of the water cycle by watching movies that coordinated the splash of rain with the word term Precipitation. The fall in Mental Effort ratings demonstrates that the YouTube Kids environment, when selected by the researcher, serves as a Cognitive Filter.

YouTube Kids eliminates seductive details such as irrelevant ads, recommended clickbait, and comment areas, in contrast to the regular YouTube app. The instructional design took into consideration the Pakistani Alpha Generation's working memory restrictions by utilizing high-coherence movies, which have clean animation and vocabulary that is chunked into 5-minute chunks. Because they weren't distracted by noise, students' attention could be diverted to Germane Load, which is the real encoding of scientific information. The increase in self-efficacy implies that YouTube Kids videos' personalization fulfills an essential social purpose. Many Pakistani students may find science to be abstract. Nonetheless, YouTube Kids frequently has enthusiastic, diverse hosts (social models).

Students go through social modeling when they see a model on screen carry out an experiment, like creating a "volcano" or recognizing planets. These kids increased self-efficacy scores show that they have changed their perspective from science is a hard book subject to "I can do this experiment myself." The foundation of social cognitive theory is this internal change. The study comes to the conclusion that YouTube Kids serves as a cognitive scaffold rather than a substitute for the teacher. This technology-driven pedagogy helps Pakistan's Generation Alpha, who were raised in a world of touch-screen literacy, bridge the gap between their internal cognitive architecture and the external digital world, leading to deeper and more valid conceptual learning.

RECOMMENDATIONS

Pedagogy & Curriculum Design

Dual-Coded Multimedia should replace textbook-based instruction in Generation Alpha curricula. YouTube Kids playlists that adhere to the Spatial and Temporal Contiguity Principles which guarantee that labels and animations appear together should be created to go along with science modules. Complex

science subjects, like photosynthesis, should be taught using three-to-five-minute micro-videos in order to reduce intrinsic cognitive load. In addition to preventing working memory fatigue, this enables the segmenting effect, which enables kids to digest knowledge in manageable portions before going on to the next.

Classroom Integration of YouTube Kids

The Timer and Pause functions on YouTube Kids should be used by educators to perform mid-video check-ins. Based on the evidence, teachers should choose films with relevant characters or child hosts since they demonstrate high levels of self-efficacy through social modeling. In order to strengthen the Social Cognitive Theory (SCT) loop of observation and imitation, teachers should urge their students to mimic the host during science demonstrations after they have watched.

Policy and Infrastructure

Digital classrooms should have a minimal hardware standard defined by the Ministry of Education. Along with a screen, this also comes with top-notch speakers. The advantages of multimedia are negated by a "split-attention" barrier caused by poor sound quality in a noisy classroom, as CTML mostly depends on the auditory channel. Policymakers should collaborate with internet service providers (ISPs) to make data-free particular educational YouTube Kids channels in order to close the digital divide and guarantee that pupils from lower socioeconomic backgrounds may use these very effective learning tools.

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