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Title:

AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

Submitted by:

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Declaration:

I, Mariyah Ambreen, Student Number: EIU241340, hereby declare that this thesis, titled "AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Ages (6-12), in Speech-Motor Planning and Phonological Working Memory Domains" is my own work and represents original research conducted after my registration for the Professional Doctorate in Special Education at European International University.

To the best of my knowledge, this work contains no material previously published or written by another person, except where due acknowledgement has been made in the text.

I confirm that all sources used have been properly cited and referenced, and that this work has not been submitted for any other degree or qualification.

I have read and adhered to the University's research ethics guidelines, taking responsibility for ethical conduct and participant rights.

Date: January 20, 2026.

Signature:

Approved by:

Supervisor Name: Dr. Gargi Chakraborty.

Signature: _______________

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Abstract:

In Middle East countries, specifically KSA, students with Childhood Apraxia of Speech (CAS) are barred at schools that claim to be inclusive. This practice has produced a wide gap in education sector, as the option left for students are either homeschooling or unschooling. Lack of awareness, limited knowledge and training, and reluctance in using modified Artificial Intelligence (AI) tools in practice, hinder the success of students. The main objective of this qualitative study is to explore the importance of AI-based teaching methods for children with Apraxia of Speech aged 6-12. The study describes how special needs educators, therapists, and parents perceive the integration of AI-based tools, into intervention for children with in school settings or at home, relative to their experiences with traditional tabletop therapies like pointing and imitating sounds. Data are generated from in-depth interviews with parents, special educators, and Occupational and Speech Language therapists, then thematically analyzed through the lens of Cognitivism and Bloom's Taxonomy. The analysis reveals that various strategies and programs are available to make these children more adept to expressive and receptive language. Proper training of educators can bring drastic changes to allow coping with challenges in educating students with CAS. AI tools have brought a revolution in speech development and special educational needs, various programs in different languages are available to fill the gap. Moreover, implementing strategies like DTTC (Dynamic tactile and temporal cues) help students achieve their milestone. The study reveals to create an inclusive AI based educational environment for all children with learning disabilities. Children with CAS can achieve milestones with interventions. Introducing AI assisted proprioceptive activities, such as VR obstacle courses, sensory inputs like AI powered sensory calming stations in a classroom setting enhance the cognitive ability of children with Apraxia of Speech. Integrating these physical programs with education can bring a positive learning environment. Findings suggest educators, therapists and parents need to understand the importance of time saving, repetitive practice and excellence in achieving educational milestones in a student by automatically generated targeted goals set by the programs and applications. Rigorous practice, actual cue and timely correction empowered by AI can lead to improvement of language disorders.

Keywords: CAS, special educational needs, AI-based learning, inclusion, language disorders.

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Chapter 01: Introduction: AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

Childhood Apraxia of Speech (CAS) is one of the rarest neurological language disorders occurring in about 1 to 2 per 1,000 children with special needs (Forrest, 2003). It is often misdiagnosed as speech delay if handled unprofessionally. Limited knowledge and consciousness about CAS have resulted in significant gap for the diagnosis and interventions needed by children with CAS aged (6-12). Such children are barred at schools that claim to be inclusive. Martikainen (2011) and Dodd (2018) have mentioned that this practice has produced a wide gap in education sector, as the option left for students with CAS are either homeschooling or unschooling because of time limitation in completing academic year as well as, limited trained staff. Artificial intelligence (AI) has revolutionized the world. Several AI applications and programs are launched to help children with CAS to overcome and improve their speech motor planning and phonological working memory skills in shorter span of time with effectiveness and accuracy (Case, 2024; Teams, 2025; Furlong, 2017). However, unawareness, limited knowledge and training, and reluctance in using modified AI tools in practice by therapists and educators hinder the success of students. Most of the evidence-based interventions to date use the traditional medium of tabletop materials (e.g., board games, physical objects, and/or pictures). However, there is an increasing interest in use of digital media as suggested by (McCormack, 2017; Nanjundaswamy, 2018). AI based methodologies based on educational theories, such as, Cognitivism by Jean Piaget, Bloom's Taxonomy framework by Benjamin Bloom, and principle of Motor learning embedded in Dynamic temporal and tactile cues (DTTC) can bring promising achievements in targets set for CAS interventions. However, limited understanding of the condition, uncertain prevalence, comprehensive and complex needs approach and access to the applications and programs make it difficult to practice. Limited research has been done in the field of CAS aged 6-12. Numerous apps and programs need to be developed in different languages to overcome language barrier (Bennett, 2025). Hence, the indispensable requirement is to understand and include AI based teaching interventions that will be time saving, offer repetitive practice and results in excellence in education. Rigorous practice, actual cue and timely correction empowered by AI can lead to improvement of language disorders.

Schenk (2023) explains Occupational therapy significant role in motor planning by addressing underlying skills, such as improving motor skills which involve the strength and coordination of the mouth, tongue, and jaw muscles, crucial for articulation. Also, sensory processing by improving the ability to better focus on and process auditory and tactile information. And executive functions like planning, organization and sequencing which are crucial for speech development

To facilitate the process, different Generative AI applications and programs like Imago Rehab, Apraxia Ville, Apraxia Cards, Koro, Articulation station hive, and Arrowsmith Program etc. help the child to get to know the exact pronunciation with the accurate number of trials for each stimulus, backed by enhancing cognitive efficiency, concept building, sensory regulation, number facility, and cognitive processing speed (Chinmoy, 2024). That results in overall improvement in expressing language. These tools can help with speech-motor planning by offering real-time modeling, feedback, and plenty of practice opportunities. They also work on cognitive skills like phonological working memory, number fluency, processing speed, and concept formation, all of which play a big role in developing expressive language (Zahna, 2023).

Rigorous practice, actual cue and timely correction lead to improvement of Childhood Apraxia. However, lack of awareness, limited knowledge and training, and reluctance in using modified tools in practice hinder the use of AI for benefitting the client (Suh, 2024; Kelly, 2023).

Educators, therapists and parents are required to understand the importance of time saving, repetitive practice and excellence in achieving speech milestones in a client by automatically generated targeted goals set by the programs and Apps (Utepbayeva, 2024).

1.1 Research Objectives:

1. To explore the perceptions of teachers, parents, and speech therapists about the role of AI-based interventions in supporting cognitive abilities, such as phonological working memory and speech-motor planning, in children with Childhood Apraxia of Speech (CAS) aged 6–12.

2. To understand how teachers, parents, and speech therapists perceive the influence of AI-based interventions on communication development, particularly oral vocabulary and expressive language, in children with CAS aged 6–12.

3. To describe how special needs educators, speech therapists, occupational therapists, and parents perceive the integration of AI-based tools into therapy and educational interventions for children with CAS aged 6–12 at home and in school settings, relative to their experiences with traditional tabletop imitation therapies, as explored through interviews and observations.

1.2 Research Questions:

1. How do teachers, parents, and therapists perceive the role of AI-based interventions in supporting cognitive abilities (e.g. phonological working memory, speech motor planning) in children with CAS aged 6–12?
2. How do teachers, parents, and speech therapists perceive the influence of AI-based interventions in enhancing communication development, particularly oral vocabulary and expressive language in children with CAS?
3. How do special needs educators, speech-therapists, occupational therapists, and parents describe the integration of AI-based tools, into interventions for children aged 6-12 with CAS at home and in school settings, relative to their experiences with traditional therapies like tabletop imitation sessions, as explored through interviews and observations?

This qualitative study constructs an aim to explore and interpret the perceptions, experiences and processes of special needs educators, therapists and parents using AI-based teaching based on the researcher's experience faced because of in availability of interventions for children with CAS in improving speech-motor planning and phonological working memory academically and performance of activities of daily living (ADL), hence providing evidence based strategies with AI tools to incorporate in learning settings which are thematically analyzed through the lens of cognitivism, principles of motor planning and Bloom's Taxonomy.

1.3 Definition of Key terms:

Speech motor planning: the ability to come up with an idea, plan how to say or express that idea and then finally say it.

Phonological working memory: brain's temporary store for holding and repeating sounds.

Sensory processing: ability to take information through our senses, interpret that information and organize a meaningful response.

Chapter 02: Literature Review: AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

There has been a very little academic research on children with Apraxia of speech aged 6-12 and interventions provided to them in regions like Saudi Arabia, Middle East countries (Khoja, 2018; Alasiri, 2024), and under developing countries like Pakistan. Children with language disorders, such as CAS are barred to be enrolled in schools claiming to be inclusive, due to shortage of interventions and trained staff (Elsahar, 2019). There are several AI apps and applications which can be integrated in speech and integrated language literacy, hence providing a proven intervention for children with Apraxia of speech aged (6-12) (Amery, 2022; Bhardwaj, 2024). Thus, this review will draw upon literature concerning a diverse range of AI tools and strategies which shaped researcher's ideas of possible interventions for children with Apraxia of speech aged 6-12, in places like Saudi Arabia and Pakistan.

2.1 Historical Context and Background.

Childhood apraxia of speech (CAS) is a neurological motor speech disorder that often results in severely impaired speech intelligibility and has historically been resistant to traditional intervention approaches (ASHA, 2007). It is a rare speech sound disorder that occurs in approximately 1 to 2 children per every 1,000 children (Shriberg, 1997).

Guyette (1981) mentioned that there has been controversy regarding CAS as a separate diagnostic category, and was once described as a "label in search of a population". Forrest (2003) claimed that there was a lack of consensus on diagnostic features of CAS, and clinicians did not have the necessary tools to identify, evaluate, and/or treat this disorder in children.

In 2007, the American Speech-Language-Hearing Association (ASHA) released a Position Statement that recognized CAS as a distinct speech sound disorder and provided a comprehensive consensus feature of this disorder. Three consensus features of CAS are identified:

(1) impaired ability to transition speech movements between sounds and syllables.

(2) inconsistent errors on repeated productions of sounds, syllables, and words.

(3) impaired prosody, specifically using inappropriate stress patterns and intonation when speaking (Stringer, 2024).

Hammer (2009) describes a school setting for students with apraxia of speech can benefit from individualized accommodations and supports tailored to their specific needs. These include preferential seating, extra time for assignments, modified testing formats, and assistive technology, such as use of AI generated programs like Arrowsmith and applications for CAS like Speech Blubs. Etc. (McCormack, 2017; Cera, 2025). Creating a supportive and understanding environment with the help of AI interventions, where students feel comfortable communicating and receiving feedback, is crucial for their academic and social-emotional well-being (Martikainen, 2011; Dodd, 2018).

2.2 Childhood Apraxia of Speech- a neurological disorder:

Neurological disorders are conditions affecting the brain, spinal cord and nerves, leading to a wide range of symptoms of movement inability, sensation limitations and communication and cognition inabilities (Stringer, 2024). Similar patterns are observed in children with CAS, having difficulty and inability in moving lips, jaws and mouth to articulate a word (Stringer, 2024).

2.2.1 Neurological disorders:

A neurologic disorder is caused by a dysfunction in the brain or nervous system (i.e. spinal cord and nerves). This dysfunction can result in physical and psychological symptoms (Hopkins, 2025).

The brain is self-organizing. It selects information to forward its growth. It also adapts to the environment (Hopkins, 2025). An individual experiences their environment through: Touch, Smell, Sight, Taste, Hearing. These senses produce connections in the brain.

Neurologic disorders involve the brain, spinal column, and nerves. Symptoms depend on where damage occurs. Affected areas may control: Movement, Sensation, Communication, Vision, Hearing, Thinking, Emotion (Shriberg, 1997).

2.2.2 Childhood Apraxia of Speech:

Childhood apraxia of speech (CAS) is a rare neurological childhood speech sound disorder, sometimes can be motor neurological disease, in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits (e.g. abnormal reflexes, abnormal tone) (Forrest, 2003). CAS may occur as a result of known neurological impairment, in association with complex neurobehavioral disorders of known and unknown origin, or as an idiopathic neurogenic speech sound disorder. The core impairment in planning and/or programming spatiotemporal parameters of movement sequences results in errors in speech sound production and prosody (Hair, 2018; Bennett, 2025).

Children with CAS have trouble controlling their lips, jaws and tongues when speaking. In CAS, planning for speech movement by the brain is compromised. The brain finds difficulty to direct the speech muscles to properly move needed for speech. The speech muscles aren't weak, but the muscles don't form words the right way, hence accurate sounds and rhythm is affected (Forrest, 2003; Shriberg, 2017).

Bennett (2025) argues Speech therapy is needed to treat CAS. During speech therapy, a speech-language pathologist teaches the child to practice the correct way to say words, syllables and phrases, which is achievable by AI tools, but limited literature is available to incorporate AI tools like speech blubs in practice.

2.2.3 Symptoms of CAS*:*

Hammer (2009) explains children with childhood apraxia of speech (CAS) have a range of varying speech and language symptoms depending on a child's age and the severity of the speech problems. Such as less babbling and fewer vocal sounds, using a limited number of consonants and vowels and often leaving out sounds when speaking that makes the speech hard to understand.

These symptoms are usually noticed between ages 18 months and 2 years. Symptoms at this age may indicate suspected CAS. Suspected CAS means a child may potentially have this speech disorder. The child's speech development should be watched to determine if therapy should begin (Teams, 2025).

Children with AOS can also have language problems, such as reduced vocabulary or trouble with word order.

Some characteristics of CAS differentiated from other types of speech disorders are as below:

- Difficultly in moving smoothly from one sound, syllable or word to another.
- Groping movements with the jaw, lips or tongue to try to make the correct movement for speech sounds.
- Vowel distortions, such as trying to use the correct vowel but saying it incorrectly.
- Using the wrong stress in a word.
- Using equal emphasis on all syllables.
- Separation of syllables, such as putting a pause or gap between syllables.

- Inconsistency, such as making different errors when trying to say the same word a second time.
- Having a hard time imitating simple word.
- Voicing errors (Shriberg, 2017; Teams, 2025).

However, 75 % of the cases are misdiagnosed as CAS is difficult and challenging to be diagnosed (Barnett, 2015). It's a slow process and needs rigorous training, knowledge, flexibility and consciousness to develop strategies that works for CAS aged 6-12. Little literature is available about AI applications that can enhance the cognition and understandings of the children aged 6-12, with appropriate usage by educators, therapists and caregivers training is required (Stringer, 2024).

2.2.4 Diagnosis and treatment*:*

Diagnosis involves assessing speech characteristics and ruling out other potential causes. Treatment primarily focuses on intensive, individualized speech therapy, often utilizing techniques like Rapid Syllable Transition Treatment (ReST) or Dynamic Temporal and Tactile Cuing (DTTC). Alternative communication methods like sign language or augmentative and alternative communication (AAC) devices are included but not widely practiced (Alasiri, 2024; Pyke, 2025). This reveals a lot of time requirement and limited competent professionals available to do the task, that eventually slows down or halts the process for suspected children with Apraxia of Speech.

2.2.5 Educational and therapeutic challenges:

Despite advancement in the field of cognition and speech, nearly 75 percent of the cases are misdiagnosed or not diagnosed (Shriberg LD, 2017). The incompetence of speech pathologist, unfamiliarity of using protocols correctly and lack of flexibility in practice brings more cases. Negligence towards this area of disability has left a gap to include these children aged 6-12 in classroom settings. They are often left alone or unattended because of limited or no verbal communication (Khoja, 2018).

2.2.6 Intervention strategies for educators:

Some facts as shared by Amy W. Anzilotti (2025) such as IEPs, tutors familiar with motor learning techniques, use of assistive devices which are practiced in inclusive school settings.

However, Hammer (2009) suggested students with CAS aged (6-12) are neglected in the education field because its full scope is not recognized, rigidity in following IEPs leading to narrow focus on language as a communication channel in educational planning rather than addressing the broader motor planning, cognitive, and sensory issues that impact academic performance, it is backed by Alasiri (2024). The condition's prevalence is uncertain and its causes are not fully understood. Moreover, the necessary intensive speech therapy is costly, and the condition requires significant educational accommodations for motor skills, social-emotional well-being, and literacy, which are often overlooked in educational settings. Short courses should be introduced to train the staff to deal with children aged 6-12 with CAS, this can be potentially achieved by incorporating AI applications like AAC for significant expressive language (Colenbrander, 2010; Stoeckel, 2021).

2.3 AI based apps on principles of DTTC.

Alam (2023) & Pace (2023) explain how apps can build through the lens of Cognitivism by Piaget and Bloom's Taxonomy; ideas can by generated by bringing up learning to create a schema by presenting it in a digital environment and recording the responses digitally. Dynamic Temporal and Tactile Cueing (DTTC) is a treatment approach designed for children with Apraxia of Speech; it is well known approach for children older than 3 years of age. The technique incorporates rigorous practice with sensory inputs depending upon the need of an individual child aged above 3. It has shown proven improvement and positive results in children with CAS aged 6-12 (Grigos, 2024).

2.3.1 AI applications: revolutionizing Education:

Artificial Intelligence (AI) applications for students with speech delays use technologies like AI-powered speech recognition, natural language processing (NLP), and machine learning to provide personalized therapy and assistive tools. Connectivism emphasizes on the importance of incorporating and updating the existing knowledge in a digital aur computerized way, hence providing wider range of usage (Siemens, 2005). These applications can offer real-time feedback on pronunciation, generate tailored practice exercises, help with early diagnosis, and support communication through enhanced Augmentative and Alternative Communication (AAC) devices. AI tools also assist educators and parents by analyzing speech patterns, providing data-driven insights, recommending personalized strategies, and creating accessible educational materials (Abrams, 2025). For students AI applications help in providing personalized practice and feedbacks, tailored learning and exercises, Improved communication and social skills development. For therapists and educators AI has proved to assist in enhanced diagnosis and assessments, data-driven interventions, resource creation and support for special needs (Bhardwaj, 2024; Green, 2024; Vaughn, 2024). However, Bhardwaj (2024) highlights limited language options available for these apps and programs.

2.3.2 Phygital games for sensory inputs*:*

Bloom's Taxonomy level 'apply' and 'analyze' explain learning by doing, based in experiential learning. This results problem solving, critical thinking and real-world connections by focusing on the whole child that promotes active student-centered learning (Singh, 2025). Sensory integration based on cognitivism, plays a role of backbone in interventions needed for children with apraxia aged 6-12. Like all children, they feel more learnable and excited when games/ plays incorporating sensory input, such as, touch, balance and proprioception. Augmented reality (AR) based games bring a more positive change in a child's speech as they can experience the sense their body is seeking. Interactive obstacles courses, smart playgrounds can incorporate vestibular and proprioception. For example, a smart swing can track how high a child swings, and that data can be used to control a projection, making it appear that the child is flying through a digital landscape. Motion sensors and projected graphics can track players' movements, offer real-time feedback, and introduce creative challenges (Banik, 2021; Batat, 2022; Hyes, 2025).

Tactile games focus on the sense of touch through textured and weighted objects. Digital sensory bins combine traditional sensory play with a digital layer. A bin filled with rice or sand can be equipped with sensors that react to a child's interaction, creating a projection of rippling water, digital fish, or other visual effects when they touch or move the physical contents. (Matt, 2023; Skalen, 2023; Cristina, 2024).

Augmented reality (AR) enhances the real world by overlaying digital information, such as images, sounds, and other stimuli, onto a user's physical environment in real-time. AR hunting games for children with CAS aged 6-12 can be set where players explore a physical space while using a tablet or smartphone to interact with AR elements. An AR scavenger hunt, for instance, might require players to find physical objects and then scan them to reveal a digital puzzle or animation (Arif, 2021; Hyes, 2025).

Literature shows the positive outcome of these phygital games, however, how can they be installed and used in educational setup is not explained.

2.3.3 DTTC- a strategy based on Principles of Motor Planning Theory:

Dynamic Temporal and Tactile cueing (DTTC) by Dr. Edythe A. Strand, Ph.D., CCC-SLP is an approach used for CAS aged 6-12. The approach is based on the principles of motor learning theory that enables a learner to learn speech by pre- practicing, frequent number of trials per target (typically 50), use of variable random and blocked practice, complex movements that enables a learner to sense the target, and constant feedbacks that turns into gradual and then delayed feedbacks (Bislick, 2012; Wambaugh, 2013; Park, 2016; Case, 2024).

DTTC should be applied with flexibility and as per the learner's need (Case, 2024), however, sticking to the rules don't bring out the required results always. Rigidity shown by teachers, therapists and parents blocks the wonders this technique can bring in treating CAS.

2.3.4 AI applications and programs based on DTTC:

There are various applications based on DTTC approach for children with Apraxia of Speech aged 6-12 years, such as, **Practice picture sound card, Apraxia Ville, Apraxia rainbow bee, Arrowsmith Program, Speech blubs.** These applications make the target accessible for multiple trials, in less time and more accurate data is generated. Each program is designed to alter as per the client/learner's need and hence, generates accurate results (Donaldson,2023; Case,2024).

2.3.5 Cost, Reliability, accessibility and training challenges of implementing AI apps:

AI based technology has helped children with apraxia of speech aged 6-12 years. However, rigorous training of the instructor, familiarity with the application's modes, and accessibility to all is still a challenge. These programs are at the expensive usually not covered under insurance; hence, all parents/ institutes cannot provide them. Most of the therapists, educators and caregivers are reluctant to use these applications as they are not well trained or qualified. Reliability of the developer is another challenge to cope with. Unavailability in different languages brings limitation in the use of AI applications and programs (Zisk,2019; Donaldson, 2023; Koerner,2023).

2.4 AI based teaching for enhancing cognitive efficiency:

Jean Piaget proposes in cognitivism that learning is an active, mental process built on prior understanding through hands on activities and collaborations. Teachers act as guides, promoting inquiry and critical thinking (McLeod, 2025). That leads to cognitive efficiency (CE), generally defined as qualitative increases in knowledge that are achieved in relation to the time and effort invested in acquisition of knowledge. It explains the relationship between the cognitive inputs (effort, resources) and cognitive outputs (performance, knowledge gained), Targeting maximum results with minimal mental strain/work. CAS is a motor speech disorder, and is associated with cognitive differences, especially working memory deficits and executive functioning challenges. These cognitive differences, particularly in children aged 6-12 with CAS, can affect speech production and overall communication ability hence, altering the cognitive efficiency (Hoffmann, 2019; Zaitoun, 2024).

CAS is an inability to make a voluntary and organized movement of mouth, jaw and tongue with a specific purpose, depend on a series of cognitive functions that allow planning, coordinating and executing these movements to produce a sound and articulate the word. Understanding the cognitive areas involved is crucial to design an effective cognitive intervention in CAS. Such as, attention enables the child to focus on the motor task to be performed, ensuring the correct execution of coordinated movements of mouth, jaw and tongue to produce the sound. Procedural and working memory are essential for storing and retrieving sequences of learned movements and for handling information during task execution. Spatial perception is key to orienting the body and objects in space, crucial for the execution of precise facial movements to produce a sound. Verbal comprehension and association between words and actions are critical, where following verbal instructions is required by planning the instructions given. Executive functions allow planning, sequencing, and coordinate the actions necessary to perform a complex motor task, like saying out a word. Motivation influences the patient's willingness to engage in motor activities, while emotions can modulate attention and memory, affecting task performance (McKechnie, 2018; Schenk, 2023; Zaitoun, 2024).

2.4.1 Improving Speech Production using AI:

AI is primarily improving speech production and language, technologies based on connectivism and digital learning theory, like automatic speech recognition (ASR) and deep learning provides personalized feedback, identify patterns, and increase practice intensity for therapy. For example, AI can analyze a child's speech command for accuracy and provide immediate, tailored feedback, which helps improve word production over time. The underlying AI technologies are foundational for developing more complex, multimodal systems that could potentially integrate visual cues with speech therapy for a more holistic approach to communication and action. Machine learning (ML), is the subfield of Artificial intelligence that intends to enable computers to learn from data and make predictions without being explicitly programmed. The main goal of machine learning is to build a model that performs well on both the training and test datasets. Data, comprising features and labels, is used for model training (Brahmi, 2024). Deep learning (DL) algorithms can automatically identify and analyze language deficits and speech patterns, aiding in assessment and rehabilitation. ASR-based feedback systems allow individuals to practice more frequently, a critical factor for self-management and skill maintenance. DL models, which mimic the human brain with extensive neural networks, are used to recognize complex patterns in speech signals and can be integrated into AI-assisted therapy. ML algorithms are the foundation for AI in this field, enabling the creation of predictive models and sophisticated tools for language analysis (Hair A,2018; McKechnie,2018; Kang,2022; Schenk, 2023; Zaitoun,2024).

2.4.2 Reasoning and logical relations in children with CAS:

The precise nature of the relationship between language and thought is an intriguing and challenging area of inquiry for scientists across many disciplines. With the help of cognitivism the realm of neuropsychology, research has investigated the inter-dependence of language and thought by testing individuals with compromised language abilities and observing whether performance in other cognitive domains is diminished (Kang,2022; Palumbo,2023).

2.4.3 Predictive Speech – Encoding of language in CAS:

The idea refers on using brain's ability of predictive coding by using AI to encode and process speech sounds, which involves internal "rehearsal" of language to anticipate and process incoming sounds. This process helps in understanding syntax, learning vocabulary from context, and forming meaningful internal speech to guide thoughts and actions. It is evidence based that brain regions like the superior temporal gyrus are crucial for extracting linguistic features, and predictive coding allows the brain to predict upcoming speech, which facilitates comprehension and learning. Predictive processing accelerates word recognition and supports the learning of new words by providing context. The ability to mentally rehearse words and ideas allows for planning and sequencing actions, similar to using a script is internal dialogue. Predicting grammatical structures helps in producing and understanding complete, well-formed sentences. The system always works to minimize any surprise mistakes by experiences. This process allows for efficient information processing by focusing resources on unexpected or novel information, rather than constantly re-processing predictable data (Bhardwaj,2024; Brahmi,2024).

2.4.4 AI assisting cognitive efficiency in CAS:

Predicative speech encoding in AI-assisted therapy for apraxia focuses on using Artificial Intelligence (AI) to predict and analyze errors in a person's speech, guiding motor-based interventions by providing real-time feedback or generating customized training programs. AI tools, like the Chaining AI system, use algorithms to analyze speech sounds and compare them to clinician judgments, helping to improve speech accuracy through automated and personalized practice, supplementing traditional therapy with consistent, home-based sessions. Many AI interventions for apraxia are built on motor learning principles, which emphasize the importance of consistent practice and feedback to improve motor skills. AI systems can analyze speech samples, even those with errors, to identify patterns and characteristics of distorted sounds or movements. Clients receive immediate feedback on their speech, allowing for continuous practice and adjustment of their motor movements (Lian,2015; Lesourd,2025).

2.4.5 Speech motor chaining using AI: advancement in Auditory speech discrimination cognitive function.

Speech motor chaining is a technique where a syllable is introduced followed by single syllable word, then multi syllable word, followed by a phrase and lastly a sentence. The AI system, specifically the PERCEPT-R Classifier, analyzes recorded speech attempts and predicts a clinician's perceptual judgment of the production. Chaining AI acts like an AI clinician by making within-session decisions about practice difficulty, feedback type, and presentation, adapting to the learner's performance. The tool is designed to simulate a clinician's ability to adjust practice parameters based on a learner's performance, providing high-quality, personalized practice. It allows for more intensive practice, particularly between clinical sessions, which is crucial for speech learning. AI-driven feedback and adaptation streamline the learning process and improve the efficiency of practice (Preston, 2019).

2.4.6 Limitations in AI techniques:

Although AI has proven to bring a lot of improvement and enhancement in CE of children with CAS aged 6-12, but accuracy is sometimes altered by the interventions, accent is another challenge faced using AI, as different regions have different dialects, also technological glitch, if not known to the user brings mistakes in the data generated and the commands given. Overall, in utilizing AI interventions one has to be an expert to point out these challenges, in order to get accurate data of the student with CAS aged 6-12.

Phonological working memory (PWM) refers to the part of working memory responsible for temporarily storing and manipulating sound-based information, like speech sounds and words. It's crucial for understanding language, acquiring new vocabulary, processing sentences, and learning to read. Phonological working memory enables to repeat a set of numbers or a made-up word immediately after hearing it. Children with CAS aged 6-12, struggles in the sequence to utter a word accurately, though they are able to do so in the first time. As the children aged 6-12 with CAS struggles with speech motor planning and executing it, they show a lower range PWM capacity. They struggle in articulate the word accurately, however rigorous practice employing motor planning and programming techniques bring a positive outcome, with repetition and continuous drills using evidence-based approaches like DTTC. The link between CAS and WM deficits suggest that the core problem in apraxia might not solely be with the motor execution itself, but with the planning and programming of speech movements, which are essential for effective verbal working memory. Time efficient applications can increase the connection between speech motor planning and articulatory rehearsal process to improve PWM. AI applications and programs like Apraxia World (say bananas) and Open Brain AI generate personalized feedback, repetitive practices based on the individual data, and continuously monitoring the working of a child with CAS aged 6-12 (Ortiz,2010; Anzilotti,2025; Bennett,2025).

However, these AI applications are costly and need proper training and understanding to be used for interventions. Also, technical faults can hinder and alter the progress of data collection of the client. Introducing these applications and programs in class room settings can be challenging yet possible to bring about an efficient change in the development of a child with CAS aged 6-12 (Zahna, 2023; Cera, 2025).

Speech motor planning is the brain's abstract process of transforming a linguistic message into precise instructions for the muscles that produce speech, including the mouth, tongue, and jaw. It involves determining which sounds are needed, their order, and how the muscles of the vocal tract should move to articulate them, occurring just before the actual execution of speech movements. Difficulties with speech motor planning can result in a motor speech disorder known as apraxia of speech, where a person struggles to plan and coordinate the muscle movements for speech, rather than having weak muscles. Children with CAS aged 6-12 know what they want to say but have difficulty producing the sounds. Manual repetitive practice can be time consuming and might have human error in recordings, AI tools can smoothly record the data and give feedback in less time with more chances to practice a target.

The whole process mainly depends on the professional qualification of the therapist, educator or caregiver in implying the use of these AI based applications and programs for children aged 6-12 with CAS (Mass, 2014; Rvachew, 2017; Hyes, A. 2025; Mori, 2025).

Augmentative and Alternative Communication (AAC) tools are applications proving cognitivism, and digital learning theory alignments in education that helps children/ individuals with speech disorders. It helps children with CAS to express themselves by writing, drawing and typing. There are several versions of AAC devices and applications based on the needs of a child/ client. It enables the child/ user to establish a link between existing knowing words and those which are new or not known yet. This way, children with CAS aged 6-12 learns how to communicate well utilizing cognitivism. AAC can be Low Tech like picture based and alphabet-based systems, and High tech such as Speech generating devices and mobile applications. SymboTalk, Avaz, and Proloqou2go are few to mention. They can be set in different languages and styles based on the user's need. AAC devices help a child to enhance expressive abilities, increased engagement in a task, self-advocacy and flexibility. It can easily be used in a classroom setting, provided the teacher is well trained in using and decoding the process. However, the programs and applications need to be updated timely, also subscriptions and other maintenance bring in cost factor that hinders its common use in all children with CAS aged 6-12. A child should not only depend on the use of AAC, and should be encouraged to speak and imitate the sounds made in the application. Sometimes features are not available as per the child's way of expressing hence a regular monitor should be kept by a qualified person to see timely settings and updates (Elsahar, 2019; Yacoub, 2023; Jacky, 2025).

2.5 Theoretical Framework:

Cognitivism by Piaget talks about internal mental processes and knowledge structures, whereas, Bloom's Taxonomy by Benjamin Bloom works well with AI based education and CAS by categorizing a certain goal/ target into six cognitive complexity levels of Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating resulting in schemas formation for processing the information and knowledge in the minds of a learner (Zorluoğlu, 2024) . Learning is an active construction of mental process known as schemas, enabling speech motor planning in CAS interventions and is achieved by applying DTTC approach based on Principles of Motor Learning. This aligns with the goals set for children with Apraxia of Speech and increases practice intensity, phonological accuracy and cognitive level of task management through instructed practice. The emphasis on setting the objectives more clearly enables a learner to exhibit the knowledge depending upon the level of cognition achieved by facilitating multisensory inputs for phonological accuracy (Ajayi, 2024; Zorluoglu, 2024). The target phonic is set as a goal with multisensory stimuli till its mastered by the child with CAS, hence enhancing phonological working memory and motor planning (Hoffman, 2019; Olugbenga, 2021).

2.6 Conceptual Framework:

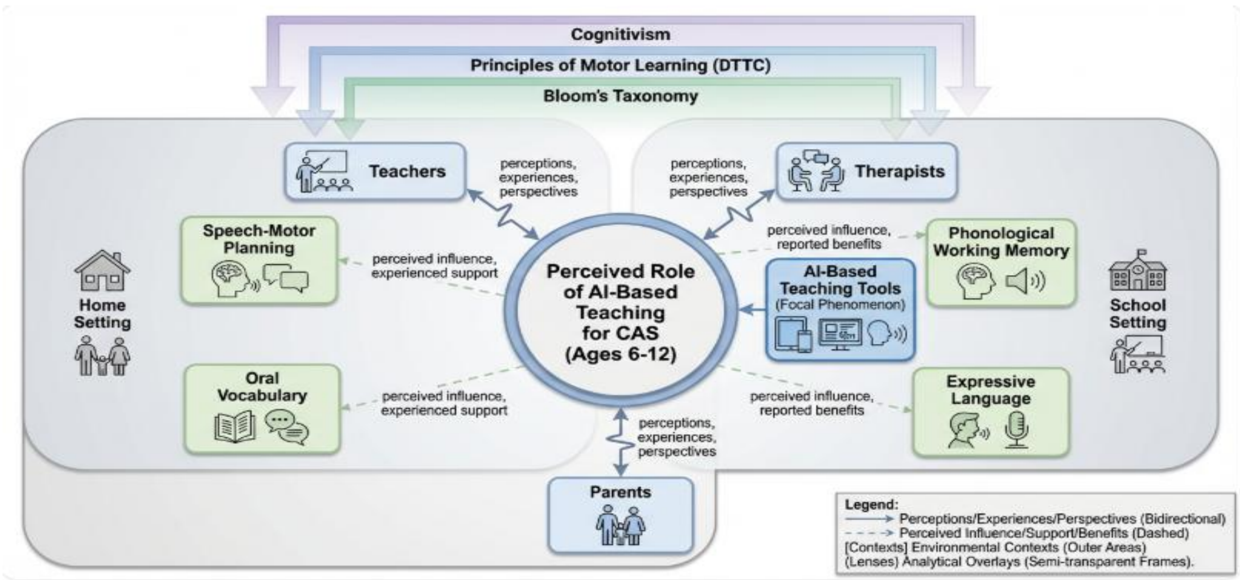

Figure 1 Conceptual framework

2.7 Literature gap:

Though AI has brought immense ease, and can be used in a varied form, ranging from individual use to organisational outcomes, but following are the identified gaps after exploring the literature; it's a challenge to develop the exact program or app needed, as it brings hefty cost factors, understanding of developer, limitations in available languages, accuracy and precise translations (Drigas, 2013; Amery, 2022). Technical glitches that can hinder the use of these applications, and fail to examine the effect on incorrect sound/word pronunciations (Brahmi, 2024). Offline mode availability and strong internet connections are a challenge, which is essential for repeated practice to increase phonological working memory and speech motor planning (Drigas, 2013; Bhardwaj, 2024). Cost effectiveness and public access is not yet achieved, that are the key role for using AI tools for academic interventions (Banik, 2021; Brahmi, 2024). Rigid training programs for special educators, without formal trainings on dealing with rare learning disabilities like CAS (Abrams, 2025). Reluctance of therapists and educators to include simple AI apps and tools (Bhardwaj, 2024).

In conclusion, the literature discloses a consistent focus on emerging AI apps and applications for speech and language development in multi-sensory scenarios, and interventions available for treating CAS in children aged (6-12), but significant gaps continue regarding awareness, application, training, legalisation and validation of AI apps, and acceptance to include these programs in languages and cost at a level reachable to all communities. These findings stress the demand for deeper understanding, particularly concerning AI based teaching strategies for cognitive enhancement in phonological working memory and speech motor planning in children with CAS aged (6-12). This review has established that while much is known, current research overlooks actual practice of AI tools in classroom and therapeutic settings. The aim of this study is to address gaps in actual practice of AI tools in classroom and therapeutic settings and awareness in the possible advancement of interventions to CAS, which may inform future research on improving accessibility and interventions in developing countries.

Chapter 3: METHODOLOGY:AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

This chapter focuses on the methodology for a descriptive, exploratory qualitative study focused on how do teachers, parents, and speech therapists perceive the role of AI-based interventions in supporting cognitive abilities (e.g., phonological working memory, speech motor planning) in children with CAS aged 6–12. Also, inquiry about enhanced communication development, particularly oral vocabulary and expressive language in children with CAS has been done. Furthermore, how special needs educators, speech-therapists, occupational therapists, and parents describe the integration of AI-based tools such as speech blubs, Proloqou, and SymboTalk into therapy for children aged 6-12 with CAS at home and in school settings, relative to their experiences with traditional therapies like table top activities and pointing, had been explored through interviews and observations.

3.1 Research Design:

Qualitative research methods have been receiving increasing recognition in education and healthcare, specially dealing with lived in experiences of people with rare mental/physical disorders, such as Apraxia of speech, and various learning abilities focusing educational interventions for children with apraxia of speech (Shorey, 2022).

This study had adopted descriptive exploratory qualitative design to explore the lived in experiences and perceptions of parents, teachers, and therapists regarding AI-based interventions for CAS, aiming to capture rich, contextualized insights not attainable through quantitative approaches.

Given the rarity of Childhood Apraxia of Speech and the limited research on AI-based interventions in this population, this study adopted a qualitative approach to explore participant perspectives in depth. Such an exploratory design was appropriate in under-researched areas and generated insights that informed future large-scale quantitative studies.

3.2 Research Location

This study was conducted within Saudi Arabia, UAE and Pakistan, owning to rising number of undiagnosed cases of CAS, in availability of skilled professionals and unawareness of the therapeutic and academic interventions in these countries (Alrudayni, 2025). Due to rarity and being under research neurological disorder, international online interviews with participants having same diagnosis of CAS aged 6-12 had been conducted.

It was reported by (Alduais, 2024) that the children suffering with language disorders specifically in KSA is increasing at an alarming rate, researcher's son remained misdiagnosed for 5 years of his life because of incompetent therapies available in KSA. Professionals dealing with Apraxia of speech and language disorders need to intervene more professionally and accurately; rather than depending on traditional ones. The places with appropriate facilities are out of reach of a commoner, and a strategy has to be made to make the right intervention available to all (Alrudayni, 2025). Semi structured open-ended online and in-person interviews with any professional dealing with Childhood apraxia of speech, were conducted in KSA, UAE and Pakistan, as the regions show steep increase in cases with Apraxia of speech in children aged 6-12 (Alduais, 2024; Alrudayni, 2025).

3.3 Research Participants

Following stakeholders participated: 3 Special educators who taught children with CAS aged (6-12), 2 Occupational therapists, 3 Speech language pathologists, 1 Cognitive Behavior therapist dealt with CAS clients aged 6-12, and 3 parents of children aged (6-12) with childhood apraxia of speech. The above-mentioned professionals shared valuable information about educational interventions as well as life skills for children with Apraxia of Speech. *Parents:* whose children had articulation, speech prosody and vocabulary issues and those who had been diagnosed with CAS (aged 6–12). *Therapists*: Occupational therapists who dealt for a year or more with a child with language disorder and CAS aged 6-12. Cognitive behavior therapists experienced with at least a year of providing therapy sessions to children having cognition and behavior issues because of CAS and speech/language disorder, finally speech and language pathologist who dealt directly with children having language disorders such as, Apraxia of Speech aged 6-12. *Teachers:* who recently taught or assisted children with CAS in inclusive or special education settings at least for a year. The data was collected from online CAS communities, and special educational centers present in KSA. The purpose of this study was to explore AI based interventions for children with CAS aged 6-12, which is a rare neurological disorder, hence professionals and parents who dealt directly offered a better yet vivid insight of the knowledge required to assess the credibility of AI applications. As limited resources were available, the lived in experiences shared by each participant enriched the available information about AI interventions for Apraxia of speech aged (6-12). Participants comprised of varying professional backgrounds enabled member checking, triangulation, transparent documentation, reflexive journaling to reach the goal of the study, without geological limitations and ethnical or religious values.

3.4: Data Collection Methods

Data was collected through interviews, which consisted of semi-structed, open ended questions of 40-50 minutes duration on Online platform Zoom, and Google Meet for an in-depth understanding of AI interventions, to achieve maximum knowledge from the experience of stakeholders (See Appendix 1). A pilot study had been done for authenticating the questions. The questions were guided but flexible. As being participant centered, the method prioritized understanding the participant's view point, by allowing them to provide rich, detailed and personal insights (Hammer D. W., 2018).

Conducting open-ended, semi- structured interviews was a reasonable method, as then only the researcher was able to gauge the participants' knowledge about AI and assessed their perception of the impact of AI-based teaching methods for the children with CAS aged 6-12 in depth, and was able to acknowledge their skills and understanding. Also, open ended question gave a chance to know the limitations and struggles seen in each area of participant. Hence, this approach made the interview spontaneous yet fixed to the point.

3.5: Sample Size

The sample comprised of: 3 Special educators experienced in teaching children with apraxia of speech aged (6-12), 2 Occupational therapists, 3 Speech language pathologists, 1 Cognitive Behavior therapist who dealt with CAS clients aged 6-12, and 3 parents of children with childhood apraxia of speech.

For open-ended, semi-structured interviews, there is no single rule, but a common sample size is between 5 and 25 participants, with many researchers suggesting 12-13 interviews are often enough to reach saturation. The ideal number depends on the specific research question, the complexity of the topic, and when new themes stop emerging from the data. As the topic was narrower, more focused to a specific group of people who dealt with Apraxia of Speech aged 6-

12, it was anticipated to reach the saturation point so no new theme emerged from the set of interviews (Vasileiou, 2018).

Role	Years of Experience	Country
Speech and language Pathologist	More than a year, closely dealing with children with Apraxia of speech aged 6-12	KSA, UAE and Pakistan
Occupational therapists	More than a year, closely dealing with children with Apraxia of speech aged 6-12	KSA, UAE, and Pakistan
Special needs Educators	Worked for more than a year in Apraxia of Speech inclusive setup for children aged 6-12	KSA, UAE, and Pakistan
Congnitive behavioral therapist	Worked for more than a year with CAS child aged 6-12	KSA, UAE, and Pakistan
Parents of children with CAS	Children aged 6-12	KSA, UAE, and Pakistan

3.6: Sampling Technique

Purposive sampling had been opted for sampling technique. Purposive sampling is a non-probability sampling technique where researchers intentionally select participants based on their specific knowledge or characteristics relevant to the study's objectives. This method, also known as judgmental or selective sampling, relied on the researcher's judgment to identify participants who can provide "information-rich" data, making it particularly useful for qualitative research and small-scale studies (Tajik, 2024).

3.7: Research Process

Participants presented in Riyadh or KSA were personally invited for the interview sessions, whereas those located outside were interviewed through media channel zoom, teams and meet. Responses in audio were converted into transcript by using AI transcription, then coded and themes were generated.

Time management and availability of the therapist were the biggest challenge, because centers in KSA operate at different working hours. It is restricted in therapy and educational centers to observe the classroom settings and sessions, therefore, access to live sessions was not possible. Online sessions were observed on the time zone of respective location that differs from researcher's location zonal time. Being an in-depth interview, it required time to discuss and dove into details by taking comfort of participants, sitting arrangement, hustle free hours and a peaceful environment into consideration.

3.8: Reflexivity

The researcher is a parent to a child with CAS, and an experienced SEN educator; hence more effective and convenient contrast was drawn on the findings by reflecting on researcher's own beliefs and experiences on AI based teaching interventions as compared to the data collected, the researcher's positionality was not sacrificed, however potential bias was actively managed, by keeping varied CAS professionals for data collection. Open ended semi structured interview paved a way to seek out disconfirming evidence, therefore, providing information that challenges the preexisting beliefs on AI based teaching for children with CAS aged 6-12.

3.9: Validity

Lincoln and Guba proposed four criteria for evaluating the trustworthiness of qualitative research, which they considered more appropriate than traditional quantitative validity and reliability. These four criteria are **credibility**, **transferability**, **dependability**, and **confirmability**. They suggested these criteria reflect the unique nature of qualitative research, which sought to understand phenomena in their real-life contexts (Stahl, 2020). This study ensured credibility was achieved by prolonged engagement with participants in order to better understand their perspective, credibility was achieved by double checking the findings with the participants called member checking. To boost credibility, significant time was invested with each participant and had them review the findings to confirm them. Transferability refers to helping other researchers determine whether the findings are relevant to their situations (Hammer D. W., 2018). Transferability was achieved in this qualitative research by providing rich, detailed descriptions of context such as Literature review, current AI interventions to develop cognitive abilities in children with Apraxia of speech aged 6-12,targeted participants such as special educators who taught in inclusive setup and teaching children with Apraxia of speech, Occupational, speech and language therapists and cognitive behavioral therapists who worked with CAS clients, and parents and caregivers of children with CAS aged 6-12. Dependability focuses on stability and consistency in the research process which was achieved by documenting every step in research, external reviewer accessed the methodology and findings. An external competent reviewer had reviewed the methodology and identified blind spots and broader issues that helped in achieving confirmability to reduce personal bias and ensured that findings were based on data set itself (Stahl, 2020).

3.10: Ethical Consideration

Written and verbal consent were taken from all participants. They were informed about the process and purpose of the study with clear explanation of the study's procedure. Confidentiality was achieved by keeping data saved in the researcher's password protected drive and anonymity had been achieved by keeping the name, workplace and location confidential, and assigned code names or numbers to the participants. Right to self-determination had kept throughout the process such as psychological pressure or stress was avoided, if a participant was not comfortable in giving the response he/she was not forced to answer. For the principle justice and fairness, each participant was given fair right to express and contribute their experiences without judgement and prejudice (Mirza, 2023). Confidentiality was achieved by keeping data saved in the researcher's password protected drive and anonymity had been achieved by keeping the name, workplace and location confidential, and giving code names or numbers to the participants. The participation in this study was voluntary, the participants had the option to not to participate, even after consent, if they felt to leave at any moment, they could, without any reason to be given, or affecting the relationship, if any, with the researcher. Conflict of interest such as financial interests and relationships and affiliations between the researcher and participants and in subject matter or materials discussed had no personal gain to the researcher. The study was solely done for research and professional development of the researcher, and the data will be destroyed after five years (Mirza, 2023).

3.11: Data Analysis

Thematic analysis approach was taken to analyze the data collected in this qualitative research. Braun and Clarke's thematic analysis is a flexible, six-step qualitative method for identifying patterns in data, The process involves familiarization with the data, generating initial codes, searching for themes, reviewing them, defining and naming themes, and then writing up the analysis, which emphasizes the researcher's role in interpretation. This method is known as reflexive thematic analysis because it requires researchers to be self-aware of their own perspectives and assumptions when interpreting the data (Braun, 2012).

The six steps of Braun and Clarke's thematic analysis

1. **Familiarization of data:** it was achieved by reading and re-reading the qualitative data (e.g., transcripts, notes) to become deeply familiar with its content. Data was read several times to familiarize with similar words and phrases used by respondents and highlighted similar context to gather as a source of initial coding. Like 'Increased vocabulary recall, better comprehension and retention, Improved fine motor skills, better executive functioning, Helpful as supplemental tool, Provides increased practice and repetition, offers instant corrective feedback, enhances engagement and motivation, promotes independence, Improvement in sequencing sounds, Clearer articulation, better multi-syllabic word production, some minimal or no improvement observed. Etc.' were grouped together to generate codes.

2. **Generating initial codes:** data coding was started by identifying and tagging interesting and meaningful features. Codes were labels for data extracts. Such as, Academic improvements, speech articulation enhanced etc.

3. **Making initial themes:** codes were grouped into potential themes, which were broader patterns of meaning. It was achieved by keeping alike codes together. For example, phonological working memory skills improved, speech motor planning is improved etc.

4. **Review themes:** themes were checked if they worked in relation to the coded extracts and the entire data set, and needed to merge, split, or discard themes at this stage.

5. **Define and name themes:** the essence of each theme was clearly defined and a name was given to capture its meaning. This involved writing detailed descriptions and providing illustrative quotes as mentioned in chapter 4 of this study.

6. **Write up the analysis:** analysis was presented by telling a coherent story about the data, linking themes, and explaining their significance. It included an interpretation of the findings and acknowledged the researcher's reflexivity.

Chapter 3 has presented the methodology for collection of data for this qualitative study. Chapter 4 will discuss the findings, and Chapter 5 will emphasize on discussion following conclusion and recommendations in Chapter 6.

Chapter 4: Finding and Analysis: AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

The main aim of this qualitative study was to explore the perceptions of special education teachers, parents and therapists about the role of AI interventions in supporting cognitive abilities, communication developments and to describe how they perceived the integration of AI-based tools, into therapy and educational interventions for children with CAS aged 6–12 at home and in school settings, relative to their experiences with traditional tabletop imitation therapies, as explored through interviews and observations. This chapter comprises of reflexive thematic analysis (Braun & Clarke), where themes were created by categorizing codes in academic skill development, speech and language development, engagement and motivational benefits, perceived values and limitations of AI and future needs and expectations from open ended interviews of 12 participants including special educators, speech and language pathologists, occupational therapists and parents of children with childhood apraxia of speech located in Saudi Arabia, UAE and Pakistan.

4.1 Presentation of findings:

4.1.1 AI Apps Support Gradual but Meaningful Academic Growth:

Special educators, parents and therapists described improvements in foundational literacy (word recognition, reading fluency), better comprehension, math skills, and increased class participation by AI interventions in the children with apraxia of speech aged 6-12.

Respondents described literacy and language-based skills as:

- Recognition of words improved.
- Reading fluency increased.
- Accurate spelling increased.
- Construction of sentences improved.
- Vocabulary memorization increased.
- Correspondence between sound and letter enhanced.

These skills were attributed to AI’s repetitive models, auditory–visual pairing, and instant corrective feedback (Maamor, 2024). Parents noted that AI apps provided structured repetition that built essential literacy foundations.

Participants also described general academic and cognitive skills as:

- Numeric solutions and math literacy improved.
- Executive functioning improved.
- Ability to be attentive increased.
- Fine motor skills polished.

These were linked to interactive visuals, game elements, and increased willingness to engage. Several special needs educators observed classroom participation as:

- Participation in class activities with more confidence
- Articulation in academic answers are improved
- Reading aloud attempts are improved and increased.

These outcomes appeared to stem from both improved communication and increased self-esteem.

A special educator said, “Using AI apps and programs with some children who have Apraxia of Speech has led to several noticeable academic and communication improvements. First, these children have shown progress in phoneme recognition and pronunciation, as AI tools provide consistent modeling, repetition, and immediate feedback. Second, there has been improvement in early reading readiness, including letter–sound awareness and basic decoding skills, because many AI programs reinforce these skills through interactive activities.”

Another Occupational therapist shared her expertise, “From my observation, such tools can indirectly enhance academic performance, might not be that major or observable at once but gradual, as due to repeated exposure it generates sound letter correspondence which is the baseline for developing neural networks through consistency and repetition, it can also aid in class participation, which increases the confidence and self-esteem making them socially mergeable. Although it's not a direct replacement, it often reinforces the skills for literacy and academic engagement.”

Parent of a child with CAS said, “He can understand his work more efficiently.” While other expressed their ward improvement in numeric skills, creativity and executive functioning.

Whereas a special educator denied any improvement in academics seen by responding as,” I work with children with CAS and AI is not an effective tool for speech intervention.”

Another professional special educator added, “My student now has more confidence reading aloud and is better at articulating answers in class. Their vocabulary recall for subjects has improved.”

4.1.2 AI Enhances Speech Practice but Cannot Replace Therapy

AI tools contribute to articulation clarity, phoneme accuracy, and motor planning—but only as supplemental practice.

Speech language pathologists, special educators and parents observed:

- Clarity in speech and smooth transition.
- Sequencing of sounds getting better.
- Word production especially multisyllable improved.
- Consistent speech attempts increased.

On the contrary, others remarked:

- Less improvements.
- Very minute changes.
- Physical methods are more promising in motor planning than AI

One of a special educators said, “AI apps can be helpful for children with Apraxia of Speech by providing extra practice, clear sound models, and interactive activities. However, they should only be used as a supplement—not a replacement—for professional speech therapy. When combined with guidance from a therapist, AI tools can support progress in communication and early learning skills.”

A parent added, “These apps can help up to a certain limit and not in the long run. As nothing can replace conversations and speaking to humans.”

An experience speech language pathologist said, “it can be a supplemental support to provide unlimited practice, consistency, also it provides the scope of self-correction through instant feedback and is an accessible and engaging factor for home practices, not only the child but families can engage along which has been my always a concern and factor of strategic planning for treatment support at home.”

Another SLP said, “Yes, I’ve noticed that some children with Apraxia of Speech show slight improvements in speech motor planning when using AI apps. The consistent repetition, clear modeling of sounds, and structured practice seem to help them plan and sequence movements more effectively. However, these improvements are usually gradual, and AI should be used as a supportive tool alongside professional speech therapy.”

Another said, “Yes, significant improvement. Their speech is now smoother and more consistent, especially with multi-syllabic words and complex sound sequences.”

Clinicians emphasized the need for human-guided intervention for true speech motor development.

4.1.3 AI Tools Highly Increase Engagement, Motivation, and Independence

Children demonstrate significantly higher engagement due to **gamified learning**, instant rewards, visuals, and curiosity-driven interaction.

Children demonstrated positive patterns in engaging activities:

- AI-based tasks are strongly preferred.
- Attention span is increased.
- Attempts for speech production is increased.
- Independence is highly achievable
- Curiosity driving exploration for learning.

Parents and therapists shared their experience, that children often requested to use AI tools, which is uncommon in traditional practice tasks.

A few respondents communicated:

- Passive use that is occasional ("comfortable but blank")
- Usage needs to be limited

Despite this, no participant experienced avoidance or refusal.

A special educator said, "I've observed that many children show higher engagement and motivation when using AI tools. The interactive activities, visuals, and instant feedback keep them focused and make practice feel more enjoyable. They also tend to participate more willingly and stay attentive for longer periods compared to traditional exercises."

An occupational therapist said, "Engagement is excellent. The gamified approach makes it fun. They are highly motivated by the immediate rewards and actively ask to use the app."

A parent shared the thoughts as, "Children are tech savvy and thrive when they have ownership over their worlds. Thus, AI gives them a level of access and independence that allows them to feel empowered and confident."

An occupational therapist said, "something I would always laugh about, screens are the BEST reinforcers for any age and it triggers curiosity which is a baseline to any learning in life. Most clients mainly I would say children show higher engagement and sustained attention, it increases their motivation, persistence and more sense of independence."

AI offers a sense of independence and confidence often not seen in traditional therapy tasks.

4.1.4 AI is Viewed Positively but Requires Balanced, Controlled Use

Most participants saw AI as helpful, accessible, and supportive.

Most respondents stated that AI tools:

- Are Offering valuable supplementary practices

- Give Instant feedback and error correction
- Aid in Consistent increased practice at home
- Are motivating due to visuals, rewards, and gamification
- Make learning fun and engaging

AI was commonly viewed as particularly helpful for repetition-based speech tasks and literacy practice.

A few participants expressed concerns such as:

- AI is not a replacement for clinical speech therapy
- Overuse may lead to screen dependency
- Current AI apps lack robust motor-speech diagnostic features

One of a parents said, “There’s improvement but still it has to be under control and not open tool for them.”

A therapist said, “Engagement is excellent. The gamified approach makes it fun. They are highly motivated by the immediate rewards and actively ask to use the app.”

A special educator emphasized saying, “A lot of new skills are learned especially executive functions and confidence building, but needs monitoring to check the screen time”.

However, concerns included:

- Over-screen time
- Incomplete replacement for human interaction
- Varied professional opinions on therapeutic effectiveness

AI is valued when strategically integrated with real therapy.

4.1.5 Need for Personalization, Professional Control, and Advanced Speech Features

Personalization & Adaptive Learning is seen in AI interventions, however more options were requested by respondents such as:

- Individualized pathways
- difficulty levels that are customized as per the requirements of the child.
- Integrating school-specific vocabulary
- Support for multilingual families

Participants—especially SLPs and educators requested:

- A professional dashboard
- Progress tracking and analytics
- Ability to set or adjust goals

- Motor-speech analysis beyond simple speech-to-text.
- Multisensory feedback (visual, tactile, verbal)
- Culturally diverse and age-appropriate content
- Affordable and stable applications

A special educator said, “In future versions of AI tools for Apraxia of Speech, I would like to see more personalized speech exercises that adapt to each child’s specific needs, clearer real-time feedback on pronunciation, and stronger integration with therapist-designed goals. It would also be helpful to include progress tracking, more engaging interactive activities, and tools that allow parents and therapists to customize sessions easily”.

A parent included’ “I'd like to see simulated conversational practice and the ability to easily integrate school-specific vocabulary for practice.”

A speech language therapist said, “Opportunities to write a d create multiple means of artistic expressions as additional/supporting modes of communication.”

“Something that can help children talk in sentences n not just one word.” A parent told.

A special educator said, “Customized less cost applications without a lot of glitches and available in other languages.”

An Occupational therapist said, “from a therapeutic and service provider point of view, I would expect to see more personalization options rather than generalized ones, accurate motor speech analysis not just speech to text, therapist's dashboard to control the program, keep track of progress and adjust the program according to varying levels of difficulties, multisensory feedback and culturally diverse which plays a pivotal role while considering therapeutic model.”

Participants wanted future versions to include:

- Personalized, adaptive speech exercises
- Motor-planning–specific analytics
- Therapist dashboards for progress tracking
- Multi-language and culturally inclusive content
- Sentence-level speech support
- Lower cost and improved stability of apps

This theme highlighted a desire for more academically and clinically aligned AI tool.

4.2 Analysis and Interpretation:

4.2.1. Interpretation of Academic Improvements

Interview responses indicated that AI apps contribute to notable improvements across several academic domains. The most frequently observed benefits include increased word recognition, enhanced reading fluency, improved spelling accuracy, and stronger sound–letter correspondence.

Parents also reported gains in mathematics, executive functioning, and fine motor coordination. While not traditionally associated with speech interventions, these improvements reflect AI's capacity to sustain attention, reinforce cognitive skills, and provide structured practice. Such findings demonstrated the potential for AI tools to influence cross-domain academic abilities, indirectly supporting learning readiness.

4.2.2. Speech Development and Motor Planning: A Supplemental Yet Valuable Tool

Although therapists marginalized relying on AI for core motor-planning shortfalls, many parents reported that they observed improvements in articulation, phoneme accuracy, and production of multisyllabic words. These findings align with motor-learning theory, which emphasizes the value of high-frequency, low-pressure practice—precisely what AI apps provide (Bhardwaj, 2024).

However, the results also showed variability. Some participants reported little or no improvement, underscoring that motor planning in CAS requires individualized, therapist-led approaches. AI appears beneficial primarily as a reinforcement mechanism. Theory Cognitivism explains repeated exposure and practice opportunities outside therapy sessions is a great reinforcer that aligns with the findings (Hoffman, 2019). This highlighted an important contrast: AI supports but does not substitute for the specialized intervention required for CAS.

4.2.3. Engagement and Motivation: One of AI's Strongest Advantages

Across all responses, engagement emerged as a dominant theme. AI's gamified elements—visual rewards, badges, levels, and interactive design—significantly increased children with Apraxia of Speech motivation, sustained attention, and willingness to practice skills they often resist in traditional therapy contexts.

These were pivotal findings because motivation is a known challenge in speech intervention, especially when tasks require repetitive motor practice. The interview results suggested that AI may reduce emotional resistance, increase independence, and create more positive learning experiences.

4.2.4. Balanced Perceptions: Appreciation With Caution

Participants viewed AI favorably but with careful consideration and emphasized that:

- AI tools should be supervised in home and classroom settings.
- Sessions must be time-limited.
- Usage must remain purpose-driven.
- AI should complement—not replace—clinical methods.

This balanced perspective reflected a mature understanding of digital learning tools, recognizing both their strengths and limitations. The finding showed that uncontrolled screen exposure can reduce learning quality, but structured, targeted use produce meaningful outcomes.

4.2.5. Need for More Advanced, Personalized AI Features

A recurring finding was the desire for AI tools that provide:

- Therapist/educator dashboards
- Motor-speech analysis
- Customizable difficulty
- Integration of school vocabulary
- Multisensory feedback
- Multilingual and culturally inclusive content

These requests reflected a gap in current AI technologies: existing tools often lack the depth and precision required for motor-speech intervention. Participants expressed a clear preference for platforms that mirror clinical practices, support progress tracking, and adapt to individual speech goals.

This suggested that the next generation of AI tools for CAS should shift from generic language games to educational and clinically informed, personalized, adaptive learning systems.

4.2.6. Alignment Between Parental and Professional Perspectives

Interestingly, while professionals were more cautious, both groups recognized similar benefits:

- Enhanced engagement
- Increased independence
- Improved academic readiness

- Positive reinforcement

This alignment suggested strong potential for collaborative integration of AI into home and therapy environments. Such harmony may improve continuity between sessions, encourage generalization of skills, and increase parental involvement—an essential component of effective CAS intervention.

Thus, the following patterns are seen throughout the data set:

1. *Academic skills improved*—particularly in literacy and early phonological awareness.
2. *Speech development benefited*, especially in phonological working memory: articulation and phoneme practice, though motor planning showed noticeable improvements.
3. *Engagement and motivation were consistently high*, driven by gamification and instant feedback.
4. *Participants value AI as a supplemental tool*, emphasizing the need for clinical supervision.
5. *Future AI tools should offer personalization, analytics, and multisensory features* to better support children with Apraxia of Speech.

Chapter 4 described findings from the data collected through open ended interviews with Special educators, occupational therapists, speech and language pathologists and parents with children having apraxia of speech aged (6-12). It concluded that AI enhances phonological working memory skills that polishes academic and literacy skills, it also contributes to boost classroom confidence. AI supports speech-motor planning development by supplementing therapeutic and educational interventions. Children's motivation, attention, and engagement boost up to significant levels due to tools with gamified and interactive versions.
Parents and clinicians showed positive interest with balanced and checked usage of AI tools. Emphasis was more on personalized, affordable, culturally diverse, and clinically integrated AI features by all participants.

Chapter 5: Discussion: AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

Chapter 5 provides discussions based on research findings from data collected on how parents and clinicians perceive the role of AI apps in supporting children with Apraxia of Speech (CAS), particularly in academic, speech motor learning, phonological working memory and engagement-related outcomes. This chapter will review the purpose of the study, research questions, literature review, and findings of the study. It will then present discussions of the findings.

The findings revealed that while AI tools are not viewed as a replacement for professional therapy, they are considered a valuable supplemental resource that enhances phonological working memory skills, speech motor learning, supports skill development, and increases motivation. This chapter focuses on how can AI be embedded in current classroom settings and educational interventions for the children with Apraxia of Speech aged 6-12.

5.1 Overview of Key findings:

The findings showed a positive outcome about AI interventions for children with CAS aged 6-12, with noticeable improvement in phonological working memory skills: phonological awareness, speech motor planning and improvement in numeric skills (Abrams, 2025). This aligns with the theory of cognitivism that emphasizes on the development of new neurological pathways known as schema that enriches cognitive domain (Hoffman, 2019). Improvement in speech motor planning by repetition and word articulation based on the level of a learner, conforms Bloom's Taxonomy level of 'understand' (Ajayi, 2024). Numeric literacy and math problem solution is improved in children by repeated practice and conceptual reasoning. This answers the question on how do teachers, parents, and therapists perceive the role of AI-based interventions in supporting cognitive abilities (e.g., phonological working memory, speech motor planning) in children with CAS aged 6–12. The outcomes are consistent with literature suggesting that repetition, multimodal input, and immediate feedback strengthen early literacy foundations (Chinmoy, 2024). This aligns with the principles of cognitivism that emphasizes on internal mental processes to enable learning through organizing and sorting information in long-term memory (Hoffman, 2019). The Audiolingual method (ALM) is utilized in these apps which is driven by repetition, drilling, and memorization of patterns in speech and language building.

Also, lexical approach is used by making language taught in chunks focusing more on the vocabulary build. This aligns with the principles of Bloom's Taxonomy (Ajayi, 2024).

Communication and vocabulary development is recorded in children with Apraxia of speech aged (6-12). This marks the valuable insight for the development of receptive and expressive language in children and improves phonological working memory, as reported by the professionals and parents. Smoother and clearer sound production with consistency is seen that aligns Bloom's Taxonomy to enable a child to remember and achieve a goal by varied difficulty levels (Ajayi, 2024). However, few participants noticed very little improvement in accurate speech production using AI. Hence, explaining how do teachers, parents, and speech therapists perceive the influence of AI-based interventions in enhancing communication development, particularly oral vocabulary and expressive language in children with CAS aged 6-12.

Engagement and motivation serve as a back bone for any learning as argued by Grigos (2024) and are required more in children with apraxia of speech, this has been increased by using AI based interventions for cognition and understanding of several targets with increased attention span and exploring features resulting in curiosity to learn the targeted goal in the AI driven activity, embedding in the principles of cognitivism such as mental processes internally to achieve attention, memory and problem solving and not just depending on the external factors like environment and stimuli, explaining the usefulness of AI interventions as compared to traditional setups of physical rewards and reinforcers to target a certain activity (Olugbenga, 2021). This finding abides by the principles of Digital Game Based Learning (DGBL) (Arif Yüce, 2021). AI should be used to enhance the interventions and used as a supplementary tool for it. This will help in reading fluency, vocabulary recall, math readiness, and basic literacy skills, answering the question for better interventions as compared to traditional methods such as imitation and pointing, because it offers more practices, in less time and effort. However, few participants reported limited improvements in attention and engagement motivation yet no participant reported complete refusal to the use of AI interventions.

5.2 Interpretation of findings*:*

Academic growth in the domains of phonological working memory: word recognition, fluency in reading and comprehension, recalling vocabulary, math skills and numeracy improvement with self-esteem and confidence is observed in children with Apraxia of speech aged 6-12 when intervened with AI based apps. It is always been a challenge for therapeutical session or a goal in IEP that addresses frequent and varied practice routines in one set for the children with apraxia of speech. Most of the students need various multi-sensory inputs and interventions to aid the learning process. With AI applications and programs this is achieved in much less time and repeated trials over shorter time span makes it more efficient to use (Donaldson A. L., 2023). By employing Bloom's Taxonomy differentiated instructions and scaffolding learning, goals are achieved in much shorter time because the applications feature varied levels of difficulty and giving each task in multiple ways to enhance cognitive abilities in a child (Ajayi, 2024). They can apply their knowledge in different situations and this can be achieved in less time with more accuracy by using AI apps.

Brahmi (2024) describes Machine learning and Automatic speech recognition as a core for developing Speech motor with gains in articulation, phoneme accuracy, multi-syllabic word production.AI based apps and programs show Speech motor-planning improvement to initiate and target specific articulation is by using the principles of motor learning and incorporating techniques followed in DTTC approach. Research work by Schenk (2023) shows positive results achieved by using DTTC methods to develop speech production and development in children with apraxia of speech. This enables a child to apply and analyze what is being told or taught to articulate, hence improving cognition and reasoning abilities as emphasized in digital learning and connectivism. Batat (2022) argues auditory inputs with various sound effects and motion technology enables a child to experience multi-sensory input that results in increase attention and focus over a task resulting to achieve a target in less time. This is seen while using AI apps having different functions and effects of sound and colors, as well as some 'jerks' for multi-sensory inputs such as, visual, auditory and tactile for the user to experience (Banik, 2021). Connected art surfaces can be made with touch-sensitive material on tables and floors. As participants use their hands or feet to paint with different materials like play-dough or finger paints, the surface reacts with a digital projection. This allows players to create collaborative digital artwork through physical touch (Matt, 2023; Skalen, 2023; Cristina, 2024).

Auditory and visual senses can be enhanced by introducing reactive play spaces that are rooms set up with projectors and microphones to create an immersive, responsive environment. For example, a "sound safari" game might project jungle animals onto the walls, which disappear or make noise in response to a child's clap or other sound, this can be combined with a verbal cue to say out the name, or action verbs can be introduced (Matt, 2023; Skalen, 2023; Cristina, 2024).

Cognitivism emphasized on the importance of new schemas, that are developed using previous knowledge learned, hence curiosity is the first step in learning and acquiring new schemas, that is achieved my more engagement and motivation in a given task. AI apps and programs boost motivation and engagement in children with apraxia of speech. Gamified features, rewards, visuals and consistency increase persistence and independence in children (Cruz, 2021). Motor planning improvements are gradual but consistent, proving the previous literature about enhancement of learning with AI integration (Maas, 2014).

The findings showed that AI apps significantly enhance literacy, engagement, and speech practice for children with Apraxia of Speech when used in a structured and clinically supervised manner. While not a replacement for therapy, AI tools offer valuable support that can improve motivation, consistency, and foundational academic skills. However, future AI development must address personalization, clinical alignment, policies and laws for the regulations of these implements that will enable cultural inclusivity to maximize their effectiveness for the children with Apraxia of Speech.

Chapter 6: Conclusion and Recommendations: AI-based Teaching for Enhancing Cognitive Abilities in Children with Childhood Apraxia of Speech Aged (6-12), in Speech-Motor Planning and Phonological Working Memory Domains.

This exploratory qualitative study was conducted to explore the perceptions of teachers, parents, speech language pathologists and occupational therapists about the role of AI-based interventions in supporting cognitive abilities, such as phonological working memory and speech-motor planning, in children with Childhood Apraxia of Speech (CAS) aged 6–12. Furthermore, to understand how teachers, parents, and speech therapists perceive the influence of AI-based interventions on communication development, particularly oral vocabulary and expressive language, in children with CAS aged 6–12 and to describe how special needs educators, speech therapists, occupational therapists, and parents perceive the integration of AI-based tools into therapy and educational interventions for children with CAS aged 6–12 at home and in school settings, relative to their experiences with traditional tabletop imitation therapies, as explored through interviews and observation. The participants were special educational needs educators with minimum 1 year experience working with children of apraxia of speech aged 6-12, therapists both speech and language pathologists having clients with CAS aged 6-12, and parents of children with apraxia of speech aged 6-12. Improvement in academic skills embedded in Bloom's Taxonomy with DTTC approach are seen, such as phonological awareness, articulation, vocabulary enrichment, numeric skills, art, and creativity. Speech development mainly in areas like articulation and phoneme practice with motor planning has been seen. Consistent engagement and motivation are reported by the use of AI interventions. A sense of self-esteem, confidence and independence has been reported by all stakeholders. AI app and programs are valued as supplement tools in the interventions given to children with apraxia of speech aged 6-12. More emphasize is given on personalization and multi-sensory features launched in such apps to support children with apraxia of speech aged 6-12.

It is perceived that AI apps and programs are the most impactful reinforcers for children with Apraxia of speech aged 6-12, thus this finding can be utilized in a more benefitted way by implementing these AI tools in the classroom settings and home sessions.

The findings strongly support a model that is hybrid in nature, with goals and targets set by therapists, opportunities to practice repeatedly and reinforcing trials to execute mastery by using AI apps and programs, consistent home use supported by parents, and special educators connecting lessons with goals and hence building up speech and language literacy by integrating AI activities and tools. Such a model aligns with Bloom's taxonomy, digital learning and principles of motor learning, ensuring engaging and efficient AI tools benefits for children with apraxia of speech without fading the essence of human insights essential for complex motor-speech development.

Countries like Saudi Arabia and UAE are multi cultured hence different nationalities are living in these regions (Alasiri RM, 2024). Multilingual applications should be developed, needing more developers to design programs that run in different languages especially Arabic and Urdu. Cultural content should be introduced, this is achievable when special educators, therapists and application developers collaborate, resulting future AI tools to be personalized, and multisensory featured. There is very little literature available comprising developing countries with children having CAS and AI based interventions. The main aim is to fill the gap by introducing language and culture friendly applications and programs that bring an awareness in a generalized form. Hence, proper trainings of developers, teachers, therapists and parents is required. Educators and therapists specially speech language pathologists need to collaborate AI in the interventions for a better outcome. School year policies ought to include proper installation and maintenance of such apps in order to facilitate children with apraxia of speech**.** Proper training sessions, seminars and workshops should be periodically offered to the parents, free of cost, in order to bring inclusion at a public level irrespective of socioeconomic factors**.** AI models must be developed using diverse and representative datasets to avoid bias against children from different linguistic, cultural, and socioeconomic backgrounds. Insurance policies should promote equitable access to technology and ensure that AI does not exacerbate existing disparities in healthcare access. Although, vision 2030 of KSA supports the inclusion and participation of all individuals with disabilities, yet proper guidelines and rules are needed for children with CAS aged 6-12.

6.1 Limitations:

The qualitative study limits the generalizability of the findings. Although the responses were rich and diverse, a larger over longer time span sample size would provide more strong evidence and a clearer understanding of trends across different stakeholders, and severity levels of Apraxia of speech. Variability of AI tools and applications can differ greatly on quality, features, goals and design offered by different applications used, instead of one app used by all. Potential technology access bias can be reported as those who were interviewed are comfortable with AI use, and technology friendly. Cultural differences in parents, educators and therapists' attitude, language diversity, socioeconomic factors and educational level of parents can heavily influence the effectiveness and acceptance of AI tools in interventions.

6.2 Future Scope:

Future research should focus on larger, longitudinal, and clinically grounded studies, with objective measures, standardized tools, comparative analysis, and attention to cultural and multilingual variation. This will happen when more awareness and use of AI tools in interventions is available and in practice by facilitators. Exploring hybrid intervention models and the ethical implications of AI use will also be crucial for advancing the field.

AI tools and applications paved the way for dramatic positive cognitive changes for children with Apraxia of speech aged (6-12). AI apps and programs for CAS such as, SymboTalk, Apraxia village etc. are an innovation proved to facilitate and encourage inclusion. The success of AI based teaching in Phonological working memory and speech motor planning domains is achievable only when special educators, therapists and parents are well trained, aware and knowledgeable about the available AI tools. This practice can bring a robust solution to the struggles faced by children with apraxia of speech aged 6-12. It is an essential requirement to create, innovate and develop such AI apps that are accessible, cost effective, multilinguistic, and personalized opted. Insurance policies should be made to include cost bearings for such AI tools in schools and in personal use. Special educators, SLPs, Occupational therapists and parents should be trained and obliged to incorporate usage of these apps and programs in their professional and personal lives thus empowering children with Apraxia of speech.

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Appendix 1

Interview questions

1. What are your thoughts on AI apps and programs for children with Apraxia of Speech aged (6-12)?
2. What are your observations on your child's engagement and motivation when using the AI tool?
3. What features would you like to see in future versions of AI tools for Apraxia of Speech aged (6-12)?
4. Have you seen any improvement in Speech Motor Planning in your child with Apraxia of Speech aged (6-12)?
5. What improvements in academics have you noticed in your child with CAS aged (6-12)?