Multimedia guidelines for vocabulary apps assisting early language learning in children with Autism Spectrum Disorder

by

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at the

UNIVERSITY OF PRETORIA

Supervisor: Dr. Ronel Callaghan
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Prof. J. Heléne Gelderblom

MARCH 2018

DECLARATION

I declare that the dissertation/thesis, which I hereby submit for the degree Philosophiae Doctor at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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Ilse de Bruin

25 March 2018

ETHICAL CLEARANCE CERTIFICATE

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RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **SM 15/08/02**
DEGREE AND PROJECT	PhD (CIE) Multimedia guidelines for vocabulary Apps assisting early language learning in children with Autism Spectrum Disorder
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DATE OF CLEARANCE CERTIFICATE	05 October 2017

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This Ethics Clearance Certificate should be read in conjunction with the Integrated Declaration Form (D08) which specifies details regarding:

- Compliance with approved research protocol,
- No significant changes,
- Informed consent/assent,
- Adverse experience or undue risk,
- Registered title, and
- Data storage requirements.

ETHICS STATEMENT

The highest ethical standards were maintained in this thesis. The ethical considerations for this study are discussed in detail in Section 5.10.

DEDICATION

To all the app developers that REALLY want their vocabulary app to help a child with autism.

ACKNOWLEDGEMENTS

Soli Deo Gloria – without God I am nothing; without Him I would never have had the courage to fight the good fight and overcome the obstacles on the long journey to completing my studies.

To my awesome family – a HUGE thank you to: my husband Christo for allowing me to complete my studies full-time and being tender towards me when I was frustrated; my sons Pierre and Milan for your encouraging words: “Mamma is amper klaar, nog net so ‘n bietjie…”; to my mom Sita and dad Leon for their emotional support and understanding in my times of absence; and to my sister and her family -Yvette, Nelius and Desna that always wondered how it’s going with my studies and making me laugh by saying “…that I will finish one of these years…” BAIE, BAIE LIEF VIR JULLE.

I would like to express my extreme gratefulness towards all three my supervisors Dr. Ronel Callaghan, Prof. Marlien Herselman and late Prof Helene Gelderblom for your expertise, insight and interest in my studies. Your advice and guidance were very valuable and greatly appreciated.

Thank you to Pretoria University specifically the Department of Research and Innovation Support for granting me the unforgettable opportunity to visit Yale University which helped add depth to my study.

Thank you to Yale University for allowing me the opportunity to gain a better perspective regarding children with autism and how to do research that can help.

ABSTRACT

Numerous educational apps fall short when it comes to design, instruction, content and various other features that high-quality educational software should have. A miniscule number of designers incorporate research-based approaches when designing educational apps. It is considered near impossible to scientifically study and evaluate all the educational apps available in the various stores. The sudden inundation of apps forms part of the digital revolution whereby games and learning are integrated from non-digital forms to digital forms in an unregulated manner. Each app has its own unique approach to design which may include illustrations, drawings, photographs, abstract concepts, animations, sounds and various tactile activities. Vocabulary apps should be designed to effectively draw attention to letters and words being taught, positively contributing to language learning. However, the effectiveness of the design of vocabulary apps specifically for children with ASD is brought into question since the visual processing in ASD is unique and different. The study identified multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD. A Design Science Research Model was incorporated creating an artefact (multimedia design guidelines) which was developed and validated throughout four phases. The expert opinions of speech therapists and an educational specialist were collated with the results of eye tracking data of children with ASD interacting with vocabulary apps. In addition, video coding and checklists were utilised to identify multimedia learning principles, graphic design elements and principles as well as auditory and tactile stimuli. The identification of effective multimedia design guidelines occurred by identifying the vocabulary app with the highest number of fixations on letters and words. The result was effective multimedia design guidelines for vocabulary apps. Various learning theories were incorporated into the conceptual framework which included the engagement of sensory, working and long-term memory. The engagement of these different memories provided a greater prospect for language learning to take place successfully. This study anticipates that these

identified multimedia design guidelines will be the starting point of vocabulary apps that contribute more effectively to early language learning for children with ASD.

Key terms: Apps, Autism Spectrum Disorder, Design Science Research, eye tracking, multimedia design guidelines, video coding.

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TO WHOM IT MAY CONCERN

This is to confirm that the thesis titled ***"Multimedia guidelines for vocabulary apps assisting early language learning in children with Autism Spectrum Disorder "*** by Ayodele Abosede Ogegbo was proof read and edited by me in respect of language.

I verify that it is ready for publication and / or public viewing in respect of language and style.

Please note that no view is expressed in respect of the subject specific technical contents of the document or changes made after the date of this letter.

Kind regards

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LIST OF ABBREVIATIONS

AAC	Augmentative and Alternative Communication
ADHD	Attention-Deficit Hyperactivity Disorder
apps	Applications
AS	Asperger Syndrome
ASD	Autism Spectrum Disorder
ASSQ	Autism Spectrum Screening Questionnaire
CD	Compact Disc
CDD	Childhood Disintegrative Disorder
CTLM	Cognitive Theory of Learning with Media
CTML	Cognitive Theory of Multimedia Learning
DR	Design Research
DS	Design Science
DSM-V	Diagnostic and Statistical Manual of Mental Disorders, fifth edition
DSR	Design Science Research
DSRM	Design Science Research Model
EPF	Enhanced Perceptual Functioning
HCI	Human Computer Interaction
HF	High Functioning
HFASD	High Functioning Autism Spectrum Disorders
ICT	Information and Communications Technology

IQ	Intelligence Quotient
IS	Information Systems
IT	Information Technology
ISTJ	Introverted-Sensing-Thinking-Judging
LPS	Learning Preferences and Strengths
m-learning	Mobile Learning
MHP	Model Human Processor
MTMM	Multitrait Multimethod
OS	Operating Systems
PDD-NOS	Pervasive Developmental Disorder Not Otherwise Specified
SAACA	Single Attention and Associated Cognition in Autism
ToM	Theory of Mind
TD	Typically Developing
USA	United States of America

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1. CHAPTER ONE - INTRODUCTION TO RESEARCH STUDY

"If you've met one person with autism, you've met one person with autism," Dr Stephen Shore

1.1 Focus of Chapter

The main purpose of this research study is to identify effective multimedia design guidelines for a vocabulary app that assists early language learning in children with Autism Spectrum Disorder. This chapter presents the motivation for and overview of the study in Section 1.2, the problem statement (Section 1.3), the purpose of the study (Section 1.4), the research questions (Section 1.5) and an introduction to the research methodology (Section 1.6), ending with brief explanations of the chapter to follow (Section 1.7).

1.2 Motivation and Overview of the Research Study

Technology has infiltrated so many aspects of day to day life and can either be seen as a hurdle or stepping stone. The ample benefits that Information and Communications Technologies (ICTs) have for schools, learners and teachers are mentioned in reports (Bavin, 2009; Saidi & Mongi, 2018)(Bavin, 2009; Lemke & Fadel, 2006, p. 2). Reference is made that technology improves learning realised in improved academic performance and improved learner engagement. In addition, ICTs prepare learners for the future helping them to become more productive; ICTs incorporate relevant day-to-day activities and real-world applications thereby helping to decrease the digital divide and develop skills such as critical thinking, scientific reasoning, visual literacy, global awareness, productivity and creativity(X. Hu, Gong, Lai, & Leung, 2018; Manches, Bligh, & Luckin, 2018).

Glaeser (2015, p. 2) reviews the work of Hill on educational technology for children with special needs. In the review the assertion is made that the use of tablets to educate children with special needs such as Autism Spectrum Disorder (ASD) can be considered a breakthrough. The use of tablets comes with distinct advantages. Some of these advantages include: the apps on a tablet can be customised to suit the specific needs of the ASD child's interest and the tablet can be voice activated making it interactive, advancing knowledge and skills. (Martinho, Sangokoya, Martinez, & Pestre, 2018)Another recent article by Grynszpan, Weiss, Perez-Diaz and Gal (2014, p. 358) mentions that technology successfully contributes to the development of children with ASD and that this presents a special challenge to designers to develop interventions that will be effective.

Multimedia design guidelines will be identified that promote early language learning in children with ASD that can be incorporated into the design of vocabulary apps. Achieving success in this regard necessitates that relevant topics in literature be studied such as: autism spectrum disorder, early childhood development, education and learning, multimedia learning, graphic design elements and principles, and eye tracking studies. These various topics will have a central focus point and role to play in helping to identify multimedia design guidelines that will assist early learning of language in children with ASD. Next the problem statement of the research study will be discussed.

1.3 Problem Statement

A large number of mobile applications (apps) can be found on the Android and Apple stores with many of these apps claiming to promote early language learning for children with ASD. Each app has its own unique approach to the design of the app. The apps either include illustrations and drawings ranging from black and white stick figures to full colour line drawings or photographs of objects or abstract concepts for example - a talking dog. Many of the apps are filled with animations, sounds and tactile activities that provide abundant entertainment for the child interacting with the app. This begs the question: how much attention is given to the letter or word that is being taught by the app amongst all the extraneous stimuli? If apps are not effectively designed attention to letters and words is lost. If the letter or word is not effectively placed in the layout the child will focus his or her attention somewhere irrelevant to learning the specific letter or word. Multimedia design guidelines can address issues relating to loss of attention, extraneous material, tactile and auditory overstimulation and the general design of a vocabulary app.

Effective language learning can take place especially for children with ASD if a deliberate approach is taken in the design of vocabulary apps.

The success of technological interventions for children with ASD are well documented (Glaeser, 2015; Hourcade, Bullock-Rest, & Hansen, 2012; Hourcade, Williams, Miller, Huebner, & Liang, 2013; Kagohara et al., 2013; Neely, Rispoli, Camargo, Davis, & Boles, 2013; Ploog, Scharf, Nelson, & Brooks, 2013; Venkatesh, Greenhill, Phung, Adams, & Duong, 2012). The use of these technological interventions are dependent on various factors namely accessibility, ease of use, and cost (Grynszpan et al., 2014). In conjunction with these technologies are the numerous mobile applications that claim to assist children with ASD, affirms Hourcade et al. (2013, p. 3197). However what needs to be considered is the effectiveness of the design of these apps for teaching vocabulary to children with ASD.

Effective design elements and principles that promote deep learning have been incorporated for use with computers, animations and e-learning specifically for college students (Mayer, 2003; Mayer & Moreno, 2002a, 2002b) but effective multimedia design guidelines for the design of vocabulary apps for children with ASD are lacking. Little research can be found relating to multimedia design guidelines for vocabulary apps benefitting language learning in children with ASD. A number of authors (Behrmann, Thomas, & Humphreys, 2006; Dakin & Frith, 2005; Simmons et al., 2009; Vandenbroucke, Scholte, van Engeland, Lamme, & Kemner, 2009) mention that the visual processing in ASD is unique and different. This being the case the use of multimedia design guidelines to promote language learning could be of great value for children with ASD, their parents or caregivers, and speech therapists.

Next the purpose of the research study is discussed.

1.4 Purpose of the Research Study

The aim of the research study was to address multimedia design issues in vocabulary apps by identifying multimedia design guidelines that support early language learning in children with ASD.

A practical, theoretical and methodological contribution will be made. The practical contribution will be in the form of multimedia design guidelines. The theoretical contribution will be the culmination of learning theories presented in the conceptual framework. In terms of the methodological contribution, the adaptation of a Design Science Research Model specifically for its utilisation with children with ASD will be incorporated.

The premises and structure of the research study focus on the constructs of early learning in general (Bruner's Stages of Learning), early language learning in ASD (Oelwein's methodology), multimedia learning and human computer interaction (HCI). All these theories involve sensory (visual, tactile and auditory) memory, working memory and long-term memory in the language learning process.

The research will:

- Incorporate learning theories across different disciplines;
- Identify vocabulary apps with the help of children with ASD;
- Identify the educational, multimedia learning and graphic design guidelines from the chosen vocabulary apps;
- Identify the visual, tactile and auditory guidelines from the chosen vocabulary apps;
- Identify effective multimedia design guidelines that can be incorporated into the design of vocabulary apps to assist early language learning in children with ASD.

In the process:

- Various learning methods and memory processes utilised for learning will be identified and discussed; and
- Multimedia design guidelines will be identified that will be effective for language learning in children with ASD.

The end product:

The end product will be multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD.

The research study will not:

- Measure learning in children with ASD.

However, the educational and multimedia learning processes present in each of the chosen vocabulary apps, as well as the memories utilised will be identified. This will be achieved by the administration of checklists discussed later.

1.5 Research Questions

Considering the introduction and problem statement mentioned earlier the main research question followed by three sub-questions - if thoroughly explored - will provide greater insight into the identification of **Multimedia design guidelines for vocabulary apps assisting early language learning in children with Autism Spectrum Disorder**

1.5.1 *Main Research Question*

Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?

1.5.2 *Sub-Questions for Research*

1. What are the educational qualities of an effective vocabulary app?
2. How are different memories activated in vocabulary apps?

3. How is emphasis placed on letters and words used in a vocabulary app?

To effectively answer the research questions the research methodology has to be carefully considered.

1.6 Introduction to the methodology

The research methodology as discussed in detail in Chapter Five for this research study incorporated pragmatism thereby linking theory to research (Creswell, 2009). A mixed method approach was taken focusing on an embedded design collecting both qualitative and quantitative data to address the research problem (Creswell, 2005). The design strategy was Design Science Research (DSR) which included different phases, and each phase produced an artefact that addressed the research problem and questions according to the Design Science Research Model (DSRM) (Cronholm, Göbel, Lind, & Rudmark, 2013).

1.7 Brief Explanation of the Succeeding Chapters

Chapter One provides an overview of the reasons the study took place. Presenting the focus of the chapter, the motivation and overview, the problem statement and purpose of the research study and the research questions with an introduction to the research methodology addressing these questions.

In **Chapter Two** a detailed discussion is found relating to Autism Spectrum Disorder (ASD). The cognitive theories of ASD are explained, followed by learning and early language learning in ASD, reading and ASD, and pictures and ASD, educational technology and ASD and ending with pictures and ASD.

In the next chapter, **Chapter Three** literature relevant to the context of the study is discussed. Explaining education and learning, multimedia learning, learning styles, memory, early childhood development and education and early language learning in general. The literature includes topics describing instructional graphics, multimedia, multimedia design principles, graphic design elements and principles, technology and learning, eye tracking, eye tracking in autism and mobile applications.

Chapter Four presents the conceptual framework which includes the Cognitive Theory of Multimedia Learning, the Cognitive Theory of Learning with Media, Oelwein's Methodology, Bruner's Three Stages of Learning, and Human Computer Interaction (HCI).

The Research Design and Methodology are discussed in **Chapter Five.** Following the layers of the research onion the choices were: Pragmatism as research philosophy; inductive and deductive reasoning is the approach taken; Design Science Research as the research strategy; mixed methods as methodological choice incorporating an embedded design. A longitudinal study was implemented concluding with the data collection and analyses.

Chapter Six provides the results and findings of the Design Science Research Model's phase one and phase two including the various undertakings involved in each phase.

Chapter Seven, similar to the previous chapter, provides the results and findings of Design Science Research Model's phase three and four with the corresponding activities.

The final chapter of the thesis, **Chapter Eight**, returns to the research questions, provides a summary of the research process, the phases of the Design Science Research Model and a reflection on the findings. In addition, the contributions of knowledge are discussed, recommendations are offered, the delineations and assumptions of the study as well as the way forward are conversed ending with a few closing thoughts.

2 CHAPTER TWO - AUTISM SPECTRUM DISORDER

2.1 Focus of Chapter

Developing further on the brief discussion in Chapter One of Autism Spectrum Disorder (ASD), this chapter will provide greater detail about ASD aiming to provide insight into the different aspects of ASD.

The content will include: ASD (Section 2.2), Augmentative and Alternative Communication (Section 2.3), Cognitive Theories of Autism Spectrum Disorder (Section 2.4), Learning and Autism Spectrum Disorder (Section 2.5), Visual perception and Autism Spectrum Disorder (Section 2.6), Educational Technology and Autism Spectrum Disorder (Section 2.7) and Reading and Autism Spectrum Disorder (Section 2.8).

2.2 Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) consists of a group of developmental disabilities resulting in social, communication and behavioural challenges and is considered to be a neurodevelopmental disorder (Black, Grant, & American Psychiatric, 2014). This disorder tends to manifest itself in various ways depending on the seriousness of the autistic condition, the stage of development and chronological age and for this reason the term *spectrum* is used(Bölte, Poustka, & Geurts, 2018).

Characteristics common to Autism are engaging in repetitive activities and stereotype movements; poor eye contact; difficulty socialising; resistance to change in daily routines; and unusual responses to sensory experiences such as loud noises or the texture of food (Grandin & Panek, 2014; Ryan, Hughes, Katsiyannis, McDaniel, & Sprinkle, 2014). Situational demands, switching thoughts and cognitive flexibility are tremendously challenging for ASD learners. When a transition has to take place verbal and visual cues are needed to help this process. The majority of children with ASD have Intelligence Quotient (IQ) scores that indicate intellectual disability although one third have average to above average IQs. This is referred to as high-functioning Autism or Asperger Syndrome (Hume, Sreckovic, Snyder, & Carnahan, 2014, p. 38).

The world famous activist for autism, animal scientist and author, Temple Grandin (Grandin, 2006; Grandin & Panek, 2014) being autistic herself, has provided valuable information about her life as an autistic person by being the voice behind autism. This has helped society to better understand autism(Silberman, 2015).

According to Grandin (2006) and Panek (Grandin & Panek, 2014) autism can best be identified through observation and evaluation of behaviours and vary from person to person. Grandin and Panek (2014, p. 107) and a number of other authors (Kim, 2015; McPartland & Volkmar, 2012; Ritvo, 2005; Turkington & Anan, 2007; Xavier, Bursztejn, Stiskin, Canitano, & Cohen, 2015) mention that Leo Kanner was the first physician to diagnose and write about Autism in 1943, recognising the consistent behaviour for the need of solitude and sameness in a world that never change. These traits were exhibited by eleven children Kanner first reported on showing stereotypical behaviour such as the incapacity to associate with others, not being able to talk and being exaggeratedly concerned with change. The children that could talk experienced difficulty with language in a number of forms namely (McPartland & Volkmar, 2012, p. 1): echolalia - a meaningless repetition of words said by another person as well as idiosyncratic language – referring to language used by the autistic child that has a private meaning or only has meaning to the child or children familiar with the origination of the word. Moreover Kanner noticed atypical behaviours, specifically repetitive movements such as hand flapping or body rocking. Kanner took this a step further commenting that the parents of Autistic children were rarely warm-hearted, emotionally distant and had a strong tendency towards science, or literature or art with little to no interest in people.

In the same time period that Leo Kanner was busy with his observations and research on autism. Hans Asperger an Austrian paediatrician identified certain children that had similar but distinct behaviours such as: lack of empathy, little ability to form friendships, one-sided conversations, intense absorption in a special interest, and clumsy movements(Silberman, 2015). Asperger (Grandin & Panek, 2014, p. 245) recognised that these children could talk unendingly about topics that were of keen interest to them and called them “little professors”. These children were diagnosed as having Asperger syndrome.

Recently the *Diagnostic and Statistical Manual of Mental Disorders, fifth edition* (DSM-V) (Black et al., 2014, p. 40) (American Psychiatric, American Psychiatric, & Force, 2013)used by professionals in the United States of America (USA) has (World Health, 2016)summarised the central features of ASD into two criteria:

Criterion A: Persistent deficits in reciprocal social communication, in nonverbal communicative behaviours used for social interaction and in developing, managing, and understanding relationships. This is seen in an abnormal social approach and a failure of normal back-and-forth conversation; reduced sharing of interests, emotions or affect; failure to initiate or respond to social interactions; poorly integrated verbal and nonverbal communication; abnormalities in eye contact and body language; deficits in understanding and use of gestures; total lack of facial expressions and nonverbal communication; deficits in developing, maintaining, and understanding relationships; difficulties adjusting behaviour to suit various social contexts; difficulties in sharing imaginative play or in making friends and an absence of interest in friends(American Psychiatric et al., 2013; Black et al., 2014) (Association, 2013)

Criterion B: Restricted, repetitive patterns of behaviour, interests, or activities. This is seen in stereotyped or repetitive motor movements; the insistence of sameness; inflexible adherence to routines; ritualised patterns of verbal or nonverbal behaviour; highly restricted fixated interests abnormal in intensity or focus; hyper- or hypo reactivity to sensory input or unusual interest in sensory aspects of the environment (indifference to pain or temperature, adverse response to specific sounds or textures, excessive smelling or touching, visual fascination with lights or movement) (American Psychiatric et al., 2013; Black et al., 2014)(Association, 2013).

(American Psychiatric et al., 2013; Black et al., 2014)Hyman (2013) mentions that ASD is likely to appear four times more in males than females although females are inclined to show greater intellectual disabilities. The features of autism are manifested in early childhood by lack of interest in social interaction, odd play patterns, repetitive behaviours and delayed language development most often observed in the first two years of the child's life. Roughly one third of children with ASD are nonverbal.

The severity of ASD is classified into three different levels As set out in Table 2.1 below:(American Psychiatric et al., 2013, p. 52):

Table 2-1 Severity Levels of ASD

SEVERITY LEVELS OF ASD		
Severity Level	Social Communication	Restricted, repetitive behaviours
Level One: 'Requiring support'	Without support, noticeable impairments in social communication can be observed, difficulty is experienced in initiating social interactions	Inflexibility of behaviour causes significant interference with functioning in one or more contexts; difficulty switching between activities; organisation and planning problems hamper independence.
Level Two: 'Requiring substantial support'	Marked deficits in verbal and nonverbal social communication skills; social impairments even with support in place; reduced or abnormal responses to social overtures from others.	Inflexibility of behaviour; difficulty coping with change; restricted or repetitive behaviours obvious to casual observer and interfere with functioning; distress and/or difficulty changing focus or action.
Level Three: 'Requiring very substantial support'	Severe deficits in verbal and nonverbal social communication skills causing severe impairments in functioning; very limited initiation of social interactions; minimal response to social overtures from others.	Inflexibility of behaviour; extreme difficulty coping with change; restricted or repetitive behaviour interferes with functioning in all spheres. Great distress or difficulty changing focus or action.

ASD is considered to be one of the fastest growing disabilities in the United States of America (USA) as one child in 150 is diagnosed with ASD, as proclaimed by Ryan et al (2014, p. 94). This statement is argued against by Baxter et al (2015, p. 1) since allegedly no distinct evidence indicates a change in the occurrence of ASDs. According to Baxter et al (2015, p. 1): "… there was little regional variation". However, their study only considered the time period between 1990 and 2010. No research has been published for the growth rate of ASD in sub-Saharan Africa as indicated by Franz, Chambers, von Isenburg and de Vries (2017).

(American Psychiatric, 2000)(American Psychiatric et al., 2013)Different types of disorders fall under the ASD (Ryan et al., 2014, pp. 94-95), the DSM-IV identified five different possible diagnoses (Kim, 2015, p. 9) listed as: Autistic Disorder, Asperger Syndrome, Childhood Disintegrative Disorder, Rett Syndrome, and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS). However DSM-V *(American Psychiatric et al., 2013)* has not included Asperger Syndrome, and Pervasive Developmental Disorder Not Otherwise Specified as part of ASD(2016, p. 485)(American Psychiatric et al., 2013, p. 51)(Yaylaci & Miral, 2017).

2.2.1 *Autism Disorder*

Children with an autism disorder have an inability to relate to people or situations, appear self-sufficient and want to be left alone. Not even their parents seem to be important to them and they cannot relate to them. They appear to be deaf but their hearing is not defective. At four months of age they do not display the normal anticipatory posture of babies their age being picked up (Bakwin, 1954; Kanner, 1944).

Childhood autism was examined by Rutter (1978) and later expanded on by Schopler, Reichler, DeVellis and Daly (1980, p. 94) to include the following features: impairment in human relationships; imitation; inappropriate affect; bizarre body movement and persistence in stereotypes; peculiarities in relating to nonhuman objects; resistance to change, peculiarities of visual responsiveness i.e. avoiding eye contact; peculiarities of auditory responsiveness i.e. avoid auditory stimuli or overreact to certain sounds or noises; near receptor responsiveness i.e. preoccupation with tactual exploration, mouthing, licking, smelling, and rubbing objects; anxiety reaction; verbal communication i.e. echolalia, pronoun reversal, peculiar language; nonverbal communication i.e. use or response to gestures; activity level i.e. apathy or hyperactivity; intellectual functioning i.e. cognitive skills and unusual extraordinary good performance in music or numbers; general impression i.e. the degree of autism observed.

Atypical autism is considered to be a pervasive development disorder that does not fulfil the diagnostic criteria of autism disorder and is considered a separate condition to autism. Abnormal or impaired development is only noticed after three years of age. Atypical autism is prevalent in persons who are extremely retarded or have severe specific developmental disorders of receptive language, making autism difficult to diagnose. Children with atypical autism exhibit insufficient abnormalities in reciprocal social interactions, communication and restrictive, stereotyped, repetitive behaviour which are the three areas of psychopathology required to diagnose autism (Organization, 1992, p. 200).

In autism, aggression and non-compliance are customary although aggression is the most recurrent, habitual and disruptive of all behaviours (Dawson, Matson, & Cherry, 1998).

2.2.2 *High Functioning Autism and Asperger's Syndrome*

High Functioning (HF) autism and Asperger syndrome have caused a number of arguments among professionals. Some professionals argue that they are one and the same while others argue that they are different but related. Mesibov and colleagues (Mesibov, Shea, & Adams, 2006, p. 5) declare that the term '*high functioning autism'* is not a diagnosis in any diagnostic system. They point out that it is rather an informal and descriptive manner of referring to autism with an intelligent quotient (IQ) of 70 or above. Turkington and Anan (2007, p. 9) reason that Asperger syndrome is considered to be a "

… a subtype of high-functioning autism …". Asperger syndrome is considered to be the mildest form of autism but falls under the autism spectrum.

To differentiate between children that have high functioning autism and Asperger syndrome (2018)remains a difficult task as the experts disagree on whether they are indeed different disorders. The symptoms of the disorders overlap considerably therefore the term High Functioning Autism Spectrum Disorders (HFASDs) is applied to describe the broader group of these type of children (Volker et al., 2010). The biggest difference between high functioning autism and Asperger's syndrome relates to early language skills. Children with Asperger's syndrome do not experience any difficulty with learning language and talking (2009).

High functioning children with autism have (Mesibov et al., 2006, p. 21):

- Less impaired responsiveness in infancy
- Better cooperative play and emotional expressiveness
- Fewer unusual social interactions
- More rituals but less resistance to change and attachment to odd objects
- Less self-injurious behaviour
- Fewer hand stereotypes

On average high functioning autism children speak their first word at two and a half years and their first phrase at four years and eight months (Mesibov et al., 2006).

On the contrary Asperger, a pioneer of autism did not provide any diagnostic criteria for the syndrome named after him. The term '*Asperger syndrome'* was first used by Wing in 1981 when Kanner's definition of autism was only applicable to 10 percent of children with autism and a broader definition was sought (Attwood, 2006; Mesibov et al., 2006). Wing (1981) found the diagnostic boundaries to be limited and felt the need for a more balanced approach which included the most typical features.

The major diagnostic criteria for children with Asperger syndrome is that they function at a very high cognitive level and do not show any delays in verbal communications.

However, they do show difficulty in understanding nonverbal communication (Turkington & Anan, 2007). As mentioned Asperger syndrome is without language or intellectual impairment. The difficulty experienced in making an Asperger syndrome diagnosis is that not all the features satisfy the diagnostic criteria and it is based on observable behaviours (Foster, 2015; Rhode, 2011).

A high functioning autism spectrum screening questionnaire (ASSQ) was developed as an instrument for identifying Asperger syndrome in children (Ehlers, Gillberg, & Wing, 1999, p. 139). The indication is that Asperger syndrome includes the following traits:

1. Old-fashioned or precocious;
2. Regarded as a “eccentric professor” by other children;
3. Lives in a world of his or her own with restricted idiosyncratic intellectual interests;
4. Accumulates facts on certain subjects (good rote memory) but does not really understand the meaning;
5. A literal understanding of ambiguous and metaphorical language;
6. A deviant style of communication with a formal, fussy, old-fashioned or “robot-like” language;
7. Invents idiosyncratic words or expressions;
8. Has a different voice or speech;
9. Expresses sounds involuntarily: clears throat, grunts, smacks, cries or screams;
10. Surprisingly good at some things and surprisingly poor at others;
11. Uses language freely but fails to make adjustment to fit social contexts or the need of different listeners;
12. Lacks empathy;
13. Makes naïve and embarrassing remarks;
14. Has a deviant style of gaze;
15. Wishes to be sociable but fails to enter into relationships with peers;
16. Can be with other children but only on his or her terms;
17. Lacks a best friend;

18. Lacks common sense;
19. Is poor at games: no idea of cooperating in a team, scores “own goals”;
20. Has clumsy, ill coordinated, ungainly, awkward movements or gestures;
21. Has involuntary face or body movements;
22. Has difficulties in completing simple daily activities because of compulsory repetition of certain actions or thoughts;
23. Has special routines: insists on no change;
24. Shows idiosyncratic attachment to objects;
25. Bullied by others;
26. Has markedly unusual facial expressions; and
27. Has a markedly unusual posture.

This instrument was not intended for making a diagnosis but to help identify HF children with ASD that needed to be evaluated more comprehensively.

One deduction that can be made is that the similarities between high functioning children with ASD and children with Asperger syndrome are wide-ranging and the distinguishing features slight.

2.2.3 *Childhood Disintegrative Disorder*

In 1908 Theodore Heller discovered *Dementia Infantilis* while observing young children which more recently has become known as Childhood Disintegrative Disorder (CDD) in the DSM-IV (Volkmar & Rutter, 1995).

These young children presented normal growth and development up until their third or fourth year. During their third or fourth year these children started exhibiting deterioration in their moods, behaviour and intellectual functioning. They lost the ability to talk, became incontinent and had to receive full time care (Hendry, 2000; Malhotra & Gupta, 2002; Mouridsen, 2003). (Patel & Samani, 2018)

CDD has similar behavioural features to autism although distinguished by the extended period of normal development with the sudden and dramatic forfeiture of skills. CDD also appears to be more prevalent in males than females. Once regression has taken place further improvements on development are less likely (Mouridsen, 2003).

CDD is progressive and is first noticed when the children present defects in speech and then complete loss of speech. The early stages of CDD exhibit restlessness, fear and sometimes hallucinations. Language ability, social skills, appropriate play and motor skills are impaired. All of these symptoms occur before the age of ten (Hendry, 2000).

2.2.4 *Pervasive Developmental Disorder Not Otherwise Specified*

(Yaylaci & Miral, 2017)Children that exhibit certain features but not all the characteristics of autism may be diagnosed as having Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) according to Turkington and Anan (2007). PDD-NOS has fewer autistic symptoms specifically related to repetitive, stereotyped activities. These children fall between autism and Asperger syndrome (AS) on IQ, adaptive behaviour and language milestones. Showing less delays in language than children with autism but more delays than children with Asperger's and have fewer repetitive behaviours than both groups (Walker et al., 2004, p. 178).

The diagnosis of PDD-NOS in clinical practice is seen in several areas such as being hyperactive, easily distracted, disorganised behaviour, cognitive and learning problems as well as odd and one-sided social approaches (Buitelaar, Van der Gaag, Klin, & Volkmar, 1999, p. 34). Children with PDD-NOS withdraw from social situations and have little interest in people or their immediate environment. (Woestelandt et al., 2018)Severe anxiety or rigidness are observed in PDD-NOS children and in most cases they have Attention-Deficit Hyperactivity Disorder (ADHD) as mentioned earlier. However the main characteristic in most cases is impaired social interactions before the age of three.

A different perspective provided by Buitelaar et al (1999) is that PDD_NOS children share some similar traits to autism such as deficiencies in social interaction and communication but additional deficiencies such as anxiety, thought disorder and aggressiveness can be observed.

Table 2-2 provides a summary of Autism and related disorders.

Table 2-2 Characteristics of Autism and Related Disorders

Disorder	Characteristics
Autism	Restricted patterns of interest, [lacks] varied make-believe play, [fails] to use or understand nonverbal behaviour, earlier age of onset (Walker et al., 2004, p. 173)
Atypical Autism	Children older than 36 months with impairments in social reciprocity and in verbal and nonverbal communication but who show few, or transient, repetitive stereotyped behaviours (Walker et al., 2004, p. 180)
Asperger Syndrome	Childhood onset. Very high cognitive level, no delays in communication, old fashioned, precocious, idiosyncratic intellectual interest, attachments to objects, accumulation of facts, deviant style of communication, different voice or speech, involuntary expression of sounds, lacks empathy, makes naïve or embarrassing remarks, deviant style of gaze, fails at relationships with peers, lacks best friends, lacks common sense, clumsy, poor team work skills, involuntary face or body movements, compulsory repetitive actions or thoughts, special routines, unusual facial expressions and posture, difficulty identifying nonverbal communication (Ehlers et al., 1999; Turkington & Anan, 2007).
CDD	Onset between three and four years of age and before ten years, normal development until age three or four, then speech defects, loss of speech, restlessness, fear, impaired language, social, play and motor skills (Hendry, 2000).
PDD-NOS	Relates easier to others, better self-help skills, better language capabilities, better social skills, improved skills relating to people, improved object and body use, ADHD, easily distracted, disorganised behaviour, cognitive and learning problems, odd one-sided social approaches (Buitelaar et al., 1999; Walker et al., 2004).

As is evident the characteristics of autism fall under a spectrum hence the term Autism Spectrum Disorder. There are also a number of cognitive theories that can be linked to autism and are discussed in the sections to follow.

2.3 Cognitive Theories of Autism Spectrum Disorder

The focus of cognitive theories in ASD is to identify the shortcomings that result in the specific cognitive impairments familiar to ASD such as communication, socialisation and imagination (Pellicano, Maybery, Durkin, & Maley, 2006). The various theories involved to explain the concept of cognition in ASD are explained in the paragraphs to follow. The theories that will be explained are theory of mind, weak central coherence, executive dysfunction, and the more recently introduced enhanced perceptual functioning.

2.3.1 *Theory of Mind*

Theory of mind (ToM) was first introduced and used in 1978 by Premack and Woodruff to determine the ability of an individual to ascribe a mental state to him or herself or others and predicting the behaviour of such mental states (Fletcher et al., 1995; Hill & Frith, 2003; Leslie, 1987). This requires recognising that another person's belief is based on his or her experiences, perspective and knowledge, thereby developing social understanding. (2018)

A lack of ToM is referred to as '*mind blindness*' and *'mentalising failure'* and has been researched extensively (Baron-Cohen, 2002; Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, Lombardo, Tager-Flusberg, & Cohen, 2013; Baron-Cohen, Ring, et al., 1999; Baron-Cohen, Wheelwright, Stone, & Rutherford, 1999). ToM is said to be absent in moderate and low functioning ASD people, there are instances where high functioning ASD individuals have taught themselves to identify various mental states even though it is not intuitive to them (Hill & Frith, 2003).

The process of identifying and predicting mental states is impaired in people with ASD as mentioned, explaining their aloofness, lack of empathy and undiscerning social approaches according to Baron-Cohen et al (1985). People with ASD show shortfalls in their understanding of pretence, bluffing, white lies, and lack intuitive understanding of the motives of other people. Furthermore their cause and effect reasoning when told a story is impaired by not being able to predict or explain certain behaviours of characters within a story (Baron-Cohen et al., 1985; Jacobsen, 2005). A normal person's way of thinking is considered to be strange and difficult to understand for ASD people (Jacobsen, 2005).

These statements have been challenged by various authors (Dahlgren, Sandberg, & Hjelmquist, 2003; Lawson, 2011; Mason, Williams, Kana, Minshew, & Just, 2008; D. Williams, Goldstein, & Minshew, 2006) questioning the legitimateness of ToM specifically the concept that there is: "… only 'one normality' and all else outside of this development paradigm is disordered and deviant" (Lawson, 2011, p. 808).

The arguments that exist against ToM is that the understanding of self and others can be developed in various ways and that ToM should not be specifically assigned to children with ASD. Furthermore, it is argued that ToM assessments involve other abilities as well such as pretending and emotive play. The ToM assessments can be completed with success without true understanding of false belief bringing into question the relevance and validity of ToM. The reason for this is that social understanding and development have not been taken into consideration neither have the mental states of the participants. Each person uses a different approach to make sense of his or her world (Lawson, 2011).

In conclusion research done by Minshew and Williams (2007) has indicated the children with ASD process information in a different manner using different abilities to compensate for language problems. This could be as a result of their more visually inclined brains and the way information is processed in ASD. For this reason ToM is considered to lack scientific evidence of the cognitive development of children with ASD.

2.3.2 *Weak Central Coherence Theory*

The weak central coherence theory was first introduced in 1989 and entails two principles (Vanegas & Davidson, 2015, p. 78):

Principle 1: Individuals with ASD possess a natural bias to focus on the local properties of information and;

Principle 2: Individuals with ASD exhibit difficulties integrating the local properties of information into meaningful representations.

Looking at central coherence as described by Hill and Frith (2003, p. 284) it is described as an information processing style that manages incoming information in context resulting in a higher level meaning. So when varied information is received it is processed so that a higher meaning is constructed aiding comprehension so that the gist of a story or situation is understood, resulting in the creation of a global meaning that will be remembered and understood, although not all the details will be remembered or be completely accurate (Jacobsen, 2005).

On the other hand poor or weak central coherence does not process information in a contextual manner but rather focuses on certain aspects of incoming information. Details are focused on and remembered and the central idea or gist is not considered. The focus becomes local instead of global.

An example is provided whereby a child with ASD when asked to recall a story will recall the exact words but not grasp the meaning of the story therefore not identifying the higher meaning of the story. On the other hand -typical developing children did not recall the detail but understood the overall meaning of the story (Hill & Frith, 2003).

Research has shown that weak central coherence is unrelated to the Intelligence Quotient (IQ) of an ASD child (Jacobsen, 2005). Hill (2004b) argues this point by stating that her research has shown the IQ influences performance, difficulties are experienced by ASD participants that have a lower than normal IQ.

Additional research (Fletcher-Watson, Leekam, Turner, & Moxon, 2006; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009) has shown that people with ASD do exhibit normal attention, identify the context and make conclusions although at times slower than typical developing persons. Individuals with ASD process information in a different way which may take longer due to specific intellectual functioning needs. Factors such as attention, interest and sensory-motor processing need to be taken into consideration (Lawson, 2011).

2.3.3 *Executive Dysfunction*

Executive function is an umbrella term for various functions such as: "… planning, working memory, impulse control, inhibition, mental flexibility and the initiation and monitoring of action", states Hill (2004b, p. 1).

Executive function refers to maintaining appropriate problem-solving skills to achieve future goals by involving various high order cognitive functions. These cognitive functions help with decision-making by keeping information about likely choices in working memory(Garon, Smith, & Bryson, 2018). The integrated knowledge of working memory is then combined with information about the present situation resulting in the best action to be taken for the current situation (Tsatsanis, 2004; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

Explained in another way by Jacobsen (2005, p. 33) executive function is " … the capacity to control our own attentional focus." Executive function involves multitasking whereby a person attends to or does more than one task at a time and realises its relevance. The skills involved in executive function are attention, organisation and generalisation, resulting in a person not being distracted by things that are irrelevant, only focusing on what is relevant.

Poor executive function or executive dysfunction results in attentional problems of a different kind – getting the ASD person to shift their attention to what is relevant. Seeing the bigger picture and knowing, remembering and attending to what is important to others is a difficult task for a person with ASD. Furthermore similarities between various situations are not easily noticed by the ASD person, since they lack the ability to generalise (Jacobsen, 2005).

People with ASD experience weakened (Hill, 2004b, p. 3):

- **Planning abilities** as was made evident in research where puzzles were involved that had a longer sequence of moves (Hill, 2004b). Difficulty was experienced in planning certain actions, constantly monitoring the actions, re-evaluating the actions and updating them.
- **Mental flexibility** whereby difficulty is experienced in the ability to shift focus from one thought or action to another as a situation changes.
- **Inhibition -** referring to the impaired response of an ASD person when having to make a choice or decision. ASD people do not make an immediate decision but exhibit '*prepotent inhibition*' also known as 'response inhibition' (Urben, Van der Linden, & Barisnikov, 2011). They perseverate (repetition of a behaviour) noticeably more than typically developing people when having to make a decision.

The understanding of executive dysfunction in ASD people has advanced in the last decade. Certain components of intact executive function and dysfunction have been identified in the ASD. The ability ranges of executive function differ from one ASD person to another and performance across various tasks should be taken into consideration. The argument exists that poor executive function does not necessarily cause ASD. Executive function peaks when ASD people participate in their field of interest and their attention is engaged (Lawson, 2011).

2.3.4 *Enhanced Perceptual Functioning Theory*

Enhanced perceptual functioning (EPF) is a more recent theory relating to ASD(2001). EPF refers to brain processes involving sensory and motor information that is absorbed in excess. The excess or over processing of information results in some information being focused on more readily while other information is left out or lost (Lawson, 2011).

Happé and Frith (2006) explain that EPF foretells that autistic people will have better performance at certain tasks than non-autistic people specifically those with Asperger's. Superior performance in visual and auditory modalities are achieved.

The role of perception is of a different and superior ability in autistic cognition. Cognitive processing occurs differently in ASD people than non-ASD, with a specific autistic pattern that explains the accomplishments of enhanced perceptual functioning (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006).

Lawson (2011) argues that interest has not been taken into consideration for EPF and could provide an explanation for the extraordinary ability of autistic people in certain tasks.

2.3.5 *Single Attention and Associated Cognition in Autism*

Single Attention and Associated Cognition in Autism (SAACA) is said to provide an explanation as to why some autistic individuals reveal extraordinary ability or pass tests that they are expected to fail or act empathetic towards people, animals or objects according to Lawson (2011) who identified the SAACA theory. Lawson (2011), having ASD, discussed the SAACA theory in her doctoral studies.

Single attention takes place in ASD individuals when extreme focus occurs relating to a specific area of interest and this is known as monotropism. With monotropism a particular channel is used to access and process information similar to tunnel vision. Attentional differences occur in ASD individuals incorporating single attention and single interest whereby certain senses are exaggerated above another sense or underdeveloped. These senses include visual, tactile, hearing and tasting. ASD individuals' brains are 'wired' differently " … using different neural systems to interact socially and to work out intention and connections…" (Lawson, 2011, p. 1765). They exhibit different patterns of connectivity in their brains which causes them to focus on one thing only with only one area of interest in one specific period of time. Incorporating two senses at a specific time can be challenging for ASD individuals.

The effects of monotropism are that multiple connections cannot be made leading to poor identification of context, and not being able to come up with alternative solutions and viewpoints to a situation or problem.

The opposite is true for non-ASD individuals, they can shift their focus and attention with little effort from one entity to another depending on their interests at that given moment.

Table 2-3 provides a brief summary of the different theories and their meaning.

Table 2-3 Summary of Cognitive Theories of ASD

Theory	Definition
Theory of Mind	Ascribing a mental state to others or him or herself and predicting the behaviour of such mental states (Baron-Cohen et al., 1985; Jacobsen, 2005).
Weak Central Coherence Theory	Information is not processed in a contextual manner and the focus is only on certain aspects of the incoming information resulting in the central idea or gist being lost (Hill & Frith, 2003).
Executive Dysfunction	Lack of problem solving, planning, organisation and multitasking skills to achieve goals. Being distracted by irrelevant things not focusing on the problem at hand, response inhibition occurs when having to make a decision (Hill, 2004a, 2004b).
Enhanced Perceptual Functioning	Brain processes involving sensory and motor information that is absorbed in excess. The excess or over processing of information results in some information being focused on more readily while other information is left out or lost (Lawson, 2011)

Single Attention and Associated Cognition	Explains why some autistic individuals reveal extraordinary ability or pass tests that they are expected to fail or act empathetic towards people, animal or objects described by Lawson (2011)

These theories provide insight into how vocabulary applications (apps) need to be developed for children with ASD learning language. Taking into consideration that pretence or bluffing may cause confusion, and that a lesson or story used in a vocabulary app can lose its impact if the gist or central idea is not grasped.

Finally, that vocabulary apps should be developed in such a way that the ASD child is not easily distracted, allowing for a distinct focus on the letter or word being taught. This leads to the next section that explains about learning and ASD.

2.4 Learning and ASD

Autism Spectrum Disorder impairs the way information is processed. An increased awareness of the visual learning style of children with ASD has occurred as academics attempt to understand ASD (Broun, 2004). In the book *Thinking in pictures and Other Reports From My Life with Autism* (Grandin, 2006, p. 569) the author Temple Grandin herself autistic with a PhD in animal science, explains how the use of different pictures helped her to understand different concepts by thinking in photographically specific images. Grandin (Grandin, 2006, p. 587) points out: “If I have no picture, I have no thought.”

Grandin believes that nouns are the simplest to teach the children with ASD since they could be directly linked to pictures. Children with ASD with a high verbal capacity can in a similar fashion to Grandin learn to read with the use of phonics. Low functioning children with ASD learn better with the help of association when objects have word labels on them. Highly impaired children with ASD have greater success in learning to read and speak when they use plastic letters that they can touch and feel when a word is spelled out to them. Certain children with ASD see patterns and relationships between patterns instead of photographic images, these children are known as music and math thinkers. Children with ASD suffering from speech delay are also inclined to be music and math thinkers. Other children with ASD are known as verbal logic thinkers that think in word details enjoying subjects such as history, languages, weather statistics and stock market reports (Grandin, 2006; Grandin & Panek, 2014).

Interesting research about children with ASD's learning strength's and preferences, specifically a Learning Preferences and Strengths (LPS) model, was introduced by MacKenzie (2008).

Influenced by the work of Gardner (2011), Jung (2014) and the Myers-Briggs Type Indicator and focusing on the passions and brain power of children with ASD the foundation for the LPS model was created. This was achieved by looking beyond ASD to the strengths and cognitive style of ASD. (2018)

Mackenzie (2008) identified from her research of 71 parent surveys that the trend for children with ASD is towards the Introverted-Sensing-Thinking-Judging (ISTJ) type. The **introverted** traits are: slow to warm up, in depth focus, selective interests, likes to work alone. The **sensing** traits are: focuses more on objects, facts and concrete information than people, remembers specific detail, trusts information gained through senses, prefers familiar and practised methods and distrusts people who are not careful about facts. The **thinking** traits are: identifies what is wrong or different in a person, situation or event, not concerned with what his or her social groups is doing, analytical and interested in routine and rules and prefers logic-focused rather than people-focussed activities. The **judging** traits are: prefers to live in a planned and orderly way, with orderly details, orderly categories and planned schedules, routines and rules, finishes what he or she starts, is dependable and perseverant in things important to him or her, finds it hard to change from one thing to another (MacKenzie, 2008, pp. 38-40).

Two learning strengths of children with ASD were identified by Mackenzie's (2008) research namely Musical-Rhythmic and Visual-Spatial. The traits for **Musical-Rhythmic** are: seeking out music and rhythm and listening with interest, enjoys and responds to a variety of musical and rhythmic sounds, recognises and remembers music, musical patterns and rhythm and is sensitive to pitch, rhythm and melody. The traits for **Visual-Spatial** are: understands, retains and remembers information that can be seen, creates visual experiences, shows sensitivity to colour, line, shape, form, space, and relationships – noticing minute details, and prefers orderly, tidy environments. However, these learning strengths were only found in approximately forty percent of the learners.

The LPS model involves three key components when designing a programme (see Figure 2-1).

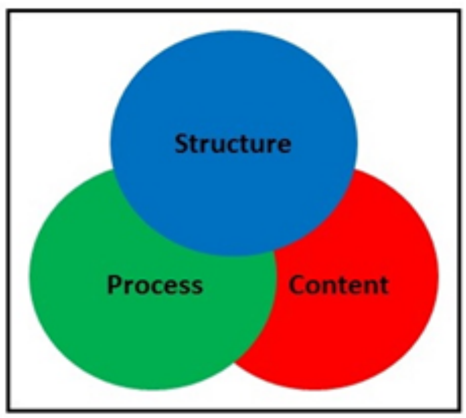


Figure 2-1 The Learning Preferences and Strengths (LPS) model

Programme structure: this involves the most appropriate structural features such as a sensory reduced environment where sounds, sights, smells and other sensations are controlled. The environment is organised and orderly so that the ASD child is not distracted. A distinct, visually-obvious structure and organisation is presented so that the ASD child knows what is expected of him or her by when and where. The tasks and activities are planned in a logical and structured manner so the ASD child knows what to do and when it will be finished. Opportunities must be provided for downtime (MacKenzie, 2008).

Learning content: Extended time is given to process and respond to information. A step-by-step method is used focusing on detail and tangible facts. Sensory systems are used to acquire information and important facts. The tasks are planned and orderly and have a clear beginning and end (MacKenzie, 2008, p. 94).

The Visual-Spatial aspects of learning content according to MacKenzie (2008, p. 95) incorporate information that can be seen, thereby promoting understanding and remembering. The strategies involved are intensely visual and spatial. These strategies include (MacKenzie, 2008, p. 97):

- Working left to right or right to left
- Using the 'finder finger' – the index finger helps the brain find information
- Working top to bottom or bottom to top
- Labelling
- Determining what is important
- Ignoring what is not important
- Using signs and clues
- Using models
- Rehearsing
- Grouping and categorising
- Finding and using patterns
- Connecting past tasks and events
- Looking for similarities and differences
- Planning precise responses
- Developing specific listening behaviours
- Recalling object descriptions
- Visualising

MacKenzie (2008) however provides minimal information about where the Musical-Rhythmic traits fit in. Songs with actions and pictures with spoken words are mentioned which help with focus and the recall of words.

Program process: involves mediated learning whereby a person such as a teacher or parent - the mediators - provide interactions that are thorough, planned and clear. The information provided to the ASD child is sifted to provide only the important and relevant information also rules and principles are developed. The mediators act as catalysts arousing curiosity and interest in the ASD child connecting new learning to current knowledge, situations and tasks. Mediation is considered to be an exceedingly verbal process supported by visual prompts (MacKenzie, 2008, p. 172). The ASD child knows what is expected of him or her and which learning processes are taking place.

MacKenzie (MacKenzie, 2008, p. 174) points out that there are seven pillars of mediated learning (see Figure 2-2).

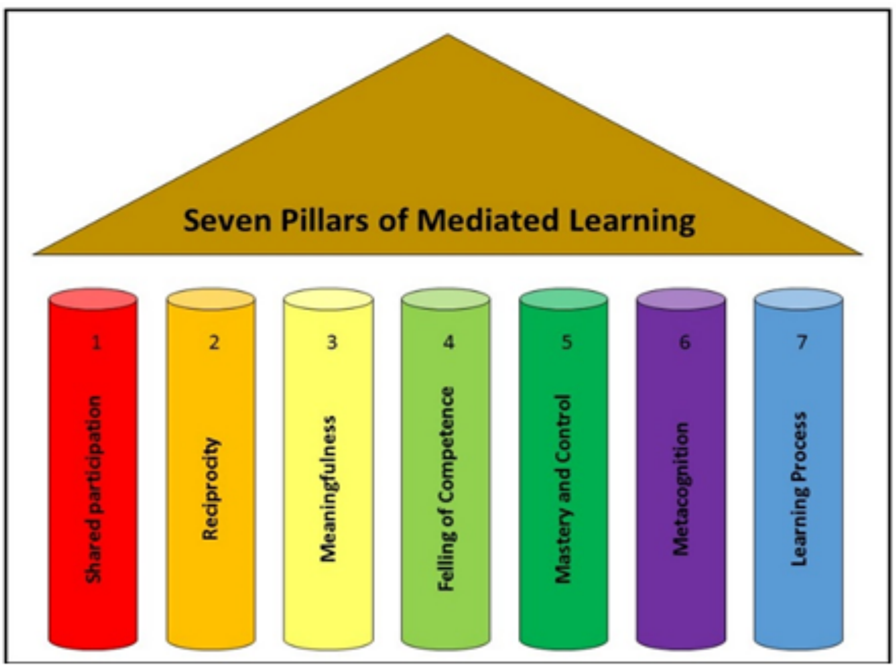


Figure 2-2 The Seven Pillars of Mediated Learning

1. **Shared participation:** the child is encouraged to play an active role in learning and in obtaining information and knowledge. This develops the child's own abilities and creates a positive attitude towards learning. The mediator urges the child to explore and solve problems on his or her own, taking from past experiences and

knowledge. Focus, attention and persistence to overcome obstacles are fostered, developing a tolerance to frustration.

2. **Reciprocity:** denotes the back and forth interaction that takes place between the mediator and the child. Both influence and learn from each other. The mediator challenges the child's thinking and learning.
3. **Meaningfulness:** the child understands the purpose, importance and relevance of the task or activity and how these fit in with his or her interests and experiences. The mediator's purpose is to stimulate interest and curiosity in the child.
4. **Feeling of Competence:** making sure the child feels competent as a learner and motivated about the tasks and activities. When the child's competence and power is developed he or she will be more driven to succeed and experience a sense of achievement and satisfaction. The mediator encourages and supports the child's abilities and skills. Less competent performance can be challenged by questions. Errors can be seen as chances to grow and learn more.
5. **Sense of Mastery and Control:** this is when the child becomes aware of his or her learning strengths, preferences and weaknesses and how to overcome them. Good learning choices are made by being responsible towards his or her learning. The mediator creates an environment that encourages the child's learning preferences and strengths.
6. **Metacognition:** the child's understanding of what it means to learn through planning, monitoring, and revising his or her approach to learning. Revising includes reflection relating to learning strengths and needs, what works for him or her and how to incorporate what works. This encourages freedom and autonomy in learning. The mediator's role is to assist the child in realising what he or she has learnt as well as the experience gained.
7. **Learning Processes:** refers to the mental activities that make learning more effective and efficient. Information is taken in by the brain, various operations are performed to process the information and the locating and storing of it in the

relevant memories (more technically referring to intake, integration and elaboration, and finally output)

These seven pillars can also be used when designing vocabulary apps for children with ASD. From the work of MacKenzie (2008) a comprehensive learning model incorporates the thinking and learning style of the ASD child, a clear philosophy, goals from the philosophy , strategies that are consistent with the philosophy and the goals derived from it. Learning also helps with language development. Early language learning in children with ASD will be discussed next.

2.5 Early Language Learning in children with ASD

Language development in typically developing children can be seen in their first few months when they recognise their mother's voice, synchronise their eye gaze and facial expressions with their parents and take turns in vocal sounds. Their nonverbal communication includes gestures, requesting objects or actions, such as being picked up, rejecting offers by pushing objects away or shaking their heads, and pointing to objects of interest. First words are usually uttered at twelve months and simple words or phrases are understood.

One of the earliest signs of ASD is the delay in the development of speech in young children during their second year according to Tager-Flusberg, Paul and Lord (2005). In most cases ASD (except Asperger syndrome) is first recognised by parents when their young child shows delays in speech development and language and are less responsive to their names or when someone speaks to them. However, children with ASD have different patterns of learning when it comes to language due to varying linguistic and social opportunities presented to them (Tager-Flusberg et al., 2005).

This delay in speech is recognised by slow or unusual patterns of speech although this is not the only deciding factor in diagnosing ASD. This delay in speech is a result of the poor development of motor skills in children with ASD which in turn negatively impacts early language learning. These motor skills are either delayed, impaired or atypical (McCleery, Elliott, Sampanis, & Stefanidou, 2013). The poor learning of early language skills impairs development in other areas for example social, emotional and cognitive development according to Maljaars, Noens, Scholte and van Berckelaer-Onnes (2012).

Children with ASD experience difficulty in learning new words and having conversations. The words learnt by two years of age are lost and is referred to as language regression which is unique to these young children with ASD. A corresponding correlation can be found between the Intelligence Quotient (IQ) of ASD learners and early language learning, however nonverbal IQ cannot always be associated with high levels of language learning. Language and communication skills continue to improve through adolescents into adulthood except in the case of children with ASD with severe language deficits (Maljaars et al., 2012; McCleery et al., 2013; Tager-Flusberg et al., 2005).

2.5.1 *Reading and ASD*

Another area of concern for children with ASD is learning to read. According to Westerveld, Paynter, Trembath, Webster, Hodge and Roberts (2017) children with ASD experience comprehension impediments which influences academic performance negatively. These difficulties may be a result of literacy development in the years before starting school. For children with ASD to positively recognise a word they must be exposed to the letter's name and sound, and the letter in print. Teaching vocabulary to young children with ASD includes phonological and semantic learning. Phonological learning is defined by Joseph (2011) as creating an awareness of the sounds of spoken letters and words. These sounds are stored in working memory so that a link can be made between the spoken and printed letter and word. Semantics has to do with the meaning of words, semantic learning is when the children with ASD learn the meaning of new words being taught. Gladfelter and Goffman (2017) indicate that children with ASD learn words different to typically developing (TD) children accessing semantic information differently. In typically developing (TD) children semantic learning is improved by involving the auditory and visual senses. For children with ASD the new words were learnt more effectively phonologically. Research has shown that children with ASD performed better than TD children at matching phonological sounds to objects (Lucas & Norbury, 2015).

Little research is available on developing literacy skills in young children with ASD. The research that is available indicates that a great variety in literacy skills exists among young children with ASD (Westerveld, Trembath, Shellshear, & Paynter, 2016). However, some recommendations were made for developing literacy skills in children with ASD. These recommendations by Mucchetti (2013) included spending a lot of time reading to children with ASD; taking part in nonverbal interactive reading by pointing to words being read and imitating what is happening in the story with props or acting; reading signs displayed in the nearby environment; discussing the stories with assisted communication devices; and reading and writing with speech-generating devices.

Reading integrates phonics, sight words, contextual fluency, oral vocabulary and comprehension (Carberry, 2014). In general reading involves active readers that comprehend what they are reading as well as understanding the gist of the story. The text is looked over with specific goals in mind, evaluating what is being read – the quality and value - and making predictions. Unfamiliar words and concepts are decrypted drawing from previous knowledge. Decisions are made as to what text should be skipped over and what needs to be reread, thereby monitoring understanding and concluding what has been read and understood (Duke & Pearson, 2008). This however is not the case for children with ASD as identified and discussed by the Weak Central Coherence Theory (see Section 2.3.2).

Reading literacies come in various forms such as paging through a book with pictures, having a conversation, listening to a teacher, reading a story, illustrating an idea, telling a joke, reciting the alphabet and even learning how to use sign language (Kluth & Darmody-Latham, 2003, p. 533).

Technology has contributed successfully in helping children with ASD in different areas of development. The same can be said for reading and learning new words. Computers have helped children with ASD become more focused and motivated to learn new words as stated in the research of Moore and Calvert (2000). Another study conducted by Williams, Wright, Callaghan and Coughlan (2002) concluded that children with ASD spent more time reading with a computer than with a book.

Another manner is which language learning is promoted is through augmentative and alternative communication.

2.5.2 *Augmentative and Alternative Communication*

Mirenda (2013) explains augmentative and alternative communication (AAC) as clinical and educational practices that addresses any limitations or restrictions in language by producing spoken or written text, thereby helping persons with language difficulties to communicate their needs and assisting communication between parties. In addition, AAC helps foster understanding of language and emotion through pictures and writing. Recently mobile technologies (such as touch phones and tablets) have played a pivotal role in improving communication for persons with language disabilities by socially creating a greater acceptance of AAC (McNaughton & Light, 2013).

The same can be said for ASD. By incorporating AAC, young children with ASD can learn to message using symbols. (Doak, 2018; Patch, Mortner, & Joseph, 2018)(Doak, 2018; B. Mahoney, Johnson, McCarthy, & White, 2018; Patch, Mortner, & Joseph, 2018)Furthermore, positive changes in behaviour and communication takes place with the help of AAC. When peers helped each other using AAC, greater success was achieved in communication, specifically when preferred contexts were chosen (Cobb, 2017; Finke et al., 2017; Thiemann-Bourque, McGuff, & Goldstein, 2017).

AAC plays a vital role in improving quality of life for all people with language difficulties and definitely for children with ASD. By understanding the cognitive impairments experienced by persons with ASD, communication hurdles can be overcome.

2.5.3 *Educational Technology and ASD*

Playing is considered to be the most necessary activity in developing a child physically, cognitively, linguistically, emotionally and socially as pointed out by Cankaya and Kuzu (2010, p. 825). These aspects are developed in typical developing children through educational computer games which have been proven to be just as effective for children with ASD. Games act as incentives to help children learn because of their interactive qualities that allow for mistakes and to build on experience.

Over the past couple of years technology has played an increasingly important role in the lives of children with ASD. Computers have helped encourage social interactions and improve social skills, getting shy or socially withdrawn children with ASD to engage with other children more often. Other types of technologies such as videos have helped improve communication. In addition, various devices such as iPods, iPads and iPhones have positively contributed to overcoming developmental disabilities as reported by Kagohara et al (2013). Likewise robot dolls have been designed to help improve social interaction through imitation, speech and gestures thereby becoming interactive "friends" for children with ASD (Sehaba, Estraillier, & Lambert, 2005).

The results of the meta-analysis by Grynszpan et al (2014) conclude that technology-based interventions have proven to be overall effective. Technology can be adapted according to the needs of the therapists, specialists and children with ASD as seen in the research of Venkatesh et al (2012). This contributes to the success of delivering complex activities and addressing the ASD child's learning needs as well as achieving the goals of the therapists, specialists and children with ASD.(2017)(Boster & McCarthy, 2018; Guldberg, Parsons, Porayska-Pomsta, & Keay-Bright, 2017; Londono, Wallace, & Qayyum, 2018; Macy, 2015; Parsons, Guldberg, Porayska-Pomsta, & Lee, 2015; Yakubova, Hughes, & Shinaberry, 2016)

However, the technology interventions will not be effective for the visual perception of children with ASD is not taken into consideration.

2.6 Visual perception in ASD

"Seeing is believing for children with ASD" according to MacKenzie (2008, p. 45), although this statement can result in misperceptions. The reason is that the authors Dakin and Frith (2005, p. 497) indicate that there are three classes of perceptual phenomena that can be directly associated with ASD.

1. Superior processing of fine detail (local structure)
2. Inferior processing of overall or global structure or an inability to ignore disruptive global or contextual information and;
3. Impaired motion perception.

Irregularities in sensory perception are considered to be one of the characteristic features of ASD. Children with ASD see the world differently. This is evident in some of the children with ASD's exceptional performance in visual tasks, attention to detail, finding hidden figures, attention to minute features and learning extremely complex patterns. In addition they can have extraordinary drawing abilities with a tendency towards perceptual detail (Dakin & Frith, 2005). It may be a possibility that children with ASD focus on individual letters instead of the whole word and that this can impact their success at language learning.(2018)

Facial recognition is also a problem for children with ASD for a number of reasons(Lewis, Shakeshaft, & Plomin, 2018; Loth et al., 2018; Lynn et al., 2018)(C. S. Lee, Lam, Tsang, Yuen, & Ng, 2018; Lewis, Shakeshaft, & Plomin, 2018; Loth et al., 2018; Lynn et al., 2018). One reason is the feeble social interaction of children with ASD. An alternative reason is a visual perceptual impairment. Children with ASD process faces in an atypical manner with little consensus on the root cause of this problem. Children with ASD are prone to be more focused on detail and not the entire picture or in this case the face, they see the parts and not the whole. This phenomena has been termed as a specific cognitive processing style involving the weak central coherence theory (Behrmann et al., 2006).

While lecturing in animal science Grandin noticed that certain students in her class experienced difficulties with their design assignments. Drawings were submitted where the lines were bumpy and wavy instead of smooth arcs. Because of her own experiences with Autism she came to understand that print on pages could seem to move, jiggle and become blurred, and the lines would disappear. To address this problem Grandin suggested to her learners to use different types of pastel coloured paper for their drawings until they could identify the pastel colour that remedied the blurry lines. An additional suggestion was that her learners try sunglasses with tinted lenses to treat the problem with lines. (Grandin & Panek, 2014)

2.6.1 *Pictures and ASD*

The authors Glenberg and Langston (1992, p. 2) remark that: "Pictures help people to comprehend and remember texts." Grandin (2006) provides an insight as to how the minds of certain children with ASD process information. Parents and teachers of children with ASD are advised to Google a specific topic to get a better understanding of how visual associative thinking works. Details are divided into specific categories that help to form a concept similar to a jigsaw puzzle. This concept can be identified when only twenty percent of the 'jigsaw' is put together (Grandin, 2006). A large 'database' of pictures similar to each other is kept in the ASD child's memory and recalled whenever the need arises. This however is only applicable to visual thinking children with ASD. Children with ASD have different ways of visual processing in a manner superior to typically developing children (Van Eylen, De Graef, Steyaert, Wagemans, & Noens, 2013).

Some, but not all, children with ASD make use of visual representations in their minds to perform tasks or activities. This poses a problem when abstract concepts are introduced (Kunda & Goel, 2008, 2011). An abstract concept such as God for example to which a specific image cannot be linked can become a challenge to explain to children with ASD.

The Dual code theory of Paivio discussed by Kunda and Goel (2008) identify content and encoding as the two key role players for knowledge. Content refers to ***what*** knowledge is being represented and encoding to ***how*** the knowledge is represented. The type of representation therefore places certain constraints on the type of knowledge and how it is interpreted.

Some children with ASD think in pictures and are visual thinkers, while others think in words and are verbal thinkers, and yet others in patterns and are pattern thinkers. These different ways of thinking result in different conclusions being drawn about the same image (Grandin & Panek, 2014).

All these factors need to be taken into consideration when designing vocabulary apps for children with ASD.

2.7 Concluding comments

Autism Spectrum Disorder has many pieces to a puzzle, pieces that do not seem to fit together. Research is still continuing to find the possible cause of ASD and the best way to improve upon its related traits (Hughes & Henderson, 2017). The information in this chapter provided an overall view of ASD and its associated aspects. These aspects need to be taken into consideration when designing lessons for young children with ASD. Specifically, when noting the fact that technology has a positive influence on learning for these children apps must be designed with deliberation.

In the next chapter the focus will be on learning, the different learning styles of learners and the role memory plays in learning.

3 CHAPTER THREE - LITERATURE REVIEW

3.1 Focus of Chapter

In Chapter 1 the main constructs of the research study were presented providing the purpose of the study. Autism Spectrum Disorder was explored in Chapter 2. This chapter will examine the different aspectsdifferent aspects of learning of which there are many; technology and the role it plays in learning are discussed; instructional graphics is explained; followed by an explanation of what graphic design elements and principles are; then the principles relating to multimedia design are specified; multimedia is defined in the context of the study; the details relating to eye tracking are provided and lastly mobile applications are discussed.

3.2 Background to Education and Learning

Around 3500 B.C.E. writing systems were developed that helped create physical records of oral history. These physical records rflected the formal education that took place in Egypt at that time namely: language and communication skills, trading customs, mathematics, reading and writing, warfare, hunting as well as agricultural and religious practices (Tokuhama-Espinosa & Willis, 2011).

Further along the education timeline Confucius the famous Chinese philosopher influenced and formed the curriculum of formal education placing emphasis on logical thinking. More importantly Confucius was concerned with teaching according to the learner's ability.

Later Hebb, Pavlov and Piaget made significant contributions to education and learning by linking brain science to learning, introducing associative learning from conditioned stimulus and identifying the different stages of cognitive development (Hebb, 2005; Pavlov, 1941; Piaget, 1952). Taking cognitive development a step further was Vygotsky's through the scaffolding teaching-learning structure strongly influencing modern pedagogy regarding play and its role in mental development (Vygotsky, 1967)

(Piaget, 1952; Vygotsky, 1978)During the 1980s Gardner introduced the theory of multiple intelligences resulting in the shift from behavioural studies to cognitivist and constructivist theories. A period whereby knowledge is constructed through experience involving multiple intelligences (Gardner, 2011). These multiple intelligences help to ease the learning process.

3.3 Learning

Initially learning takes place in very young children when they play, explore, build, create or pretend. As the children grow older they learn by experimenting, finding out how things work, becoming involved and concentrating on something. By coming up with their own ideas and making links with what they know and what they observe, learning increases. Choices are made about how to go about achieving a specific outcome and being persistent until the set goal is achieved, resulting in learning becoming a lifelong process (Stewart, 2017).

According to Holt (2017) young children are more effective at learning than adults because they use their minds in a different way than adults do. Learning comes naturally because they are interested in their surroundings and the new things they come across. Therefore, attention to the development and education of young children should be of vital importance. Given the appropriate attention in early childhood, learning can take place more effectively.(Watson, 1920)(Pavlov, 1941)(Skinner, 1981)(Pritchard, 2013)(Piaget, 1952)(Pritchard, 2013; Vygotsky, 1967, 1978)(Piaget, 1952; Pritchard, 2013; Vygotsky, 1967)(Bhat, 2018; Husmann & O'Loughlin, 2018; Smets & Struyven, 2018; Willingham, 2018)(Bhat, 2018; Cuevas & Dawson, 2018; Husmann & O'Loughlin; J.-Y. Kim, 2018; Smets & Struyven, 2018)(2018, p. 28)(Friedlander, 2010)(Güneş & Şahin, 2018)(Ansari, De Smedt, & Grabner, 2012)(2008)(Jensen, 2008)(Pritchard, 2013)(Pritchard, 2013)(Caine & Caine, 1991)(Joldersma, 2018)(2012)(Ansari et al., 2012)(Coch, 2018; Howard-Jones, 2014; Mandinach, Friedman, & Gummer, 2015)(Ansari et al., 2012)

(Hwang & Tsai, 2011; Peng, Su, Chou, & Tsai, 2009; Wishart, 2018)(2009)(Huang, 2015)(Yu, Ally, & Tsinakos, 2017)(2015)(Yu et al., 2017)(Pritchard, 2013, p. 58)

3.4 Early Childhood Development and Education

Early childhood development has been of interest from very early, for instance when cnsidering the research of Piaget (1952) and Vygotsky (1978). Adding to this, the last two decades has shown an increase in awareness in the field of early childhood development and education. Various articles (Barnett, 1995; Cortázar, 2015; Li, Lv, & Huntsinger, 2015; Smidt, 2006; Tarlov & Debbink, 2008) have shown that early childhood development and education programmes have a positive influence on the future development of children. The short term benefits being an improvement in the children's intelligence quotient (IQ) and the long term benefits reflecting on achievements at school level, resulting in improved cognitive and social development (Barnett, 1995; Cortázar, 2015).

Barnett (1995, p. 27) remarks that the major impact of early childhood development and education can especially be seen in low to medium socio-economic status children. Children from disadvantaged homes that spent more years in education and development programmes showed improved reading abilities. Furthermore, children that spent more than 45 hours a week in an education and development programmes likewise had higher academic scores, with direct improvement in their IQ - as much as eight points.

This improved cognitive development is a result of resources that provide stimulation to young minds, resources that are relevant to the children's interest (Moylett & Stewart, 2012). However Cortázar (2015, p. 5) explains improved academic performance is dependent on the quality of the programme or intervention.

This is also the case with early language learning. The greater exposure to resources that introduce young children to the words the greater their chance of learning language as discussed in the next section.

3.5 Early Language Learning

Language is learned by making sounds and imitating voices heard within a child's environment. The amount of words learned is dependent on the child's home and community language (Smidt, 2006). Children's initial conversations tend to be limited to certain areas of interest and mostly focused on the current activity they are busy with. With the help of additional linguistic assistance by parents and teachers young children's language can be developed further (Demir, Rowe, Heller, Goldin-Meadow, & Levine, 2015).

A skill such as alphabet knowledge is believed to accurately predict reading achievement. By incorporating the alphabetic principle - to identify letters and the way the letters sound -words can be correctly pronounced and reading developed. A number of factors are involved in the learning of early language: developmental speed, cognitive ability and social interaction (Cunningham, Etter, Platas, Wheeler, & Campbell, 2015).

The reasoning ability of children - that forms part of early language learning - develops through four stages in the following order according to Piaget in Taylor, Branscombe, Burcham, and Land (2011, p. 4):

1. Sensorimotor: knowledge construction of self and environment;
2. Preoperational (toddler and early childhood): imagination and memory are developed, symbols are used, improved language use;
3. Concrete operational (elementary and early adolescence): logical and systematic manipulation of symbols takes place and operational thinking is established;
4. Formal operational (adolescence and adulthood): symbols are used that relate to abstract concepts, hypothetical thinking and deductive reasoning takes place.

This developmental process as well as their emergent thoughts differs for each child. The emergent thoughts are communicated in a language familiar to the child's world (Taylor, Branscombe, Burcham, & Land, 2011). This can take place if the child's phonological, lexical, grammatical, semantic and pragmatic development is normal. If any of these areas are found to be lacking language learning is hindered (Bavin, 2009).

By the time children enter early childhood development and education programmes the teacher is faced with the diverse language and literacy experiences of young learners (Kelley, Goldstein, Spencer, & Sherman, 2015). Teachers involved in the learning of early language are expected to have solid knowledge of emergent literacy, being aware of the different levels of progression and how to impart and develop literacy skills (Cunningham et al., 2015).

Various interventions such as shared book reading and language enhancement have had a moderate to large effect on children's early language skills, states Kelley et al (2015, p. 48). Oral language skills are most effectively developed when interactive instruction takes place. This type of instruction is purportedly concentrated since children are repeatedly exposed to vocabulary. In addition, this type of instruction is designed to help develop a better comprehension of words.

Language and behaviour have also been explored with renewed interest according to Clegg, Law, Rush, Peters and Roulstone (2015). A link between social, emotional and behavioural difficulties and poor communication skills has been identified resulting in teaching and learning difficulties. However, these problems were greatly reduced with language learning.

Early language learning plays a crucial role in pre-school development, helping children to improve their reading abilities as well as emotional and behavioural qualities for future academic and social success. The use of language in normal developing children begins at around twelve months whereby clear indications are given of the understanding of certain words and simple phrases. From twelve to eighteen months vocabulary increases to include social words such as those used when greeting, as well as two-word sentences. The majority of sentence structure is developed by the age of five and vocabulary is developed further within the school environment (Tager-Flusberg et al., 2005).

An effective way to learn new words is with technology and, as proven by research (Mayer, 2005, 2009; Mayer & Moreno, 2002a, 2002b, 2003), making use of multimedia learning.

3.6 Multimedia Learning

Multimedia learning includes instructional material with words and pictures. The words are either in printed or spoken format and the pictures or graphics are static (not moving) or dynamic (animations and videos). Technology in the form of computers, smartphones, and tablets has provided immense opportunity to present learning opportunities in an interactive way (Mayer, 2009).

According to Mayer (2009, p. 15) there are three different views of multimedia learning. The first is the response-strengthening view, where the association between a response and a stimulus is either strengthened or weakened through rewards or punishment. The second view is information-acquisition which involves the accumulation of information which is transferred to memory. Learning according to the information-acquisition view is concerned with information that is transferred from one place to another. The learner takes a passive role while the teacher presents the information and the learning is presented as resourceful as possible through multimedia (words and pictures). The third view is knowledge-construction where the learner has to make sense of what is being presented. Knowledge is interpreted by the learner in his or her own unique manner. The learner becomes actively involved in the learning process where multimedia is presented in an understandable way. The learner must organise and integrate information with the guidance of a teacher that helps with the sense-making process. (2018, p. 202)(Van Lieshout, Egyedi, & Bijker, 2018)

For the learner to effectively own the information that is being presented by the teacher, the teacher has to be knowledgeable of the different learning styles.

3.7 Learning Styles

The term learning style falls under the umbrella term *intellectual style* referring to the way information is processed by different people and the way people deal with certain tasks. Other similar terms falling under the intellectual style umbrella are: cognitive style, thinking style, mind style, mode of thinking, or teaching style.

Various theories exist about learning styles but the crux of these theories is that everyone learns in a different way and that learning should be personalised in accordance with the learner's style. Three core types of learners have been identified:

1. Visual learners that learn through watching;
2. Auditory learners that learn through listening and;
3. Kinaesthetic learners that learn through moving or touching.

This has been a successful approach in fostering learning and instructional design. Various forms of learning styles exist and have been identified as families of learning styles (Coffield, Moseley, Hall, & Ecclestone, 2004). One of these styles was the Myers-Briggs indicator test that greatly added to the tremendous success of learning styles (Pashler, McDaniel, Rohrer, & Bjork, 2008; Pritchard, 2013; Willingham, Hughes, & Dobolyi, 2015; Zhang, Sternberg, & Rayner, 2011).

The term *learning style* was first introduced in 1962 and became more commonly used in the 1970s referring to a more rounded way or style of extraordinary learning according to Zhang, et al. (2011, p. 25). Varying definitions exist for learning styles and are defined as follows (Pritchard, 2013, p. 41):

- A particular way in which an individual learns;
- A mode of learning – an individual's preferred or best manner(s) in which to think, process information and demonstrate learning;
- An individual's preferred means of acquiring knowledge and skills;
- Habits, strategies, or regular mental behaviours concerning learning, particularly deliberate educational learning that an individual displays.

Willingham, Hughes and Dobolyi (2015, p. 266) have a more concise definition of learning styles namely differential preferences exist for processing certain types of information or for processing information in certain ways. This reiterates the point that people learn in different ways.

Learning styles have to a certain degree become integral to the educational practice and thinking and are believed to have transformed all levels of education. Many teachers have felt that the traditional way of teaching has been analytical and biased while learning styles should support and address diverse learning needs making the teacher more sensitive to his or her way of teaching. Learning styles resulted in teaching and learning being explored more intently. Focussing on what makes learners fail or succeed and how to represent the instructional material and classes more interactive, thereby enhancing the quality of learning (Coffield et al., 2004).

However the success of the learning styles approach has come into question by a number of researchers (Pashler et al., 2008; Willingham et al., 2015). Valid and reliable research regarding the success of learning styles is found to be lacking. Arguments exist that people cannot be divided into distinct groups. Also, that the learner's *preferences* on how information is to be represented and *abilities* to process the information are not distinguished even though the two concepts may be interconnected. An example would be visual learners learning geometry with visual-spatial materials while they may not necessarily have the ability to grasp the complex formula used to determine the value of a certain point, say x.

Another argument as mentioned by Willingham et al (2015, p. 267) are the two predictions made by learning style theories that firstly " … a learning style is proposed to be a consistent attribute of an individual [and] should be constant across situations." Secondly that "… cognitive function should be more effective when it is consistent with a person's preferred style …" Statistical evidence is found to be wanting between learning styles and academic achievement (Willingham et al., 2015).

The deductions made from the various researchers (Pashler et al., 2008; Willingham et al., 2015) arguing against learning styles are that there are certain aspects of learning that do differ but also some that do not differ. There exists a common aspect of learning across learners. To add to this point the researchers Zhang et al (2011) commented that style overlap takes place. The most successful form of categorisation is said to be the differences in prior knowledge and ability. Focusing on these commonalities of the learners has resulted in greater success in the classroom than learning styles state Willingham et al (2015).

Another point of concern of learning styles is that added pressure is placed on the teacher. When learners experience learning difficulties it is believed that the teaching style of the teacher is the problem (Coffield et al., 2004).

Even though arguments for and against learning styles are copious the learning style field has flourished in the last three decades. Furthermore, learners have benefited from the incorporation of one learning style above another guiding the type of instruction deemed to be most successful for learning to take place. Reiterating the point that learners learn differently, each having different learning styles.

Identifying the ideal learning style helps the information to be processed and stored into memory.

3.8 Memory

Memory entails recalling information that has been learned with the help of association or experiences (Webster, 2006) . Different memories exist and are described as follows:

3.8.1 *Sensory Memory*

The sensory memory records every sensation or stimulus namely taste, touch, vision, smell and hearing. (Mikkelsen, Wodka, Mostofsky, & Puts, 2016; Puts, Wodka, Tommerdahl, Mostofsky, & Edden, 2014; Tavassoli et al., 2016)The sensory memory has various subtypes, visual, auditory and tactile, for each specific sensory modality. Sensory memories are of short duration usually from one-fifth of a second to a few seconds. The purpose of such a fleeting sensory memory is to create a filter to sift through the vast number of unimportant stimuli that can become overwhelming, helping to not overload the working or long-term memory. If the stimulus is of any importance the sensory memory will transfer it to the working memory (Hudmon, 2006, p. 44).

3.8.2 *Working Memory*

Hudmon (2006) informs that working memory is also known as short-term memory. The working memory is found situated between the sensory memory and the long-term memory and stores transitory information from the sensory memory that may be required further on. Working memory similar to sensory memory is limited in time and capacity but can be improved through repetition or rehearsal of items verbally or in writing. This helps the transition of information from working memory to long-term memory. By focusing attention on a specific task and retaining the information that is relevant to the task, working memory is activated (Fougnie, 2008).

3.8.3 *Long-term Memory*

Although long-term memory is believed to lack detail of incidents stored in it, it can store copious amounts of information particularly images according to Brady, Konkle, Alvarex and Oliva (2008). Information can be stored for lengthy periods even up to a lifetime. Long-term memory takes the required information out of the working memory and stores the information in a more secure environment that has less stimuli to cause interferences or disturbances (Hudmon, 2006). Semantic knowledge relating to the different meaning of words or symbols along with episodic knowledge relating to separate or related parts that are loosely connected form part of the long-term memory.

Activating all three memories when introduced to new concepts such as letters or words will result in effective learning.

3.9 Technology and Learning

Since the first personal computer was announced over thirty years ago technology has evolved from portable cassette players and personal digital assistants (PDA's) to MP3 players, iPods, iPads and various tablets. Phones have mutated into mini computers, with larger touch screens, higher resolutions and powerful processors. All these factors contribute to improved usability which has brought about mobile learning (m-learning) (Godwin-Jones, 2011).

Technological innovations have furthermore contributed to the education environment and has created an educational reform (Falloon, 2013). Learners can interact in a manner that is natural to them. Technology has become intuitive for young learners aged between zero and eight years old (Nacher, Jaen, Navarro, Catala, & González, 2015). Children have rapidly adapted to technology and the use of technology in the classroom has also grown considerably. Between the ages of two and seventeen the average time spent interactively with technology is one hour per day. The time spent interactively with technology increases considerably with teenagers, specifically children from twelve to fifteen (Read & Markopoulos, 2014).

Arguments against these new technologies can be found stating that several claims are made that are unrealistic. One of these claims mention that these new technologies are not aligned with teacher pedagogical models (Falloon, 2013). Technological limitations such as slow internet connections, poor audio quality, limited storage memory, problematic operating systems (OS's), modelling, feedback, text-to-speech functionality, and interaction parameters were all factors that contributed to the argument against technology use in classrooms. These arguments resulted in a request by Falloon (2013, p. 505) for " … researchers, teachers and developers to work together and adopt methodologies [and to] gather data to radically improve the design of apps used by young students for learning."

As mentioned in Chapter 1 the purpose of this study is to identify effective multimedia design guidelines for vocabulary apps that will assist early language learning in children with ASD. Various features that are presented in vocabulary apps will be investigated, one of these features being the instructional graphics.

3.10 Instructional Graphics

The term ‘instructional graphics’ for this research study refers to pictures, visuals and illustrations such as photographs, line drawings, animations, sketches and cartoons. Instructional graphics can be seen as "… *iconic expressions of content* that are designed to *optimise learning and performance…*" (Clark & Lyons, 2010, p. 27).

"People learn better from graphics and words than from words alone", state Clark and Lyons (2010, p. 11) referring to the multimedia design principle. Instructional graphics promote learning, understanding and reasoning and helps build skills and knowledge. However not all instructional graphics can be deemed equally effective. This is the case when instructional graphics are haphazardly added for decorative purposes and not planned in such a manner as to utilise their full potential. The learning value of the instructional graphics is dependent on three interactive factors: the first factor –features of the visual, how they look; how they are created; how they convey information and how they facilitate learning ; the second factor – the content and goal of the lesson and the third factor – the characteristics of the learners and their prior knowledge of the content (Clark & Lyons, 2010, p. 25).

Instructional graphics are made up of graphic design elements and principles which are discussed next.

3.11 Graphic Design Elements and Principles

The design elements and principles are not consequent across the design arena. Differences in the number of elements and principles occur and appear to be dependent of the type of design and the expertise of the designer, each having different opinions about what elements and principles are in their books on design. For example Murphy (1995) provides four basic design principles for the novice designer. While Samara (2007) only mentions elements and presents these elements in the form of twenty rules. Sherin (2012) writes about design elements, where the focus is mainly on colour, as an element. The author Cullen (2012) also writes about design elements with the exception that the focus is mainly on typography. For credibility and reliability, and most comprehensive. concerning the elements and principles of design, the book written by O'Connor (2014) was used for the study. O'Connor has written numerous articles on design and visual literacy (O'Connor, 2010, 2011, 2014, 2015; 2013; Rourke & O'Connor, 2008, 2009).

Visual communication takes place with the conventional use of elements and principles of design. These elements and principle of design can portray information effectively if used sensibly. As O'Connor (2014, p. 46) indicates: " …the process of encoding and decoding visually-based information is not a simple matter and relies on the effective application of the various elements and principles of design." This is especially true when designing vocabulary apps for children with ASD.

The following guidelines are provided when using design elements and principles (O'Connor, 2014, p. 242):

- The design must communicate a message or idea
- The elements must relate to each other
- The elements must create a focal point promoting focus and not confusion
- Colour must be used strategically
- Contrast must be used strategically
- Negative space must be used strategically
- Type must contribute to the design
- Balance and rhythm must be used strategically

3.11.1 *Elements of Design*

The elements of design are colour, light-dark contrast, line, direction, shape, size, texture and typographic form and are described as follows (O'Connor, 2014, p. 275):

Colour – used to attract attention; can be monochromatic (one colour) or multi-coloured; be monotone (the same tone with different hues) or contrasting.

Light-dark contrast – creates atmosphere; includes a large range of light to dark variations (major tonal chords) or darker colours with less lighter colours. Minor tonal chords are when a small range of colours is used.

Line – used to direct attention and create focus; include straight, linear, freeform lines that are coloured, achromatic, opaque or transparent.

Direction – used to draw attention and create a focus point; occurs within line, form, text, texture, and colour.

Shape – Conveys meaning and connotation; can be geometric, realistic or abstract.

Size – helps to create focal points and direct attention; variation in size is created through proportional design of shape, line and light-dark contrast.

Texture – conveys atmosphere and connotative meaning; can be rough, rugged, grainy et cetera.

Typographic form – communicates information; or supports and reinforces the theme; used to convey meaning

3.11.2 *Principles of Design*

Principles of design are used in a deliberate manner to draw attention to key elements of a design. The principles of design include (O'Connor, 2014, p. 579):

Simplicity-Complexity: simplicity in design reduces visual clutter drawing attention to specific elements in isolation; complexity in design can hamper understanding making text and information difficult to read or identify.

Unity-Variety: the use of common elements in a design creates a feeling of unity; visual cohesion occurs when there is similarity of shape and style in the design. Variety can create a hectic design and a loss of visual cohesion and should be incorporated into a design with caution. Variety can be used to convey meaning and information.

Rhythm-Movement: rhythm refers to a sense of movement, excitement or vitality that is created by the repetition of lines, shapes, textures or text. When these design elements are not repeated tranquillity, stillness and peace are portrayed in the design.

Balance: Symmetry and Asymmetry: the arrangement of elements within a design can create balance with the elements being symmetrical; this can be achieved by mirror-imaging, rotational or diagonal arrangement. Asymmetry is when the design appears unbalanced and can create a sense of movement, speed, tension or unease.

Contrast: elements are used to create contrast adding a focal point and visual interest.

Hierarchy and dominance: when specific elements are placed within a design to be more dominant than others making that element appear more important than others. These elements could include colour, and light-dark contrast thereby creating visual dominance and directing attention. A visual path is created directing attention from one part of the design to the next resulting in cognitive processing.

Positive-negative space: Positive space refers to the foreground of the design and negative space to the background of the design decreasing visual clutter and drawing attention to a focal point such as text.

Realism-Abstraction: is dependent on the objectives of the design and can create an area of interest in the design. However, abstraction used in design can create confusion and loss of focus.

Compositional Techniques

The Golden Mean: being in existence for hundreds of years, is an underlying framework which a design is based on or elements arranged according to, to create visual cohesion.

The Rule of Thirds: is a compositional technique used in design and divides the design into thirds vertically and horizontally. The key elements are placed at intersections of the grid**.**

The correct presentation of design elements and principles in vocabulary apps will contribute to language learning in children with ASD. The most effective design elements and principles presented in the vocabulary apps used in this study will be identified.

Multimedia and its role in this study is discussed in the next section.

3.12 Multimedia in the context of this Research Study

Multimedia is seen in three different contexts according to Mayer (2009). The first is delivery-media whereby the material or lesson is presented with the help of two or more devices. An example would be a lesson making use of speakers and a video projector to view the lesson and listen while the teacher speaks. Mayer (2009) argues that this is not effective because it causes confusion since the focus more on the devices through which the lesson is presented than on the learner. The second context is presentation-modes referring to how the material is presented using two or more presentation modes. In this context the lesson is produced verbally with on-screen text or narration as well as with pictures that are static or animated. Very similar to the second context, the third context is sensory-modality where the learner integrates two or more sensory systems such as eyes and ears to process information (Mayer, 2009, p. 8).

The term multimedia relevant to this research study refers to the occurrence of both visual and verbal material. The visual material includes images and animations, and verbal material includes printed or spoken words. The purpose of the visual and verbal material is to inform, introduce and explain new knowledge to learners. This new knowledge is made available to learners through technology such as computer software, education programmes, games, and mobile applications (Issa et al., 2013).

Issa et al (2013) informs that in order for education material to be effective in multimedia the design has to be effective, resulting in enhanced cognitive processes. With the help of effective multimedia designs learners can attend to, organise and integrate knowledge, and combine existing knowledge to new found information. The opposite is also true, multimedia materials designed inadequately can lead to confused and overwhelmed learners.

Poorly designed multimedia material can be addressed in two ways: Firstly by incorporating the cognitive theory of multimedia learning principles designed by Mayer (Mayer, 2009) and secondly with Mayer's empirical research using real-world applications on cognitive load theory.

3.13 Multimedia Learning Principles

The multimedia learning principles fall under three different processing categories. These three processing categories influence learners' cognitive capacity. Learners can engage in three different types of cognitive processing while learning, also known as the triarchic model of cognitive load. These three cognitive processes according to Mayer (2009) are:

1. **Extraneous cognitive processing:** does not serve the instructional goal causing confusion as a result of the instructional design. The learner may have to scan the screen up and down to understand the instructional material, thereby wasting cognitive capacity on poorly designed instructional material. This results in no learning taking place, poor retention and poor transfer of knowledge (Mayer, 2009).
2. **Essential cognitive processing:** represents the essential material in working memory determined by the complexity of the material. If the learner is familiar with the learning material it will be less complex than for a learner unfamiliar with the learning material. Pre-training helps the learner build a mental representation in working memory. Essential cognitive processing results in rote learning and retention but poor transfer performance (Mayer, 2009).
3. **Generative cognitive processing:** has the main purpose of making sense of the essential material and is linked to the learners' level of motivation. Deeper

processing takes place by means of an engaging learning environment resulting in proper retention and transfer of knowledge (Mayer, 2009).

Extraneous processing needs to be reduced by designers, essential processing carefully managed and generative processing fostered, asserts Mayer (2009, p. 140). In conclusion, these three cognitive processes can influence the success of a vocabulary app designed for children with ASD. The principles relevant to extraneous, essential and generative processing are discussed further.

Principles for Reducing Extraneous Processing

1. **The Coherence Principle-** states that learning takes place more effectively when the design excludes extraneous or unneeded words, pictures, symbols, music and sounds. The unneeded material can result in working memory not being used to its fullest capacity since the learner's attention is misplaced. Organising and integration of information are hindered if there is unnecessary information in a design. The coherence principle plays an important role in learning for children with special needs (Mayer, 2009, p. 89).
2. **The Signalling Principle-** learning takes place more effectively when there are cues that highlight essential material. This principle focuses the learner's attention on the key elements in the lesson. Signals and cues should only be used when necessary and can be useful when the design is disorganised with extraneous material that distracts the learner. This principle is also useful for learners with poor reading abilities (Mayer, 2009, p. 108).
3. **The Redundancy Principle-** states that learning takes place more effectively when there are graphics and narration than when there are graphics, narration and printed text. Although the redundancy principle is less relevant when: the captions only have a few words and are placed next to the graphic; the spoken text occurs before the printed text instead of simultaneously; there are no graphics and the spoken text is short (Mayer, 2009, p. 118).

However, when considering the purpose of the study, the redundancy principle will be less relevant. The reason is that for vocabulary learning to take place effectively there should be graphics, narration and printed text. For example: the child with ASD should see a picture of an apple, hear the word “apple” being narrated, and see how “apple” is spelled in the form of printed text.

4. **Spatial Contiguity Principle-** learning takes place more effectively when the words are placed near the related pictures instead of far away from the pictures. When the words and pictures are placed near each other the information is stored more efficiently in working memory. If the words and pictures are placed far from each other cognitive processing is increased because visually scanning takes place to make sense of the information displayed (Mayer, 2009, p. 135).
5. **Temporal Contiguity Principle-** learning takes place more effectively when the words with their related pictures are presented at the same time instead of the one after the other. The reason is that a mental representation can be made in working memory resulting in a verbal and visual connection to be made. Exception can be made for this principle if the number of words are short or the lesson is under the control of the learner (Mayer, 2009, p. 153).

<u>Principles for Managing Essential Processing</u>

6. **Segmenting Principle-** learning takes place more effectively when multimedia lessons are user-paced instead of being continuous. If the lesson is continuous, information can be lost, resulting in insufficient learning. This is especially the case if the material presented is difficult and the learner inexperienced in the topic being taught (Mayer, 2009, p. 175).
7. **Pre-training Principle-** effective learning takes place when the learner knows the names and characteristics of the main concepts presented in the multimedia lesson. The learner has a preconceived mental model of what is being taught

specifically when the lesson material is complex and the learner is unfamiliar with the new material (Mayer, 2009, p. 189).

8. **Modality Principle-** learning takes place more effectively from pictures and spoken words than pictures and printed words. The reason is that information is received visually and auditory instead of only visually. This principle is applied when the material is complex and the learner familiar with the words. However if a learner has special needs, printed words in the lesson is necessary (Mayer, 2009, p. 200).

Principles for Fostering Generative Processing in Multimedia Learning

9. **Multimedia Principle-** learning takes place more effectively from words and pictures than words alone. Verbal and visual mental models are created and connections made. This principle relates strongly to learners with special needs by providing guidance in connecting the visual with the auditory (Mayer, 2009, p. 223).
10. **Personalisation principle- -** learning takes place more effectively from multimedia presentations when words are spoken in a conversational style rather than formal style. The learner is able to relate better to a conversational style and tries harder than when formal language is used, however the conversational style must not be overdone. The personalisation principle works well with young learners (Mayer, 2009, p. 242).
11. **Voice principle-** learning is more effective when words in a multimedia message are spoken by a friendly human voice rather than by a machine voice. Specifically when the friendly voice is the same gender, race, ethnicity and emotional state as the learner (Mayer, 2009, p. 255).
12. **Image Principle-** learning doesn't necessarily take place more effectively from a multimedia presentation when the speaker's image is on the screen than not on the screen. However, there are certain instances where an on-screen character

may be effective for learning such as directing the learner's attention to a specific part of the lesson (Mayer, 2009, p. 258).

The key purpose of these multimedia learning principles is to facilitate deep learning. Other principles for design also exist such as the Universal Design for Learning (UDL) framework that also provides insight and guidance to multimedia representations and includes the following recommendations (More & Travers, 2012, p. 4):

- Equitable use,
- flexibility in use,
- simple and intuitive,
- perceptible information,
- tolerance of error,
- low physical effort, and
- size and space for approach and use.

Churchill (2011a, 2011b) likewise provides advice on the design for multimedia representations:

- design for observation,
- design for analytical use,
- design for experimentation,
- design for thinking, and
- design for reuse.

For this research study the work of Mayer (2009) formed a solid foundation to create an artefact, providing insightful detail and thoroughness that can be linked to the different memories involved in learning. This helps to recognise multimedia design guidelines presented in vocabulary apps that will assist early language learning in children with ASD.

In order to determine whether any attention is given to words or letters presented in the vocabulary apps used in the study, eye tracking will take place.

3.14 Eye-tracking

Tobii's (Tobii, 2017a) eye tracker was used in the study, defining eye tracking as a sensor technology identifying the exact location of a person's focus. The natural eye movements of people are studied while they view a specific display or interface to address issues such as usability and interaction with a device. Gaze direction, duration of fixation, and fixation count are used to indicate cognitive processes while the saccades indicate the visual path followed. Fixations are defined as pauses at areas of interest and saccades are the movements from one fixation to another (R Jacob & Karn, 2003; Salvucci & Goldberg, 2000)

Fitts' law (Fitts, 1954) expands on these eye-tracking indices by informing that fixation frequency can be linked to the measure of the display's importance; fixation duration is the difficulty experienced with information mining and interpreting; and the pattern of the fixation gives an indication of how efficiently the elements of the display have been arranged. With the help of eye-tracking systems, parts of a picture found most intriguing can be identified and studied (Y.-Z. Hu et al., 2013).

Eye tracking has gained popularity, specifically for research in areas such as psychology, psycholinguistics, marketing, product design, and human computer interaction. A number of different eye tracker devices are used for research. Some eye trackers are attached to the eye, known as eye-attached tracking. Another form known as optical tracking makes use of infrared light that is reflected from the eyes and video recorded through a head mount or a computer screen mount or tablet mount (Majaranta, 2011).

Research using eye trackers has shown that the pattern of reading text differs from person to person. When text and pictures are presented the focus is more on the text than the pictures (Rayner, Rotello, Stewart, Keir, & Duffy, 2001). However more recent research has proved that visualisers focus on pictures and verbalisers on words while learning. In addition, the visualisers comprehended what was taught to a greater extent than the verbalisers (Koć-Januchta, Höffler, Thoma, Prechtl, & Leutner, 2017).

3.14.1 *Eye-tracking in Autism*

One of the many indicators for ASD is the difficulty experienced in paying visual attention to other people in a co-ordinated manner. With the help of eye-tracking the areas of interest can be precisely identified for children with ASD while they are completing a task. In addition, deficits or abnormal attention to information in children with ASD can be identified helping to determine any performance difficulties administering the task. Eye-tracking provides information on how patterns are viewed and how interaction takes place relevant to specific tasks, also what children with ASD are fixated on or not (Riby & Doherty, 2009). (Chita-Tegmark, Arunachalam, Nelson, & Tager-Flusberg, 2015; Hahn, Snedeker, & Rabagliati, 2015; Norbury, 2016)

3.15 Mobile Applications

The term *app* is the shortened version of the word application and was announced as the word of the year by the American Dialect Society in 2010. In the past an applications was usually known as either a computer program or software (More & Travers, 2012).

An app is software that performs a specific function and can be used on numerous technological devices. Examples of desktop apps are word processors, games, media players and web browsers and apps can be downloaded from the internet or a compact disc (CD). Mobile device apps can be downloaded on smartphones and tablets and are comparatively inexpensive compared to desktop apps although an internet connection is required (Kim, 2015)

More and Travers (2012, p. 2) mention that apps are being developed at lightning speed. In 2009, 85 000 apps were available for download on the Apple iTunes App store. More recently in July 2014 the Apple iTunes App store had 1 200 000 apps with the Android store – Google Play taking the lead at 1 300 000 apps (Statista, 2014). In January 2015 the Apple store had 80 000 apps that were classified as educational (Hirsh-Pasek et al., 2015).

Contentions against apps, their quality and implementation exist. Numerous educational apps allegedly fall short when it comes to design, instruction, content and various other features that high-quality educational software should have (More & Travers, 2012, p. 3). However the visual design and user interaction of apps are subject to guidelines provided by both Apple (Moylett & Stewart, 2012) and Android (Demir et al., 2015) on their specific websites. This however does not address the contentions mentioned as these guidelines address mostly technical issues and not the quality of the contents or its purpose.

Hirsh-Pasek et al (2015) state that the development of apps is influenced by current technological and design trends and often by the designer's own experiences and ideas of how learning takes place. A minute number of designers incorporate research-based approaches when designing educational apps. It is considered nearly impossible to scientifically study and evaluate all the educational apps available and these are seen as major unplanned experiments.

The sudden inundation of apps forms part of a digital revolution. A digital revolution whereby games and learning integrated from non-digital forms to digital forms in an unregulated manner, with little or no thought given to whether any learning was taking place. More recently extra thought was put into the design of apps to make them fun and educational (Hirsh-Pasek et al., 2015).

This was achieved by incorporating the strategies from the science of learning. Six themes from the science of learning with their related tips are presented (Gooding, Mann, & Armstrong, 2017):

THEME 1: PROCESSING INFORMATION

1. Reduce extraneous load whenever possible.
2. Help learners with difficult tasks and assist learners with the topic being taught.

THEME 2: PROMOTE EFFORTFUL LEARNING

3. Provide opportunities where information can be retrieved from the content being learned.

4. Distribute the practice of retrieving information over a period of time and connect past learning with present learning.

THEME 3: APPLICATION OF LEARNING TO NEW AND VARIED CONTEXTS

5. Distinctly prepare learner to transfer knowledge to new learning experiences.

THEME 4: PROMOTE THE DEVELOPMENT OF EXPERTISE

6. Engage the learners in developing their expertise.
7. Help the learner create goals that promote learning.

THEME 5: HARNESS THE POWER OF EMOTIONS FOR LEARNING

8. Teach learners to identify their emotions and how it can help them learn.
9. Create psychologically safe learning environments.

THEME 6: LEARNING IN RELATIONSHIP AND CONTEXT

10. Focus on the social nature of learning in the specific context.
11. Create authentic learning experiences.
12. Help learners identify how they learn.

These themes and tips are valuable for the design of vocabulary apps, although not all of the tips could be applied to children with ASD. For instance, Tip eight where learners have to identify their emotions and how their emotions can help them learn is an example. However there are common interests in children with ASD such as fossils and vacuum cleaners (Anthony et al., 2013). These common interests could contribute to positive emotions towards learning, thereby fostering learning, especially if these common interests were to be incorporated into a multimedia lesson for a vocabulary app. (Tuedor, Franco, White, Smith, & Adams, 2018)*(Tuedor et al., 2018, p. 12)*(2018)(Khowaja & Salim, 2018)(Bozgeyikli, Raij, Katkoori, & Alqasemi, 2018)(Boster & McCarthy, 2018)

3.16 Concluding comments

The information provided in this chapter provides insight to the various features that need to be considered when designing an effective vocabulary app, features that will contribute effectively to early language learning in children with ASD. With the abundance of information on learning and learning styles, learning can take place with greater success within a vocabulary apps.

4 CHAPTER FOUR - CONCEPTUAL FRAMEWORK

4.1 Focus of Chapter

This chapter describes and integrates various learning theories to create a conceptual framework specific to the study.

First the cognitive theory of multimedia learning (CTML) is explained; then the cognitive theory of learning with media (CTLM) which is closely related to CTML is discussed. Afterwards explanations are provided for Oelwein's methodology, Bruner's three stages of learning, and Human Computer Interaction. Finally, an amalgamation of the conceptual framework is presented.

4.2 The Cognitive Theory of Multimedia Learning

Mayer (2009), an authority on multimedia learning, describes that the design of multimedia learning material is often influenced by the designer's perception of how the mind works. When the design involves multi-coloured words and images that are flashing and moving all over the screen, the designer's underlying perception is that the learners have an unlimited capacity to cognitively process information in one single channel. The assumption of the designer is that the learner can process unlimited amounts of material without cognitive overload. This is in contrast with how multimedia learning actually takes place.

The cognitive theory of multimedia learning (Mayer, 2009) is founded on how learning takes place with words, pictures, and sounds, being attentive as to how information is processed. Multimedia messages should therefore be carefully contemplated and executed by designers that make informed decisions about the presentation of information(Allen, 2015; Bozkurt et al., 2015; Dandashi et al., 2015; Saad, Dandashi, Aljaam, & Saleh, 2015).

There are three assumptions for the cognitive theory of multimedia learning (Mayer, 2009, p. 63):

1. **Dual channels:** separate channels exist in humans that process visual and auditory information;
2. **Limited capacity:** there is a limit to the amount of information humans can process per channel at a time;
3. **Active processing:** active learning is engaged when the relevant information is given the necessary attention; the relevant information is organised into coherent mental representations and other knowledge is integrated with mental representations.

In Figure 4-1 below the multimedia presentation of words and pictures enters the sensory memory. The signals are received in sensory memory and transferred to working memory. Working memory organises the words and images into verbal and pictorial models, drawing from prior knowledge stored in the long-term memory.

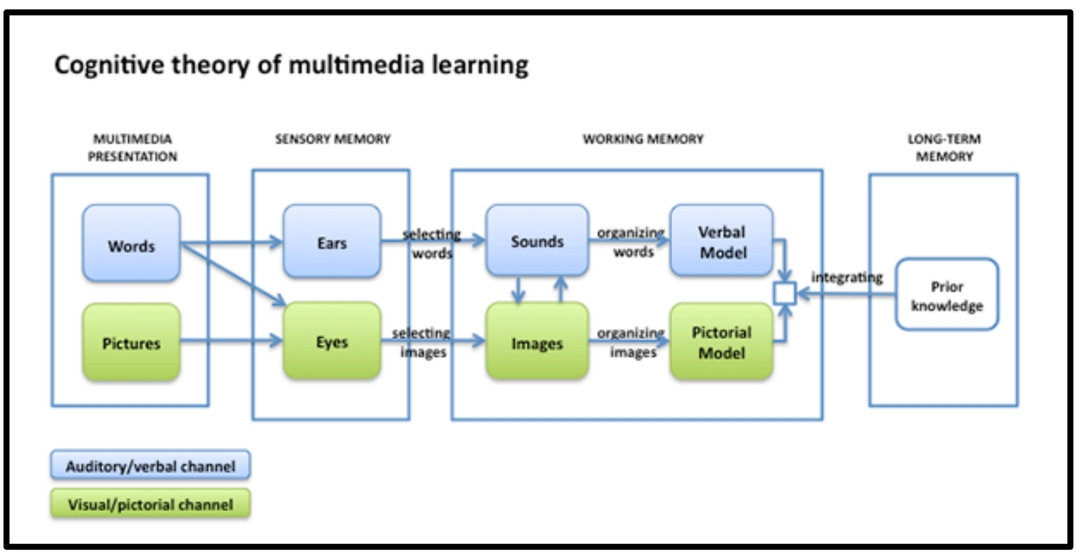


Figure 4-2 Cognitive theory of learning with media

With regards to multimedia learning, Mayer (2009) indicates that for active thinking to take place about learning material in long-term memory it should be transferred to working memory. Created knowledge is integrated with knowledge from the long-term memory.

For multimedia learning to take place effectively the multimedia environment must be compliant. A multimedia environment is defined by Mayer (2009, p. 123) as “ … one in which material is presented in more than one format – such as words and pictures.” Five cognitive processes are involved in learning within a multimedia environment (Mayer, 2009, p. 123):

1. Selecting relevant words for processing in verbal working memory,
2. Selecting relevant images for processing in visual working memory,
3. Organising selected words into a verbal mental model,
4. Organising selected images into a visual mental model, and
5. Integrating verbal and visual representations.

These processes do not occur successively but simultaneously in different ways and result in integrated learning.

However, the techniques used to promote learning and the vehicles or devices used to deliver the learning material differ. In order to guide the design of instructional technologies, Moreno (2006) set out to provide a framework addressing this matter. This framework is based on the cognitive theory of learning with media.

The cognitive theory of multimedia learning involves the ears and eyes to send information to the sensory memory. This is achieved by pictures and text that are registered in the visual sensory memory, and spoken words and other sounds that are registered in the auditory sensory memory (Mayer, 2009).

The majority of multimedia learning takes place in working memory (see Section 3.8 about a discussion on memory). Knowledge is temporarily stored and manipulated in working memory. According to Mayer (2009) working memory is made up of two sides, the right and the left. The left side represents the raw materials such as pictures and sounds obtained through the visual and auditory senses. Knowledge is created from the right side of working memory by means of the visual and auditory stimuli received. Mental conversions take place in the right side of working memory of the visual and spoken information received.

4.3 The Cognitive Theory of Learning with Media

Building upon the cognitive theory of multimedia learning, Moreno (2006) proposed a framework involving the cognitive aspects of learning with media. Media according to Moreno (2006, p. 63) " … refers to the physical systems or vehicles used to deliver the information – such as face-to-face interaction, textbooks, or desktop computers …".

As mentioned previously learning takes place when new information from the surrounding environment is transferred to long-term memory. The cognitive theory of learning with media is explained as follows: for learning to be meaningful active learning has to take place. Active learning takes place when the learner utilises a number of cognitive processes to understand the information presented to him or her. The cognitive processes involved in meaningful learning entail selecting information that is relevant; arranging the information into coherent representations and integrating the information into existing knowledge. This type of learning involves: retention - that which can be remembered; transfer - how to solve a problem; mental load - how difficult the learning is and; relative efficiencies influenced by the instructional conditions, mental load and performance (Moreno & Valdez, 2005, p. 36).

The assumptions for multimedia learning are (Moreno, 2006, p. 63):

a) Learning starts when information is processed in separate channels for different sensory modalities;
b) Only a few pieces of information can be consciously processed at any one time in working memory;
c) Long-term memory consists of a vast number of organised schemas;
d) Knowledge may be represented in long-term memory in verbal and non-verbal codes;

e) After being sufficiently practised, schemas can operate under automatic processing; and
f) Conscious effort needs to be spent in selecting, organising, and integrating the new information with existing knowledge (active processing).

Once all this information has been processed in the long-term memory, learners can retrieve the information as required to make sense of new information or to use as guidance. The result of active learning is a mental model that can be used as a schema in the working memory of learners to promote further learning. The newly created schema can be automatically retrieved with minimal taxation on the working memory (Moreno, 2006).

In Figure 4-2 the CTLM is presented. The instructional media makes use of verbal explanations and nonverbal information that are detected by the sensory memory (auditory, visual and tactile senses) of the learner. The learner then focuses on the multiple incoming information sources with the help of his or her working memory which has limited capacity and is of short duration. The working memory allows only for a few pieces of information to be processed at a time which are stored for further processing. This forces the learner to make decisions on how to connect and organise the pieces of information together and integrate this new information with prior knowledge. The long-term memory guides this process by retrieving information which can be helped along with external guidance (Moreno, 2006, p. 64).

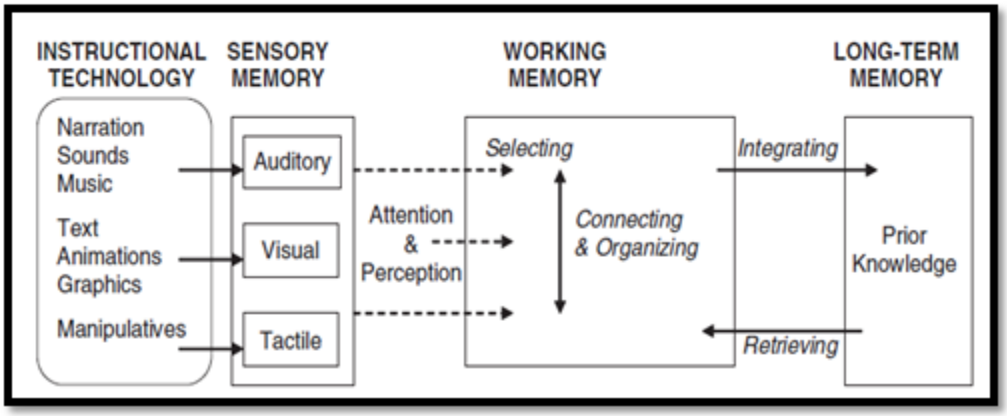


Figure 4-3 CTLM representation

The CTLM is a comprehensive theory encompassing diverse and varied instructional technologies involving three senses –auditory, visual and tactile - for learning with technology. Therefore, it forms the crux of this research study upon which other imperative disciplines (discussed further along) will be integrated, to create a conceptual framework.

The most evident difference between the cognitive theory of multimedia learning and the cognitive theory of learning with media is that the sense of touch (tactile) is included under sensory memory. This can be valuable for the study as many vocabulary apps make use of tactile activities which could hinder or help early language learning for children with ASD. In addition, the assumptions are expanded on to include additional aspects such as the schemas found in long-term memory and the verbal and non-verbal codes of knowledge.

Next a methodology will be discussed on a learning style to help children with developmental disabilities.

4.4 Oelwein's Methodology

The methodology used by Oelwein(Broun, 2004; Oelwein, 1995) discussed by Broun (2004) makes use of a visual learning style that builds on the strength of children with developmental disabilities. This visual methodology includes pairing spoken words with printed words. The spoken and printed words activate the auditory sense in sensory memory. The kinaesthetic component involves the matching and selecting of words for sentence construction involving long-term memory. The final style is digital or spoken or hand signing of a word depending whether the child is capable.

Most children with ASD learn by recognising whole words. The sounds of letters as well as the letters themselves can appear abstract and worthless since they aren't recognised in isolation. This results in phonics not being the starting point in learning words but rather making use of sight vocabulary.

The Oelwein method (Broun, 2004, p. 38) consists of various stages of learning (see Figure 4-3):

1. The ***Acquisition stage*** where the child is learning to recognise words.
2. The ***Fluency stage*** where the child recognises the word with some degree of consistency, recognising the word more often than not.

3. The ***Transfer stage*** where the child recognises the word printed on different surfaces, in different contexts, and with different fonts.
4. The ***Generalisation stage*** where the child recognises the word in any context.

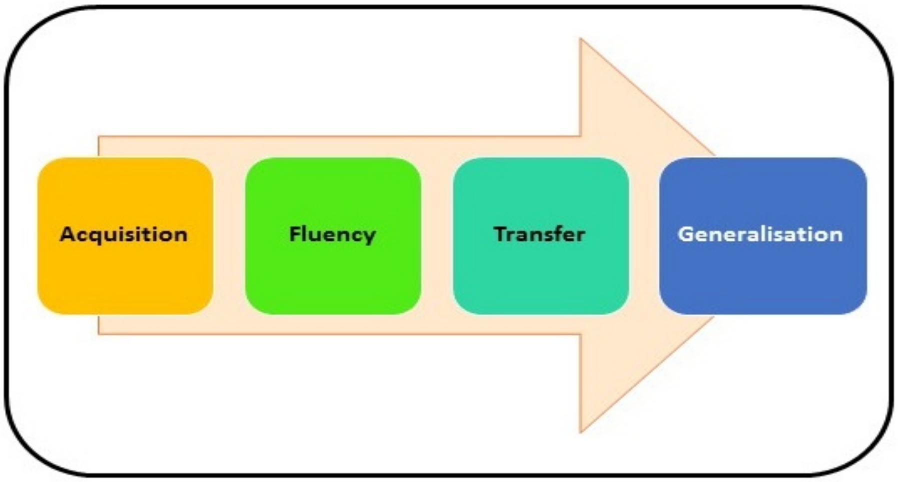


Figure 4-4 Oelwein's Methodology

Although not overtly mentioned in Broun's article (2004) the different memories used for learning are present in Oelwein's methodology. Based on the explanation in Section 3.8 about the different memories the following assumptions can be made: Sensory memory is involved when incorporating the visual and auditory learning style in the acquisition stage. Working memory is involved in the fluency and transfer stages and long-term memory is used in the generalisation stage. These different memories can be linked to the CTLM mentioned previously. Oelwein provided insight on how learning words can take place effectively for children with ASD.

To provide further awareness on how learning takes place in general for children Bruner in Smidt (2011) explains the three stages of learning which correspond significantly with Oelwein's methodology.

4.5 Bruner's Three Stages of Learning

Jerome Bruner, a famous psychologist, made numerous significant contributions to the field of educational psychology. The works of famous theorists Piaget and Vygotsky had a great influence on Bruner's work. Bruner's work integrates the nature of knowledge and logic combined with the science of correct reasoning. Learning according to Bruner is seen as an active process that helps learners create ideas and concepts that are founded upon past and current knowledge(Bruner, 1966, 1985, 1996, 2017)(J. Bruner, 1985, 2017; J. S. Bruner, 1966, 1996; Smidt, 2011) (Smidt, 2011).

Bruner in Smidt (2011, p. 21) indicated that children progress through three stages of learning namely (see Figure 4-4):

1. The ***enactive stage:*** children begin to develop understanding through actively manipulating objects. The implication is that this is the stage or phase where children learn through play and should be encouraged to play (Smidt, 2011, p. 21).
2. The ***iconic stage:*** children become able to make mental images of something and no longer need to have the physical object or experience in front of them. Children here use memory to store experiences and can use the mental images stored to refer to in order to help them understand things. (Smidt, 2011, p. 22)
3. The ***symbolic stage:*** here children use abstract ideas to represent the world. The ability to use symbols and symbolic systems allows them to evaluate and make judgements and to think critically (Smidt, 2011, p. 22).

Knowledge is represented in three different ways through these stages. Bruner encourages the use of all three stages into adulthood when solving problems and to foster creative thinking (Lee, Thomas, & Baskerville, 2015; Smith, Cypher, & Tesler, 2001).

Bruner's three stages of learning can be linked to the CTLM and the different memories involved (Section 3.8). The enactive stage where the child manipulates objects involves sensory memory. The iconic stage involves working memory, storing information from a specific tasks, things or experiences. The symbolic stage involves long-term memory where abstract ideas can be created from symbols and experiences from the working memory.

4.6 Human Computer Interaction

Human Computer Interaction (HCI) is a term that is broadly used across numerous disciplines and is considered to be "… an information-processing task" according to Jacko and Sears (2003, p. 44). (2015)(S. Reeves, 2015)(Kostakos, 2015)HCI focuses on the interaction between people and computers in order to achieve a better understanding of the relationship between people and devices and systems and how to improve upon this relationship (Carroll, 2003; Weyers, Bowen, Dix, & Palanque, 2017)(Carroll, 2003). (Oulasvirta & Hornbæk, 2016, p. 4965)

When engaging with a computer, the user has specific objectives in mind and has to interact with the computer to achieve these objectives. The user performs specific tasks on the computer by activating software programs that allow specialised functions to accomplish the desired objectives. The output from the software programs displayed on the computer screen provides the user with the necessary steps to complete the objective. The user has to follow the prompts of the software program to achieve the desired output. This is a series of alternating sequences where certain responses are required by the user and information is displayed that helps the user with his or her corresponding response. An interactive process takes place between the computer and the user whereby information is processed to achieve the set objectives (Jacko & Sears, 2003)

According to Jacko (2012) various processors are involved in HCI specifically the perceptual, cognitive and motor processors. These processors are interconnected and in certain instances work in serial format or simultaneously whereby information is transferred from the perceptual processor to the cognitive processor and finally to the motor processor where actions are executed. The function of the perceptual processor is to detect light and transfer this information to the cognitive processor which decides the suitable response. This response goes to the motor processor which converts the response into action. HCI makes use of "… two powerful information processors human and computer…" Jacob (1993, p. 1) articulates. (2007, p. 97)The(1983)(Byrne, 2007) Model Human Processor (MHP) which is an information-processing model that entails a series of processors and memories that are interlinked according to a set of operation principles. This can be seen in Figure 4-5. Information from the stimulus of the visual and auditory stores streams into working memory with the help of the Perceptual Processor. In working memory, the information is processed by the Cognitive Processor and activates the Motor Processor to initiate actions. The Cognitive Processor aids information in working memory to be modified and linked to long term memory (StuartK Card, Moran, & Newell, 1986).

(Olier, Gómez, & Caro, 2018)(Honig & Oron-Gilad, 2018)(Nass, Jung, Groen, Villela, & Holl, 2018)

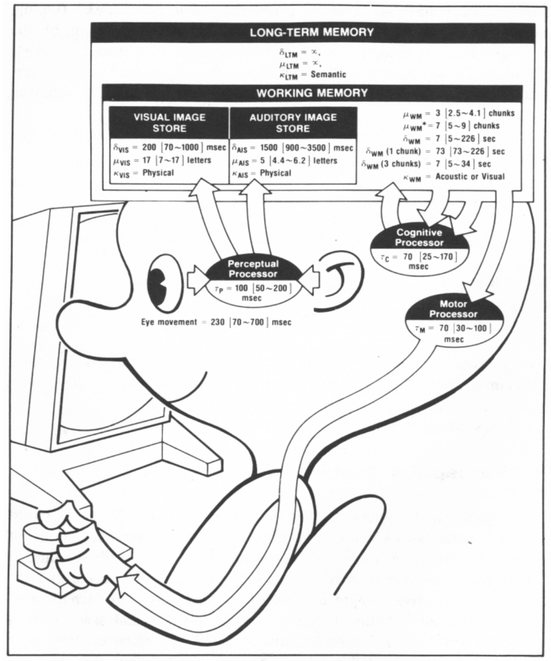


Figure 4-5 Human Computer Interaction

The authors Kieras and Meyer (1997, p. 391) remark that past HCI placed greater emphasis on cognitive aspects only such as how humans recognise their environment and react to it and declare this approach to be 'seriously misleading'. The authors argue that in multiple tasks the stimulus depends on whether the eye is aware of the stimulus and for this reason they introduce another information-processing model known as EPIC – Executive Process-Interactive Control, which is very similar to the Model Human Processor.

The difference is that EPIC specifies separate processors. The first is the perceptual processors, each having distinct characteristics involving different processing times for each sensory modality. Also, the separate motor processors for vocal, manual and eye movements that provide feedback from various pathways. The cognitive processor identifies an object that will be explored acting as mediator between the auditory and motor processors. The perceptual processor identifies the properties of objects while the auditory processor receives auditory input. The manual motor processor aids various movements such as tapping, swiping and poking (Kieras & Meyer, 1997).

According to the EPIC model auditory and visual input from the interactive device is transferred to the auditory, visual, tactile and manual motor processors. The sensory inputs from these processors are then sent to working memory (Kieras & Meyer, 1997, p. 399).

The information-processing models of HCI namely the Model Human Processor and EPIC can be linked to the different memories discussed in Section 3.8. The auditory, visual, and tactile processors form part of sensory memory that sends impulses to working memory and then proceed to long term memory.

4.7 {Card, 1983 #321}(1983)(Byrne, 2007, p. 97)(Byrne, 2007)(Bovair, Kieras, & Polson, 1990; Kieras & Meyer, 1997)(Byrne, 2007, p. 98)(Byrne, 2007)(Byrne, 2007; Just & Carpenter, 1992)Conceptual framework for learning

The conceptual framework used for the research study is a culmination of specific disciplines which are centred on multimedia learning, more specifically the cognitive theory of learning with media (CTLM). The various memory processes are involved in all of the disciplines linked to the CTLM.

The CTLM forms the focal point of the conceptual model highlighting the three different memories and the sequence for successful learning with media. The conceptual framework for learning (Figure 4-6) represents the following four disciplines: CTML, Oelwein's methodology, Bruner's three stages of learning and HCI, specifically the Model Human Processor (MHP) model. These four disciplines are separated by **red lines**. The three types of cognitive processing are also represented in separate sections entitled: **extraneous**, **essential** and **generative** cognitive processing. The three memories are represented by different colours: sensory memory is **blue**, working memory is **green**, and long-term memory **purple**.

Sensory memory's connection to the acquisition stage of Oelwein's methodology is indicated with a **blue dotted line** and to Bruner's enactive stage by a **blue solid line** and the model human processor HCI with a **black solid line**.

Working memory makes use of a **green dotted line** to encompass the fluency and transfer stages of Oelwein's methodology; a **green solid line** to link with the iconic stage of Bruner's learning stages and a **black solid line** to connect with both the cognitive and motor processors involved in the model human processor HCI.

Long-term memory connects a **purple dotted line** to the generalisation stage of Oelwein's methodology. Further linking to Bruner's symbolic stage using a **purple solid line** and lastly connecting to the cognitive and motor processors of the model human processor HCI with a **black solid line**.

When more than one memory is involved in a specific discipline the respective memory colours are combined.

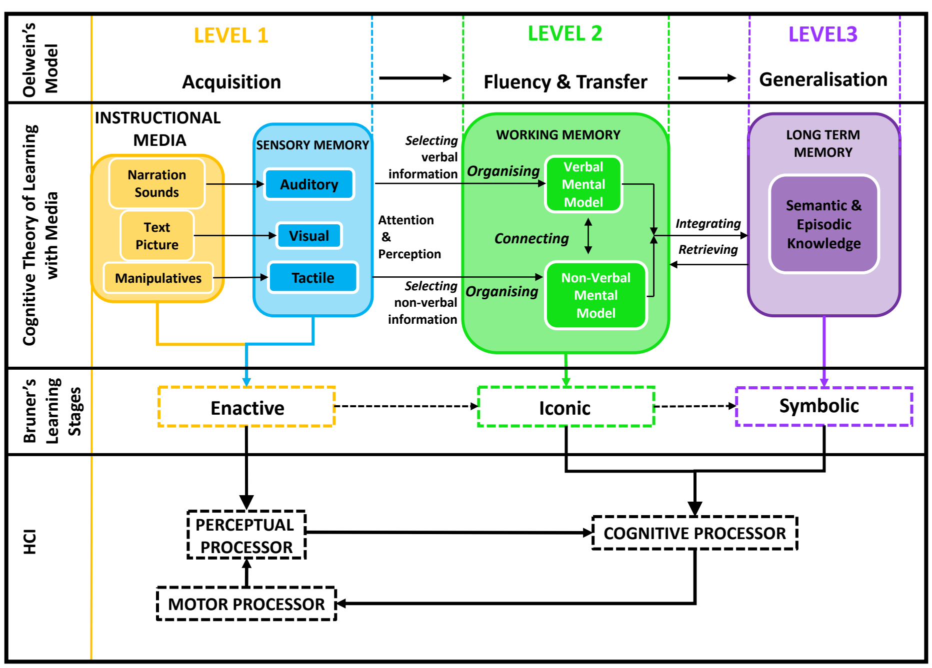


Figure 4-6 Conceptual Framework of Study

In Oelwein's methodology the acquisition stage involves **sensory memory**. The learner receives either auditory or visual or tactile stimuli or all stimuli simultaneously. The fluency and transfer stages involve attention to the task at hand and rehearsal and repetition which involve **working memory** – the child sees a word in different fonts (repetition), and on diverse materials (rehearsal). Finally, the generalisation stage is where the child makes use of **long-term memory** and recognises the word in any context.

Bruner's three stages of learning also incorporate the different memories. During the enactive stage the children make use of their **sensory memory** by using their auditory, visual and tactile senses to develop their understanding. In the iconic stage mental images are made and there is no need for the physical object since the object or information about the object is retained in **working memory**. In the symbolic stage the children make use of abstract ideas using symbols and symbolic systems where the **long-term memory** stores multiple symbols for later recollection.

The Model Human Processor (MHP) model involves the perceptual, cognitive and motor processors that can be linked to the different memories. The perceptual processor involves the visual and auditory senses, and can also be linked to **sensory memory** although the MHP model links it to working memory. The cognitive processor is involved with **working memory** and **long-term memory** and the motor processor is involved in **working memory** only.

As indicated all the concepts mentioned are interlinked with CTLM which guides the research study. The general assertion is that children with ASD's cognition can be analysed in terms of the different stages of memory, from sensory memory to long-term memory. Multimedia design can either be a hindrance or advantage to learning for all learners depending on whether the design principles provided by Mayer (Issa et al., 2011) have been incorporated correctly. Through the identification of the multimedia design guidelines identified in this study, that are then incorporated into the design of vocabulary apps for children with ASD, early language learning can hopefully be enhanced.

4.8 Concluding comments

The conceptual framework presented for this study integrates various learning theories that are necessary for learning to take place effectively. These learning theories engage sensory, working and long-term memory which result in effective learning. Vocabulary apps that incorporate the features of the learning theories presented in the conceptual framework will contribute positively to early language learning in children with ASD.

5 CHAPTER FIVE - RESEARCH DESIGN AND METHODOLOGY

5.1 Focus of Chapter

This chapter will discuss the research design and methodological procedures used to answer the research questions. First the ‘research onion’ provides a quick overview of the entire methodology of the research. The research philosophy, pragmatism, and its related assumptions are discussed guiding the study. An explanation of the approach the study takes is provided. Next the research design strategy specific to the research study will be explained as well as the model will be implemented. The methodological choice is then discussed subsequently followed by the reasons for doing longitudinal research. Thereafter a description of the data collection and analyses is specified and the validity and reliability discussed. Concluding with the ethical undertakings incorporated in the research.

An infographic showing the methodology of the research study is presented in Figure 5-1.

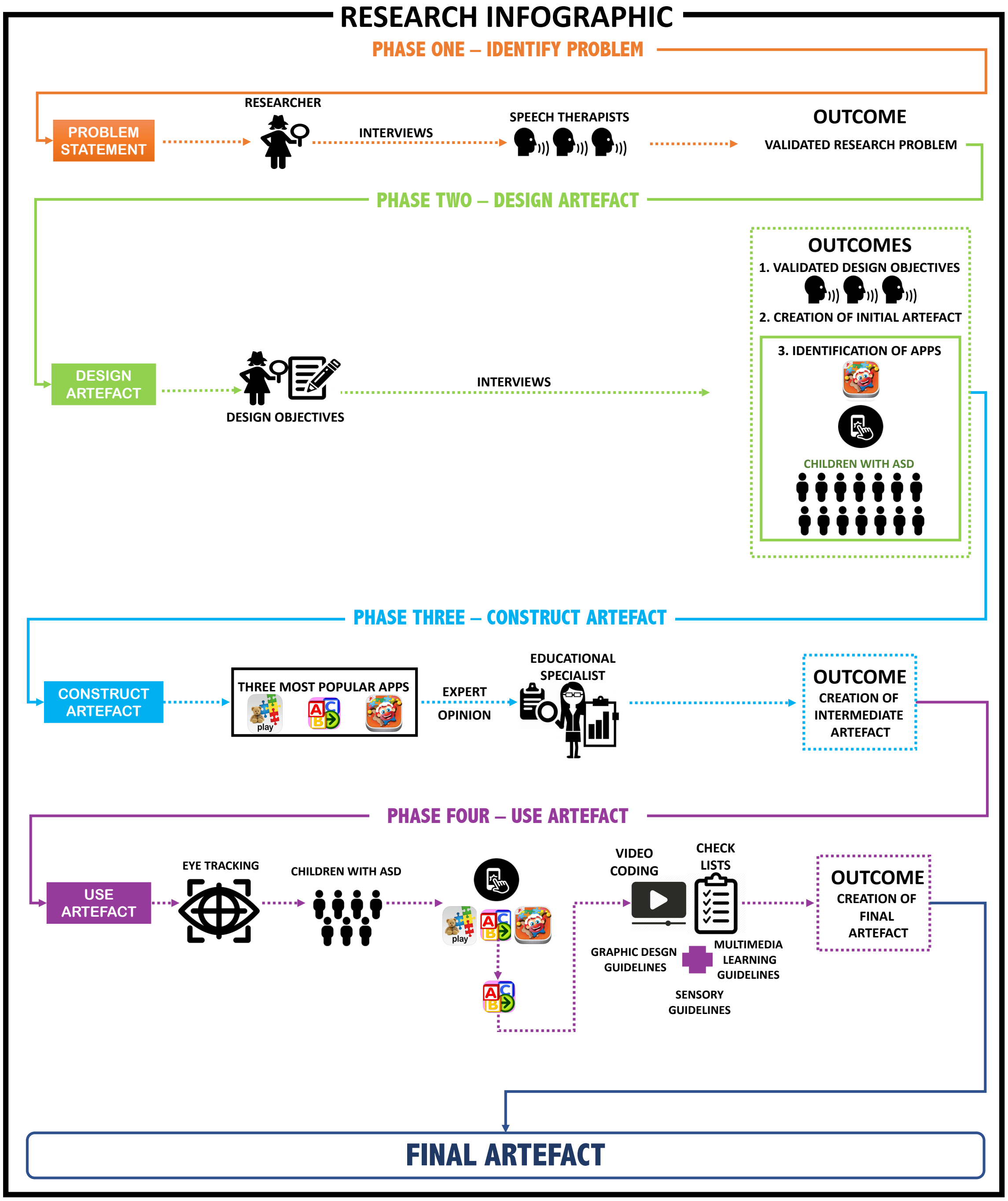


Figure 5-1 Research Infographic of Methodology

5.2 The Research Onion

Various techniques are used to acquire and analyse data by making use of the elements in the metaphor of the '*Research Onion*' (Saunders, 2011; Saunders & Tosey, 2012). The outermost layer of the research onion provides the research philosophy and its influence on the research design and the research approach. The subsequent layers have to do with implications of the methodological choice, strategies and time horizon for the research design, concluding with data collection and analysis. In Figure 5-2 the different procedures used to answer the research questions are presented.

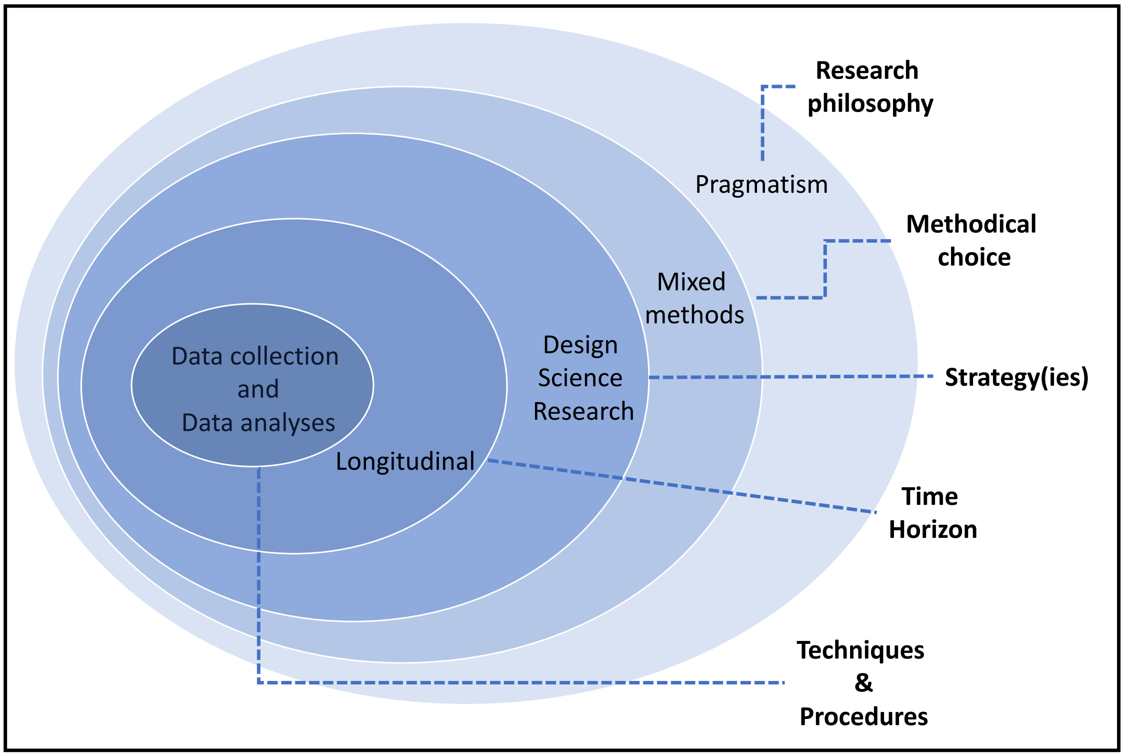


Figure 5-2 Research Onion

The different layers represent the entirety of the research progressing from one level to the next ultimately addressing the research questions. The answers of which will contribute to improved knowledge on how to design vocabulary apps to support language learning in children with ASD.

Four common beliefs or worldviews or paradigms exist that are based on a set of beliefs that guide a research approach. These paradigms are driven by epistemologies – how we know what we know- and ontologies – the nature of reality. These four paradigms are: postpositivism, constructivism, advocacy/participatory, and pragmatism and each have different assumptions (Creswell, 2014).

The postpositivist paradigm assumptions are grounded in quantitative findings and incorporates a scientific approach to research. Absolute truth is questioned and statements made about human behaviour are questionable. Research results are not perfect but rather indicate whether a hypothesis can be accepted as true or not. Theories are tested so that claims can be made or rejected. Knowledge is gained from data and evidence from which true and relevant statements can be made. No bias is involved, only objectivity (Creswell, 2014).

Constructivism according to Creswell (2014) incorporates qualitative research and is based on the assumptions that the world needs to be understood better. Meaning is subjective for each experience and based on different views. Meaning is derived from interaction triggered by open ended questions. The answers to the open-ended questions provide greater insight into the history and culture of people and result in an improved understanding of the world. Interaction with the world is studied and interpreted to derive meaning. The context and setting of individuals are studied to collect data which are interpreted by the researchers own referencing framework. Meaning is generated and forms the end result.

The advocacy and participatory approach has a political agenda promoting reform that results in change. Issues that are addressed are empowerment, inequality, oppression, domination, suppression, and alienation. These issues drive the research study in collaboration with the participants who assist with the design and data collection of the study. The research becomes a voice for the participants that will hopefully result in reformation and change. Participation involves discussion on how to bring about change and help problems identified in society, media, language, work, and relationships of power. A practical approach is taken where the participants engage in counsel to encourage reformation and change (Creswell, 2014).

The last paradigm to be discussed is pragmatism that develops from actions, situations, and consequences – what works and what does not work. This philosophical paradigm's research practices were incorporated into the study including its theories, research methods, assumptions and standards. Pragmatism represented the first layer of the 'research onion' and the ontological, epistemological, axiological, rhetorical. Methodological assumptions of this paradigm are also discussed.

5.3 Pragmatism as Research Philosophy

The exertion to decipher how ideas come about was the lifelong work of Charles Sanders Peirce an American philosopher and founder of Pragmatism (Råholm, 2010).

The research philosophy incorporated in the research study was pragmatism. The focus of pragmatism being on practical findings relating to a certain logic. As Creswell distinctly describes: "The pragmatists, for example, believe philosophically in using procedures that "work" for a particular research problem under study and that you should use many methods when understanding a research problem" (Creswell, 2005, p. 537). With pragmatism no single viewpoint can represent the complete picture and multiple realities exist. The purpose of this viewpoint is to create credible, reliable and relevant data that can support subsequent action (Saunders & Tosey, 2012).

The ideology or proposition integrating pragmatism has to work satisfactorily if it is to be accepted as true. Pragmatism can only be true if the consequences are accepted and practical. The concept is either confirmed or denied and there is "absolutely nothing more in it" declares the founder of pragmatism Peirce (1905, p. 162). Ideas are considered to play an altered role moving away from reporting and registering of past experiences and moving toward arranging prospective observations and experiences (Cherryholmes, 1992).

Pragmatism is about a shared understanding of what is possible and to connect theory to research. Emphasis is placed on the difference the research can make and not on assumptions, being concerned about what is effective and what actions help to solve problems, knowledge and actions are interconnected. Pragmatism therefore justifies combining qualitative and quantitative methods (Creswell, 2009; Goldkuhl, 2012; Morgan, 2007).

The following qualities are present when following a pragmatic approach with research (Creswell, 2009, 2014):

- Pragmatism does not follow one system of philosophy or reality but encompasses both qualitative and quantitative assumptions in research – a mixed methods approach.
- Freedom of choice is provided regarding the methods, techniques and procedures that will answer the research questions.
- The research makes use of what truth or reality presently works to help provide greater insight to the research problem.
- Focus is placed on what to research and how to go about the research based on the final purpose of the research which provides the rationale for the research.
- Research takes place in different contexts such as social, historical, political or other contexts.
- A world exists that is independent to the mind and the thoughts related to the mind.
- Pragmatism is based on different views of the world, different assumptions and different ways of collecting data and analysing it.

These qualities provide greater insight into the research that needed to take place for the study. With these qualities in mind this research study incorporated interviews, observations, checklist matrices as well as eye-tracking to combine both quantitative and qualitative data collection and analysis techniques.

The assumptions related to pragmatism as a paradigm of choice are discussed next.

5.3.1 *Ontological assumptions*

To answer the question of what constitutes reality according to the research study involved the identification of multimedia design guidelines for vocabulary apps that would assist early language learning in children with ASD. The result would be an artefact that would be designed and developed to identify effective multimedia design guidelines. The study included the recommendations made by speech therapists and app developers and included eye tracking and video coding, resulting in a multi-faceted approach with subjective and objective deliberations. Subjectivity was applied during interviews with the speech therapists and their recommendations and objectivity pertaining to the eye tracking and video coding results. The combination of subjectivity and objectivity helped with the identification and creation of the artefact.

Various data collection techniques were used to ensure that the artefact (multimedia design guidelines) was indisputably effective in promoting language learning in children with ASD when incorporated into a vocabulary app. This was achieved by linking the multimedia design guidelines to educational theory presented in the conceptual framework and supporting these findings with the results of the eye tracking and video coding.

5.3.2 *Epistemological Assumptions*

Valid knowledge was attained by incorporating several data collection techniques steering the triangulation of results which lead to the creation of the artefact. The knowledge gained from the interviews, observations, eye tracking and video coding would contribute to greater insight into promoting early language learning for children with ASD with the help of an effectively designed vocabulary apps. In addition, the triangulation of data helps construct, demonstrate and evaluate the artefact. The construction of the artefact takes place through the identification of educational, multimedia learning and graphic design features of vocabulary apps. The demonstration takes place when the children with ASD interact with the vocabulary apps. The evaluation takes place when the eye tracking recordings are video coded and the number of fixations on letters, words and objects determined (see Figure 5-1).

5.3.3 *Axiological Assumptions*

Axiological referring to the role of values were imperative to the research study. By means of triangulation the results of the various research methods could be proven to have a high degree of validity and reliability. The preliminary interviews with the speech therapists were used to collect information about vocabulary apps that would be chosen for research and help create the artefact.

5.3.4 *Rhetorical assumptions*

The rhetorical assumptions used for this research are based on the terminology of mixed methods research, providing descriptions and critical thinking regarding the different results of data analyses.

With this pragmatic perspective, the research is guided to the next layer of the 'research onion' namely the methodological choice.

5.4 Approach

Peirce the founder of pragmatism as mentioned earlier, believed that a rational manner existed to make logical discoveries. Logical discoveries involved three stages: the first stage was abduction where an idea originates; the second stage is induction integrating occurrences that guide; and the third stage deduction, which is the logical consequences of applying general principles (Råholm, 2010).

Morgan (2007, p. 71) explains that a pragmatic approach relies on abductive reasoning that: "moves back and forth between induction and deduction – first converting observations into theories and then assessing the theories through action." The abductive reasoning of pragmatism can be taken even further by evaluating the results of previous inductions through the "…ability to predict the workability of future lines of behaviour" (Morgan, 2007, p. 71).

A different viewpoint of abduction is articulated by Lipscomb (2012, p. 244) as "the creative, imaginative or insightful moment in which understanding is grasped – or is thought to be grasped." Relying solely on an abductive approach can be challenging since it is based on assumptions. In a concept analysis of abductive reasoning it was stated that this type of approach could be beneficial for novice researchers since it includes different ways of knowing and incorporating a universal approach to knowledge (Mirza, Akhtar-Danesh, Noesgaard, Martin, & Staples, 2014).

Abductive reasoning is a new approach to research that incorporates grey areas unlike inductive and deductive reasoning. Therefore, both inductive and deductive approaches were used in the study.

An inductive approach is concerned with the context in which occurrences take place and is ideal for small sample sizes. Data is collected and examined to identify themes or issues that can be further researched. Relationships between the different data collected are identified, resulting in a theory (Saunders, 2011).

A deductive approach as Saunders (2011) points out, helps identify key concepts and patterns. The data can be analysed and examined to identify emergent patterns. The analyses are guided by the theoretical approach adopted by the study and propositions can be tested several times and explanations provided where needed.

Although both approaches appear similar there are differences, these differences are presented in Table 5.1.

Table 5-1 Deductive and Inductive approaches

Deductive approach	Inductive approach
Uses scientific principles	Gains understanding of the meanings humans attach to events
Moves from theory to data	A close understanding of the research context
The need to explain the causal relationships between variables	The collection of qualitative data
Quantitative data	A more flexible structure to permit changes of research emphasis as the research progresses
Application of controls to ensure validity of data	A realisation that the researcher is part of the research process
The operationalisation of concepts to ensure clarity of definition	Less concern with the need to generalise
A highly structured approach	
Researcher independence of what is being researched	
The necessity to select samples of sufficient size in order to generalise conclusions	

Based on the assumptions explained in Sections 5.3.1 to 5.3.4 this study will follow Design Science Research (DSR) as research strategy. DSR is explained as the creation of new knowledge in the form of an innovative artefact (Vaishnavi & Kuechler, 2004).

5.5 Design Science Research as Research Strategy

Design research is recognised by different terminologies namely Design Science Research or Design Research or Design-Based Research. The differences in terminologies is due to the fact that research involving design is considered to be in its beginning stages (Anderson, 2005). Many authors (Anderson, 2005; Bereiter, 2002; Bryman, 2006; Collins, Joseph, & Bielaczyc, 2004; Kelly, 2004; T. C. Reeves, Herrington, & Oliver, 2005) use the term Design Research (DR) while many other authors (Botha, Herselman, Smith, & Coetzee, 2012; Cronholm et al., 2013; Cross, 2001; Gregor & Hevner, 2013a; Hevner, March, & Park, 2004; Lee et al., 2015; March & Storey, 2008; Offermann, Levina, Schönherr, & Bub, 2009; Peffers et al., 2006; Peffers, Tuunanen, Rothenberger, &

Chatterjee, 2007) use the term Design Science Research (DSR). However, the purpose of both terminologies is to contribute value to the end user.

5.5.1 *Design Research*

Design research (DR) similarly has numerous names such as: design experiments, design theories, educational design research and developmental research. All of these merge instructional design with educational research (Prediger, Gravemeijer, & Confrey, 2015). DR takes place in an educational environment where the research places emphasis on an intervention that contributes meaningfully to learning. This is achieved through designing and testing the founded intervention. A mixed method approach is used involving multiple iterations similar to action research (Anderson & Shattuck, 2012).

DR originated during the seventeenth century from the father of modern physics - Galileo Galilei, according to Buchanan (2001). A discussion about design took place in the arsenal of Venice where Salgredo and Salviati were astounded at the superior competencies of the artisans to design and develop instruments and machines involving different mechanics. Francis Bacon also contributed to DR with his motivation to create the 'artificial' in his project called the *Great Instauration.* However, design in the twentieth century was considered the work of artisans who did not possess the capabilities to explain the underlying principles that motivated their creations (Buchanan, 2001).

To better understand DR the word 'design' must first be clarified as many different descriptive definitions exist. Design is seen by some as being part of creativity in art and by others the creation of materials for an area of specialisation, such as seen in the professions of graphic design and industrial design. Graphic design makes use of visual symbols, words and images to communicate information. Industrial design created artefacts that were tangible physical objects. Associated specifically to DR, Buchanan (2001, p. 9) offers the following definition: "Design is the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes."

DR is considered to be any type of research that produces findings that are tweaked to produce innovative design. DR takes on various forms exploring individuals, society and culture, and includes education. DR is considered to be an effective educational research tool, whereby design in education places emphasis on developing the learner through materials, tools and techniques of design. These materials, tools and techniques are artefacts that promote understanding within human sciences according to Buchanan (2001).

DR in education only started to emerge in the 1990's when there was a need for an improvement in education. The expression 'design experiments' was introduced in education to test and refine educational activities (Bereiter, 2002; Collins et al., 2004). The role of DR in education was at this time poorly understood. Bereiter (2002, p. 326) in an attempt to address the confusion stated that DR cannot be "…defined by methodology". , rather DR incorporates various methodologies to refine research procedures to come up with an innovative product or technique or artefact, according to Kelly (2004). However, Collins et al (2004) point out that DR does not solely consist of refining but attends to theoretical questions and problems. DR in education has a link to basic science and the purpose of repeated efforts at improvement. Anderson (2005) applies a different terminology namely 'design-based research' concluding that it is a multidimensional process of conducting educational research incorporating various assessments of interventions within an educational environment.

The characteristics of DR in education are as follows (Bereiter, 2002, p. 326):

- The research is carried out by a designer or in collaboration with designers
- It is fundamentally an intervention
- It provides solutions to problems based on apparent deficiencies and impediments
- Vision guides the research providing goals that evolve during the cycles of DR.

Reeves, Herrington, and Oliver (2005, p. 103) add to the characteristics of DR in education:

- DR focuses on a wide range of multifaceted problems
- DR integrates hypothetical design principles with technological affordances to identify plausible solutions to multifaceted problems
- DR supports rigorous and reflective inquiries to refine learning environments and identify new design principles
- It is a continuing process refining the protocols and questions
- It supports collaboration among researchers and practitioners
- It Creates theories and explanations while solving real life problems.

The characteristics provided by Prediger et al (2015, p. 4) provide greater insight:

- The purpose of DR is to create and study new forms of instruction making it interventionist rather than naturalistic.
- The goal is to generate theories relating to the process of learning and how to support learning. Design experiments are pragmatic to produce theories that are refined to be topic-specific and to inform design.
- The connection between theory and experiment is prospective and reflective. The theory is prospective by informing the design of the experiment and then further developed through reflective thought regarding any deviances between the expected and observed teaching and learning processes.
- Iterative cycles of invention and revision take place. Conjectures are refined from one experiment to the next or between experiments following micro and macro design cycles. Analysis leads to adaptation and revision through knowledge gained from iterations and retrospective analysis.
- Emphasis is placed on ecological validity and practice orientation whereby the theory must be effective. The theories must describe the conditions in which the learning process took place since this could have an influence on learning. Since

> the research takes place in real classrooms, the conditions of the study represent the complexity of the conditions of practice. The theories that are tested are closely related to the activities of the students and teachers and revised often.

DR involves a substantial amount of reasoning and contemplation in the design of the educational artefact, exploring new technologies incorporating innovation and intervention, creating engagement of old and new information resulting in reformation within the learning environment.

Although this study does involve research related to learning specifically in early language learning the tenets lean more towards Design Science Research, which is discussed next. For this study an artefact was created specifically to guide the design of vocabulary apps for young children with ASD.

5.5.2 *Design Science Research*

Design Science Research (DSR) focuses on the process of creating solutions to complex problems in a pragmatic manner. These problems could include ill-defined environmental contexts that can be solved by creativity and team work (Herselman & Botha, 2014, p. 13). DSR is considered to be an "…important and legitimate Information Systems (IS) research paradigm" asserts Gregor and Hevner (2013b, p. 337). DSR originates from either an opportunity that has significant value, a problem that is perplexing, or an idea of something innovative resulting in the design of a new artefact (Cronholm et al., 2013; Gregor & Hevner, 2013b).

The author Simon (1996), explaining the origin of DSR in his book titled 'The Sciences of the Artificial', has a different opinion to Buchanan (2001) who stated that the origin was from Galileo Galilei (See 6.5.1). In his book he states that the science of design started growing from the 1970's at the Carnegie Mellon University's Design Research Center, after much neglect. The main objective of Design Science (DS) is to 'design to serve', so that competencies can be improved through the inventive creations of artefacts. Design science evolved from engineering and sciences of the artificial, focussing on problem solving (Hevner et al., 2004).

Design Science Research (DSR) involves information systems (IS) and information technology (IT) artefacts and endeavours to solve identified problems within an organisation. Practised in fields such as Computer Science and Software Engineering to develop new architecture, programming languages, algorithms, models, databases et cetera, DSR is an evolving research field. DSR utilises multiple methodologies including theories, systems, experimentations, and observations to provide a specific solution (Iivari, 2007; Peffers et al., 2007). Carlsson, Henningsson, Hrastinski and Keller (2011) indicate that the main purpose of DS is to identify useful information regarding a specific problem in a related field that can be utilised by professionals within that field.

Information according to researchers in IT is defined as "data that has been processed into a form that is meaningful to the recipient and is of real or perceived value in current of prospective actions or decisions" (March & Smith, 1995, p. 251). On the other hand technology is defined as "practical implementations of intelligence" that is useful and valuable in the form of an artefact rather than a concept. Information technology is when technology ("practical implementations of intelligence") is applied to obtain and process information to benefit society. IT originates from hardware, software, procedures, data and people within an organisation (March & Smith, 1995, p. 251).

The main areas of research in DS are people, organisations and technology. The artefact that is created through DSR is based on various knowledge bases using different methodologies and evaluation techniques to finally create an artefact. The artefact is assessed and refined numerous times to produce a final innovative and effective artefact. Figure 5-3 provides a framework for DSR.

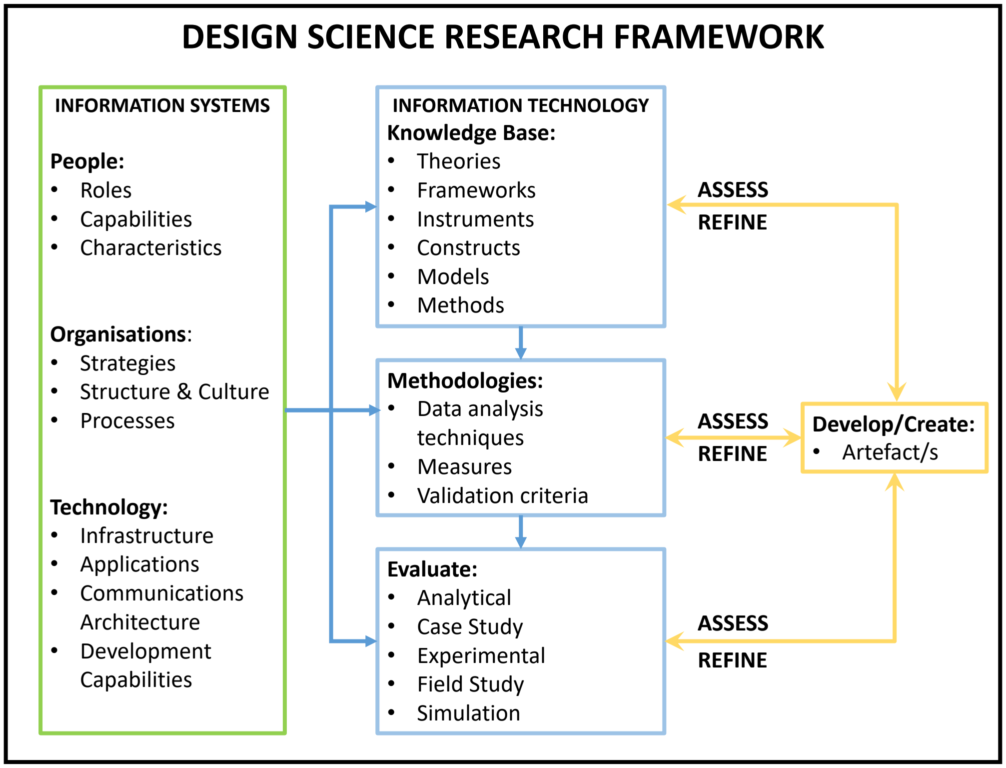


Figure 5-3 Design Science Framework

The knowledge base contains unfiltered information that needs to be worked through thereby providing the foundation on which the DSR is built. The different methodologies guide the evaluation phase. Rigour in evaluation is achieved through the employment of existing foundations and methodologies. In general, DSR is evaluated computationally and mathematically, however empirical techniques may also be used (Hevner et al., 2004).

Cross (2001, p. 3) explains that scientific design is based on scientific knowledge involving intuitive and non-intuitive design methods. A distinction can be made between natural sciences and the sciences of the artificial. DS is an "explicitly organised, rational and wholly systematic approach to design; not just the utilisation of scientific knowledge of artefacts, but design in some sense a scientific activity itself" (Cross, 2001, p. 3).

The DSR framework for this study is presented in Figure 5-4.

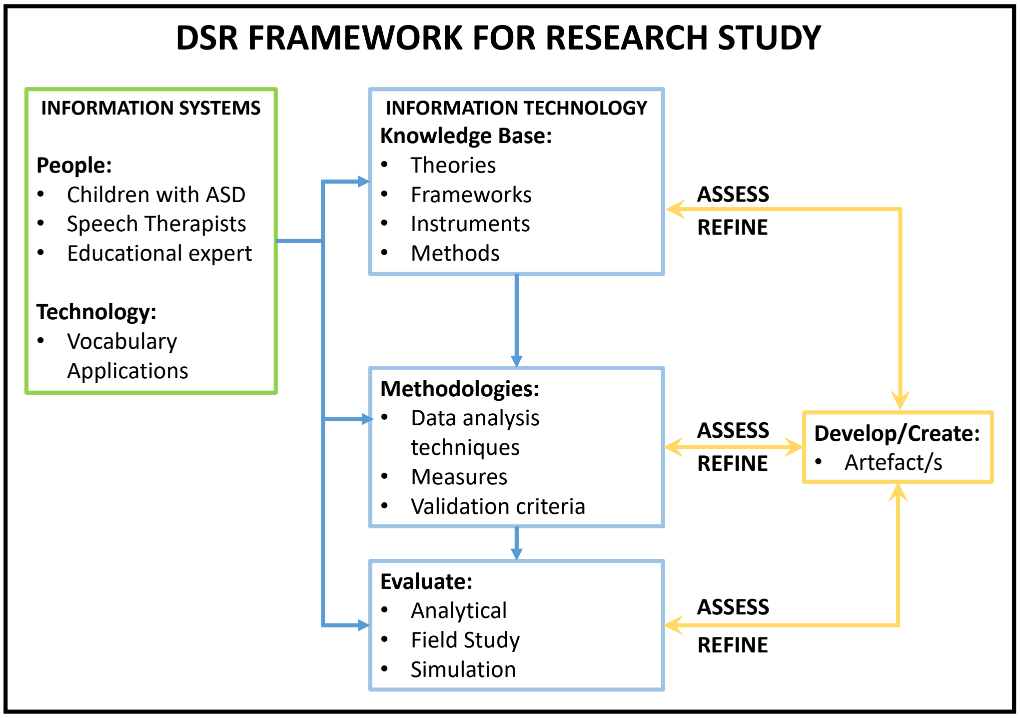


Figure 5-4 DSR Framework used for Research Study

In order to create the artefact, which for this study was effective guidelines for vocabulary apps assisting early language learning in children with ASD, the DSR framework was incorporated as follows: The **information systems** used for the research included children with ASD, speech therapists specialising in language learning for children with ASD and an educational expert. The **technology** investigated included applications specifically vocabulary apps used on tablets for language learning. The **knowledge base** involved different learning <u>theories</u>, a <u>conceptual framework</u>, <u>instruments</u> including semi-structured interviews, questionnaires and checklists. The <u>methods</u> utilised were eye tracking and video coding to refine the artefact. The **methodologies** included different data analyses techniques and measures integrating mixed methods and triangulation for validation. The **evaluations** that took place were iterative occurring a number of times analysing the artefact after each phase of the DSR model. This was achieved by analysing the data from the speech therapists, educational experts and eye tracking results. In addition, the children with ASD were observed interacting (simulation) with the chosen vocabulary apps in their own environment (field study). The artefact (multimedia guidelines) was continually assessed and refined producing the final effective artefact.

5.5.2.1 *The Design Science Research Artefact*

An artefact is created to solve a specific problem and it can be: constructs, models, methods, instantiations, or better theories (Herselman & Botha, 2014, p. 14). The drive behind DSR is to create advancement by innovative and new artefacts and to support these processes. Past knowledge is used to help innovative design of new artefacts that promote further improved designs (Hevner, 2007).

Hevner et al (2004) articulates that design involves activities which result in an artefact. The artefact is a construct or model or method that addresses unresolved problems and is created through ideas, practices, technical capabilities and products that are analysed. The creation of the artefact is based on theories that are applied, tested, and modified expanding the "experience, creativity, intuition, and problem solving capabilities of the researcher" (Hevner et al., 2004, p. 76). Research employing DS involves the building and evaluation of an artefact which meets an identified need as mentioned, with the main goal being effectiveness. The artefacts of IT vary from software, formal logic and rigorous mathematics to informal natural language descriptions. The mathematical basis of DSR allows for the IT artefact to be evaluated quantitatively. While the information that materialises from the interactions with the people, organisations and technology can be evaluated quantitatively. Both the quantitative and qualitative evaluations optimise the design of the artefact (Hevner et al., 2004).

Lee et al (2015) point out that there are different types of artefacts: the information artefact, the technology artefact and the social artefact and combined these to make up the IS artefact. Simon (1996, p. 5) identified the following traits of an artefact:

- Artefacts are created after deliberation from the researcher
- Artefacts imitate the appearance of natural things

- Artefacts are characterised according to functions, goals, and adaptations.
- Artefacts are discussed when being designed regarding their requirements and features.

Understanding the purpose and function of an artefact, the ontology and epistemology of identifying and creating an artefact of Design Science will be discussed next.

5.5.2.2 *Ontology of Design Science*

Livari (2007) explains that the DSR is about nature, consciousness and mental states, institutions and theories. The DSR artefact can be found in different areas and can also differ in design as seen in Table 5-2. The artefact can be presented in physical states such as objects or natural phenomena and form the ontology of DSR.

Table 5-2 Ontology of Design Science

Areas of Research	Research Phenomena	Examples
Nature	IT artefacts + Nature	Evaluation of IT artefacts against natural phenomena
Consciousness and mental states	IT artefacts + Consciousness and mental states	Evaluation of IT artefacts against perceptions, consciousness and mental states
Institutions, Theories, Artefacts: • IT artefacts • Meta IT artefacts	IT artefacts + Institutions IT artefacts + Theories IT artefacts + Artefacts	Evaluation of organisational information systems. New types of theories made possible by IT artefacts. Evaluation of the performance of artefacts.

For this study the area of research occurs in the third area namely institutions, theories and artefacts. An evaluation of existing vocabulary apps takes place in order to create a new effective artefact. The artefact – multimedia design guidelines - is created from an artefact that is evaluated numerous times to create a final robust artefact (see Figure 5-1).

5.5.2.3 *Epistemology of Design Science*

Three different levels of research are identified in DSR (as shown in Table 5-3): level one is the conceptual level, level two is the descriptive level, level three the prescriptive level as seen in Table 5-3. Singular and wide-ranging concepts are involved in the conceptual level. The qualities, relationships and characteristics of various concepts are identified at this level. The purpose of this level is to aid in theory development in the next level – the descriptive level. The descriptive level aims to describe, understand and explain the 'how' of things. The final prescriptive level determines how things can be and how to go about achieving this in an innovative fashion (Iivari, 2007).

Descriptive knowledge originates from natural and social sciences describing natural, artificial and social occurrences in the environment, as explained by Gregor and Hevner (2013a). The authors further describe how this knowledge is gained from research activities such as observations, classifications, measurements, and cataloguing. The purpose of these research activities is to make sense of the occurrences with the assistance of natural laws, principles, regularities, patterns and theories.

Prescriptive knowledge produces artefacts that make the world a better place and is related to the sciences of the artificial. Specific to prescriptive knowledge are constructs, models, methods, and instantiations. Constructs provide vocabulary and symbols which explain the problem for better comprehension on how to solve the problem. Models are representations of the problem as well as the possible solutions. Methods are algorithms, practices, techniques or recipes to complete a task. Instantiations are physical realisations such as design knowledge (Gregor & Hevner, 2013a).

Table 5-3 Epistemology of Design Research

Level	Knowledge	Example
1	Conceptual Knowledge (no truth value)	Concepts, constructs, classifications, taxonomies, typologies, conceptual frameworks
2	Descriptive Knowledge (truth value)	Observational facts, empirical regularities, theories and hypotheses = (causal laws)
3	Prescriptive Knowledge (no truth value)	Design product knowledge

The different epistemological levels of DS provide insight to creating an effective and innovative artefact. Creating artefacts is considered to be a creative deed since the artefacts do not explain or describe any existing certainties but are based on what is new, innovative and beneficial. Artefacts are created out of rigorous and practical research methods using no single research method, as mentioned previously.

For this study, conceptual knowledge was gained by the conceptual framework incorporating various learning theories that contribute to learning. Descriptive knowledge was acquired through the numerous structure observations that took place. By completing all the activities of all four phases of the DSRM additional knowledge was gained about the artefact to assist in the creation of an effective final artefact. The artefact progressed from an initial, to intermediate to the final artefact.

5.5.2.4 *Evaluation of Design Science Research*

The evaluation of an artefact is critical to the success of the artefact. To evaluate the artefact competently, metrics have to be developed and the artefact measured accordingly. The purpose of the metrics is to measure what is set out to be accomplished by the artefact. In other words, the metrics assess the performance of the artefact. In DSR this could be done through observations and measurements of the success of the artefact in its ability to address the identified problem. Observations provide descriptive knowledge which have a truth value (March & Smith, 1995). Hevner and Chatterjee (2010, p. 109) define evaluation as follows: “Evaluation is the systematic determination of merit, worth, and significance of something (information resource, healthcare program) or someone."

Accurate and thorough evaluations of the artefact are crucial to DSR. Evaluation method types for DSR can be logical arguments that include face validity; expert evaluations whereby the artefact is assessed by an expert or experts; technical experiment where an algorithm implementation is evaluated to assess technical performance; subject-based experiments involving subjects to determine whether a specific assertion is accurate; action research whereby an artefact is used in a real-world environment being part of the research intervention assessing the effect of the artefact; prototype - involving the application of the artefact in order to validate its utilisation and effectiveness; case study where the artefact is applied to a real-world situation so that its effect can be observed in a real-world situation and an illustrative scenario where the artefact is applied to either a real-world or artificial situation to demonstrate the effectiveness of the artefact. The evaluation method preference is determined by the choice of artefact. The choice of artefact results in a specific evaluation method (Peffers, Rothenberger, Tuunanen, & Vaezi, 2012).

Concurring with the importance of evaluation in DSR Venable, Pries-Heje and Baskerville (2012) provide further discernment regarding the centrality of evaluation to produce meticulous DSR. The purpose of evaluation is to provide proof that the artefact is effective in what it was designed or created to do. However, the authors feel that insufficient guidance is provided as to what strategies and methods should be included for evaluation in DSR.

The purpose of evaluation in DSR is as follows (Venable et al., 2012, p. 425):

To evaluate:

- An instantiation of a designed artefact to establish the utility and efficacy of the artefact to achieve its stated purpose

- The formalised knowledge about a designed artefact's utility for achieving its purpose
- A designed artefact or formalised knowledge about it in comparison to other designed artefacts' ability to achieve a similar purpose
- A designed artefact or formalised knowledge about its side effects or undesirable consequences of its use
- A designed artefact formatively to identify weaknesses and areas of improvement for the artefact under development

Two different classifications of artefacts exist. The first classification is the product artefact, and the process artefact, the second classification is the technical artefact and the socio-technical artefact. Product artefacts are technologies such as tools, diagrams, software et cetera which are used for a specific task: Process artefacts are methods, procedures et cetera that provide guidance to accomplish a task or how to go about something; Technical artefacts do not need any interaction with people and lastly socio-technical artefacts requires interaction with people. Product artefacts may only be technical or only socio-technical while process artefacts are only socio-technical (Venable et al., 2012).

Various evaluation activities of DSR have specific purposes which contribute to the construction and effectiveness of the artefact and are explained as follows (Sonnenberg & vom Brocke, 2012, p. 394):

Evaluation One:

Starting with the identification of a problem, literature is reviewed to create a knowledge base and justify the value of creating an artefact. This is achieved by determining the purpose, objectives and scope of the artefact. Constructs can be used in the form of prescriptive knowledge received from either surveys or interviews or both.

Evaluation Two:

Evaluation Two provides insight into the design of an artefact which will provide a solution to the problem. This evaluation could include design specifications, objectives, information, tools and methodologies. The specifications of the design are evaluated to ensure accuracy and determine whether the design objectives are being met.

Evaluation Three:

The purpose of Evaluation Three is to determine the effectiveness of the artefact. Inferences are made regarding the artefact and iterations of the design activity take place resulting in instantiations of the artefact. Evidence is gathered about the capability of the artefact to meet the specified objectives.

Evaluation Four

In Evaluation Four the effectiveness and usefulness of the artefact is validated.

The evaluations that take place in DSR ensure that the artefact is indispensable and serves a valuable purpose within the environment where it is applied. The artefact can be presented as a design theory, a construct, a method, a model, as design principles, technological rules or instantiations or software products or implemented processes (Gregor & Hevner, 2013a).

In the case of this research, the artefact is multimedia design guidelines. For this research study a socio-technical process artefact was produced. The multimedia design guidelines (process artefact) provide guidance to app developers regarding the design of vocabulary apps for early language learning in children with ASD. In order to provide the multimedia design guidelines, the socio-technical artefact included interaction with children with ASD, the speech therapists and the education expert in addition to eye tracking and video coding.

5.5.2.5 *DSR applied to Research Study*

In Table 5-4 the guidelines provided by Hevner et al (2004, p. 83) are described, including how they were implemented in the research study.

Table 5-4 Design Evaluation Methods

Guideline	Description	Study Implementation
Guideline 1: Design as an artefact	Design science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation.	This research study produced effective multimedia design guidelines (artefact) for vocabulary apps assisting early language learning in children with ASD.
Guideline 2: Problem relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems.	The objective of the study was to **identify** effective multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD. The relevance of the problem was confirmed by speech therapists. Design objectives were identified and established through theories, literature and the expert opinions of the speech therapists, to address the problem. The various activities of the phases established the fidelity and rigour of the final artefact. This was achieved through semi-structured interviews, structured observations, checklists, eye tracking and video coding.
Guideline 3: Design evaluation	The utility, quality and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods.	The DSR artefact was evaluated from Phase One to Phase Four. The initial artefact was produced after interviews with speech therapists. After evaluation, the intermediate artefact was created which included educational guidelines identified from the opinions of an educational expert. Additional evaluations which included eye tracking and checklists produced the final robust artefact.
Guideline 4: Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations and/or design methodologies.	The study contributed a robust artefact with high fidelity by incorporating various methodologies to ensure that the design objectives were effectively met. Each phase made use of various evaluation techniques that contributed positively towards the creation of an effective final artefact. The conceptual framework as well as the robust final artefact contributed to effective design science research.
Guideline 5: Research rigour	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.	The artefact was constructed and evaluated according to the 'design-evaluate-construct-evaluate' method described by Sonnenberg and vom Brocke (2012, p. 392). This ensured that the artefact produced by each phase addressed the design objectives to effectively address the identified problem.

Guideline 6: Design as a search process	The search for an effective artefact requires utilising available means to reach desired ends while satisfying laws in the problem environment.	The means incorporated to create an effective artefact were: expert opinions obtained through interviews and expert evaluations, observations, eye tracking, video coding, and checklists to create the final effective artefact.
Guideline 7: Communication of research	Design-science research must be presented effectively, both to technology-orientated as well as management-orientated audiences.	The results of the research study are recorded in this thesis. An article was published in an academic journal.

In this research study the area of research was specifically vocabulary apps that assist early language learning in children with ASD. The foundations of the DS of the study were based on educational theories used to create a conceptual framework. The artefact was identified and created using analytical strategies incorporating different data analysis techniques to ensure the created artefact was validated and effective. Various instruments and methods were used to identify and create the final effective artefact namely: semi-structured interviews with experts, structured observations, checklist utilisation, and video coding of eye tracking recordings which are discussed in detail.

5.5.3 *Design Science Research Models*

There are prominent Design Science Research Models (DSRM) within DSR. The first DSRM to be discussed is presented by Hevner (2007, p. 88) which places emphasis on three integral research cycles namely the *Relevance Cycle*, the *Rigor Cycle* and the fundamental *Design Cycle.*

The purpose of the Relevance Cycle is to commence the DSR with specific purpose and requirements. This provides insight to what is expected by specifying the criteria that will lead to successful evaluation once the requirements have been met. The Rigor Cycle makes use of an extensive knowledge base which form the foundation on which the DSR is built on. Past knowledge is used to assist innovative design that can effectively contribute as an artefact. The Rigor Cycle entails the meticulous choosing and use of knowledge, theories, and methods to construct and evaluate the artefact. The final cycle namely the Design Cycle forms the crux of the DSR. This cycle iterates back and forth in evaluations of the artefact producing alternatives until all the requirements are met and an innovative artefact can be presented. All three cycles are interdependent by constructing, evaluating and evolving the artefact until a sound artefact is created. Figure 5-5 provides an overview of the DSR cycles presented by Hevner (2007).

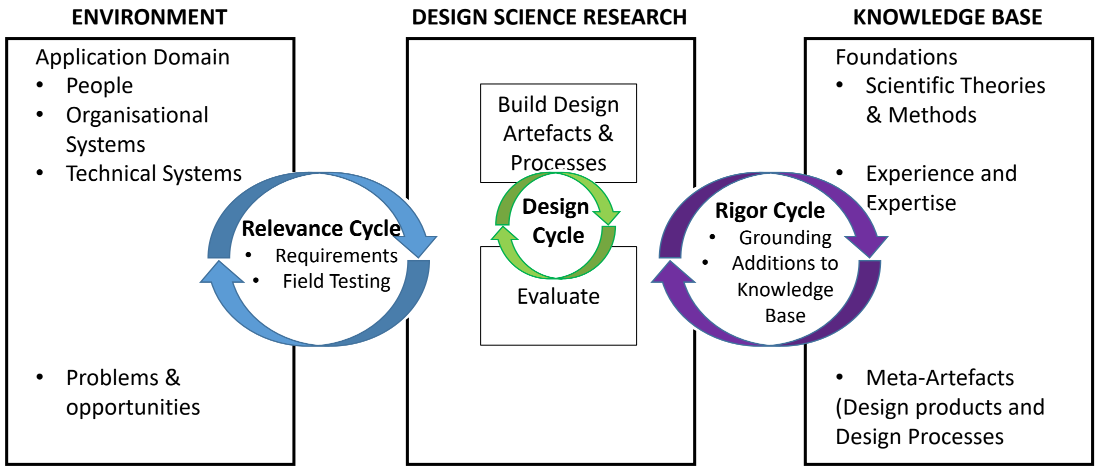


Figure 5-5 Design Science Research Cycles

The other prominent DSRM is provided by (Peffers et al., 2007) portraying the various activities involved in DSR is illustrated in Figure 5-6.

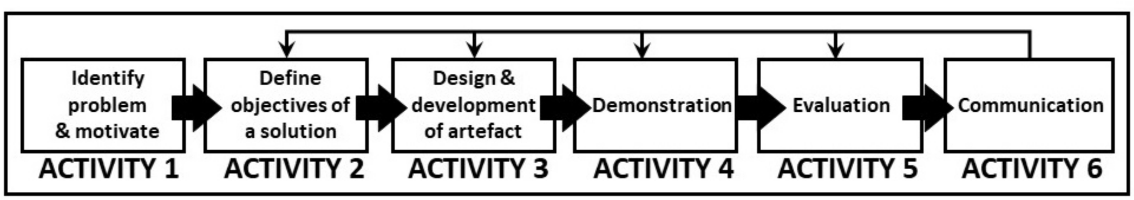


Figure 5-6 Design Science Research Model

Activity 1 - Problem identification and motivation require that the problem be identified and a solution justified. The carefully defined problem allows for the valuable creation of an artefact.

Activity 2 – Define the objectives for a solution from the carefully defined problem. The rational objectives can be quantitative or qualitative or both.

Activity 3 – Design and development of the artefact. The artefact can be in the form of a constructs, models, methods or instantiations. The research contribution can be embedded in the design. The purpose and function of the artefact must be determined.

Activity 4 – Demonstration of the use of the artefact to solve one or more instances of the problem. The artefact can be used in an experiment, simulation, case study, proof or other appropriate activity to solve the problem.

Activity 5 – Evaluation through observation and measurement of the success of the artefact. The objectives are compared to the solution of the problem when the artefact is demonstrated.

Sonnenberg and vom Brocke (2012) provide an updated and revised DSRM of Peffers et al's (2007) 'Build-Evaluate' DSR methodology. The reason behind the updated and revised DSRM is that evaluation should not only take place after the artefact has been developed but rather it should be validated from the beginning, with evaluation being the central theme. The authors explain that the objectives to the solution of the problem are compared to the effectiveness of the artefact to meet the specified objectives. Therefore, the artefact has to prove its efficacy in its application. This takes place in the form of 'design-evaluate-construct-evaluate' with the DSR activities being *problem identification, design, construction and use,* as displayed in Figure 5-7. The "ex ante evaluations validate the design of an artefact" while the "ex post evaluations validate artefact instances and artefacts in use…" describe Sonnenberg and vom Brocke (2012, p. 392).

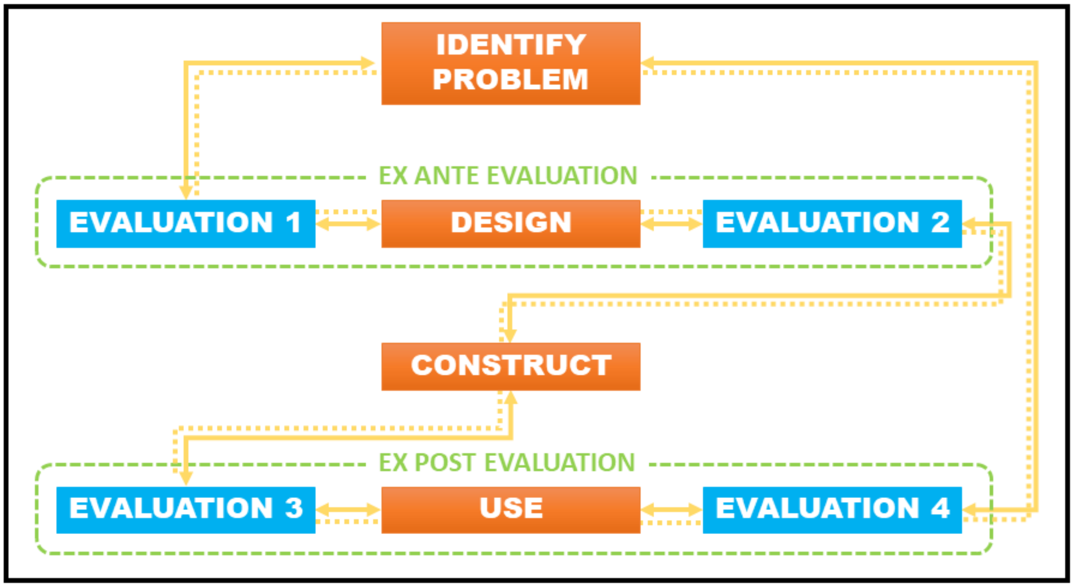


Figure 5-7 DSRM of Sonnenberg and vom Brocke

The model provided by Sonnenberg and vom Brocke (2012) ensures that an exalted degree of DSR processing takes place because of the numerous evaluations that take place. This model of DSR ensures the validation of the research findings from the first phase of the DSRM. The continuous evaluations result in the rigorous and effective design of an artefact contributing to DSR knowledge.

In Table 5-5 the DSRM of each phase and its related activities are provided (Sonnenberg & vom Brocke, 2012, p. 393).

Table 5-5 DSR Evaluation activities and criteria

Activity	Input	Output	Evaluation Criteria	Evaluation Methods
Identify Problem Phase 1	• Problem Statement • Observation of a problem • Research Need • Design Objectives • Design Theory • Existing solution to a practical problem	• Justified problem statement • Justified research gap • Justified design objectives	• Applicability • Suitability • Importance • Novelty • Economic feasibility	• Literature review • Review of practitioner initiatives • Expert interview • Focus groups • Survey

Design **Phase 2**	• Design Specification • Design Objectives • Stakeholders of the design specification • Design tool/design methodology	• Validated design specification • Justified design tool/ methodology	• Feasibility • Accessibility • Clarity • Understandable • Simplicity • Elegance • Completeness • Level of detail • Internal consistency • Applicability • Operationability	• Mathematical proof • Logical reasoning • Demonstration • Simulation • Benchmarking • Survey • Expert interview • Focus group
Construct **Phase 3**	• Instance of an Artefact (prototype)	• Validated artefact instance in an artificial setting (proof of applicability)	• Feasibility • Ease of use • Effectiveness • Efficiency • Fidelity with real world phenomenon • Operationality • Robustness • Suitability	• Demonstration with prototype • Experiment with prototype • Experiment with system • Benchmarking • Survey • Expert interview • Focus group
Use **Phase 4**	• Instance of an Artefact	• Validated artefact instance in a naturalistic setting (proof of usefulness)	• Applicability • Effectiveness • Efficiency • Fidelity with real world • Generality • Impact on artefact environment and user • Internal consistency • External consistency	• Case study • Field experiment • Survey • Expert interview • Focus group

For this research study, the DSRM of Sonnenberg and vom Brocke (2012) was implemented to ensure that significant value could be obtained from the final artefact through the execution of multiple evaluations. The DSRM of Sonnenberg and vom Brocke (2012) was slightly adjusted to suit the research study. However, no alterations were made to the original DSRM except an addition describing the final artefact as presented in Figure 5-8. As mentioned earlier, the study set out to identify multimedia design guidelines that could be incorporated into the design of vocabulary apps to assist early language learning in children with ASD.

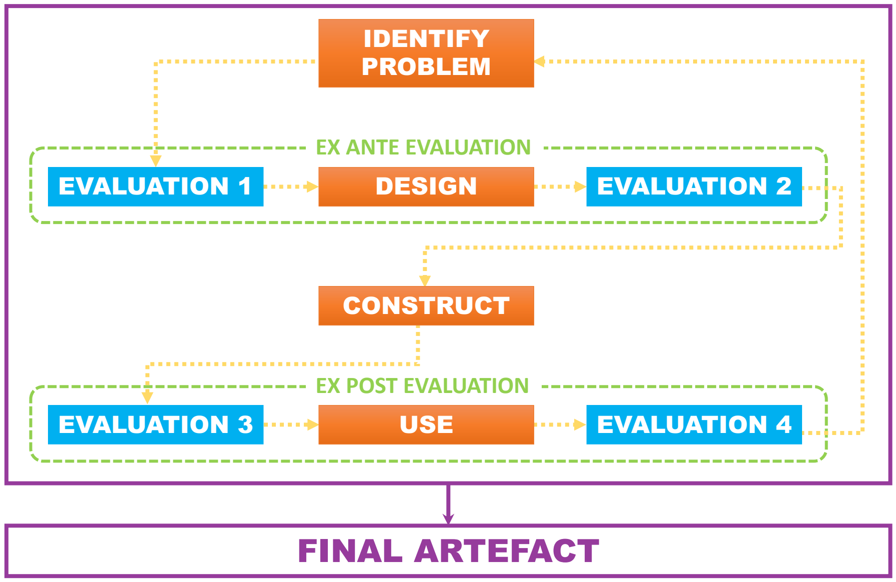


Figure 5-8 DSRM for study

In the following section detailed descriptions of how the DSRM of Sonnenberg and vom Brocke (2012) was applied to this research study are provided. A description of each phase is presented and how each specific phase relates to the research objectives according to DSR. This is concluded with the final effective artefact in the form of multimedia design guidelines.

5.5.4 *The Design Science Research Model applied to study*

The central purpose of the DSRM is to create an effective and rigorous artefact that provides a solution to the identified problem. The use of the artefact is demonstrated in its ability to solve one or more instances of the problem presented. Experiments, simulations, case studies, proof or other appropriate activities may be involved. The resources used should demonstrate how the artefact can solve the problem (Peffers et al., 2007, p. 55).

The artefact for this study refers to multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD. For each phase of the DSRM as illustrated in Figure 5-9, the artefact was developed further. The first phase validated the problem with expert opinions from three speech therapists helping children with ASD. For the second phase the design objectives of the artefact were identified and corroborated through expert opinion from the three speech therapists. The third phase included children with ASD interacting with vocabulary apps and the expert opinion of an educational specialist regarding the educational value of the vocabulary apps used in the research. Phase Four assisted in the identification of additional guidelines that contributed to language learning with the help of eye tracking and video coding. Finally, the final artefact is discussed and how it met all the identified objectives in Phase One.

The design and development of an artefact may involve: analysis, synthesis, development, suggestions, and tentative design proposals, developing a system architecture, analysing and designing a system, building a system, iterative search process and artefact. (Peffers et al., 2007, p. 53)

The DSRM applied to the study is presented in Figure 5-9 providing a general overview of each phase and how the artefact is created. Each phase is described in detail in the sections following. In Phase One Section 5.5.5 the problem is identified, in Phase Two Section 5.5.6 the artefact is designed, for Phase Three Section 5.5.7 the artefact is constructed and Phase Four Section 5.5.8 the artefact is put to use, ending with a description of the final artefact's creation in Section 5.5.9.

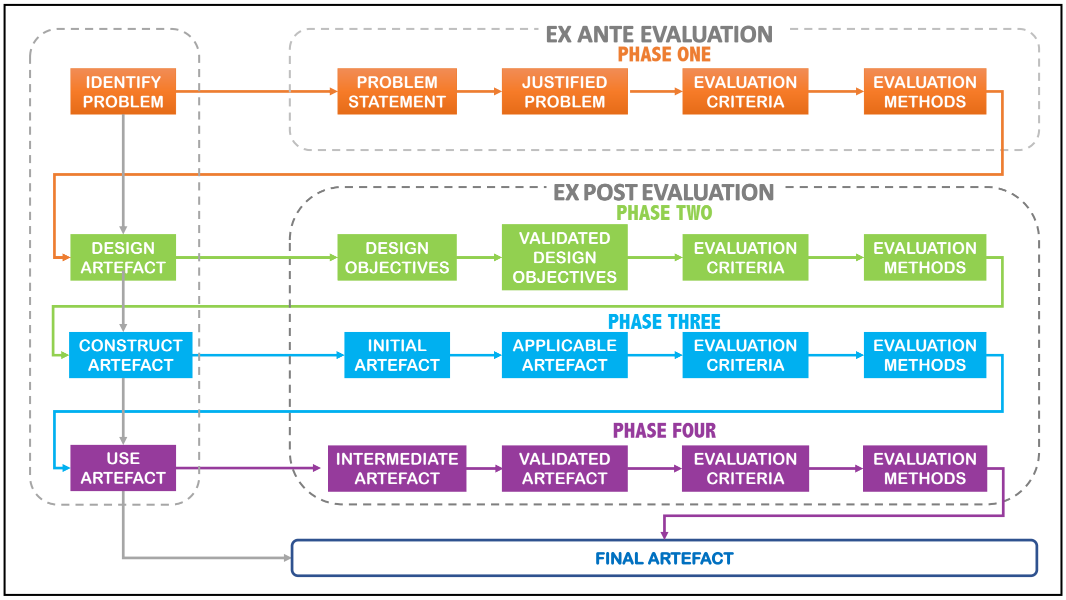


Figure 5-9 Adapted DSRM for research study

The conceptual framework discussed in Chapter Five forms the foundation on which the artefact (multimedia design guidelines) will be created. As mentioned, the multimedia design guidelines will be the final artefact for this research study. The robustness and fidelity of the artefact will be based on the identification of the most effective multimedia features identified from all four phases. The results of the data analyses of all four phases will help to create a robust artefact. Peffers (2006, p. 56) mentions that the knowledge of relevant metrics and analysis techniques are required, and that evaluation can take on many forms, such as a comparison of the artefact's functionality with the objectives identified. Evaluation may involve a confirmatory evaluation, a decision, a definite design, a testable design process, or a product hypothesis.

Since the research study follows DSR, an iterative process is followed so that the final artefact can be proven as being effective. For each phase of the DSRM followed in this study, different forms of evaluation take place similar to action research. The artefact is continually evaluated and improved upon until the identified objectives have been met and the artefact is believed to be robust and effective.

5.5.5 *Phase One: Problem identification and justification*

Figure 5-10 provides a detailed overview of Phase One of the DSRM. A specific research problem is identified and defined so that the value of a solution can be justified. The problem then guides the development of an artefact that will effectively provide a solution to the problem, motivating the researcher to come up with a solution and to justify the researcher's reasoning. The resources needed for this activity will be knowledge of the nature of the problem according to Peffers et al. (2007).

Phase One involves the evaluation of the problem with the main purpose being to ensure that the identified problem is valid and can contribute significantly to the associated discipline (Sonnenberg & vom Brocke, 2012).

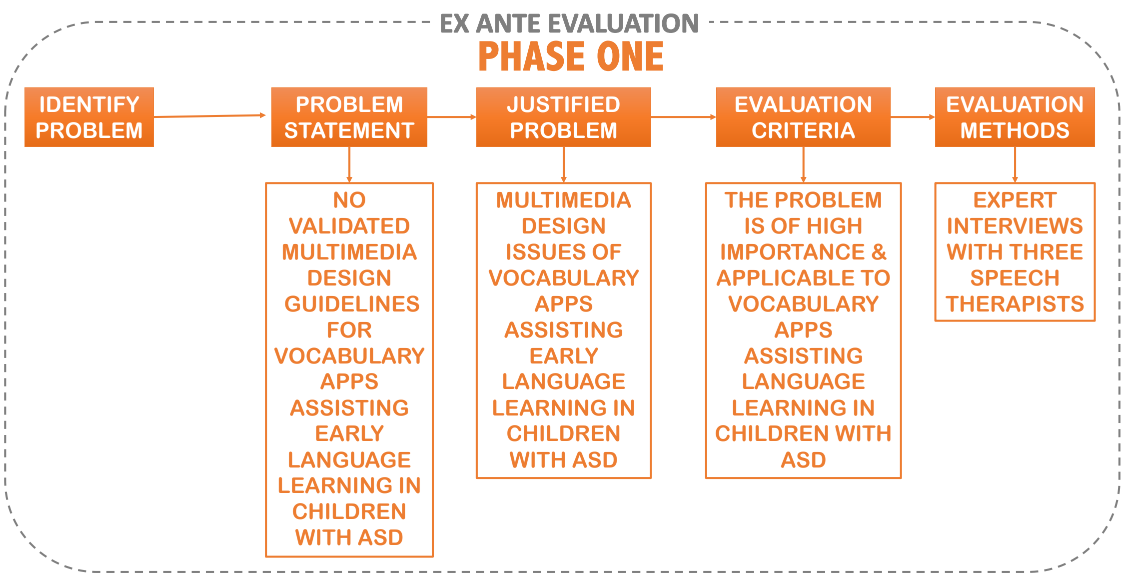


Figure 5-10 Phase One of DSRM

Identify Problem: For this research study, the research problem identified was that validated multimedia design guidelines were lacking for vocabulary apps assisting early language learning in children with ASD. Numerous educational apps can be found on both the Google Play Store and Apple App Store, many of which claim to assist early vocabulary learning. Educational apps in the App Store made up the third highest category to be downloaded in2017 (Statista, 2017). Vocabulary apps may either hinder or promote language learning for children with ASD depending on their design. As mentioned previously, some children with ASD start to speak at either a later stage, or are non-verbal, or minimally verbal. Therefore, vocabulary apps that are well-designed based on research can play a crucial role in promoting early language learning for these children.

Problem Statement: A large number of vocabulary apps claim to help children with special needs (including ASD) learn early language. Very few of these vocabulary apps are designed based on rigorous research providing validated multimedia design guidelines. Therefore, the problem statement asserts that there are no validated multimedia design guidelines to effectively assist early language learning in children with ASD.

Justified Problem: The reason that a minimum number of vocabulary apps effectively assist early language learning in children with ASD is because these apps are mostly designed according to the preferences of the app developers. Colours are used as pleased; animations and sounds are added with little thought to the affect they might have on children with ASD. Very few apps give specific consideration to the needs of children with ASD considering what their preferences to the design of vocabulary apps are. This results in the multimedia design issues of vocabulary apps assisting early language learning in children with ASD.

Evaluation Criteria: It is imperative to take into consideration the type of design that would be most effective for vocabulary apps in assisting early language learning in children with ASD. In order to design effective vocabulary apps for children with ASD, effective multimedia design guidelines which can assist early language learning in children with ASD have to be specified. Consequently, the importance of identifying effective multimedia design guidelines for vocabulary apps that assist early language learning in children with ASD is something worthwhile to consider.

Evaluation Methods: To ensure that the problem is endorsed by the associated discipline (people involved in language learning for children with ASD every day) thereby validating the design of an effective artefact (multimedia design guidelines), the opinions of experts were gathered. Three speech therapists were interviewed and the interview questions were based on the learning theories described in the conceptual framework. Additional emphasis was placed on multimedia learning questions since this formed the core of the conceptual framework. The questions were semi-structured so that the speech therapists could provide their own thoughts and opinions about vocabulary apps and to assist in the creation of the initial artefact. Their expert opinions and recommendations would validate or disprove the identified problem. The results of the interviews regarding vocabulary apps are noted and described in the chapter to follow, Chapter 6.

5.5.6 *Phase Two: Design the Artefact*

Phase Two sets out to describe the design process of the artefact that will provide a solution to the problem presented in Phase One. In this phase, the artefact has not yet been constructed or applied. Design objectives and specifications are presented that are considered important for the creation of an effective artefact. The process for Phase Two is displayed in Figure 5-11 (Sonnenberg & vom Brocke, 2012).

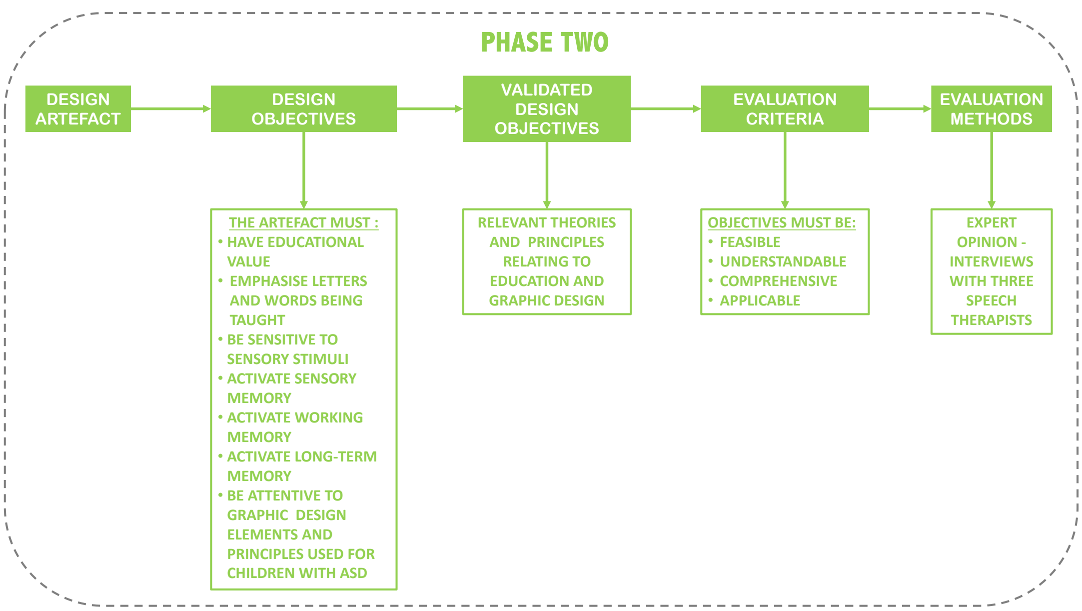


Figure 5-11 Phase Two of DSRM

Design Artefact: The appropriate design of the artefact is crucial for remedying the problem presented in Phase One. The problem, which was validated by three speech therapists, was analysed so that effective design objectives were identified for the construction of the artefact in the next phase. Validation of the problem in Phase One was necessary to ensure that the problem was worth addressing. The purpose of this phase was to identify objectives that progressed towards a solution of the recognised problem through the creation of an effective artefact. This would be achieved by first identifying the design objectives of the artefact.

Design Objectives: The objectives were identified from the description and definition of the acknowledged problem in Phase One, thereby creating an awareness of what would be feasible, understandable, comprehensive and applicable objectives.

Objectives have various purposes whereby the desired solution should be better than the current solution and the new artefact is expected to support solutions to the problems. Resources for this activity include knowledge of the state of the problem and current solutions and their effectiveness state according to Peffers et al. (2007). The current design of vocabulary apps could be improved upon and the identified multimedia design guidelines should provide effective guidance regarding the design of vocabulary apps for children with ASD.

The design objectives anticipate that the artefact must:

- Have educational value –incorporating educational theories that contribute towards language learning;
- Emphasise letters and words being taught – ensuring that the design and layout of the vocabulary app draws attention to the word or letter being taught;
- Be sensitive to sensory stimuli – producing sounds and tactile activities that are conducive to learning letters and words;
- activate sensory memory – by incorporating activities that involve different senses namely visual, auditory and tactile;
- Activate working memory – through repetition and rehearsal of letters and words taught by the vocabulary app;

- Activate long-term memory – presenting the letter or word in different contexts;
- Be attentive to graphic design elements and principles used for children with ASD – including line drawings, colour drawing and photographs, so that language learning progresses from a basic drawing to a real-life image. Also being sensitive to layout and colours of the design.

As stated the design objectives for this specific phase set out to provide multimedia design guidelines to assist with the current design issues of vocabulary apps for children with ASD. The aim of the identified design objectives was to support early language learning by ensuring that relevant educational theories were incorporated in the design of vocabulary apps and that all three memories - sensory, working and long-term - were activated. In addition, special attention was given to graphic design elements and principles that would ensure attention to letters and words within the design layout.

Validated Design Objectives: To ensure that the objectives identified were valid, relevant theories and literature for this study were identified and examined. The educational theories originated from the conceptual framework, as discussed in Chapter 5. In addition, literature concerning graphic design elements and principles (see Section 4.4) was reviewed.

The Evaluation Criteria: The identified objectives must be:

- Feasible – capable of being carried out or used in the identified area of expertise;
- Understandable – having meaning that can assist in the application of the artefact;
- Comprehensive – being thorough by including all aspects to create an effective artefact;
- Applicable – being capable and suitable to create an effective artefact.

These clearly stated objectives ensure that the artefact fulfils its purpose and that no confusion arises regarding the function of the artefact.

Evaluation Methods: To ensure that the identified objectives met the requirements for the proposed artefact, interviews took place with three speech therapists. The purpose of the interviews was threefold: firstly to validate the design objectives of Phase Two; secondly to create the initial artefact from the results of the interviews; thirdly to identify vocabulary apps to be used in for the research study assisting in the identification of effective multimedia design guidelines and fourthly to identify the final three vocabulary apps to be used for the rest of the study.

Firstly the design objectives were validated by linking the expert opinions to the design objectives. The results of the interviews from the three speech therapists were matched to the identified design objectives and presented in Table 6.3.

In order to create the initial artefact, the opinions of the speech therapists regarding vocabulary apps, were adapted to create the initial multimedia design guidelines and were also presented in Table 6.4.

Next, vocabulary apps were identified from the interviews with the speech therapists. The recommendations made by the speech therapists helped identify vocabulary apps that could be used in the research study to further develop the artefact. The recommendations were identified as follows: the interviews were annotated in Microsoft Word and the various remarks linked to the identified design objectives and presented in Table 6.3.

Initially five vocabulary apps were identified, examined and chosen for the children with ASD to interact with. These vocabulary apps claimed to promote early language learning or teach vocabulary. Certain of these vocabulary apps were specifically designed for children with ASD and others designed for children in general to foster early language learning.

The selection of the five different vocabulary apps involved various procedures. The first procedure entailed interviews with the speech therapists involved at the school where the research took place (as mentioned). Each of the speech therapists were interviewed individually. The semi-structured interview questions were formulated around the various principles of multimedia learning and their related methods of processing that are: extraneous, essential and generative. By grounding the semi-structured interviews on the principles of multimedia learning, the speech therapists' opinions could be matched to the identified objectives. The reason for focusing specifically on multimedia learning is because multimedia design guidelines formed the crux of the conceptual framework and the multimedia design guidelines.

Two of the five vocabulary apps that were chosen were definite recommendations made by the speech therapists. The other three vocabulary apps were selected based on the recommendations made by the speech therapists, app developer information asserting that the app will help children with ASD learn vocabulary and language and also the reviews of the vocabulary apps.

The five chosen vocabulary apps were loaded onto a Samsung Tablet and fourteen children with ASD were video recorded interacting with the apps. The fourteen children with ASD were given a free choice as to which of the vocabulary apps they wanted to interact with and for how long with a cut-off time of twenty minutes.

Relevance to this research study: Not all vocabulary apps have the same capacity to help children learn language or vocabulary and the case is even more so for children with ASD. Certain of the vocabulary apps have too many distractors such as attention diminishing sounds, animations or busy layouts that may result in sensory overload. This research study attempts to identify effective multimedia design guidelines for the design of vocabulary apps to assist early language learning in children with ASD. With the identified multimedia design guidelines, vocabulary apps can hopefully be designed to contribute positively towards language learning in children with ASD with special attention to sensory stimuli.

5.5.7 *Phase Three: Construct Artefact*

This phase sets out to demonstrate whether the artefact meets the identified objectives. Inferences can be made about the effectiveness of the artefact through reflection, (referring back to Phase Two for this study). Evidence is collected to determine whether the artefact is performing according to its "purpose and scope" (Sonnenberg & vom Brocke, 2012, p. 395). Phase Three is demonstrated in Figure 5-12.

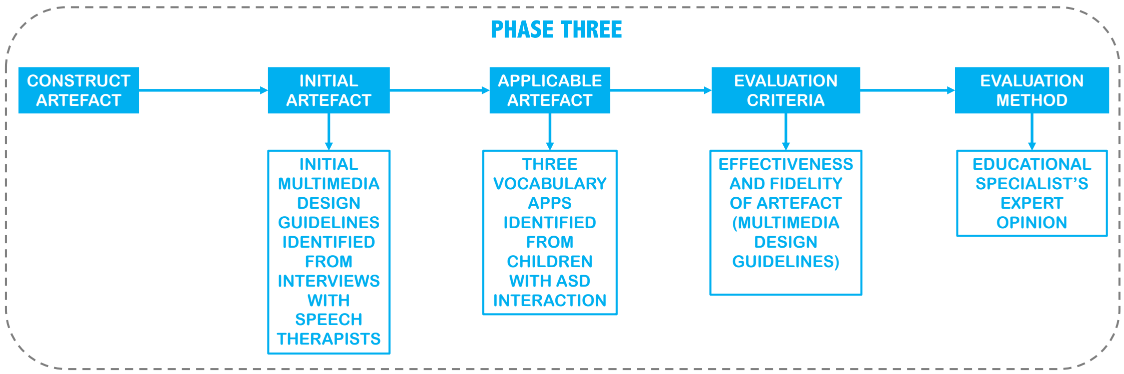


Figure 5-12 Phase Three of DSRM

Construct Artefact: The interviews with the three speech therapists conducted in the previous phase helped with the construction of the initial artefact. As stated previously the opinions of the speech therapists were converted into multimedia design guidelines resulting in the creation of the initial artefact.

Initial Artefact: The initial artefact was created by linking the expert opinions to the identified objectives depicted in Phase Two. The initial artefact forms the foundation on which the artefact is further developed ensuring fidelity and robustness of the final artefact. The initial artefact is created from the results of the interviews with the speech therapists.

Applicable Artefact: As mentioned in Phase Two, five vocabulary apps were originally chosen to help improve upon the initial artefact. This was achieved giving the children with ASD an opportunity to interact with the five chosen vocabulary apps. After the children interacted with the five vocabulary apps, three final vocabulary apps were chosen and used for the rest of the research study. These apps were chosen by noting the time the children with ASD spent interacting with each of the five vocabulary apps. The top three apps that the children spent the most time with were used for the rest of the study. These final three vocabulary apps were examined in great detail in order to identify any additional multimedia design guidelines that would contribute to an effective final artefact.

Evaluation Criteria: To improve upon the artefact identified in Phase Two, the evaluation criteria of the artefact had to be rigorous and robust with a high level of fidelity. This was achieved by attaining an expert opinion from an educational specialist regarding the three chosen vocabulary apps. The opinion of the educational specialist helped validate the initial artefact by corresponding with the opinions of the speech therapists and the identified design objectives of Phase Two. Opinions provided by the education specialist that were not offered in the initial artefact were added as additional multimedia design guidelines. The newly acknowledged additional guidelines were added to the existing guidelines to create an intermediate artefact.

Evaluation Method: By contracting the expert opinion of an educational specialist, the robustness and fidelity of the artefact could be further evaluated. The educational expert was asked to review each of the vocabulary apps in order to determine their educational value according to the educational theories incorporated in the conceptual framework (see Chapter 4).

The educational value of each of the chosen vocabulary apps was determined through a checklist incorporating the features of each of the learning theories namely Oelwein's Methodology, the Cognitive Theory of Learning with Media, Bruner's Learning Stages and Human Computer Interaction. In total, four individual checklists were developed from the four different learning theories. The various features of each learning theory were used to develop dichotomous questions for each of the checklists. In addition, the checklists helped identify the vocabulary app with the highest educational value. Through the careful examination of this effective vocabulary app that was identified by the educational specialist, the intermediate artefact was created.

Relevance to this research study: The data from the educational specialist helped with the identification of multimedia design guidelines relevant specifically to effective educational qualities.

5.5.8 *Phase Four: Use Artefact*

The final phase involves applying the created artefact in order to effectively prove its usefulness, rigour, fidelity and robustness. This can include an instance of the artefact that is rooted in the context within which it was created. This final phase may also involve a case study, field experiment, survey or applicability check, according to Sonnenberg and Vom Brocke (2012). The activities involved in Phase Four are depicted in Figure 5-13.

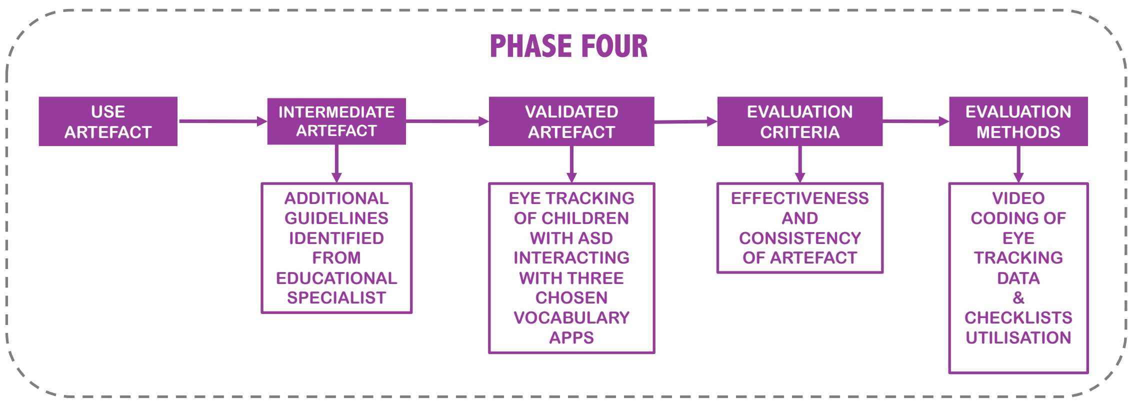


Figure 5-13 Phase Four of DSRM

Use Artefact: For this final phase, the artefact is put to use. However, for this study the artefact, in the form of multimedia design guidelines, was put to use in a manner distinctive from the usual manner expected of a final artefact. The use of the artefact relevant to this study, was that the children with ASD were given a second opportunity to interact with the three chosen vocabulary apps. However, this time the interactions involved eye tracking. The eye tracking was done to determine the number of fixations on letters, words and objects for each of the three chosen vocabulary apps. Eye tracking was incorporated to determine the number of fixations on letters, words and objects for each of the three chosen vocabulary apps. In addition, the vocabulary app that prompted the highest number of fixations on letters and words was identified and contributed to the creation of the effective final artefact. The specific vocabulary app was used to detect additional multimedia design guidelines through checklists used to identify multimedia learning guidelines, graphic design guidelines and auditory and tactile guidelines.

All three vocabulary apps were examined thoroughly to:

1. To further determine the rigour and fidelity of the artefact;
2. To identify any additional multimedia design guidelines and
3. To determine whether the identified objectives were met as described in Phase Two.

Intermediate Artefact: The initial artefact presented in Phase Three was improved upon by identifying additional multimedia design guidelines from the educational specialists' opinion of the three chosen vocabulary apps. The additional identified multimedia design guidelines not presented in the initial artefact were added, thereby improving the artefact resulting in an intermediate artefact.

Validated Artefact: Eye tracking provided useful information about where exactly the fixations occurred as the children with ASD interacted with the three vocabulary apps. The eye tracking determined whether the fixations occurred on letters and words - as required by vocabulary apps, or on other visual elements. The recording of fixations was done using the Tobii Pro X3-120 eye tracker while each child with ASD interacted with the three chosen vocabulary apps.

The eye tracking specialist together with the researcher made use of a non-invasive method of operating the eye tracking equipment. The vocabulary apps were mirrored onto a larger touch screen operating in the same manner as a tablet. The eye tracker was placed unobtrusively at the bottom of a large screen in such a manner that the children with ASD were not hampered or distracted. The children with ASD could tap, swipe and select exactly as they would on a tablet while interacting with the vocabulary apps.

The multimedia learning, graphic design, auditory and tactile guidelines were identified through the administration of checklists identifying relevant features for the creation of an effective artefact.

Evaluation Criteria:

The eye tracking results would confirm whether the artefact was robust and prove its fidelity and rigour. This was achieved as follows: for each of the vocabulary apps, eye tracking took place and the fixations of each child with ASD were recorded with Tobii eye tracking software. Thereafter calculations were done regarding the number of fixations on words, letters and objects that took place while the children with ASD interacted with the vocabulary apps. These recordings were analysed through video coding. The deductions were made that if the vocabulary app encouraged more fixations on letters and words than on objects, the app was accepted as being effective at promoting early language learning for children with ASD. The opposite was accepted as true, if the number of fixations were greater on the objects than on the letters and words, the vocabulary app was seen as less effective at language learning for children with ASD.

Evaluation Methods:

Two different procedures were involved in the evaluation. The first was the implementation of video coding, annotating the number of fixations that occurred. The second was the utilisation of checklists to help with the identification of multimedia design guidelines to prove the rigour and fidelity of the artefact.

<u>Video Coding</u>

The calculations of the number of fixations on each letter, word and object were done by analysing the eye tracking video recordings and annotating the fixations through video coding. All the eye tracking video recordings were imported into a video coding program called ELAN and the fixations per letter, word and object annotated.

ELAN is a professional software tool that helps to create complex annotations on resources such as video and audio streams. An annotation can consist of a sentence, word, comment or description or a feature observed within a video. These annotations are created in tiers or layers and can consist of a number of tiers or layers that follow a specific theme or hierarchy and can also be aligned to a specific time. Four videos can be linked to a single annotation document. These videos can be integrated and presented in one window through programs such as Windows Media Player, QuickTime or Java Media Framework resulting in high performance playback. ELAN was created by the Max Planck Institute for Psycholinguistics (Planck, 2017).

For this study, the eye tracking recordings were imported into ELAN and each fixation per letter, word and object annotated by the researcher and counted by ELAN. As mentioned previously, it was deduced that the higher the number of fixations on letters and words the more effective the vocabulary app was for language learning. If the number of fixations were higher on objects than on words and letters the vocabulary app was assumed to be less effective for language learning. The results of these fixations helped identify the vocabulary app that contributed most to language learning. The number of fixations were compared across vocabulary apps to determine which of the apps had the most fixations on letters and words. The vocabulary app that had the highest number of fixations on words and letters was considered to be the most effective out of the three apps at language learning for children with ASD. Excel graphs were used to display the results of the fixations on the letters, words and objects for each of the vocabulary apps.

Checklists

Once all the fixations were annotated and documented, checklists were utilised to assist with the identification of multimedia design guidelines. The design objectives presented in Phase Two channelled the identification of specific guidelines for each of the objectives. The results of the checklists determined whether all the design objectives of Phase Two were met and also proved the effectiveness of the artefact.

The various checklists were developed through the identification of distinctive features for each of the design objectives. These features were identified through literature as mentioned in Phase Two. The identified features were converted into dichotomous questions to help the design of the relevant checklists. Checklists were created for multimedia learning (which is the crux of the conceptual framework), graphic design elements and principles and sensory stimuli. All the learning theories were addressed by the educational specialist who utilised a checklist incorporating all four learning theories.

Multimedia Learning

The identification of the multimedia learning features presented in each of the vocabulary apps took place. The multimedia learning features were identified with the help of a checklist identifying the different features of each of the twelve principles of multimedia learning as discussed by Mayer (2009). All the questions of the checklist that resulted in a positive answer signified that that specific feature was present in the vocabulary app assisting with the creating of multimedia design guidelines.

Graphic Design Elements and Principles

The graphic design features presented in each of the vocabulary apps were also identified from a checklist. The checklist was designed from the detailed descriptions provided of the elements and principles of graphic design as discussed by O'Connor (2014). These descriptions were identified as features of graphic design elements and principles. The features were then converted into dichotomous questions that helped identify which graphic design elements and principles were present in each of the vocabulary apps. The graphic design elements and principles were identified from the positive responses to the questions in the checklist. The elements and principles from the vocabulary app that was proven to be most successful at contributing positively to language learning, were identified and converted into multimedia design guidelines. These identified graphic design elements and principles addressed the design objectives discussed in Phase Two.

Sensory Stimuli

The tactile and auditory stimuli of each vocabulary app was assessed. This was done to detect whether there were any extraneous stimuli that could result in overstimulation of the senses for children with ASD, hampering language learning.

The auditory stimuli of each of the vocabulary apps was annotated in ELAN, calculated and exported to Excel. The data from the auditory sounds were converted to graphs and compared across vocabulary apps. With this data, the number of sounds for each vocabulary app helped determine whether the sounds promoted or diminished language learning. Too many sounds were believed to act as distractors resulting in loss of focus on the words and letters displayed in the vocabulary apps. The vocabulary apps that incorporated sounds relevant to the letter or word being taught were considered as valuable for the identification of multimedia design guidelines, thereby ensuring that the sensory stimuli objectives of the artefact mentioned in Phase Two were met.

The tactile evaluation took place by documenting the number of tactile responses (tapping, dragging, swiping and so forth) required of each of the vocabulary apps. This was determined by counting each tactile response required for each one of the vocabulary apps. The tactile responses were likewise annotated in ELAN and exported to Excel. The number of tactile responses were compared across vocabulary apps with graphs created in Excel. These graphs helped identify which of the vocabulary apps had high counts of tactile responses.

Irrelevant and excess amounts of tactile responses within a vocabulary app was regarded as less effective in promoting language learning. The reason was that overstimulation of tactile responses could lead to the child with ASD's attention being drawn away from the letters and words being taught, resulting in greater focus being placed on the tactile activities than on letters and words.

The vocabulary apps that had tactile responses directly applicable to the letters and words being taught were considered most effective for language learning. Multimedia design guidelines that could be used to develop the artefact further were identified from these tactile activities.

All the multimedia design guidelines identified from the various phases were combined and linked to the relevant design objectives of Phase Two. Once all the design objectives were adequately addressed through the creation of multimedia design guidelines for vocabulary apps, the final artefact was proven to be effective.

5.5.9 *Final Artefact*

The artefact was created in the form of constructs, models, methods or instantiations of which each of these could be defined broadly. The DSR artefact can be any designed object in which the design makes a research contribution. The desired functionality of the artefact is determined as well as its architecture and only then is the artefact created. Resources for this activity include knowledge of theory that can assist in a solution to the problem (Peffers et al., 2007, p. 55).

In order for this study to create an effective final artefact that was robust in demonstrating rigour and fidelity various forms of evaluation occurred. According to Peffers et al (2007, p. 53) the final artefact can be produced through simulation, conditional prediction, experimenting with, observing or evaluation. This study made use of evaluation and observation to produce the final artefact. Evaluation took place by entreating expert opinions, the utilisation of checklists and through observation and analyses. In addition, eye tracking and video coding also contributed to a robust and effective final artefact.

The design objectives of Phase Two were addressed as displayed in Table 5-6.

Table 5-6 Design Objectives and Solutions

Design Objectives	Artefact solution
Educational values	Multimedia design guidelines that incorporated four different learning theories.
Emphasise letter and words being taught	Multimedia design guidelines that assists with focus being placed on letters and words.
Be sensitive to sensory stimuli	Multimedia design guidelines that are sensitive to auditory and tactile stimuli
Activate sensory memory	Multimedia design guidelines that activate sensory memory
Activate working memory	Multimedia design guidelines that activate working memory
Activate long-term memory	Multimedia design guidelines that activate long-term memory

Be attentive to graphic design elements and principles used for children with ASD	Multimedia design guidelines for the use of graphic design elements and principles for design for children with ASD.

The identification of the multimedia design guidelines was achieved by completing the various phases of the DSRM. The different methods of evaluation in each phase helped identify multimedia design guidelines proving the effectiveness and fidelity of the artefact. The triangulation of the results of the evaluations for each phase ensured that the final artefact addressed the design objectives, contributing positively towards the design of vocabulary apps for children with ASD.

The final artefact definitively produced effective multimedia design guidelines that addressed all the design objectives.

<u>Communication:</u>

The problem and its importance as well as the innovativeness, usefulness, effectiveness and rigour of the artefact should be communicated in the form of an article to the interested researchers and relevant audiences and published in scholarly publications. "Communicate the problem and its importance, the artefact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practising professionals…" comments Peffers et al (2007, p. 56).

This concluded the final activity of the DSRM for this study and provided answers to the research questions. The practical, theoretical and methodological contribution was communicated to the necessary parties and an article was published in a scholarly journal.

The next layer of the 'research onion' refers to the time taken for this research study to answer the research questions.

5.6 Mixed Methods for Data Collection

Remaining with the pragmatic viewpoint, the research study, as mentioned earlier, combined both qualitative and quantitative data collection and analysis techniques, resulting in a mixed methods approach as part of data collection.

Mixed methods in a research study incorporate both quantitative and qualitative methods to collect and analyse data to achieve a better understanding of the specific research problem, explained Plano Clark and Creswell (2014, p. 383). The convergence of quantitative and qualitative data leads to a distinct methodology of inquiry (Creswell, 2009). Both quantitative and qualitative research methods help improve understanding of a specific field of research. Various terms exist for this type of research namely: integrating, synthesis, quantitative and qualitative methods, multi-method and mixed methodology (Bryman, 2006; Creswell, 2009).

For mixed methods research to be successful the researcher's theoretical inceptions and ideas have to be linked to the selected research methods and practices that guide the research. This in turn determines what kind of knowledge needs to be acquired and the manner in which the evidence needs to be collected and interpreted. Data and theory can be linked by induction or deduction, the research process can involve subjectivity or objectivity, and the inferences made from the data can either provide context or be generalised (Morgan, 2007).

According to Morgan (2007, p. 73) qualitative research emphasises an inductive-subjective-contextual approach and quantitative research emphasises a deductive-objective-generalising approach. The inductive results of the qualitative approach can provide inputs to the deductive purpose of the quantitative approach and vice versa.

5.6.1 *Mixed Method Design*

There are various mixed method designs used in educational research and these are briefly discussed as follows (Creswell, 2005, p. 540):

- **The convergent parallel/concurrent design** whereby qualitative and quantitative data are collected simultaneously. The data are merged and the results lead to an improved understanding of the research problem.
- **The embedded design** is when qualitative and quantitative data is collected simultaneously or sequentially, but the one form of data verifies the other form of data.
- **The transformative design** incorporates either convergent, explanatory, exploratory or embedded design but makes use of a transforming and orientating lens to provide a certain perspective.
- **A multiphase design** is when a problem is explored with the use of various phases or separate studies.
- **The explanatory sequential design** is when quantitative data is collected first followed by qualitative data to describe the quantitative results.
- **The exploratory sequential design** firstly collects qualitative data to explore the research problem and then collects quantitative data to explain the qualitative data.

Creswell (2014) points out that the three primary models of mixed methods are the convergent parallel, explanatory sequential and the exploratory sequential mixed methods.

5.6.2 *Embedded design*

For the research study an **embedded design** (as illustrated in Figure 5.14) was applied similar to the parallel and sequential designs. The intention of an embedded design is to collect both quantitative and qualitative data whereby one supports the other. This is done to support the research study in designing an intervention “tailored to the participants” (Creswell, 2005, p. 567). Collecting both quantitative and qualitative data can explain results and provide a distinct understanding regarding the problem being researched. As discussed previously the embedded design process involves the collection of both quantitative and qualitative data during a single study. The data sets are analysed separately and address different research questions. One method of research is used to support the other method of research.

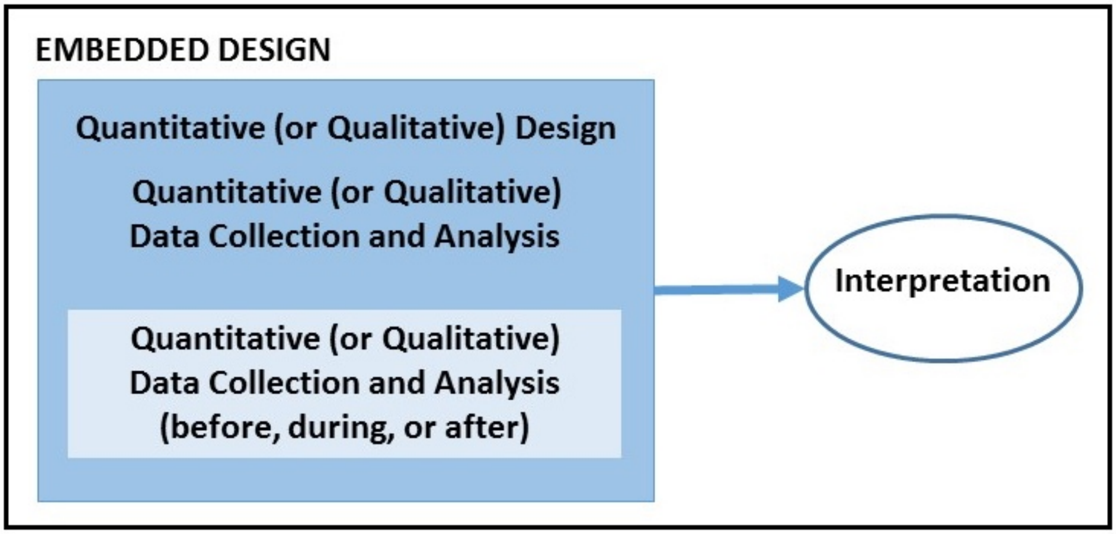


Figure 5-14 Embedded Design

The vigour behind following embedded design is that this type of mixed methods design incorporates the advantages of both qualitative and quantitative data. Qualitative data captures the experience of the participants and the quantitative data records the outcomes of the experience (Creswell, 2005).

5.7 Longitudinal Approach to Research Study

The various activities involved in each of the phases of the DSRM resulted in the creation of the final artefact. Multimedia design guidelines were identified in three phases over an extended period of time after the problem had been endorsed by the speech therapists. These phases took place sequentially resulting in the research study being longitudinal in nature. Also, the incorporation of both qualitative and quantitative research strategies to answer each research question had an influence on the length of the study. Triangulation involving both quantitative and qualitative research techniques also influenced the length of the research study.

5.8 Data Collection and Analysis

This final layer of the 'research onion' refers to the data collection techniques and analyses that took place for the research study. The data was first captured both qualitatively and quantitatively as mentioned in Section 5.6.

5.8.1 *Participants*

A small group of children with ASD participated in this research study, as well as three speech therapists who were interviewed to obtain their insight and opinion relating to what makes a vocabulary app effective for language learning for children with ASD.

Also, an educational specialist was asked to offer an expert opinion about the vocabulary apps and their educational value. The various participants are discussed in detail in the following sections.

The sample of children with ASD

Stratified purposeful sampling (Teddlie & Yu, 2007) took place for the first group. Stratified purposeful sampling is a sample consisting of a homogeneous group wherein the subjects have similar characteristics (Cohen, Manion, & Morrison, 2011).

The Johannesburg Hospital School Autism Unit was willing to allow their children to participate in the research study. The main speech therapist was recommended by the school principal and the children with ASD were recommended by the main speech therapist. The main speech therapist helped with all the necessary undertakings of the research that took place at the school.

Initially sixteen high functioning children with ASD from the ages of six to eight years old took part. They were given the opportunity to choose which of the five chosen vocabulary apps they preferred to interact with. This was done to determine the final three vocabulary apps that would be used for the rest of the study. The reason was that the eye tracking would be less problematic to implement with three vocabulary apps instead of five. Shifting between three vocabulary apps instead of five would minimise cognitive overload for the children with ASD.

In the final phase of the DSRM wherein the eye tracking took place, the sample size was minimised to seven high functioning children with ASD. These children were all from the original sample, and as mentioned ranged from six to eight years old. The children also varied in verbal capacity ranging from limited to completely verbal.

The reason for the smaller sample size was because only seven of the children with ASD had a high enough gaze percentage to use for the eye tracking results. The eye tracking data from the children with ASD that had a 50% or higher gaze percentage were accepted for further analyses. Tobii (2017a) explains that the quality of a recording is calculated by dividing the number of eye tracking samples that were correctly identified, by the number of attempts. 100% means that both eyes were tracked throughout the recording. 50% means that one eye was tracked for the full recording or both eyes during half the time. Note that the eyes cannot be tracked when a person is looking away from the screen; this will result in a lower percentage.

Appointments were arranged and interviews completed with the speech therapists to identify vocabulary apps and multimedia design guidelines. Additional appointments were arranged for the eye tracking to take place.

The Speech Therapists

The three speech therapists that were interviewed for the research study were chosen by means of stratified purposeful sampling. As mentioned previously stratified purposeful sampling is a population consisting of a homogeneous group wherein the subjects have similar characteristics (Cohen et al., 2011). In this case, the speech therapists were qualified in helping children with ASD learn to talk. They had studied towards the same degree necessary for being qualified as speech therapists. In addition, they had sessions with the children with ASD teaching the children various words and how to build sentences. All the speech therapists involved in the research study were employed by the school where the research took place.

The Educational Specialist

Stratified purposeful sampling was also used to choose the educational specialist. The educational specialist is a lecturer in the Department of Early Childhood Education at the University of South Africa. Being an expert in the field of mobile learning and Information Communication Technology (ICT) which includes solid research in mobile apps, the evaluation of apps and the sourcing of apps (Callaghan, 2017).

Initial app selection: A qualitative exploration of the vocabulary apps available for download for early language learning took place. Initially five vocabulary apps were selected for the research study. Two of the five apps were suggested by the speech therapists following interviews. The speech therapists were involved at the school when the research study took place and these vocabulary apps were used in certain speech therapy sessions.

The other three vocabulary apps were chosen based on the results of the interviews with the speech therapists, app developer descriptions and the popularity score or review of the vocabulary apps.

Final app selection: The final three vocabulary apps were selected based on the time each child with ASD spent interacting with the five chosen apps. The length of interaction time per vocabulary app was noted and the three apps with the highest interaction time were chosen.

5.8.2 *Data Collection*

The data collection took place by utilising semi-structured interviews, structured observations, checklists, and eye tracking recordings as displayed in Figure 5-15.

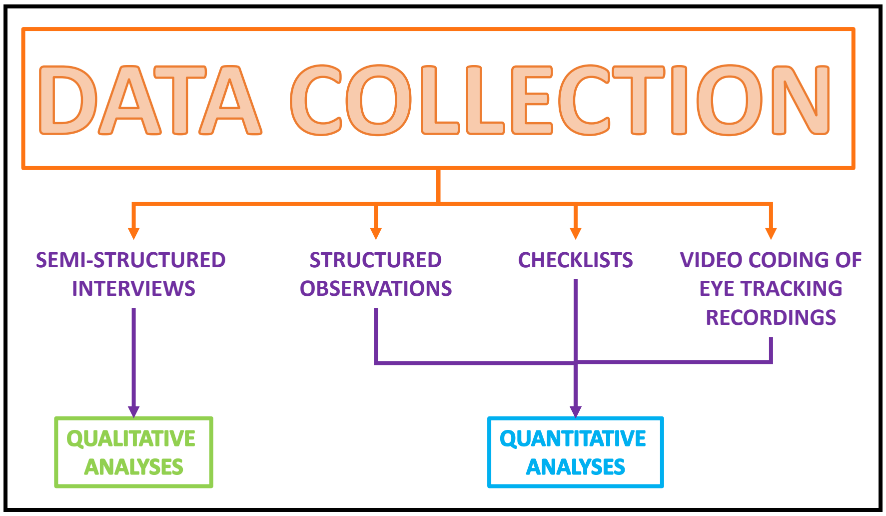


Figure 5-15 Data Collection Methodology

Each of these data collection methods are discussed in detail in the sections to follow.

5.8.2.1 *Semi-structured interviews*

The purpose of the qualitative research interview is to gain insight into certain experiences and perspectives of individuals regarding certain issues. Semi-structured interviews are scheduled to take place at a certain time and place. Questions used are open ended and can lead to other additional questions. In general the semi-structured interview lasts for approximately half an hour (DiCicco-Bloom & Crabtree, 2006). An interview is aimed at gaining knowledge, involves an exchange of views and remarks and is considered central to gaining knowledge through human interaction (Cohen et al., 2011).

The semi-structured interviews for this research study were twofold. Firstly was to acknowledge that the identified problem was endorsed by the involved parties and secondly to retrieve as much information as possible to help create the initial artefact - multimedia design guidelines. Also, to further assist in the identification of vocabulary apps which would positively contribute to the creation of the effective final artefact.

These interviews formed part of the first and second phase of the DSRM for this study. The choice for semi-structured interviews was to allow for flexibility and foster sensitivity to the developing conversational theme, moreover to identify additional topics or issues, points strongly emphasised, or unexpected topics (Gibson & Brown, 2009).

The semi-structured interview questions were formulated based on the multimedia learning processes: extraneous, essential and generative. However, these questions were not formulated from the exact features of each multimedia learning process but rather the general concepts of each process. The reason for this was to allow for open-ended questions. The open-ended questions encouraged conversation and resulted in gaining greater insight as to what the speech therapists' opinions and recommendations were concerning vocabulary apps for children with ASD. This also leads to the creation of the initial multimedia design guidelines.

The interviews were voice recorded for data collection and analyses with the consent of the speech therapists.

Qualitative Analysis

The semi-structured interviews were analysed quantitatively. Transcripts of the interviews were produced to help identify initial multimedia design guidelines as well as vocabulary apps. Gibson and Brown (2009) explain that with interviews, structural features are identified and delineated and grouped into segments. These segments, if necessary, can be further analysed into functional elements.

For Phase One which involved the justification of the identified problem, any answers from the speech therapists that related to the identified problem were underlined in the transcripts.

For Phase Two of the DSRM the opinions and recommendations made by the speech therapists regarding vocabulary apps were identified in the transcripts. The identified opinions and recommendations were marked in purple and grouped into segments. The first grouping was done to clarify and acknowledge the problem, thereby addressing the requirements of Phase One. The second grouping formed part of Phase Two wherein the initial multimedia design guidelines were identified. This was achieved by analysing the interview data of the speech therapists concerning vocabulary apps for children with ASD, resulting in the creation of the initial artefact.

5.8.2.2 *Structured Observations*

According to McMillan and Schumacher (2001, p. 40) structured observations involve direct observations including both visual and auditory cues the results of which are systematically recorded.

Observational work is considered to be a form of data analysis according to Gibson and Brown (2009, p. 107) since thinking about what is being observed takes place. Questions are asked about what is interesting, how to categorise new observations, how the observations address the research questions, which aspects are confusing and how the observations contrast or support the existing propositions (Gibson & Brown, 2009). A distinguishing characteristic of observations is that the recorded data is naturally occurring, thereby yielding more valid data. Observations can be classified as facts, examples include: the number of books in a classroom, the time taken for conversations and the time spent on a specific task. However, the aspects being observed need to be clearly defined. Through observations the researcher can gather data on the physical setting, the human setting, the interactional setting and the programme setting. (Cohen et al., 2011)

For the study, structured observations occurred during Phase Two and Phase Four of the DSRM. Phase Two involved quantitative analyses of the structured observations that included video recordings of the interactions between the children with ASD and the five vocabulary apps. The exact time each child spent with each of the five vocabulary apps was noted. The purpose of these observations was to determine which of the vocabulary apps the children with ASD interacted with the most. The top three apps that the most time was spent on out of the initial five vocabulary apps were chosen for further research.

Phase Four also included structured observations of the tactile and auditory stimuli present in the three chosen vocabulary apps.

The tactile responses were video recorded and the recordings imported into ELAN. In ELAN each tactile response which included tapping, dragging, or swiping was annotated and documented for each one of the three vocabulary apps.

Each auditory sound presented in each of the three vocabulary apps was analysed. Video recordings were imported into ELAN where they were annotated. The auditory sounds produced in each of the vocabulary apps were observed and documented.

Tactile and auditory activities can either promote or hinder learning and for this reason it was considered necessary to determine the amount of auditory and tactile stimuli for each of the three vocabulary apps. In addition, multimedia design guidelines were identified addressing sensory stimuli in vocabulary apps for children with ASD.

Quantitative Analysis

Identifying the final three vocabulary apps: The structured observations used in the research study were firstly used to document the interaction time of each child with ASD with the five initial vocabulary apps. The exact time was documented, from the moment the child selected the app to start the interaction, until the child closed the app and all interaction ceased. Each individual interaction time was documented per child per app in an Excel spreadsheet, including the beginning and the end times. This data was analysed quantitatively so that the minutes and seconds could be calculated and the time spent per vocabulary app determined. This assisted in the identification of the vocabulary apps with which the children with ASD spent the most time. The interaction time was documented from the most to the least for all five vocabulary apps. The top three apps with the highest interaction time were chosen for further research purposes.

Tactile responses: As mentioned previously the tactile responses required during each interaction from the children with ASD for each vocabulary app was annotated. These annotations formed part of Phase Four of the DSRM. The annotations were done by means of video coding whereby each tactile response from each child interacting with the final three vocabulary apps was annotated in ELAN. The annotations were exported to Excel where quantitative analyses took place. The number of tactile responses that occurred for each of the three vocabulary apps was calculated. Graphs were created to assist in the identification of the vocabulary apps with the most to the least tactile responses required during interaction.

Auditory responses: Likewise, the documentation of auditory sounds for the three vocabulary apps formed part of Phase Four of the DSRM. Each auditory sound played in the three final vocabulary apps was annotated in ELAN by means of video coding. The number of auditory responses for each app was calculated and documented in Excel. Graphs were created representing the number of auditory sounds played in each of the vocabulary apps. This provided clearer insight into the auditory stimulation produced by each vocabulary app.

Sensory stimulation can promote or hinder the learning of letters and words. For this reason careful consideration must be given when including sensory stimuli in a vocabulary app.

5.8.2.3 *Checklists*

Data Collection

A checklist as described by Freed, Ryan and Hess (1991) can be used: to guide research, as a review procedure for a study in progress, or for evaluating. Numerous types of checklists exist, distributed into three different categories: procedural, observational and design checklists. Procedural checklists are utilised to prevent errors; observational checklists are used to ensure that quality is being maintained and design checklists are used to assist in developing a new product or system (Dixon, 2018). Validity of the checklists were not determined since the checklists were only used to help identify the features of each vocabulary app. The results of the checklists were used to help with the identification of multimedia design guidelines.

For the purpose of this research study, checklists were used for the evaluation of the vocabulary apps used in the study and subsequently the identification of multimedia design guidelines resulting in a new product (artefact). The checklists were developed by identifying the features for each of the vocabulary apps.

The identified features assisted in the creation of the final effective artefact. Different checklists were used in Phase Three and Phase Four. Checklists to determine the educational features of each of the three final vocabulary apps by an educational expert were used for Phase Three. A multimedia learning checklist and a graphic design checklist was used for Phase Four.

Educational Checklists

The educational checklists consisted of four different checklists, each relating to a specific learning theory presented in the conceptual framework namely Oelwein's methodology, Cognitive Theory of Learning with media, Bruner's learning stages and Human Computer Interaction (HCI). These checklists transformed the various features found in each of the learning theories into questions for the design of the checklists. The checklists helped with the identification of educational features present in the final three vocabulary apps,
By identifying and documenting the features that made each learning theory unique, the features were converted into dichotomous questions. These dichotomous questions had either a yes or no answer that was used to design the checklists. Positive responses to the questions helped identify the multimedia design guidelines related to learning as specified by the identified design objectives of Phase Two.

Analysis of Educational Checklist

The results of the educational checklists were used to identify educational features present in each of the vocabulary apps. The checklist questions included the different features of each learning theory, which were converted into dichotomous questions with yes or no answers. The educational specialist identified which educational features were present in each vocabulary app according to the specific learning theory by selecting either the ‘yes’ or ‘no’ answer. Each ‘yes’ answer indicated the presence of a specific educational feature for the particular learning theory in the chosen vocabulary app. The identified learning features were used to create multimedia design guidelines addressing the educational aspects of the identified design objectives of Phase Two. In addition, the results of the educational checklists helped identify the vocabulary app that contributed most to language learning which was further analysed. The various analyses of this vocabulary apps assisted with the identification of additional multimedia design guidelines rendering an effective final artefact.

Multimedia Learning Checklist

One of the checklists used in Phase Four of the DSRM helped to identify which of the multimedia learning features were present in the three selected vocabulary apps. The twelve principles of multimedia learning help reduce extraneous processing, manage essential processing and foster generative processing (Mayer, 2009). The multimedia design checklist was created by adapting all the features of each multimedia principle into questions. These questions were grouped under the specific types of processing, thereby helping with the identification of features specific to the type of processing. The multimedia learning features identified by the checklists helped with the creation of the artefact. In addition, the identified design objectives were also addressed.

Analyses of Multimedia Learning Checklists

The Multimedia Learning Principles and their applicable descriptions are clearly specified by Mayer (2009). The descriptions provided for each principle were converted to questions and used to create a checklist. The checklist consisted of dichotomous questions for which the answers were either ‘yes’ or ‘no’. The answer to each question was interpreted according to the purpose of the specific principle and its related features (explained in detail in Section 4.6). Multimedia design guidelines were created from the results of the checklists.

Graphic Design Checklist

The graphic design checklist which also formed part of Phase Four of the DSRM was used to identify the graphic design elements and principles in the three selected vocabulary apps. The design elements form the foundation of the design principles. These graphic design elements and principles were not overtly described in Multimedia Learning (Mayer, 2009) and were therefore considered important when designing vocabulary apps assisting language learning in children with ASD. The graphic design elements and principles were described in detail by O'Connor (2014) and were discussed in Section 4.4. The features of each of the design elements and principles of graphic design were formulated into questions to create the graphic design checklist. Helping with the identification of graphic design elements and principles used in each of the vocabulary apps. The graphic design elements and principles identified in the app considered to be most effective for language learning, were used to create multimedia learning guidelines addressing the design objectives of Phase One.

Analyses of Graphic Design Checklists

The detailed descriptions of design elements and principles discussed in Section 4.4 as stipulated by O'Connor (2014) were converted into questions to create a checklist. The questions in the checklist had dichotomous answers in the form of either a 'yes' or 'no' answer. If the answer was 'yes' then the relevant feature of that element or principle was applied to the design of the specific vocabulary app. The opposite was true if the answer was 'no', then that specific design element or principle was not used in the design of the vocabulary app. The identification of graphic design elements and principles assisted in creating multimedia design guidelines specifically related to the design of the vocabulary app.

All the checklists described and utilised in the research study contributed to the identification of effective multimedia design guidelines for the design of vocabulary apps assisting language learning for children with ASD.

5.8.2.4 *Eye-tracking Recordings*

As mentioned in Section 4.7, eye tracking is a sensory technology identifying the exact location of a person's focus, in the case of this study the child's focus. The natural eye movements on the screen are studied while the children view a specific display or interface on the vocabulary apps

The eye tracking equipment used was the Tobii X3-120 eye tracker (see Figure 5-16). This eye tracker is slim and suitable for use outside a lab, for this study a school classroom.

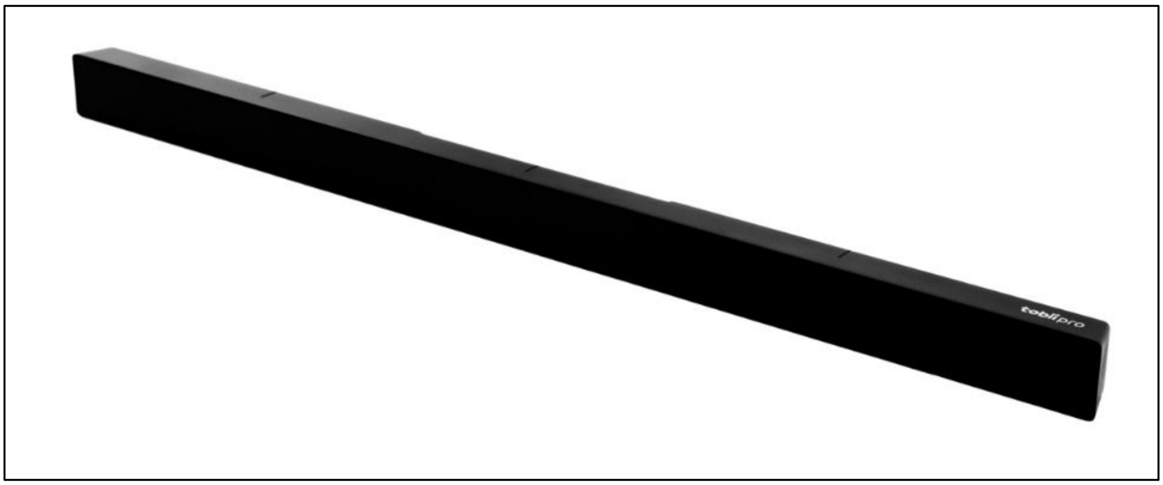


Figure 5-16 Tobii Pro X3-120 Eye Tracker

The Tobii X3-120 (Tobii, 2017a) eye tracker has a sampling rate of 120 Hz allowing flexibility that can handle a variety of human behaviours within their natural environments. The reason for the success of this eye tracker is because it is unobtrusive, preventing misplaced attention.

The eye tracking activity was planned by the eye tracking specialist and researcher. The eye tracking equipment used was the Tobii X3-120 eye tracker as mentioned. This eye tracker was ideal to use with children with ASD since it was inconspicuous and non-invasive (Tobii, 2017a).

The three chosen vocabulary apps were downloaded and played through an emulator titled Leapdroid. An emulator as defined by the Merriam-Webster (Webster, 2006) online dictionary is "hardware or software that permits programs written for one computer to be run on another computer." The reason for using an emulator was that the Tobii eye tracker in the case of the study, could not be attached directly to a tablet. For mobile tracking the eye tracker has to be mounted onto a mobile device stand which restricts how participants interact with the mobile device and it cannot be expected that children with ASD have movement restricted.

The chosen vocabulary apps were designed for tablets but with the emulator the apps could be mirrored onto a larger touch screen. Two touch screens were used while the eye tracking took place. The child with ASD was seated in front of a Lenovo 19.5-inch integrated touch screen computer while the eye tracking specialist was seated in front of the other touch screen. Both touch screens were under the control of the eye tracking specialist who monitored the screen activities on a second Lenovo 19.5-inch integrated touch screen. Both screens were under the control of the eye tracking specialist. The reason was that the eye tracking specialist could control which of the vocabulary apps would appear on the touch screen, for the child with ASD to interact with. Furthermore, if the child with ASD decided to quit the vocabulary app they were busy interacting with, the app could be reloaded onto the touch screen long enough until sufficient eye tracking data was captured (see Figure 5-17).

A further decision was made that if the child with ASD was unhappy about interacting with a certain app they were given the promise to choose the app they preferred to interact with. However, this opportunity would only take place once they finished interacting with the vocabulary apps initially chosen by the researcher.

The eye tracker - Tobii Pro X3-120 – used the Tobii Pro Studio software to record the fixations of each child with ASD while they interacted with the three chosen vocabulary apps. A fixation consists of "…slower and minute movements that help the eye align with the target and avoid perceptual fading" (Tobii, 2017b). Salvucci and Goldberg (2000, p. 71) explain fixations as "…pauses over informative regions of interest …"

The eye tracking device (circled in red) was placed unobtrusively at the bottom of the touch screen and appeared to form part of the screen as seen in Figure 5-17.

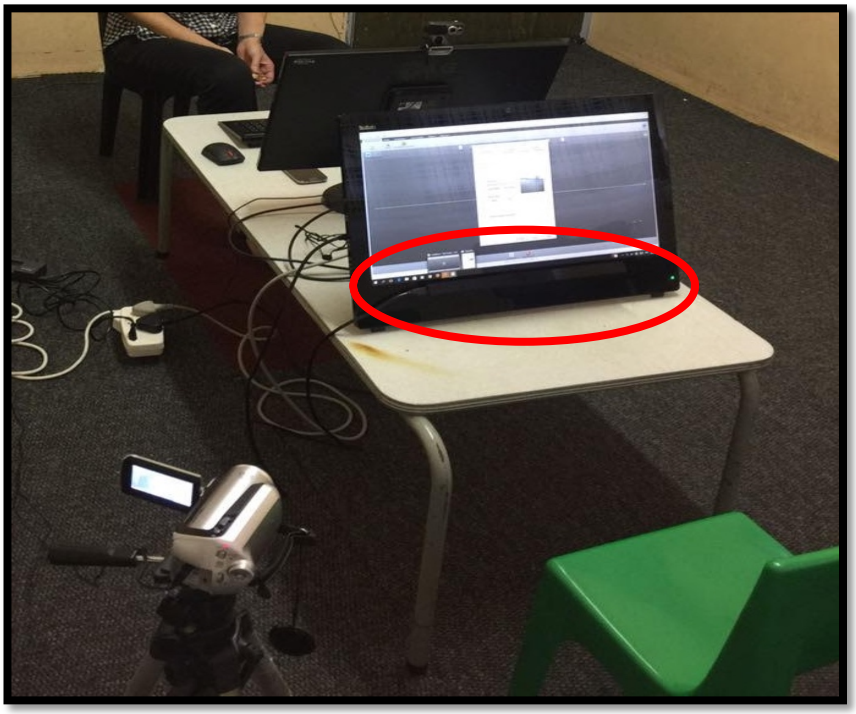
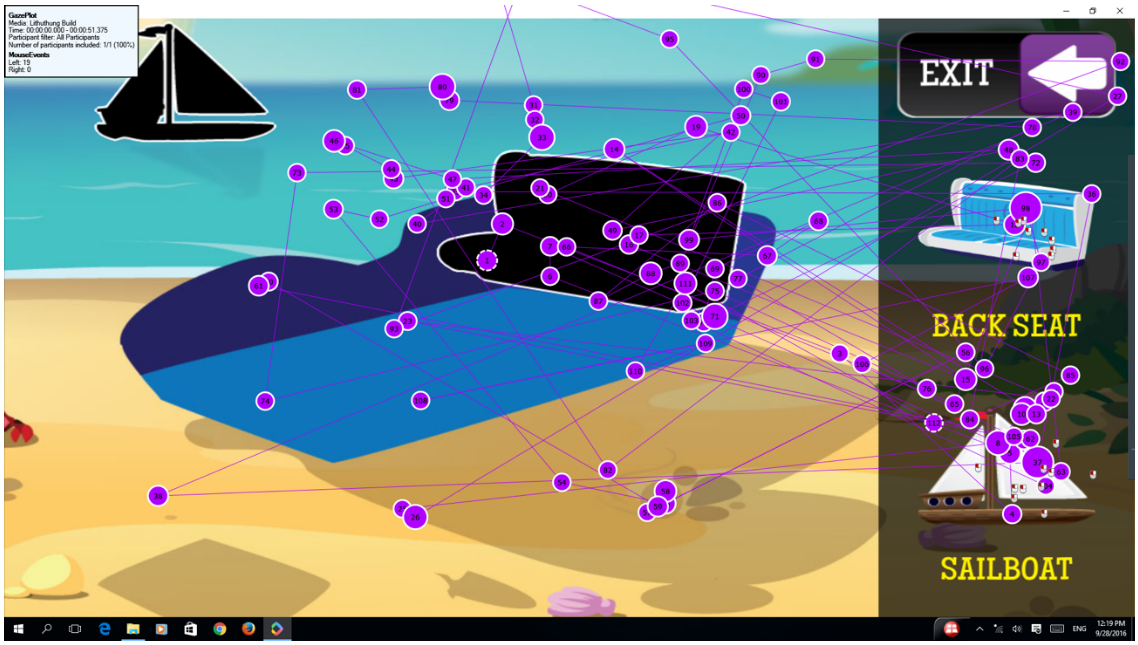


Figure 5-17 Tobii Eye Tracker used in the Research Study

The eye tracker had to be calibrated for each child with ASD for the mobile tracking. Calibration set up requires that the child concentrates on the screen, following the researcher's instructions closely as to where exactly their focus should be on the screen. A bouncing rabbit was initially used to attract the child's attention on the screen. However, this was not a viable option for the children with ASD because of their very short focus span, they avoid eye contact with the researcher or refuse to look at the rabbit on the screen. This problem was remedied by the eye tracking specialist who placed herself at the same position and height of the child in front of the eye tracker. Resulting in successfully calibrating the eye tracker so that when the child started interacting the eye movements were recorded.



Quantitative Analysis

The recordings of the fixations (gaze videos) from the eye-tracking equipment was done by the Tobii Pro Studio software saving each recording as an MP4 video. Each video recording was analysed by the researcher using ELAN video analysis software. The graphic displays of the vocabulary apps were not static but dynamic, progressing from one scene to another resulting in video coding that had to take place. Since every child's movement for each vocabulary app was unique, it did not make sense to create static gaze plots or heat maps for analysis, because they would not be comparable across the children with ASD. The gaze videos superimpose a moving dot on the screen to show how the child's eyes moved from point to point. The dots are the fixations and the lines between the dots indicate the saccades as presented in Figure 5-18.

The reason for choosing video coding was because each fixation on a letter, word and object could be counted. The software used for the video coding and annotations was ELAN.

Figure 5-19 Example of fixations and saccades

5.8.2.5 *Video Coding*

For this research study video coding is defined as the count of observational variables by means of specific software using video recordings of the research participants. Yoder and Symons (2010) explain that an observational variable has an object of measurement such as a behaviour or characteristic and a metric to quantify the object of measurement. Observation has two concepts of measurement namely *idemnotic* which is measured along a continuum, has a minimum and uses units or steps that are established independently of the variability of what is being measured. An example of an idemnotic scale would be weight that has an absolute minimum of zero. The units of measurement related to weight are either kilograms or pounds and this varies from one person to another.

The *vaganotic* concept of measurement is used when researchers are interested in individual differences. This approach is used to conceptualise the assessment of the predictors and dependant variables within a group. Observational variables can be measured using either the idemnotic or vaganotic concept of measurement. Both measurements involve physical aspects of behaviour to assess the object of measurement. (Yoder & Symons, 2010)

This research study made use of the idemnotic concept of measurement whereby minimum and maximum units (fixations in this case) provide greater insight to the effectiveness of the vocabulary apps. The number of fixations on letters and words compared to objects presented in the app resulted in inferences being made about the effectiveness of the apps in assisting with language learning for children with ASD.

Quantitative Analyses

The specific annotations (units of measure) made in ELAN for this research study were based on the number of fixations on the letters, words and objects. Each fixation on either letters, words, or objects was selected and annotated on the timeline of ELAN. ELAN calculated the number of annotations made per letter, word, and object. These annotations became the quantitative unit of measure. Once all the fixations were annotated and calculated the data was exported to Excel.

As mentioned ELAN calculates the number of times the specific annotation (in this case letter, word or object) appears and allows this data to be exported. This data was exported into Microsoft Excel and the analysis provided quantitative results for each letter, word and object. The total number of fixations per letter, word and object for each vocabulary app were displayed in both tables and graphs. The Excel tables and graphs were used to make comparisons of the results between the various vocabulary apps' data during the eye tracking activities.

The vocabulary app that had the highest fixation count on words and letters was considered to be more effective at assisting language learning in children with ASD. The reason was that evidence was provided that greater focus was placed on the letters and words than on the objects. If the fixation count was higher for the objects than on letters or words the specific vocabulary app was seen as being less effective at language learning for children with ASD.

Once all the phases of the DSRM were completed, a final artefact – (effective multimedia design guidelines) - was created. The final artefact was created through thorough evaluations that took place for each phase of the DSRM. These various evaluations ensured that a high degree of validity and reliability was achieved.

5.9 Validity and Reliability

Various types of validity and reliability exist and all play a crucial role in sound research. For qualitative data validity Cohen et al (2011, p. 133) indicate that validity can be achieved through honesty, depth, richness and scope of the data obtained, how the participants should be approached and the degree of the triangulation and the objectivity of the researcher. Quantitative validity necessitates meticulous sampling, rigorous instruments and proper data analysis. Validity should not be seen as an absolute state but rather a matter of degree (Cohen et al., 2011).

5.9.1 *Internal Validity*

The purpose of internal validity is to validate the explanation of a specific set of data by supporting it with accurate data. The qualitative data needs to be believable, convincing and credible (Cohen et al., 2011).

For this research study, the various evaluations that took place for each phase ensured the reliability of the final artefact. The several methods incorporated to identify effective multimedia design guidelines were applied with rigour. The opinions of speech therapists regarding vocabulary apps were obtained; the interaction between the children with ASD and the vocabulary apps was observed; the educational value of the vocabulary apps was determined with the help of an educational expert and the eye tracking results of the fixations on each letter, word and object annotated through video coding. The tactile and auditory stimuli of each vocabulary app were documented to determine whether any overstimulation of the senses took place. All these different evaluation methods contributed to the identification of effective multimedia design guidelines achievable through triangulation.

5.9.2 *External Validity*

External validity is "… the degree to which the results can be generalized to the wider population, cases or situations." (Cohen et al., 2011, p. 136).

With both the qualitative and quantitative data collection methods used in this research study, a distinct, thorough, and in-depth description is provided of the artefact so that others can determine whether the findings are generalisable.

To ensure that the degree of internal and external validity was acceptable, triangulation of the data readings was pursued.

5.9.3 *Triangulation*

This research study applied triangulation which is defined by Cohen et al (2011, p. 141) as using two or more data collecting methods in a research study to understand the specific behaviour. With the help of triangulation an attempt is made to explain in more detail the human behaviour observed from differing perspectives using both qualitative and quantitative methods.

There are various forms of triangulation such as time triangulation involving cross-sectional and longitudinal designs; space triangulation where the study involves cross-cultural techniques; combined levels of triangulation whereby more than one level of analysis takes place involving the individual level, the group level and the organisational level; theoretical triangulation involving alternative or competing theories instead of only one viewpoint; investigator triangulation whereby more than one observer is involved in capturing data and finally methodological triangulation which entails using the same research method on different occasions or different methods for the same object. (Cohen et al., 2011)

For this research study the methodological triangulation was chosen. The reason for this choice was that the results from each phase of the DSRM resulted in an improved artefact. The triangulation ensured that the final artefact in the form of effective multimedia design guidelines was effective and robust with high fidelity.

5.9.4 *Reliability*

Reliability is based on the assumptions that the instrumentation, data and findings should be controllable, predictable, consistent and replicable in quantitative research. For reliability in qualitative research there should be (Cohen et al., 2011, p. 148):

- **Stability in the observations:** the same observations would be made and interpreted at a different time and place;
- **Parallel forms:** would the same observations and interpretations of what was seen have been made if the researcher had paid attention to other phenomena during the observation;
- **Inter-rater reliability:** would another observer with the same theoretical framework who observed the same phenomena have interpreted it the same way.

Reliability in qualitative research ensures that the research study's data fit what happened in the research study under natural settings.

The validity and reliability for the various methods of data collection for each phase of the DSRM are discussed further.

5.9.5 *Validity and Reliability of Observations*

The observations made in the Phase Two of the DSRM in this study involved determining which vocabulary apps the children with ASD chose to interact with. The length of these interactions was noted per child for each vocabulary app, after which the three vocabulary apps with the highest interaction time were chosen. The observations were therefore not influenced by the presence of the researcher. The observations were objective and impartial. Lastly, the judgement of the researcher could not affect the data since the focus of the observation was based on the interaction time with the different vocabulary apps resulting in quantitative analysis.

The reliability of the observations was ensured by the analytic constructs used in the various phases of the DSRM used in the research study. The manner in which the data was collected and analysed also added to the reliability. The analytic constructs were measurement of time, checklists for evaluative purposes and eye tracking to determine fixations on letters and words versus fixations on objects.

5.9.6 *Validity and Reliability of Video Coding*

Behavioural observations need to be accurate and there must be valid instances of the specific behaviour. Validity differs depending on the purpose of the research, the research design and the object of measurement. The primary purpose of the observational variables need to be indicated as well (Yoder & Symons, 2010).

Validity

For this research study Multitrait, Multimethod (MTMM) Validation was included. This type of validation measures whether the **measure of interest** strongly correlates with other measures of the same construct using a method of assessment different than measures of another construct that use the same method of assessment. (Yoder & Symons, 2010, p. 197).

Yoder and Symons (2010, p. 197) indicate that multitrait "…involves using the same general methods of assessment to measure two or more different generalized characteristics." On the other hand, multimethod involves using different methods of assessing to measure the same construct.

As indicated by the different phases contained within the DSRM various assessment and evaluations took place to create the final artefact. By integrating these various forms of assessments, the MTMM validity had a high degree of fidelity.

Reliability

Reliability as specified (Yoder & Symons, 2010) is based on inter-observer similarities of the observational variable. In other words, there are similar observational scores between the different observers based on the same measurement system. Absolute scores with no variance are expected and can be accomplished through summary level agreement.

Summary level agreement is "...the extent to which two people derive the same variable score." according to Yoder and Symons (2010, p. 141). This is achieved by giving the observers the necessary training, a coding manual and detecting when an observer agrees less often with the criteria of the coding. With the help of point-by-point agreement checks reliability can be achieved.

For this research study two university students were given the necessary training and a coding manual explaining how to identify the observational variables for each vocabulary app. Once the training was completed they were asked to video code the various observational variables with the help of ELAN software. Once they completed their video coding of the first child's fixations of the selected vocabulary app, point-by-point checks took place to ensure the same variable score was attained. They were then given another video to analyse with ELAN, and a point-by-point check took place. After the third time the variable scores only differed by one point.

This point-by point checking and summary level agreement can be seen as inter-rater reliability thereby contributing to the level of reliability for this research study.

5.10 Ethics

The safety of the participants as well as their voluntary participation, informed consent, privacy and trust was imperative to the research study. Informed consent included detailed letters on what the study entailed, how the procedures worked, who was involved and participated in the study, where and when the study took place and finally why the study took place. It was of paramount importance that mutual consent was granted.

A request for permission to conduct the study was obtained from the Gauteng Department of Education and the participating school principal (see Appendix B). Letters of informed consent (see Appendix A) from the speech therapists and parents (see Appendix C) were requested. The researcher ensured that the contents of the informed consent letters were adhered to at all times. Letters of informed consent were given to the parents or guardians of the children with ASD. The letters of assent for the children with ASD were not given after mutual agreement between the principal and head speech therapist that these children have limited capacity to understand the letters. The participants were allowed to leave the study anytime they wished and the parents could similarly withdraw their child from the study if they deemed it necessary. The school principal could also remove his or her school from the study if he or she felt the need.

A teacher's assistant was present at all times during the observations and while the eye-tracking took place. In addition, the venue and time for the observations, interviews and eye-tracking were arranged according to the preference of the speech therapists. The study did not interfere with any of the school activities. The safety of the participants was of utmost importance and no incidents occurred. The trust was preserved by allowing the school principal and speech therapists access to the data if the need arose.

The interviews were voice recorded and the observations video recorded with consent from the participants. Furthermore, consent was requested to show the videos to other parties if necessary.

5.11 Concluding Comments

With the preceding design considerations and methodological choices explained, Table 5.7 connects the posed research questions with the data collection instruments and the type of data collection method. The last column in the table outlines in which chapters the data results and findings are discussed.

Table 5-7 Research questions linked to data collection strategies

Main Research Question: **Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?**			
Sub Research Questions	**Data Collection Instruments**	**Method**	**Chapter in Thesis**
PHASE THREE **What are the educational qualities of an effective vocabulary app?**	• Expert Opinion specialist • Checklists	Qualitative	Chapter 7
How are different memories activated in vocabulary apps?	Checklists	Qualitative	Chapter 7
How is emphasis placed on letters and words used in a vocabulary app?	Eye Tracking, Video Coding Checklists	Quantitative & Qualitative	Chapter 7

The ensuing chapter, Chapter 6, will discuss the results and findings according to Phase One and Phase Two found in the DSRM.

6 CHAPTER SIX - DSRM PHASE ONE AND TWO - RESULTS AND FINDINGS

6.1 Focus of Chapter

This chapter presents the findings and results for Phases One and Two represented in the Design Science Research Model (DSRM).

The purpose of this chapter is to describe each phase represented by the DSRM. Each phase of the DSRM has activities that can be directly linked to the creation of the artefact. The data for each phase of the DSRM will be analysed and the results and findings discussed.

A description will be provided of each phase, the specific data collection and analyses will be briefly reiterated before discussing the results. In the end of each phase a discussion will take place of the findings and a summary provided.

6.2 The Research Questions Revisited

The research questions for this research study found in Chapter One, Section 1.5 are:

Main Research Question

Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?

Sub Research Questions

1. What are the educational qualities of an effective vocabulary app?
2. How are different memories activated in vocabulary apps?
3. How is emphasis placed on letters and words being taught in a vocabulary app?

The amalgamation of these sub research questions will lead to the final answer of the main research question. Table 6.1 demonstrates the various phases of the DSRM and their related research questions.

Table 6-1 The DSRM linked to the Research Questions

PHASE	DSRM OBJECTIVES	OUTCOME	RESEARCH QUESTIONS
Phase One	Problem identification, justification and evaluation involving expert opinions of speech therapists	Validated research problem	
Phase Two	Design of artefact; Identification and validation of design objectives through expert opinions	• Initial artefact; • Identification of vocabulary apps	Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?
Phase Three	Construct artefact; Evaluate effectiveness and fidelity of artefact through expert opinion of educational expert	• Educational value of vocabulary apps; • Vocabulary app with highest educational value; • Intermediate artefact	• What are the educational qualities of an effective vocabulary app? • Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?
Phase Four	Use artefact; Eye tracking, video coding and checklists	Final effective artefact	• How are different memories activated in vocabulary apps? • How is emphasis placed on letters and words being taught in a vocabulary app? • Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?

With a clear indication of the link that exists between each phase of the DSRM concerning the artefacts development, Phase One of the DSRM will be described first.

6.3 DSRM Phase One – Problem Justification

Phase One consisted of justifying the problem and involved determining whether the problem is of importance and applicable to children with ASD using vocabulary apps for early language learning as seen in Figure 6-1.

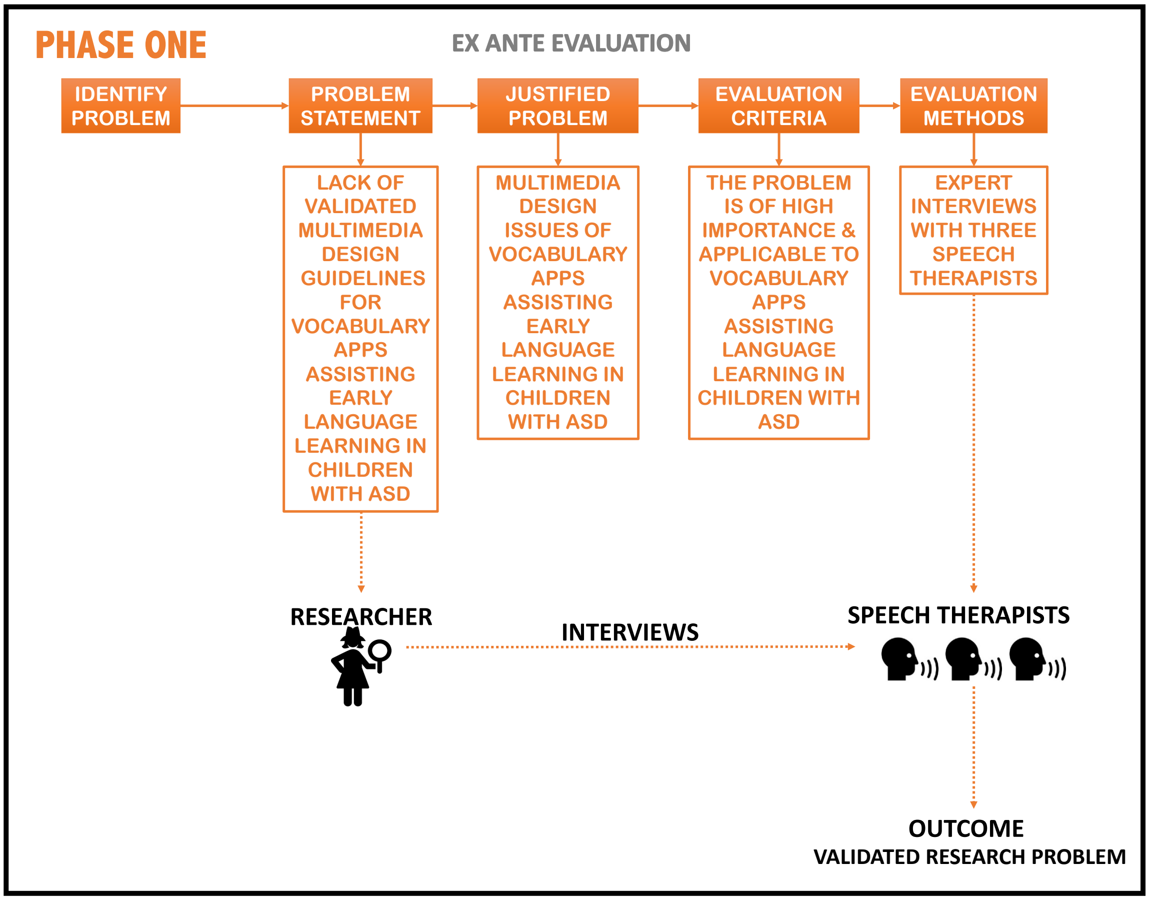


Figure 6-1 DSRM Phase One

6.3.1 *Phase One - Problem Statement*

The problem statement mentions that there is a lack of validated multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD. A large number of apps that claim to teach early vocabulary are available for download. Each app has its own unique design and approach to teaching early vocabulary. These vocabulary apps incorporate illustrations and drawings ranging from black and white stick figures to full colour line drawings or photographs. Many of these apps include animations, sounds and tactile activities that provide abundant entertainment for the child interacting with the app. However, the question remains as to whether attention is given to the letters and words being taught or whether mindless interaction takes place with little being learned concerning early vocabulary.

6.3.2 *Phase One - Justified Problem*

The problem is justified by the multimedia design issues of the vocabulary apps assisting early language learning in children with ASD. Many of the vocabulary apps are filled with animations, sounds and tactile activities that provide abundant entertainment for the child interacting with the app. The justified problem is that vocabulary apps are not effectively designed meaning attention to letters and words is lost. If the letter or word is not effectively placed in the layout the child will focus his or her attention somewhere irrelevant to learning the specific letter or word being taught. Multimedia design guidelines can address issues relating to loss of attention, extraneous material, tactile and auditory overstimulation and the general design of a vocabulary app. Effective language learning can take place specifically for children with ASD if a deliberate approach is taken in the design of vocabulary apps.

6.3.3 *Phase One - Evaluation Criteria*

The evaluation criteria for the identified problem is based on importance and applicability. The lack of validated multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD is considered to be an applicable problem of high importance.

Effective design elements and principles that promote deep learning have been incorporated for use with computers, animations and e-learning specifically for college students (Mayer, 2003; Mayer & Moreno, 2002a, 2002b) but effective multimedia design guidelines for the design of vocabulary apps for children with ASD are lacking. Little research can be found relating to multimedia design guidelines for vocabulary apps benefitting language learning in children with ASD. A number of authors (Behrmann et al., 2006; Dakin & Frith, 2005; Simmons et al., 2009; Vandenbroucke et al., 2009) mention that the visual processing in ASD is unique and different. This being the case the use of multimedia design guidelines assisting early language learning could be of great value for children with ASD, their parents or caregivers, and speech therapists.

6.3.4 *Phase One - Evaluation Methods*

The evaluation methods applied to justify the identified problem made use of interviews to attain expert opinions from three speech therapists. Each one of the three speech therapists was interviewed and the interview questions were asked to validate the problem. The speech therapists participating in the study were directly involved with the children with ASD. Their involvement included speech therapy sessions teaching words, sentences, and sign language.

The three speech therapists were interviewed individually, at a time and place that suited them best. The time taken for the interviews ranged between fifteen to forty minutes. The interviews provided valuable insight towards identifying aspects of vocabulary apps that promote early language learning in children with ASD. Furthermore, it assisted with the creation of the initial artefact. The insight and expert opinions provided by the speech therapists helped identify multimedia design guidelines for vocabulary apps that either had a positive or negative impact on language learning in ASD. The negative aspects validated the problem identified.

The questions were semi-structured (see Appendix E) so that the speech therapists could provide their own thoughts and opinions regarding vocabulary apps. Their expert opinions and recommendations would validate or disprove the identified problem. In addition, assisting in the creation of the initial artefact for Phase Two.

6.3.5 *Results of Phase One*

The problem identified in Phase One was validated by the speech therapists. This was accomplished by identifying and documenting their expert opinions. A qualitative approach was used and each problem identified and underlined according to the opinion of each one of the speech therapists from the interview results. The underlined problems of vocabulary apps were documented for each speech therapist in Table 6.2.

Table 6-2 Results of interviews with Speech Therapists

Main Speech Therapist	Speech Therapist 2	Speech Therapist 3
"…it's a language app then it doesn't actually reinforce language."	"…the less um...visually stimulating the better."	"…too much verbal stimuli and too little visual or if there… is it…it has to…that's what I look at - how exactly does the app work?"
"So, if it's like animals but the animals don't even look like animals then I wouldn't choose an app like that."	"And it's really hard when it comes to accents so and you can't really find a neutral one."	"If there is too much of sound and noise and there is not a lot of educational learning I don't like to use it."
"…instead of using language to reinforce the learner its actually just um…using sounds…"	[Referring to accent] "Yes so that is quite frustrating I think and they are working on getting a neutral accent or South African accent but for now we have an American accent so that's what we go with…"	"…changing it [activities] all of a sudden becomes difficult for them to grasp…"
"…very noisy but no actual language…"	"…so you don't often find apps that will help with like sentence development so a lot of them are just words which is great but from words you need to move on."	"…sometimes there is too much of colour and it effects the learners… it also distracts the learner"
"…they very, very abstract…"	"…[apps] first teach the word and then they ask you to identify it… with sentence development which you don't come across quite often…"	"…most apps don't actually take into consideration that there needs to be different levels of progress…"
"…they'll be apps then they'll, they'll do like things like shapes but then they'll have like pentagon so it doesn't… so they don't grade. The apps are not graded at all."	"…sometimes they [apps] are very abstract…"	"…too much movement…"
"If it's a language stimulation and it's got colours it will be all the colours and then my kids don't work like that…"	"…very animated cartoony…"	"…too much visual stimuli…"
"…the usability is quite limited it's not like a learner can take the app and play with it independently… it can be quite complex"	"…so definitely when there is too much, so it's hard for them with their…you know…their visual background and their auditory visual figure ground. And I think that's way too much [stimulation] for them and they land up looking away."	"… if they are on a new app and they don't know how to use it, it's difficult to get them to participate in that…"
"…a lot of apps, more recent apps are better at this, but	"…some of the apps aren't sensitive enough to touch and	"…extraneous stimuli that distracts them…"

they… they're very difficult to…they're very easy for the kids to just leave."	some of them are too sensitive…"	
"…a lot of time the noise, like there's a lot of background noise…"	"…think that's something to look at because a lot of them [apps] use women's voices and I think a low tone voice might be better…"	"The limitation to that is that there's sometimes not all the words that you need in there."
"…they just get overstimulated."		"…apps give the option of adding vocabulary in so it can be specific to the individual…"
"…they get frustrated when it's not clearly set out."		"I would prefer it to have the option to switch it on and off [sounds]…"
"…no clear exit, enter, next…"		"…sometimes you can't use an app because it's only English based."
"So, it's very difficult to find apps that do that, so a lot of time I find when I'm doing...using an app I have to guide the learner."		"… if we do a theme like transport, girls aren't really interested in that, because they like, 'why must I look at a car?' But they need to understand these, it's for vocab, but they are not interested in it. The same if a boy is looking at something with a Barbie doll…"
"The problem is a lot of the time it won't… it will be a word with a very abstract picture…"		
"So, I don't want them to be so absorbed into an app…cause that kind of defeats the purpose of enhancing their social interaction"		
"…you have apps that are female but you're working with males, ok so now you have a female app that is talking for a male boy."		
[Cartoons] "I think they are very abstract and um...they're too abstract for our learners"		

Through the identification of the problems, Phase One of the DSRM was properly addressed, resulting in the justification of the problem which is described in the findings to follow.

6.3.6 *Findings of the Interviews*

The justification of the identified problem was determined by the results of the interviews with the three speech therapists. The results of the interviews clearly indicated that the following was in general applicable to the design of vocabulary apps:

- overstimulating – too many noises, sounds, colours and animations;
- too abstract in the use of cartoons and pictures;
- not user-friendly resulting in frustration;
- have no levels that progress from easy to difficult;
- doesn’t reinforce language;
- doesn’t use accents that are South African. accents are American;
- isn’t sensitive to touch;
- voices used are not sensitive to gender;
- themes are not unisex but gender orientated for example Barbie, cars et cetera;
- doesn’t have the option to control sound;
- limitations of words being taught .

6.3.7 *Phase One Summary*

The problem was identified by the researcher and justified by the results of the interviews held with the three speech therapists. The resounding evidence presented, warranted the creation of multimedia design guidelines for vocabulary apps to assist early language learning in children with ASD. The results of the interviews confirmed that there is a need for validated multimedia design guidelines which are beneficial to vocabulary apps assisting early language learning and that the lack of validated multimedia design guidelines results in design issues as described by the speech therapists.

With the identified problem being justified the next phase– Phase Two – is discussed.

6.4 DSRM Phase Two – Design the Artefact

In this phase the design objectives of the artefact were identified and validated by the speech therapists' expert opinions as presented in Figure 6-2. However, for this phase three outcomes were produced namely: validated design objectives, the initial artefact and the identification of preliminary vocabulary apps.

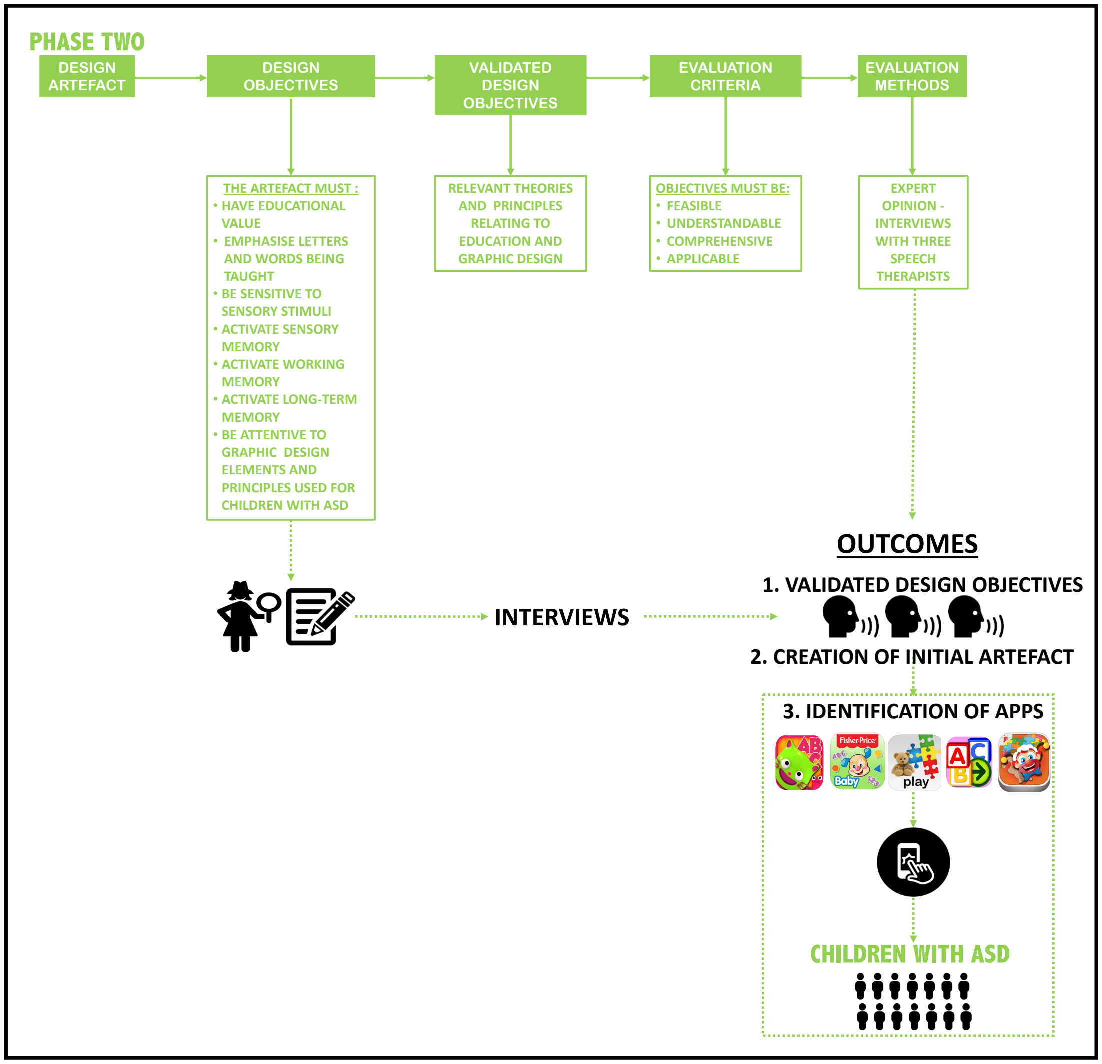


Figure 6-2 DSRM Phase Two

The appropriate design of the artefact is central in resolving the problem presented in Phase One. The objectives were identified from the description and definition of the justified problem presented in Phase One. The purpose of the objectives was to keep the identified problem in Phase One at the forefront guiding the creation of the final artefact.

6.4.1 *Phase Two: Design Objectives*

This phase involved the design of the initial artefact whereby design objectives first had to be identified. The design objectives included various aspects relating to the problem presented in Phase One such as the educational value of vocabulary apps, emphasis on letters and words, consideration for sensory stimuli, activation of different memories, and attentiveness to design.

As mentioned previously the design objectives for this specific phase were to assist in the design of the artefact. The artefact consisted of multimedia design guidelines to help improve upon the current design issues experienced with vocabulary apps for children with ASD. This was achieved by ensuring relevant educational theories were incorporated in the design of vocabulary apps, as well as activities activating all three memories - sensory, working and long-term. Special attention was awarded to the identification of graphic design elements and principles that placed emphasis on letters and words.

6.4.2 *Phase Two: Validated Design Objectives*

The identified objectives presented by the researcher were attained through the examination of various theories presented in literature, more specifically the educational theories incorporated in the conceptual framework (Chapter 5). Literature concerning graphic design elements and principals was also studied and identified (Section 4.4).

6.4.3 *Phase Two: Evaluation Criteria*

The design objectives were identified by including evaluation criteria that ensured the objectives were: feasible - for the identified area of expertise; understandable - making the application of the artefact meaningful; comprehensive - by including all features leading to an effective final artefact and applicable - being capable and suitable as an effective artefact. The clearly stated design objectives ensured that the artefact fulfilled its purpose and addressed the identified problem.

6.4.4 *Phase Two: Evaluation Methods*

The evaluation method used to validate the design objectives was by means of interviews to attain expert opinions discussed in Section 6.4.4.1.

It is important to note that for Phase Two of the DSRM three different outcomes were achieved. The first outcome was the validation of the design objectives which was the foremost purpose of Phase Two. The second outcome was the creation of the initial artefact to be further improved upon in Phase Three. The third outcome was the identification of the preliminary five vocabulary apps that were reduced to three apps for the rest of the study. Each of the outcomes are explained in detail in the sections to follow.

6.4.4.1 *Outcome One: Validated Design Objectives*

Results: The first activity was to validate the design objectives. The evaluation method involved attaining expert opinions from the speech therapists concerning the design objectives of the artefact. The interviews took place individually as mentioned in Section 7.3.4. The interviews delivered valuable evidence affirming the design objectives of the artefact. The awareness created from the expert opinions of the speech therapists helped clarify the acknowledged design objectives of the artefact for Phase Two.

All three interviews were transcribed separately in Microsoft Word and each noted description given by the speech therapists relating to the design objectives was changed to purple and then published in Table. The descriptions provided by the speech therapists were related to the specific design objectives.

The specified design objectives identified as successfully resolving the problem described in Phase One as well as the expert opinions of the speech therapists, are presented in Table 6-3.

Table 6-3 Validation of Design Objectives

Design Objectives	Expert Opinion
Educational value	• "…what the child needs are and what their abilities is." • "…what level representation the child is at." • "I look at is whether it's got language stimulation." • "…relevant to that child and that child's capabilities." • "the simplicity of the app" • "…apps that will help with like sentence development." • "…it's just exposure so children with autism cope with multiple exposures and repetition and that's the way to, to teach them. I mean often and to offer them multiple examples…" • "…they don't all learn phonetically and most of the time they learn by sight." • "…give the child time to understand and process what's happened." • "…apps that have flashcards." • "…apps give the option of adding vocabulary."
Emphasis on letters and words being taught	• "…is it actually reinforcing language, is there language stimulation?" • "…appropriate language stimulation…" • "…instead of using language to reinforce the learner its actually just um…using sounds." • "…short, clear sentences, limited descriptive language um...very, like very concrete and clear." • "…voice to be very clear for them and let them get that language…that verbal and auditory feedback." • "…first teach the word…" • "…simplified language and a simple conversation." • "…keep the language very simple very short sentences." • "…it really helps to break words up into chunks." • "…break it down into syllables and then to have the option of having a whole word." • "…it will have the word, so 'eyes' with the print word 'eyes' so they can start associating." • "…voice saying the word 'I' it's… it helps." • "…shows how to actually mouth words." • "…short phrases and sentences." • "…someone saying the word for them it directs their attention." • "…vocabulary that relate to their immediate environment." • "…write with their finger…" • "Join these dots…"
Sensitivity towards sensory stimuli	• "…look at…um…their sensory information" • "…is it a child that copes with visual and visual information over auditory information?" • "…a lot of time the noise, like there's a lot of background noise." • "…the less um...visually stimulating the better." • "…some of the apps aren't sensitive enough to touch and some of them are too sensitive." • "If there is too much verbal stimuli and too little visual…"

	• "…too much of sound and noise…" • "…not too much movement." • "Sometimes learners have tactile difficulties."
Activate sensory, working and long-term memory	• "The apps are not graded at all." • "…the level of difficulty should progress." • "…needs to be different levels of progress." • "So, we'll teach them, I'll show them how to do it, we'll do it together then I will give it to them and see if they can do it independently, and then I'll teach again. So, I'll take it away and we will try and then I will show them again. And then hopefully by that time they're able to do it independently." • "…first teach the word and then they ask you to identify it." • "So that's showing that there is reception. Have they actually understood? If you show them six pictures, can they identify the word that's being said?" • "…they like repetition..." • "…will give extra things like senses and they will have a puzzle in it, so you match, then you put the eyes, draw the person. So, it allows for association and things like that." • "Then we can even do word association with that 'so what do you do with an apple?'"
Attentiveness towards graphic design elements and principles	• "…apps that are more concrete, so have more photographs, more realistic and less cartoon and abstract." • "So, it's ideal like to have the word under the photo…" • "I would like to have the word and the picture." • "…always look for a very realistic picture." • "…expose them to text with the picture or with the object so that they always making the connection between the two." • "…have pictures on the app it's easier for them to use or follow." • "…realistic features." • "…so, if you have the word 'apple' in print at the bottom the letter 'a' then they can associate 'a for apple'." • "…there is too much of colour and it effects the learners, it also distracts the learner."

The results of the interviews were documented. The opinions of each speech therapist were presented in the column titled 'Expert Opinion'. These opinions were matched to the design objectives they related to most and indicated in the column titled 'Design Objectives'. This was done to determine whether the design objectives were valid.

<u>**Findings:**</u> The opinions of the speech therapists validated the identified design objectives. In the light of these results the validated design objectives as per expert opinion are described as follows:

Educational value: the speech therapists felt that the child with ASD's needs and abilities need to be taken into consideration when learning vocabulary. The level of the child's ability needs to be taken into consideration. Language stimulation must take place by means of sentence development. There must be repetition and multiple exposures, examples and variations of the word being taught. Time must be awarded for the child to process the words being taught so that learning can take place. By growing the number of words being taught greater educational value can be achieved as well as greater improvements in vocabulary.

Emphasis on letters and words being taught: Reinforcement of the letters or words being taught should take place through appropriate language stimulation. This can be achieved by using short, clear sentences that are concrete with limited descriptive words. The letters and words being taught should be pronounced distinctly. Simplified language use where the words are broken down into syllables will ease the process of early language learning. The letters and words being taught should be relevant. Opportunity must be provided for the child to either pronounce or write the word.

Sensitivity towards sensory stimuli: It is imperative that consideration be given to the child with ASD sensory preference. Some of the children with ASD prefer visual over auditory information and vice versa. Background noises and sounds can become a distraction for the child and if there are too many movements, tactile difficulties can be experienced and consideration must be given to the sensitivity to touch.

Activate sensory, working and long-term memory: The level of difficulty should progress. The letter or word must be taught and then the child with ASD must be given the opportunity to interact independently with the letter or word being taught. Opportunities must be provided for the child to identify or match the letter or word being taught so that association can take place - for example word and object association. When the child can successfully match the letter or word to the object, learning has progressed from sensory memory to long-term memory.

Attentiveness towards graphic design elements and principles: Realistic images in the form of photographs that progress to coloured drawings and finally black and white line drawings should be incorporated in the design. The word should be placed underneath the object for optimal vocabulary learning. The child with ASD should be exposed to both the word and the object being taught. The use of different colours should be limited to prevent overstimulation.

6.4.4.2 *Outcome Two: Creation of Initial Artefact*

The second outcome produced the initial artefact. This was achieved by converting the opinions and recommendations made by the speech therapists into initial multimedia design guidelines. As mentioned in Section 6.3.4, three speech therapists were interviewed individually to help the researcher gain knowledge regarding vocabulary apps that promote early language learning in children with ASD. The insight and expert opinions assisted in the creation of the initial artefact.

The validation of the design objectives from the expert opinions of the speech therapists facilitated the creation of the initial artefact. Table 6-4 specifies the initial multimedia design guidelines.

Table 6-4 Initial Multimedia Design Guidelines

DESIGN OBJECTIVES	APP FEATURES	RESULTS OF INTERVIEWS	INITIAL MULTIMEDIA DESIGN GUIDELINES
Educational value	**Lessons**	Be short, have specific themes, allow adding of vocabulary, provide different examples of the letter or word being taught, give time to process information before going to the next screen, provide support, follow a routine.	Vocabulary apps should • Provide various examples of the letter or word being taught • Incorporate short lessons with themes • Follow a specific routine when teaching a letter or word
Emphasis on letters and words being taught	**Activities**	Teach words then allow opportunity to identify the word, help with sentence development, be interactive, include repetition and multiple exposures, include a cause and effect relationship, have a variety i.e. puzzles, matching, incorporate flashcards, learning the alphabet, write with their finger, join the dots, word association, activities to be clearly set out and described.	The activities of vocabulary apps should: • First teach a letter or word and then let the child with ASD identify the letter or word • Include opportunities for sentence building • Include repetition • Include a variety of games such as puzzles, matching, join the dots, writing the letter or word with fingers • Allow for association of word and object
Sensitivity towards sensory stimuli	**Touch**	Cause and effect, if the child touches the picture something happens such as the object being named, sensitivity of touch should be adjustable, not too sensitive or difficult to touch, allow for fine motor difficulties.	The tactile response of the vocabulary apps should: • Result in some kind of response i.e. the word or letter being articulated • Allow for sensitivity to touch • Accommodate fine motor difficulties
	Animations (Visual)	Limit movement, not over stimulating, can be a distraction.	Animations used in vocabulary apps should: • Include limited movements • Not be a distraction
	Sounds	Should not be overstimulating, not be noisy, be able to switch of sounds or turn down the volume, auditory should not be more than the visual, use phonetics, sounds should be mouthed, allow to listen to songs and rhymes, positive reinforcement, direct attention.	Sounds used in a vocabulary app should: • Not be noisy and over stimulating • Include phonetics • Include positive reinforcements • Direct the child's attention to the letter or word being taught

Activate sensory, working and long-term memory	**Memory activation**	Apps progress from an easy to a more difficult level with the last level being the most difficult or challenging. Teach words and then allow opportunity to identify the word through association	Memory activation in vocabulary apps • Include different levels of difficulty progressing from easy to difficult. • Provide opportunities for the child to identify the letter or word being taught in different contexts
Attentiveness towards graphic design elements and principles	**Design**	Images must be more concrete, have more photographs, be realistic and with less cartoons and abstract images. The word should be placed beneath the photo presenting the text with the picture or with the object so that a connection can be made between the two. Not too many colours, can distract the learner's attention, use of colour must be limited as it effects the learners and can be distracting.	The design used in vocabulary apps should: • Not include abstract images • Images and objects must be as realistic as possible progressing from photos to coloured drawings to black and white line drawings • The object or image must be placed above the letter or word being taught The colour used in vocabulary apps should: • Be limited • Not overwhelm the child by causing a distraction

The expert opinions are presented in column three titled "results of interviews" and were converted into the initial multimedia design guidelines presented in column four "initial multimedia design guidelines". The initial artefact was further developed and validated by the other phases that followed.

In order to progress from the initial artefact to the intermediate artefact vocabulary apps needed to be identified to be used in the study.

6.4.4.3 *Outcome Three: Identification of Vocabulary Apps*

The third outcome was the identification and selection of five preliminary vocabulary apps based on the recommendations and opinions of the three speech therapists. The rationale was to choose five preliminary vocabulary apps of which the final three apps were inadvertently chosen by the children with ASD. The purpose of the final three vocabulary apps was to assist in the creation of the final artefact.

Five different vocabulary apps were originally selected for the study. Not all the chosen vocabulary apps were specifically designed for children with ASD. However, the apps claimed to help teach and develop vocabulary. The vocabulary apps chosen for the study were aimed at young children who were at the preliminary stages of learning vocabulary.

The processes involved in selecting the five vocabulary apps, were based on the recommendations made by the speech therapists and the descriptions provided by the app developers regarding vocabulary apps.

Two of the five chosen apps were suggested by the main speech therapist following an interview and observations made of the children with ASD interacting with the vocabulary apps. The identified apps were Autism iHelp Play and Fischer Price Learning Letters. The Autism iHelp Play app's data is available on Priori Data's website. Priori Data is a website which offers performance data about apps to developers, investors and advertisers, providing information about the number of downloads and revenue of apps. This information provides insight to more than three million apps across sixty countries and includes two years of historical data (Kane, 2017).

6.4.4.4 *The five chosen vocabulary apps specifically teaching early vocabulary to young children as claimed by the different app developers.*

Three of these apps were Puzzingo (mentioned by Priori Data claiming to appeal to children with ASD), Starfall ABC's, and EduKitty ABC. These three vocabulary apps were chosen based on the recommendations made by the speech therapists, their ratings on the Android store and the descriptions provided by the app developers.

The choice of vocabulary apps was based on the following:

- The apps were free;
- The apps were suitable for Android - the most used Operating System worldwide, (Goasduff & Forni, 2017);
- Full functionality of the app without having to do any in app purchases

- The apps fell under the category 'education' and involved vocabulary;
- The apps were suitable for children just beginning to learn language;
- The apps had a rating of four or higher out of five stars; and
- Recommendations made by the speech therapists (discussed earlier).

Descriptions of the five vocabulary apps chosen for children with ASD to interact with

Taking the suggestions of the speech therapists into consideration as well as the criteria mentioned previously, five vocabulary apps were chosen. These five final apps chosen for the children with ASD to interact with are described next.

6.4.4.4.1 EDUKITTY ABC APP BY CUBIC FROG

The app developers of EduKitty ABC state that the children interacting with the app are guided through a colourful world of various games for tracing, spelling, letter identification, vocabulary building and much more. Children master both uppercase and lowercase letters and strengthen core cognitive reading skills (Bruner, 1996).

EduKitty ABC is a free app available in the Android Appstore and appears under the category education. This app is also available on the iTunes App store, Google Play, Amazon, Opera and Nook.

Features

The features of EduKitty ABC are:

- Three different sets of flashcards with voice commands for capital letters and lowercase letters;
- Tracing of letters for fine motor skills and handwriting practice, both uppercase and lowercase alphabets;
- 14 different games that teach children about letter recognition, handwriting, letter tracing, alphabetical order, letter memory, spelling, uppercase to lowercase matching, and fine motor skills;

- A sensory based learning system that utilises colourful graphics with touch and sound commands;
- Fine motor skill building using touch and drag play;
- An animated three-dimensional cat with colourful balloons that guides the children in the learning process;
- High definition colourful rainbow graphics;
- Music, voiceover and sound effects;
- Easy user-friendly settings page for parents to customise which game to switch on or off;
- Rewards system and animated flying gifts; and
- Unlimited play.

Flashcards

There are three different sets of flashcards. Each card can be tapped to reveal an object that starts with the same letter as on the flashcard.

The flashcards consist of:

- A complete set of uppercase flashcards;
- A complete set of lowercase flashcards; and
- A complete set with a combination of upper and lowercase flashcards.

Games

The EduKitty games are:

- Flying letters for letter identification – the correct letter had to be identified and caught based on a question prompt;
- Connect alphabet dots to teach alphabetical order in both upper and lowercase. The letters appear on the screen and the child has to connect them in alphabetical order to reveal an image;

- Letter memory with voice announcements for letter recognition and memorisation in both upper and lowercase. The child has to choose an alphabet card and hear its name and then remember the letter;
- Flashcards with voice announcements to build vocabulary in both upper and lowercase. The child can choose an alphabet card, hear the name and then memorise it;
- A spelling puzzle with voice announcements to help promote spelling and vocabulary building. The child has to drag the correct letter to the correct spot and then a voice spells the word for him or her; and
- Match uppercase letters with lowercase letters.

Settings

- There are three different skill levels with the highest level being the most challenging.
- Each activity can be turned on or off to customise the game according to preference.

Figure 6.3 provides screenshots of what the EduKitty ABC app looks like.

Figure 6-3 EduKitty ABC Screenshots

6.4.4.5 *Autism iHelp Play by John Talavera*

The Autism iHelp app is considered to be a vocabulary teaching aid that was developed by parents of a child with autism together with a speech-language pathologist. Inspiration for the creation and design of the Autism iHelp app originated from the need for a specific language intervention tool to help children with ASD focusing on their unique strengths and difficulty with expressive vocabulary (Talavera, 2013).

Talavera (2013) states that the Autism iHelp app is considered to be a vital tool for children with ASD when difficulty is experienced in expressing their first words.

Autism iHelp Play is a free app available on the Android Appstore and appears under the category education. This app is also available on the iTunes App store, Google Play and, Amazon.

Features

The Autism iHelp Play app consists of a number of features (Talavera, 2013):

- Colourful real-life photos ;
- Easy to label format;
- 24 real world photos – Talavera (2013) indicates that it has been proven that children with ASD have a better response to photos than to illustrations and are extremely visual learners;
- The 24 photos that were chosen were based on established expressive language milestones that are divided into three groups consisting of eight photos. The reason for this grouping is to prevent over-stimulation and result in improved capability to understand concepts at a satisfactory speed;
- Each photo has a label with the correct name. After each photo has been seen the learner, teacher, or parent have the option to show the photos again.
- Learning enhancement activities to help with retention of the learned vocabulary;

- Integrate visual and auditory memory;
- Utilises photos from toys, outdoor activities and arts and crafts that are often used in therapy or at school.

Games

The games available in Autism iHelp Play are used to enhance learning and involve:

- Matching a picture with a word – the words are presented in multiple choice format; and
- Choosing a word that goes with the picture where there are four different pictures to choose from.

Settings

- Labels of object names can be turned on or off.
- Each group can be replayed to aid repetition and drilling of words.
- Photos can be shown either randomly or in order.
- Audio voice can be in a male or female voice.
- Audio can be turned on or off.
- Track child's gains with a progress report of the last three activities.

Figure 6-4 through to Figure 6-6 provides screenshots of the various scenes presented in the vocabulary app Autism iHelp Play.

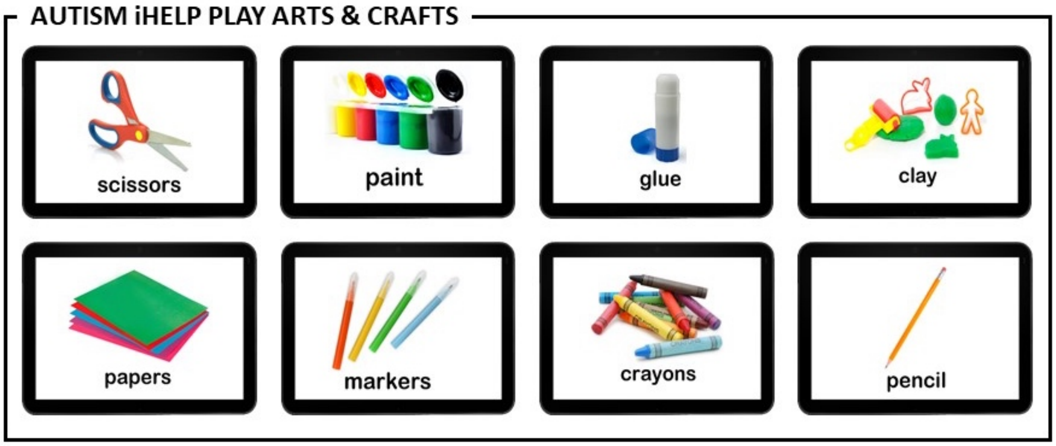


Figure 6-4 Arts and Crafts Autism iHelp Play

These photo images are directly related to the stationery used for arts and crafts and have a specific theme.

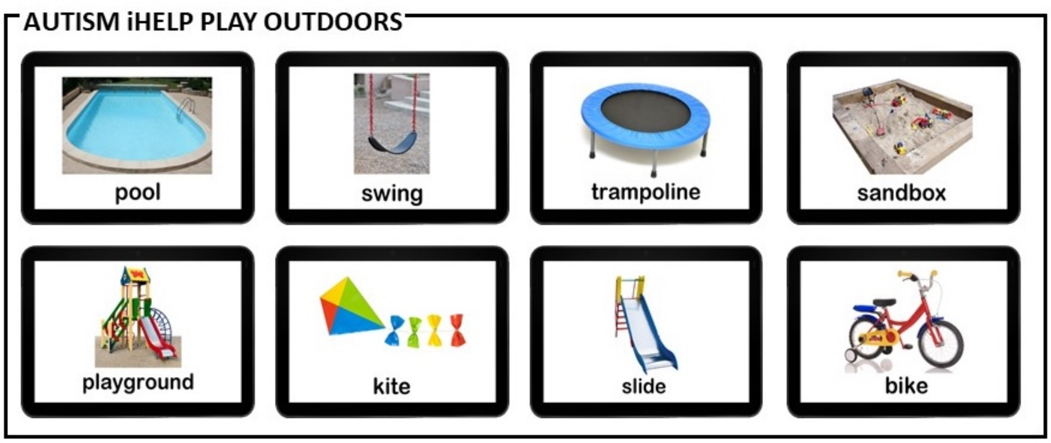


Figure 6-5 Outdoors Autism iHelp Play

The photo images used in this theme are related to the outdoors and the various objects used to play outside.

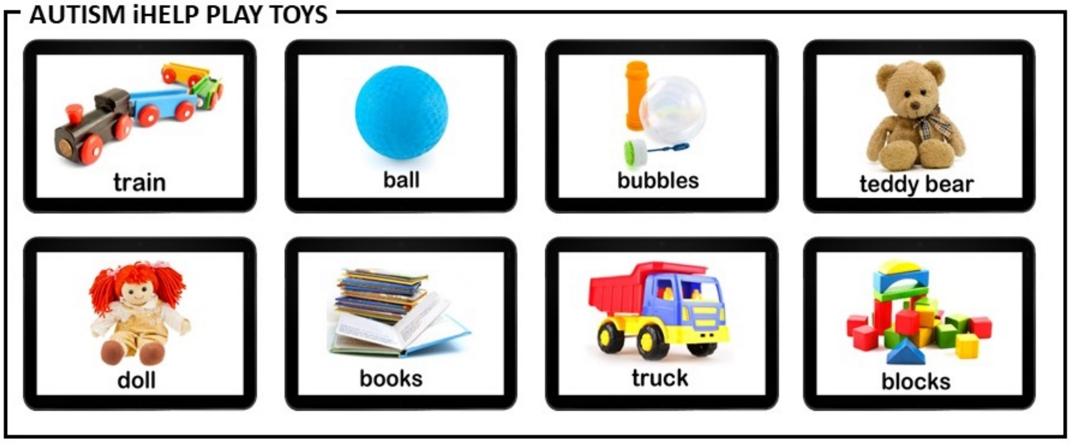


Figure 6-6 Toys Autism iHelp Play

These photo images make use of toys that most children spend time playing with and are related to the theme of toys.

6.4.4.6 *Laugh and Learn™ Learning Letters Puppy by Fisher-Price*

The Learning Letters Puppy app claims to be fun-filled with engaging animations, sing-alongs and sound effects (Price, 2015)

Learning Letters Puppy is a free app available on the Android Appstore and appears under the category education. This app is also available on the iTunes App store, Google Play and, Amazon.

Features

- Four different modes of play.
- The first mode is the ABC mode where the child has to touch the screen to proceed through the alphabet with each letter having its own animations. Once each letter of the alphabet has been viewed the alphabet song plays.
- The second mode is known as the '123 mode' whereby the child has to touch the screen to progress from one to ten. After the number ten the counting song is played.

- Mode three is shapes and colours where the child touched the screen to learn about shapes and colours through various animations.
- The final mode is the music mode. In this mode the child touches the screen and can sing and dance to four different songs.
- The device can be tilted to hear the puppy giggle.
- Teaches the alphabet and counting from one to ten, shapes and colours as well as for every action there is a reaction.

Figure 6-7 provides screenshots of the Learning Letter Puppy app of Fisher Price.

Figure 6-7 Learning Letters Puppy Screenshots

6.4.4.7 *Starfall ABCs by Starfall Education Foundation*

Starfall Education is a publicly supported non-profit organisation that developed the Starfall ABCs app. According to the Starfall website (Jacko & Sears, 2003) Starfall has been teaching phonics to children for more than a decade. This is achieved by following a systematic approach involving audio-visual interactivity for preschool, kindergarten, first grade, second grade, special education, home-school, and English language development. The children are motivated through exploration, positive reinforcement, and play.

Starfall ABCs is a free app available in the Android Appstore and appears under the category education. This app is also available in the iTunes App store, and Google Play.

Features

The features for Starfall ABC are as identified by the researcher as no detailed description could be found of the features:

- Alphabet blocks from the Letters A to Z that the child can choose from;
- A button to listen to a modernised version of the ABC song;
- A button for sign language signing the letters A to Z;
- Animated songs for all the vowels namely a, e, i, o and u;
- Twenty-six different games after each letter of the alphabet, that teach children about letter recognition of uppercase and lowercase letters. These games involve matching, sorting, arranging and fine motor skills;
- A sensory based learning experience that applies colourful graphics with touch and sound;
- Fine motor skill building using touch and drag to organise the upper and lowercase letters;
- Animated objects represent a specific letter of the alphabet for example ‘c for cat’ and ‘c for cow’;

- Once a specific letter of the alphabet is chosen the app progresses to five different sections of the same letter;
- The first section has the chosen letter in upper and lower case with a voice pronouncing the sound of the letter using phonics;
- The second section has the chosen alphabet letter in lowercase with an animated object that starts with that letter. Phonics are used when the letter is clicked on;
- The third section will also have an animated object that starts with the chosen letter of the alphabet in lowercase and can include a sentence. For example big brown bear;
- The fourth section similarly has the chosen alphabet letter in lowercase with a different object starting with the alphabet letter chosen;
- The final section has a game that either involves matching, sorting, or arranging the chosen alphabet letter;
- Sparkles, arrows and a hand guide the children in the learning process from one section to another;
- High definition colourful graphics and photos;
- Music, voiceover and sound effects; and
- Unlimited play – the child can click on the letter as many times he or she prefers to hear the phonics of the chosen letter and to see the animation again

Figure 6-8 provides the screenshots for Starfall letter A, and Figure 6-9 provides the screenshots for Starfall letter B.

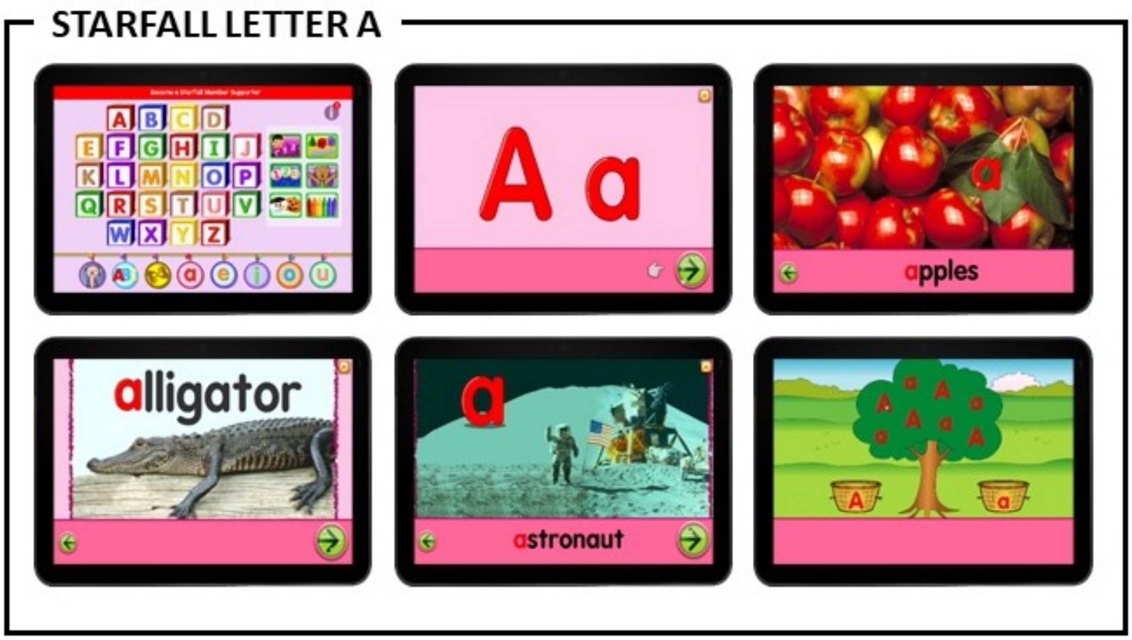


Figure 6-8 Starfall Letter A Screenshots

These images contain either photos or coloured drawings relating to the letter being taught in this case the letter ‘a’.

Figure 6-9 Starfall Letter B Screenshots

Photo images and coloured drawing of images representing or related to the letter “b”.

6.4.4.8 *Puzzingo by 77 Sparx Studio, Inc.*

The developers of the app Puzzingo point out that this app is an award-winning app that incorporates educational puzzles that are interactive, vocal and animated allowing for repeat plays. Furthermore, the developers claim that Puzzingo will promote vocabulary, memory and cognitive skills appealing to young children as well as children with special needs. Spatial recognition, matching, tactile and fine-motor skills will be developed. Professional illustrations are accompanied by the use of professional voice actors that pronounce the words clearly and accurately instead of machine generated speech. The different puzzles include core concepts such as shape, colours, numbers, food, and the alphabet. Additional themes are also available (Carroll, 2003).

The Puzzingo app received awards from the following (Carroll, 2003):

- Children's Technology Review for Excellence in Design – Editor's choice;
- Dr. Toys 10 Best Children's products
- Mom's Choice Awards Honoring Excellence
- Parent's Choice Recommended – Parent's Choice Foundation
- Editor's Favorite Appy – appysmarts.com
- 2014 NATIONAL Parenting Publications Awards Silver Winner
- iKids Finalist

Puzzingo is a free app available on the Android App store and appears under the category education. This app is also available in the iTunes App store, Google Play and, Amazon.

The data received from Priori Data

Features as described by the developers

- Highly interactive;
- Filled with animations;
- Many different sound effects;

- Every puzzle piece is named to help children learn vocabulary;
- Supports learning language;
- Builds vocabulary, spatial recognition, fine motor skills, memory and cognitive skills;
- Appeals to children with ASD, children with special needs, children in speech therapy;
- Visual and audio cues;
- Variety of fun mini games; and
- Eight free puzzles with over 100 vocabulary words and pieces.

Figure 6-10 provides screen shots of the Puzzingo app.

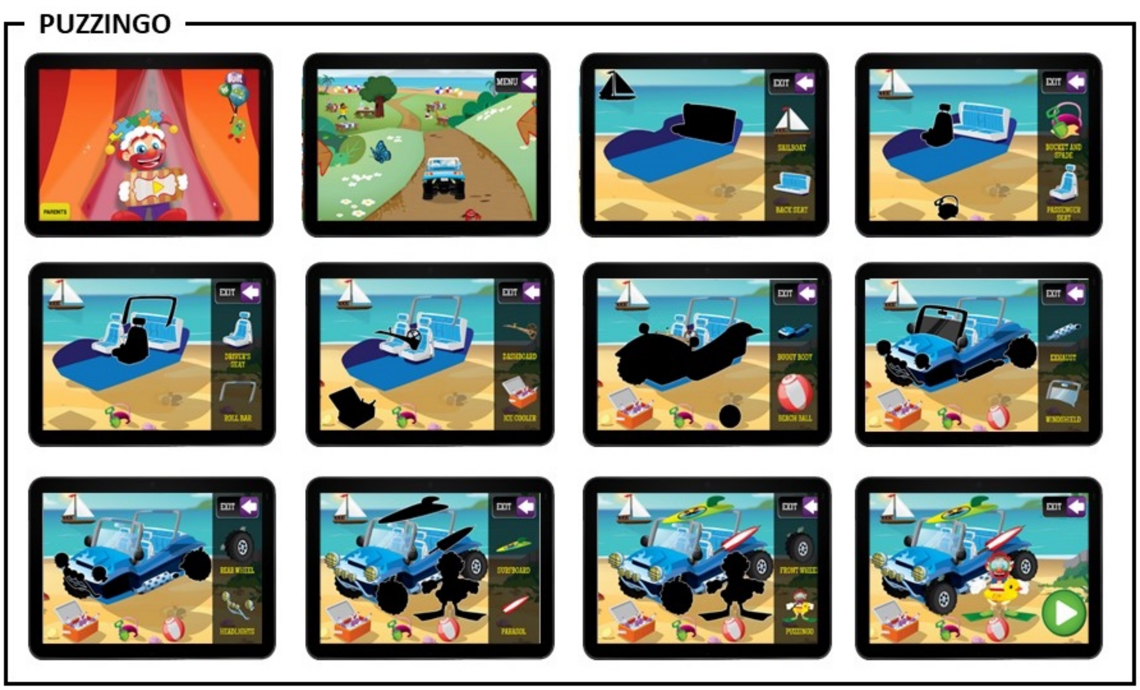


Figure 6-10 Puzzingo Screenshots

These five preliminary vocabulary apps were chosen so that the children with ASD were given the opportunity to inadvertently select the final three apps that would be researched resulting in a final effective artefact. This is described in the next phase, Phase Three.

6.4.5 *Phase Two Summary*

The design objectives were validated by the results of the interviews with the three speech therapists, which led to the creation of the initial artefact and the identification of the five preliminary vocabulary apps. These five vocabulary apps were used in the next phase – Phase Three - to determine which apps would be incorporated into the rest of the research. In addition, this assisted with the completion of an effective final artefact.

6.5 Concluding Comments

The identified problem, together with the design objectives to resolve the problem, were validated by the expert opinions of the speech therapists. With the creation of the initial artefact in Phase Two, the rest of the research commenced with rigour to ensure that the final artefact was effective and robust. This was accomplished by obtaining the expert opinion of an educational specialist regarding the educational value of the vocabulary apps incorporated in the study. Also, fundamental to the success of the artefact, the eye tracking results of the children with ASD interacting with the vocabulary apps were analysed. This resulted in the creation of an artefact that encompassed all the design objectives to successfully address the problem.

7 CHAPTER SEVEN - DSRM PHASE THREE AND FOUR - RESULTS AND FINDINGS

7.1 Focus of Chapter

With the valuable information provided by Phase One and Phase Two of the DSRM, the artefact was further improved upon by Phase Three and Phase Four. With the validation of the identified problem, design objectives were set in place to create an effective and robust artefact. The initial artefact was created which would be enhanced further with the expert opinion of an educational specialist resulting in the creation of the intermediate artefact.

Phase Three focussed exclusively on the design objectives related to education and memory as identified in Phase Two. The reason was that learning was not assessed in the children with ASD as this would be a lengthy process, not falling within the timeframe set out for this study. However, the educational value of the vocabulary apps, to ensure that effective early language learning does take place, was deemed of high importance.

Phase Four addressed the remaining design objectives. The eye tracking data of the children with ASD interacting with the final three vocabulary apps were analysed evolving the final effective and robust artefact.

7.2 DSRM Phase Three – Construct Artefact

In order to construct the artefact, the initial artefact had to be taken into consideration. The initial artefact had to be applicable and this was determined by obtaining the expert opinion of an educational specialist. The final three vocabulary apps inadvertently selected by the children with ASD were evaluated by the educational specialist to determine whether the artefact was applicable as displayed in Figure 7-1.

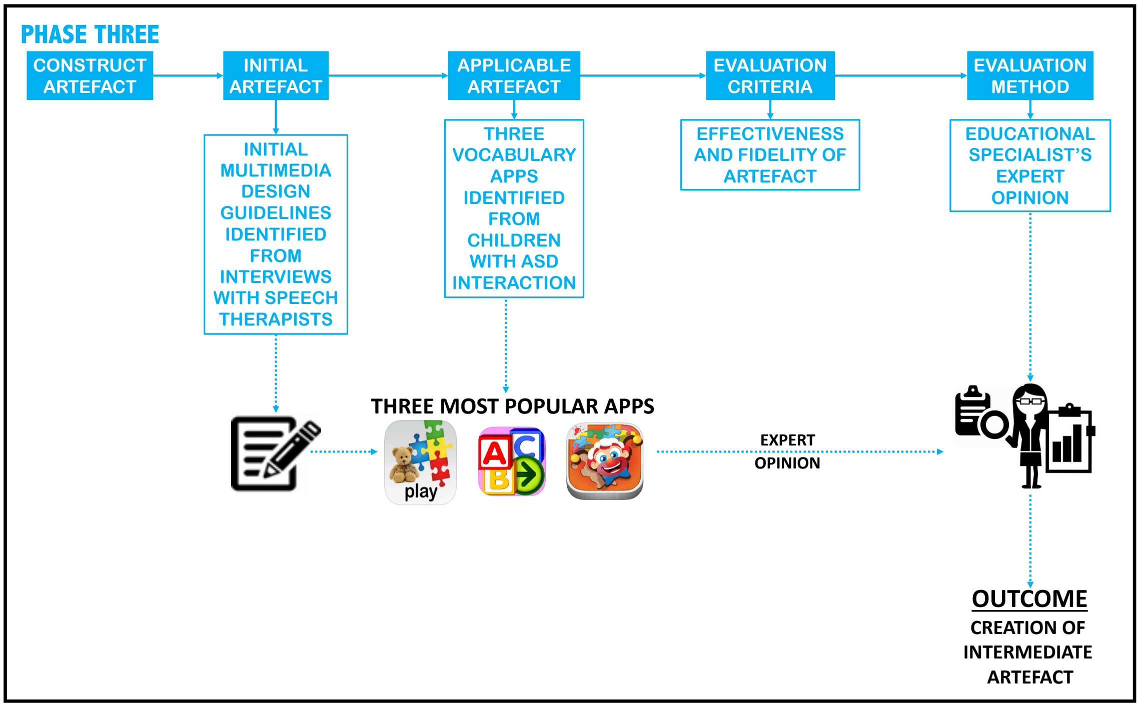


Figure 7-1 DSRM Phase Three

As observed in Figure 7-1 the initial artefact forms the starting point from which the rest of the undertakings for Phase Three occur.

7.2.1 *Phase Three - Initial Artefact*

The initial artefact helped determine the applicability of the artefact. The initial artefact was created in the previous phase – Phase Two (see Section 6.4.4.2).

The **Initial Multimedia Design Guidelines** were identified as follows:

Educational Lessons:

1. Various examples should be provided of the letter or word being taught;
2. The lessons should be short and incorporate specific themes; and
3. Specific routines should be implemented when teaching a letter or word.

Memory Activation:

1. A natural progression from easy to difficult must take place with the letters and words being taught to the child; and

2. The letter or word being taught must be presented in different contexts

Activities:

1. First teach the letter or word and then provide an opportunity to identify the letter or word;
2. Include opportunities for sentence building using the letter or word being taught;
3. Allow repetition of the letter or word being taught;
4. Incorporate a variety of games such as puzzles, matching, join the dots, writing the letter or word with finger; and
5. Provide opportunities for the child to associate the word with an object.

Sensory Stimuli

Tactile –

1. The letter or word must be articulated when the child touches the letter or word being taught
2. Consideration must be given to fine motor difficulties
3. Consideration must be given to touch with some children pressing hard and others very soft.

Visual –

1. A limited amount of animations must occur.
2. The animations must not distract the child's attention but rather focus the child's attention on the letter or word being taught.

Sounds –

1. The sound must not be noisy resulting in the child being over stimulated.
2. Letter and words being taught must include phonetical sounds.
3. Sounds should include positive reinforcement.
4. The sounds must be applied to direct the child's attention to the letter or word being taught.

Design –

1. Abstract images cannot be used in the design.
2. Photographs must be used initially then coloured drawing and lastly black and white drawings so that the association can be made that they are still the same object.
3. The word being taught must always be placed beneath the object related to it – this placement must always be consistent in the design.
4. The use of colours in the design must be limited.
5. Colour must be used to draw focus to the letter or word being taught and not distract from it.

With these initial multimedia design guidelines in place the applicability of the artefact was determined with the help of an educational expert.

7.2.2 *Phase Three - Applicable Artefact*

The identification of the final three apps used for the rest of the study took place in this phase. This was done in order to effectively develop the artefact.

In order to determine the final three vocabulary apps incorporated in the study, the interaction time of the children with ASD with each vocabulary app was recorded. The children were given the choice of which of the five vocabulary apps they preferred to interact with. These apps were applied in the study to contribute to the creation of the final artefact.

For this phase, fourteen children with ASD were given the opportunity to interact with the five preliminary vocabulary apps. These apps were uploaded onto a Samsung Tablet. The children's interaction times with the apps were recorded individually. A video recording of the 20-minute interaction time per child took place. Each child with ASD could choose which of the five vocabulary apps she or he preferred to interact with.

Once all fourteen with ASD completed the interaction with the vocabulary apps and the video recordings were completed, the video recordings were studied. The video recordings allowed for precise annotations to be made of the time each child with ASD spent interacting with his or her choice of vocabulary apps. The time spent per app was logged in a Microsoft Excel worksheet.

The exact time the children with ASD spent interacting with each vocabulary app, was logged in hours, minutes and seconds. The vocabulary apps that the children with ASD spent the most to the least time interacting with were as follows:

1. Starfall: 01:19:49
2. Puzzingo: 01:18:43
3. Fisher Price: 00:41:04
4. EduKitty: 00:40:36
5. Autism iHelp Play: 00:27:07

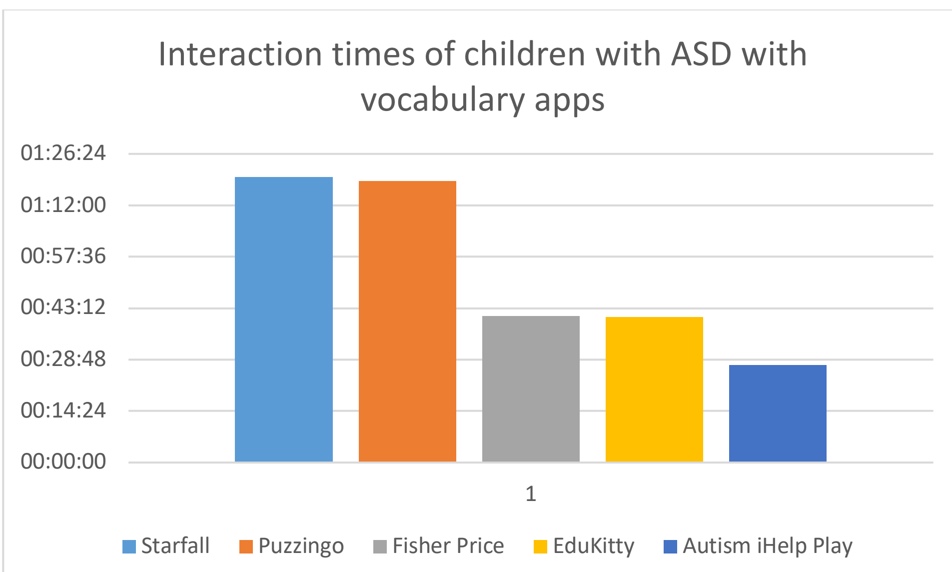


Figure 7-2 Interaction time per vocabulary app

Figure 7-2 provides a bar graph as visual representation of the total time the children with ASD spent interacting with each vocabulary app. Once all the information regarding the interaction time for each vocabulary app was presented a final decision was made regarding the apps that would be used for the rest of the research study. As evidenced the top three vocabulary apps that were most interacted with were:

1. Starfall,
2. Puzzingo and
3. Fisher Price.

However, the final three vocabulary apps that were chosen were:

1. Starfall,
2. Puzzingo and
3. Autism iHelp Play

Figure 7-3 shows the icons of the three final three vocabulary apps.

Figure 7-3 Final Three Vocabulary Apps

The reason behind choosing the Autism iHelp app even though it had the least interaction time of 27:07 minutes was because the app was specifically designed for children with ASD. Autism iHelp was purposely designed to develop vocabulary and assist language learning. A relatively large time gap of thirteen minutes and 29 seconds was apparent between the Autism iHelp Play app and the second last app - EduKitty. Although the Autism iHelp Play app had the least interaction time, this vocabulary app was considered beneficial to the research study to help create an effective final artefact. Greater insight was gained regarding features at play that promote early language learning in children with ASD.

The reason behind only choosing three vocabulary apps was related to the eye tracking that would take place in Phase Four of the DSRM. Changing from one vocabulary app to another while doing eye tracking can be stressful for children with ASD and the child could lose interest and starting fidgeting with the eye tracking equipment. This can result in insufficient eye tracking data being collected and for these reasons only three vocabulary apps were chosen.

The benefits of choosing only three vocabulary apps were:

- it would be less taxing on the children with ASD,
- it would keep the children with ASD focused and
- it would be easier to record the fixations of the children operating only three vocabulary apps.

The three final vocabulary apps would help determine the applicability, effectiveness and fidelity of the artefact through the expert opinion of an educational specialist discussed in the next section.

7.2.3 *Phase Three – Evaluation Criteria*

The effectiveness and fidelity of the artefact is imperative to successfully address the problem identified in Phase One and to effectively implement the design objectives of Phase Two. The effectiveness and fidelity of the artefact was determined by the evaluation of the final three apps by the educational specialist presented in the next section.

7.2.4 *Phase Three – Evaluation Method*

As mentioned, the expert opinion of an educational specialist was attained to determine the educational value of the three final vocabulary apps. This took place by means of checklists (see Appendix F) that were completed by the educational specialist for each of the apps.

The educational checklist was created by identifying the unique features of each learning theory incorporated into the conceptual framework (Chapter 5). The conceptual framework comprises various theories involved in learning across different fields from special education to technology. The theories included in the conceptual framework were: Oelwein's model (special education), Cognitive Theory of Multimedia Learning, Bruner's learning stages, and Human Computer Interaction. Through careful examination of each of the learning theories their distinguishing features were identified. These distinguishing features were converted into dichotomous questions to design the checklists.

The identification of the educational features presented in each of the vocabulary apps was achieved by linking the checklists to the specific features of each of the learning theories of the conceptual framework (Chapter 5). Dichotomous questions with either a yes or no answer were incorporated identifying educational features present in each of the vocabulary apps.

The evaluation results of the educational specialist were as follows:

7.2.4.1 *Oelwein's Methodology Evaluation*

The four stages of Oelwein's methodology include the acquisition stage where the child starts recognising a word. This is followed by the fluency stage where the word is recognised more often with more consistency. The next stage is the transfer stage, where the word is recognised in different font styles and in different contexts. The final stage is the generalisation stage when the word is recognised in any context (Broun, 2004). See Section 5.4 for a more detailed description.

<u>Oelwein's Methodology</u>

App: Autism iHelp Play

The following features for Oelwein's methodology were identified:

Acquisition Phase:

- Helps child to recognise words.
- Does not allow matching of spoken word to printed word.
- Allows the child to select the word.
- Allows the child to say the word.

Fluency Phase: the app helps a child to recognise a word with some degree of consistency.

Transfer Phase:

- Does not display the specific word on different surfaces.
- Does display the specific word in different contexts.
- Does not display the specific word in different fonts.

Generalisation Phase: The app does allow the child to identify the word in different contexts.

App: Puzzingo

Acquisition Phase:

- Helps child to recognise words.
- Does not allow matching of spoken word to printed word.
- Does not allow child to select the word.
- Allows the child to say the word.

Fluency Phase: The app helps a child to recognise a word with some degree of consistency.

Transfer Phase:

- Does not display the specific word on different surfaces.
- Does not display the specific word in different contexts.
- Does not display the specific word in different fonts.

Generalisation Phase: The app does not allow the child to identify the word in different contexts.

App: Starfall ABC

Acquisition Phase:

- Helps child to recognise words.
- Does not allow matching of spoken word to the printed word.

- Allows the child to select the word.
- Allows the child to say the word.
- Allows the child to say or sign the word.

Fluency Phase: The app helps a child to recognise a word with some degree of consistency.

Transfer Phase:

- Does not display the specific word on different surfaces.
- Displays the specific word in different contexts.
- Does not display the specific word in different fonts.

Generalisation Phase: The app allows the child to identify the word in different contexts.

The results of all three vocabulary apps' evaluation for Oelwein's methodology according to the educational specialist are displayed in Table 7.1.

Table 7-1 Evaluation of Oelwein's Methodology in Vocabulary Apps

Oelwein's Methodology	Autism iHelp Play		Puzzingo		Starfall ABC	
	Yes	No	Yes	No	Yes	No
Acquisition: does the app help the learner to recognise words?	X		X		X	
Does the app allow the child to match a spoken word to a printed word?		X		X		X
Does the app allow the child to select the word?	X			X	X	
Does the app allow the child to say or sign the word?	X		X		X	
Fluency: does the app help the child recognise a specific word with some degree of consistency?	X		X		X	
Transfer: does the app display the specific word on different surfaces?		X		X		X
Does the app display the specific word in different contexts?	X			X	X	
Does the app display the specific word in different fonts?		X		X		X
Generalisation: does the app help the child recognise the word in different contexts?	X			X	X	

The Autism iHelp Play incorporated three of the four features for the acquisition phase: letter and word recognition; word and letter selection and saying or signing the word or letter. For the fluency phase opportunity was provided for letter or word recognition; and one for the transfer stage the letter or word was presented in different contexts. The feature for the generalisation phase was also identified, recognising the letter or word in different contexts. In total six features were present in this app.

The Puzzingo app met two of the four features for the acquisition phase: letter and word recognition and allowing opportunities to say or sign the word or letter. One feature for the fluency phase for letter or word recognition was supported but no features were identified for the transfer and generalisation phases. In total only three features were identified out of the nine for this app.

Three features for the acquisition phase were identified for Starfall ABC. The child was presented the opportunity to identify (recognise) and select a word or letter. The fluency phase presented the word or letter with some degree of consistency. For the transfer stage, only one out of the three requirements were met namely displaying a specific word in different contexts. The generalisation stage feature whereby the child could identify the letter or word in different contexts was also identified in this app. A total of six features out of nine were present in this app.

7.2.4.2 *Cognitive Theory of Learning with Media Evaluation*

The Cognitive Theory of Learning with Media (CTLM) is made up of verbal explanations and non-verbal information involving sensory memory. Various information sources presented in a lesson are given the necessary attention with the help of working memory. Decisions are made about how to link the received information to long-term memory (Moreno, 2009). This theory is discussed in detail in Section 4.3.

App: Autism iHelp Play

The CTLM evaluation results of the educational specialist in Table 7-2 are as follows for the Autism iHelp Play app:

Table 7-2 Autism iHelp Play Evaluation incorporating CTML

Cognitive Theory of Multimedia Learning	YES	NO
Sensory Memory Auditory: Is there narration?	X	
Sensory Memory Auditory: Are there sounds?		X
Sensory Memory Auditory: Is there music?		X
Sensory Memory Visual: Is there text?	X	
Sensory Memory Visual: Are there animations?		X
Sensory Memory Visual: Are there graphics?	X	
Sensory Memory Tactile: Are there manipulatives?		X
Working Memory: Does the app have selecting activities?	X	
Working Memory: Does the app have connecting activities?		X
Working Memory: Does the app have organising activities?		X
Long-Term Memory: Does the app integrate what was learnt into activities?	X	
Long-Term Memory: Does the app retrieve previous lessons/activities in present lesson/activities?	X	

Discerning the results of the evaluation of the educational specialist, sensory memory is activated through narration. However, working memory is partially integrated into the activities for Autism iHelp through activities involving selection. However, no connecting or organising activities occur. Integration of what was learnt took place activating long term memory whereby previous lessons and activities influenced present activities.

App: Puzzingo

The evaluation results for the Puzzingo App are provided in Table 7-3.

Table 7-3 Puzzingo Evaluation incorporating CTML

Cognitive Theory of Multimedia Learning	YES	NO
Sensory Memory Auditory: Is there narration?	X	
Sensory Memory Auditory: Are there sounds?	X	
Sensory Memory Auditory: Is there music?	X	
Sensory Memory Visual: Is there text?	X	

Sensory Memory Visual: Are there animations?	X	
Sensory Memory Visual: Are there graphics?	X	
Sensory Memory Tactile: Are there manipulatives?	X	
Working Memory: Does the app have selecting activities?	X	
Working Memory: Does the app have connecting activities?	X	
Working Memory: Does the app have organising activities?	X	
Long-Term Memory: Does the app integrate what was learnt into activities?		X
Long-Term Memory: Does the app retrieve previous lessons/activities in present lesson/activities?		X

As can be seen from Table 7-3, the educational specialist's evaluation shows full utilisation of sensory memory took place. Working memory was applied to its full capacity by matching objects to their specific shapes. Selecting and organising of objects occurred. Long term memory was not activated for Puzzingo.

App: Starfall ABC

In Table 7-4 the results of the evaluation for Starfall ABC are presented.

Table 7-4 Starfall ABC Evaluation incorporating CTML

Cognitive Theory of Multimedia Learning	YES	NO
Sensory Memory Auditory: Is there narration?	X	
Sensory Memory Auditory: Are there sounds?	X	
Sensory Memory Auditory: Is there music?	X	
Sensory Memory Visual: Is there text?	X	
Sensory Memory Visual: Are there animations?	X	
Sensory Memory Visual: Are there graphics?	X	
Sensory Memory Tactile: Are there manipulatives?	X	
Working Memory: Does the app have selecting activities?	X	
Working Memory: Does the app have connecting activities?	X	
Working Memory: Does the app have organising activities?	X	
Long-Term Memory: Does the app integrate what was learnt into activities?	X	
Long-Term Memory: Does the app retrieve previous lessons/activities in present lesson/activities?	X	

The Starfall app, according to the evaluation made by the educational specialist, utilised sensory memory wholly, incorporating narration, sounds, music, text, animations, graphics and manipulatives. Working memory was also expended to its full capacity with various activities namely selecting, connecting and organising. Long-term memory was applied to its fullest by integrating what was learnt into present activities resulting in the retrieval of past information to complete present activities presented in the Starfall app.

7.2.4.3 *Bruner's Learning Stages Evaluation*

Bruner's learning stages involve three different stages of learning. The enactive stage takes place through enactive manipulation. The iconic stage is where mental images are made of objects that were manipulated in the first stage. The final symbolic stage incorporates abstract symbols developing critical thinking (Smidt, 2011). A detailed discussion of Bruner's Learning Stages can be found in Section 5.5.

App: Autism iHelp Play

The results of the education specialist are presented in Table 7-5.

Table 7-5 Autism iHelp Play Evaluation for Bruner's stages

Bruner's Learning Stages	YES	NO
Enactive Stage Does the app allow manipulation of objects i.e. learn through play?	X	
Iconic Stage Does the app have activities utilising the learner's memory to identify objects?	X	
Symbolic Stage Does the app use symbols or symbolic systems resulting in the learner making judgements, evaluations and learning to think critically?		X

Two of the three stages of Bruner's Learning Stages were incorporated in the Autism iHelp Play app. The children learnt through play with games that utilised memory to identify the objects taught. However, the app does not incorporate symbols at any stage prompting abstract or critical thinking.

App: Puzzingo

Table 7-6 provides the evaluation results of Puzzingo.

Table 7-6 Puzzingo Evaluation for Bruner's stages

Bruner's Learning Stages	YES	NO
Enactive Stage: Does the app allow manipulation of objects i.e. learn through play?	X	
Iconic Stage: Does the app have activities utilising the learner's memory to identify objects?	X	
Symbolic Stage: Does the app use symbols or symbolic systems resulting in the learner making judgements, evaluations and learning to think critically?		X

The evaluation of the educational specialist indicated that Puzzingo integrated the enactive and iconic stages of learning but the symbolic stage was not incorporated.

App: Starfall ABC

In Table 7-7 the evaluation results of Starfall ABC are presented.

Table 7-7 Starfall ABC Evaluation for Bruner's stages

Bruner's Learning Stages	**YES**	**NO**
Enactive Stage: Does the app allow manipulation of objects i.e. learn through play?	X	
Iconic Stage: Does the app have activities utilising the learner's memory to identify objects?	X	
Symbolic Stage: Does the app use symbols or symbolic systems resulting in the learner making judgements, evaluations and to think critically?	X	

Similar to the previous two vocabulary apps, the enactive and iconic stages are both applied in Starfall, while the symbolic stage was presented in this app which was not the case for the other two vocabulary apps. Learning through play and memory activation occurred resulting in critical thinking that involved making judgements and evaluations in the activities and games offered by the app.

7.2.4.4 *Educational Specialist evaluation for HCI*

Human Computer Interaction involves various interactions that take place in order to process information while engaging with technology. Specific processors are involved namely perceptual, cognitive and motor processors. For a complete discussion see Section 5.6.

App: Autism iHelp Play

The evaluation results of the educational specialist are provided in Table 7-8.

Table 7-8 Autism iHelp Play Evaluation for HCI

Model Human Processor (HCI)	YES	NO
Perceptual processor: **Is there visual stimulus?**	X	
Perceptual processor: **Is there auditory stimulus?**	X	
Motor Processor: **Is there tactile stimulus?**	X	
Cognitive Processor: **Does the app initiate actions?**	X	
Motor Processor: **Do the activities include various movements i.e. tapping, swiping, and poking?**	X	
Cognitive Processor: **Does the app help the learner to identify objects?**	X	
Cognitive Processor: **Does the app allow the learner to explore?**		X
Cognitive Processor: **Does the app allow for decisions to be made utilising prior knowledge?**	X	
Motor Processor: Do actions follow decisions made within the app?	X	

Visual, auditory, and tactile stimuli occurred incorporating the perceptual and motor processors. Actions were initiated involving various activities to help the child identify objects and make decisions through cognitive processing. The motor processor was engaged in Autism iHelp through action and reaction responses.

App: Puzzingo

In Table 7-9 the results of the evaluation made by the educational specialist are provided.

Table 7-9 Puzzingo Evaluation for HCI

Model Human Processor (HCI)	YES	NO
Perceptual processor: **Is there visual stimulus?**	X	
Perceptual processor: **Is there auditory stimulus?**	X	
Motor Processor: **Is there tactile stimulus?**	X	
Cognitive Processor: **Does the app initiate actions?**	X	
Motor Processor: **Do the activities include various movements i.e. tapping, swiping, and poking?**	X	
Cognitive Processor: **Does the app help the learner to identify objects?**	X	
Cognitive Processor: **Does the app allow the learner to explore?**		X
Cognitive Processor: **Does the app allow for decisions to be made utilising prior knowledge?**		X
Motor Processor: **Do actions follow decisions made within the app?**	X	

The perceptual and motor processors were fully utilised in the Puzzingo app. However, the cognitive processor was applied in a limited capacity, not allowing for exploration or decision making by the child involving prior knowledge.

App: Starfall ABC

The results of the educational specialist relating to HCI for Starfall ABC are provided in Table 7-10.

Table 7-10 Starfall ABC Evaluation for HCI

Model Human Processor (HCI)	YES	NO
Perceptual processor: **Is there visual stimulus?**	X	
Perceptual processor: **Is there auditory stimulus?**	X	
Motor Processor: **Is there tactile stimulus?**	X	
Cognitive Processor: **Does the app initiate actions?**	X	
Motor Processor: **Do the activities include various movements i.e. tapping, swiping, and poking?**	X	
Cognitive Processor: **Does the app help the learner to identify objects?**	X	
Cognitive Processor: **Does the app allow the learner to explore?**	X	
Cognitive Processor: **Does the app allow for decisions to be made utilising prior knowledge?**	X	
Motor Processor: **Do actions follow decisions made within the app?**	X	

For Starfall ABC the perceptual processor was completely integrated by including visual and auditory stimuli in the app. Actions were initiated, objects were identified, the child was provided the opportunity to explore different letters of the alphabet and decisions were made merging previous knowledge with present knowledge, actuating the cognitive processor. The motor processor was initiated through tactile stimuli including tapping, swiping and dragging actions producing an action-reaction effect.

7.2.4.5 *Findings of Educational Evaluation of Vocabulary Apps*

Taking the results of the evaluations into consideration, greater insight was gained regarding the educational value or effectiveness of each of the vocabulary apps. This insight helped to identify educational features that were matched to the design objectives presented in Phase Two.

From the results of the evaluation it appears that the Starfall ABC app met most of the requirements of the four different learning theories presented in the conceptual framework.

Figure 7-4 displays the number of features identified relating to Oelwein's methodology for each of the vocabulary apps. Each feature present in an app was represented with the app's icon. For example, if the Autism iHelp Play app had six features for Oelwein's methodology then six Autism iHelp Play icons were awarded.

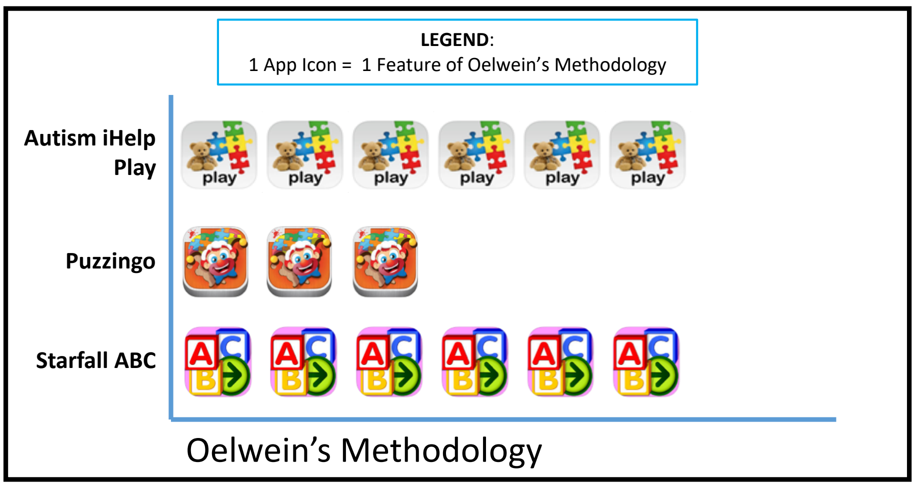


Figure 7-4 Oelwein's features per vocabulary app

Both Autism iHelp Play and Starfall ABC presented six features of Oelwein's Methodology while Puzzingo only presented three features. The next figure, Figure 7-5, illustrates the results of the features identified in each of the vocabulary apps for the learning theory CTML.

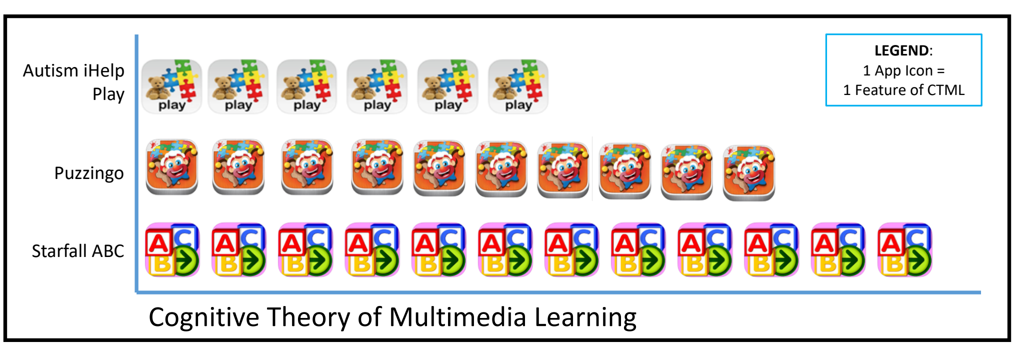


Figure 7-5 CTML features per vocabulary app

For the CTML theory, the Starfall ABC app met all the requirements for sensory, working and long-term memory thereby including all twelve features relevant to this theory.

The Autism iHelp Play app met six of the twelve requirements, not meeting the all the requirements of sensory and working memory activation.

The Puzzingo app met ten of the twelve requirements but exhibited inadequate utilisation of long term memory by not demonstrating features involving integrating and retrieving information.

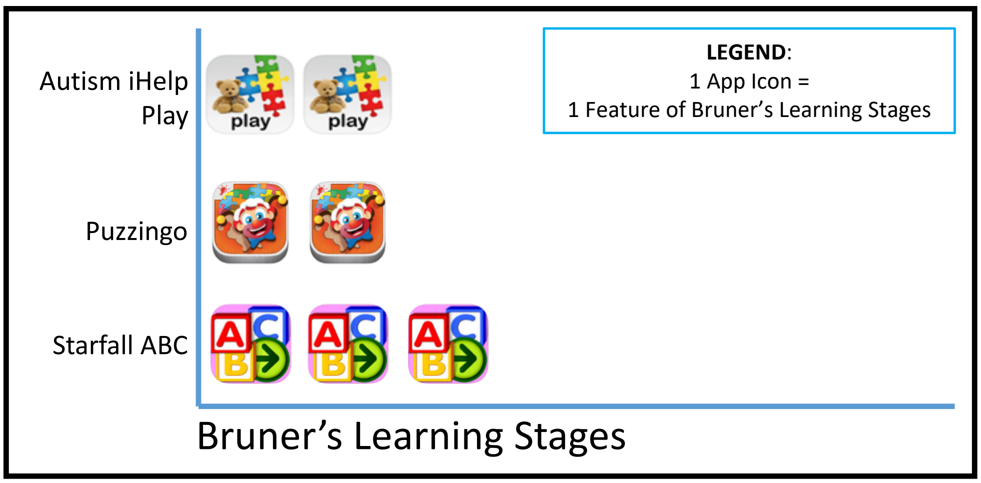


Figure 7-6 Bruner's Learning Stages features per vocabulary app

Figure 7-6 exhibits the results of the features identified for the vocabulary apps concerning Bruner's learning stages. The results of Bruner's learning stages indicated that all three stages – enactive, iconic, and symbolic - were present for the Starfall ABC app. This demonstrated that Starfall ABC allowed learning to take place through play, activating the different memories to identify objects and allowing the child to make judgements, evaluations and incorporate critical thinking.

However, this was not the case for the Autism iHelp and Puzzingo Apps. Both these apps did not incorporate the symbolic stage where judgements, evaluations and critical thinking took place. Only two of the three features were identified in each of these vocabulary apps, namely the enactive and iconic stages, permitting learning through play and memory utilisation.

Next, the features identified in the vocabulary apps for Human Computer Interaction are displayed in Figure 7-7.

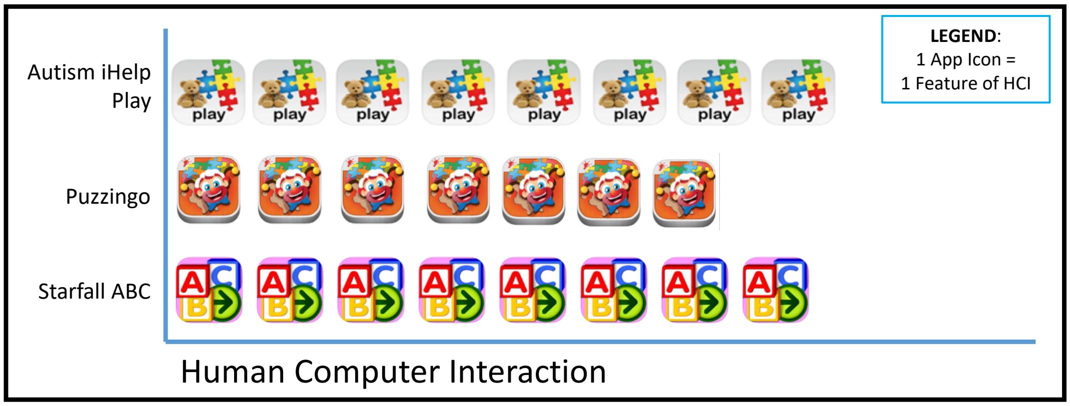


Figure 7-7 HCI features per vocabulary app

For the HCI learning theory, the Starfall ABC app demonstrated all nine features presented in the app. The Autism iHelp Play app included eight of the nine features for HCI, not allowing for exploration. Seven of the nine features of HCI were met by the Puzzingo app. Puzzingo did not allow for any exploration or decision making incorporating previous knowledge to take place.

The app exhibiting the highest educational value according to the results from the data provided by the educational specialist, was Starfall ABC. The learning theories presented in Starfall ABC were linked to the design objectives relating to educational value and memory identified in Phase Two as presented in Table 7-11. The purpose was to prove the effectiveness and fidelity of the artefact.

Table 7-11 App features relevant to artefact

DESIGN OBJECTIVES	VOCABULARY APPS EDUCATIONAL FEATURES
Educational value	• Helps the child to recognise words • Allows the child to select the word • Allows the child to say the word • Allows the child to sign the word (sign language) • Helps a child to recognise a word with consistency • Displays the specific word in different contexts • Learn through play • Association between word and object • Object identification relating to words being taught
Emphasis on letters and words being taught	• Narration of the letter or word being taught • Sounds and music related to letter or word being taught • Animated letter or words were displayed • Letters and words were pronounced when touched • Actions initiated after tactile stimulus
Activate sensory, working and long-term memory	• Activities include selecting, connecting, matching and organising • Letters and words that were previously taught were incorporated into present activities • Identifying objects by their names • Decision-making involving prior knowledge

The expert opinion of the educational specialist proved the effectiveness and fidelity of the artefact. This was achieved by the iteration of the initial multimedia design guidelines plus identifying additional guidelines. Furthermore, the artefact was improved upon (indicated in blue) with the identification of additional multimedia design guidelines relating specifically to the educational and memory aspects of the design objectives as seen in Table 7-12.

Table 7-12 Intermediate Artefact

DESIGN OBJECTIVES	INITIAL ARTEFACT	INTERMEDIATE ARTEFACT
Educational value	1. Provide various examples of the letter or word being taught 2. Incorporate short lessons with themes 3. Follow a specific routine when teaching a letter or word	4. Provide guidance helping the child recognise letters or words 5. Provide opportunities for the child to select and say the letter or word 6. Allow opportunities for the child to sign the letter or word (sign language) 7. Present the letter or word in a repetitive and consistent manner 8. Display the letter or word in different contexts 9. Allow associations to be made between words and objects
Emphasis on letters and words being taught	1. First teach a letter or word and then let the child with ASD identify the letter or word 2. Include opportunities for sentence building 3. Include repetition 4. Include a variety of games such as puzzles, matching, join the dots, writing the letter or word with fingers 5. Allow association of word and object	6. Provide narration of the letter or word being taught 7. Include animated letter or words in the activities 8. Ensure that the letters and words are pronounced when touched 9. Actions relating to the letter or word must take place when the letter or word is tapped on (tactile stimulus).
Activate sensory, working and long-term memory	1. Action and reaction relating to the letter or word being taught 2. Incorporate sensitivity to touch 3. Accommodate fine motor difficulties	4. Include selecting, connecting, matching and organising 5. Incorporate letter and word previously taught into present activities 6. Include activities where the object is identified by its name 7. Allow decision making activities involving what was the letters and words that were taught.

The creation of the intermediate artefact provided greater insight into the educational aspects which activate the different memories with activities that place emphasis on the letters and words being taught. The rest of the design objectives of Phase Two were studied further in Phase Four which led to the creation of the final artefact.

7.2.5 *Phase Three Summary*

The purpose of this phase was to firstly identify the final three vocabulary apps that would be used for the rest of the research study. The final three vocabulary apps identified were Starfall, Puzzingo and Autism iHelp Play, of which Starfall ABC demonstrated the highest educational value. These three vocabulary apps were evaluated by an educational specialist to determine the educational value. The results proved the applicability, effectiveness and fidelity of the initial artefact. The initial artefact was improved upon by identifying additional multimedia design guidelines from the data resulting in the creation of the intermediate artefact.

The intermediate artefact was further improved in Phase Four discussed next.

7.3 DSRM Phase Four – Use Artefact

This phase required that the artefact be put to use. As mentioned in the previous chapter, the artefact was used in a distinctive manner. For this phase, the children with ASD were given a second opportunity to interact with the three chosen vocabulary apps. Eye tracking was incorporated to determine the number of fixations on letters, words and objects for each of the three chosen vocabulary apps. In addition, the vocabulary app that prompted the highest number of fixations on letters and words was identified and contributed to the creation of an effective final artefact. This specific vocabulary app was used to identify further multimedia design guidelines through checklists used to identify multimedia learning principles and graphic design elements and principles. Figure 7-8 provides detail of this phase.

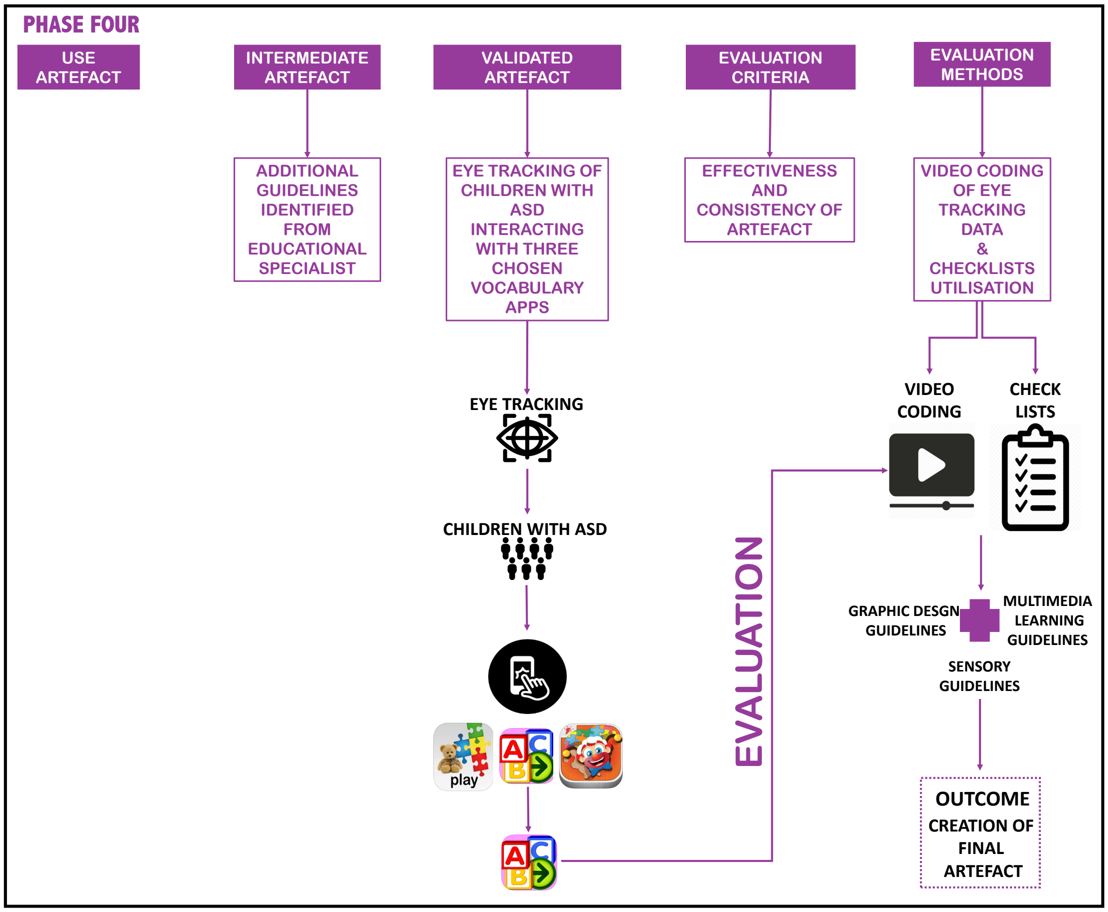


Figure 7-8 DSRM Phase Four

This final phase of the DSRM contributes to the creation of an effective and robust final artefact. The various measures appropriated in this phase ensured that the design objectives were met.

The design and development of the eye tracking method ensured that the eye tracking activities took place inconspicuously. The eye tracking activity was planned by the eye tracking specialist and the researcher as mentioned in the Methodology chapter (Section 6.8.2.4). The eye tracking equipment used was the Tobii X3-120 eye tracker. The software used was Tobii's eye tracking software and ELAN for the video coding.

The decision was made by the eye tracking specialist that each child would be given approximately five minutes interaction time per vocabulary app. The method followed was as follows: each child with ASD would first start interacting with the Autism iHelp Play app. Once they finished their interaction with the Autism iHelp Play app the next app Puzzingo was uploaded, the last app to be interacted with was Starfall ABC. Each of these vocabulary apps were launched by the eye tracking specialist when deemed appropriate.

Before any eye tracking could take place, the children's eye movements had to be synced with the Tobii eye tracker. A picture of a bunny was used to sync each child's eye movement to the eye tracker. The reason for choosing a bunny was that the bunny would hopefully be interesting and keep the child's attention long enough for the syncing to take place. The bunny moved to different parts of the screen starting at the lower left corner, then the upper left corner, then the upper right corner followed by the lower right corner and ending in the centre of the screen. The child with ASD had to follow the bunny's movement with his or her eyes so that the eye tracker would sync with their eyes. This was done so that the fixations of each child could be captured correctly. However, the challenge anticipated was that not all the children with ASD would be interested in the bunny or would look at the bunny long enough for the syncing to take place. This problem was overcome by the eye tracking specialist who would sync the eye tracking equipment with her eyes whenever such difficulties arose. This was achieved by the eye tracking specialist lining up her eyes on the same level as the eyes of the child with ASD, for the eye tracker. When the eye tracker was synced the child with ASD would take the eye tracking specialist's place in front of the eye tracker.

Because the vocabulary apps were dynamic and not static images, including animation and movement within the design, the number of fixations had to be noted manually. Tobii software only computes fixations on static images such as websites with advertisements and text.

Video Coding

Video recordings of the fixation points were made by Tobii's software. The video recordings from Tobii were imported to ELAN, where each individual fixation on either the object, word or letter was annotated. The only vocabulary app that taught letters specifically was the Starfall ABC app.

The number of fixations per letter, word and object were annotated and counted making use of video coding with the help of ELAN software as mentioned earlier. A tier for the annotation of object fixations was created, as well as a tier for the number of fixations on letters and a tier for the fixations on words. ELAN calculated the number of instances that occurred per tier, in this study the number of fixations identified through video coding. Once all the data of each app was captured, the data was exported to Excel and converted into bar graphs for greater clarity.

Design Quality Identification Methods

Not all the eye tracking data of the children with ASD that interacted with the vocabulary apps could be used. The eye tracking data from the children with ASD that had a 50% or higher gaze percentage were accepted for further analysis.

Validity and reliability of the video coding were achieved by comparing the number of fixations annotated by two independent coders. The independent coders were provided with training regarding ELAN and how-to code. The coders were then given the opportunity to note the number of fixations on each letter, word and object and their individual results were compared. Differences were discussed and sorted out and another coding session took place. Once similar coding results were achieved among the coders, validity and reliability were considered to be of a high level.

7.3.1 *Phase Four – Intermediate Artefact*

The awareness created by the speech therapists assisted with the creation of the initial artefact. Together with the expert opinion of the educational specialist the intermediate artefact was created. The final three vocabulary apps utilised in the study were elected and evaluated to determine their educational value. The result was the creation of the intermediate artefact is as follows:

EDUCATIONAL VALUE:

- Provide various examples of the letter or word being taught'
- Incorporate short lessons with themes;
- Follow a specific routine when teaching a letter or word;
- Provide guidance helping the child to recognise letters or words;
- Provide opportunities for the child to select and say the letter or word;
- Allow opportunities for the child to sign the letter or word (sign language);
- Present the letter or word in a repetitive and consistent manner;
- Display the letter or word in different contexts; and
- Allow associations to be made between words and objects.

EMPHASIS ON LETTERS AND WORDS BEING TAUGHT:

- First teach a letter or word and then let the child with ASD identify the letter or word;
- Include opportunities for sentence building;
- Include repetition;
- Include a variety of games such as puzzles, matching, join the dots, writing the letter or word with fingers;
- Allow association of word and object. Provide narration of the letter or word being taught;
- Include animated letter or words in the activities;
- Ensure that the letters and words are pronounced when touched; and
- Actions relating to the letter or word must take place when the letter or word is tapped on (tactile stimulus).

ACTIVATE SENSORY, WORKING AND LONG-TERM MEMORY:

- Action and reaction relating to the letter or word being taught ;
- Incorporate sensitivity to touch;

- Accommodate fine motor difficulties Include selecting, connecting, matching and organising;
- Incorporate letter and word previously taught into present activities;
- Include activities where the object is identified by its name; and
- Allow decision making activities involving what the letters and words that were taught were.

These identified multimedia design guidelines specific to the educational aspects of the vocabulary apps were incorporated into the final artefact. The other design objectives were determined by eye tracking, video coding and checklists.

7.3.2 *Phase Four – Validated Artefact*

For this section of Phase Four eye tracking was incorporated to validate the artefact. The eye tracking data provided useful information about where exactly the fixations occurred as the children with ASD interacted with the three vocabulary apps. Fixations on letters and words were documented and on other visual elements or objects as well by means of video coding. Checklists were incorporated to identify multimedia design guidelines to further validate the artefact.

The interaction of the children with ASD with the three vocabulary apps facilitated the identification of the app that induced the highest number of fixations on letters and words compared to objects. This vocabulary apps were further thoroughly analysed and examined to validate the artefact.

7.3.3 *Phase Four – Evaluation Criteria*

The evaluation criteria for this phase was to ensure that the final artefact was effective and consistent. This was achieved by further developing the identified multimedia design guidelines identified in Phase Two and Phase Three. The initial artefact of Phase Two was improved upon in Phase Three resulting in an intermediate artefact. The identified guidelines of Phase Four led to the creation of the final artefact that was robust and, effective with a high level of fidelity that would successfully address the identified problem of Phase One.

7.3.4 *Phase Four – Evaluation Methods*

In order the produce the final validated artefact that was effective and consistent, various evaluation methods were administered. The first method included eye tracking of the children with ASD as they interacted with the selected vocabulary apps. This was done to determine the number of fixations on letters and words compared to objects in order to identify the most effective vocabulary app for early language learning. In addition, checklists were utilised to identify graphic design, multimedia learning and sensory guidelines. These methods are discussed in the sections to follow.

7.3.4.1 *Fixations of Letters and Words per Vocabulary App*

The number of fixations were determined for each vocabulary app by means of video coding as mentioned previously. Each fixation on either a letter, or word or object was annotated in ELAN. The Autism iHelp Play app is discussed first, followed by the Puzzingo app concluding with the Starfall ABC app.

Findings of the Autism iHelp Play App

This vocabulary app was specifically designed to assist children with ASD in learning vocabulary (see Section 7.4.4.4). This vocabulary app had three distinct sections: Arts and Crafts, Outdoor Activities and Toys. An important point to note is that this app did not teach the child with ASD any letters but only words.

Autism iHelp Play Arts and Crafts Fixations:

In Figure 7-9 the number of fixations on words compared to objects is presented for the Arts and Crafts section of the Autism iHelp Play app. Only five children with ASD chose to interact with the Arts and Crafts section of the app. The number of fixations on objects were greater than the number of fixations on words. The object with the most fixations was ’paint’ and the object with the least fixations was ’glue’.

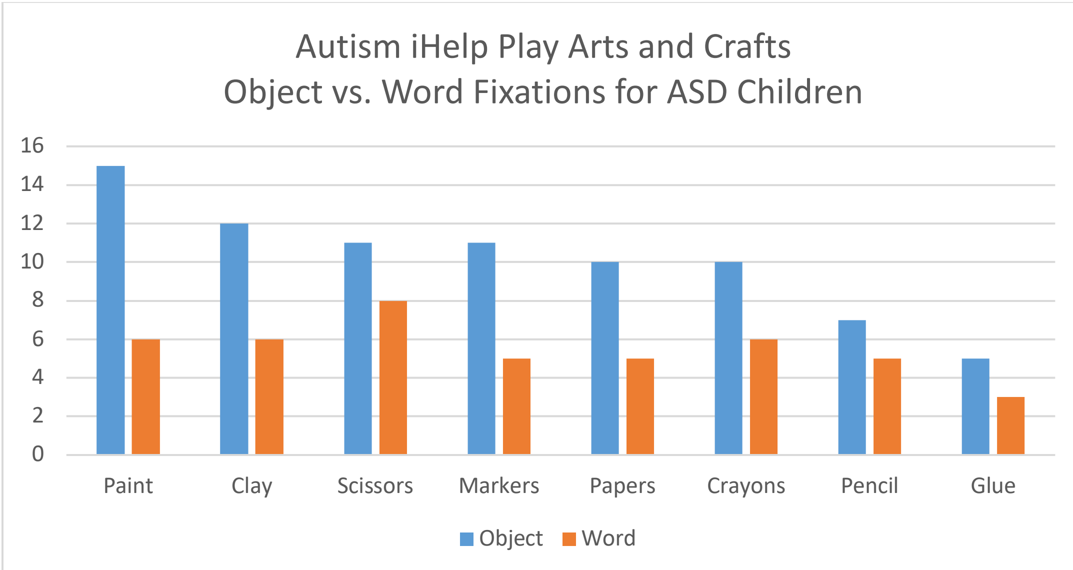


Figure 7-9 Object vs. Word Fixations for Arts and Crafts

The least difference in fixations between objects and words was ’scissors’ and ’pencil’ and the most differentiation ’paint’ and ’clay’. The word with the highest number of fixations ’scissors’ and the word with the least number of fixations was ’glue’ as depicted in Table 7-13.

Table 7-13 Arts and Crafts scene fixations

Name	Object Fixations	Word Fixations
Paint	15	6
Clay	12	6
Scissors	11	8
Markers	11	5
Papers	10	5
Crayons	10	6
Pencil	7	5
Glue	5	3

As is evident in Table 7-13 the most fixations were on objects rather than words.

<u>Autism iHelp Play Outdoor Fixations:</u>

For the Outdoor section of <u>the Autism iHelp Play app six learners with ASD participated</u>. Figure 7-10 displays the number of fixations on the objects as well as the words**.** Sizeable differences between the fixations on objects and words can be observed for the outdoor section. The smallest difference in fixations between words and objects was for 'swing' and 'slide'. The greatest difference between fixations was observed for 'sandbox' and 'bike'.

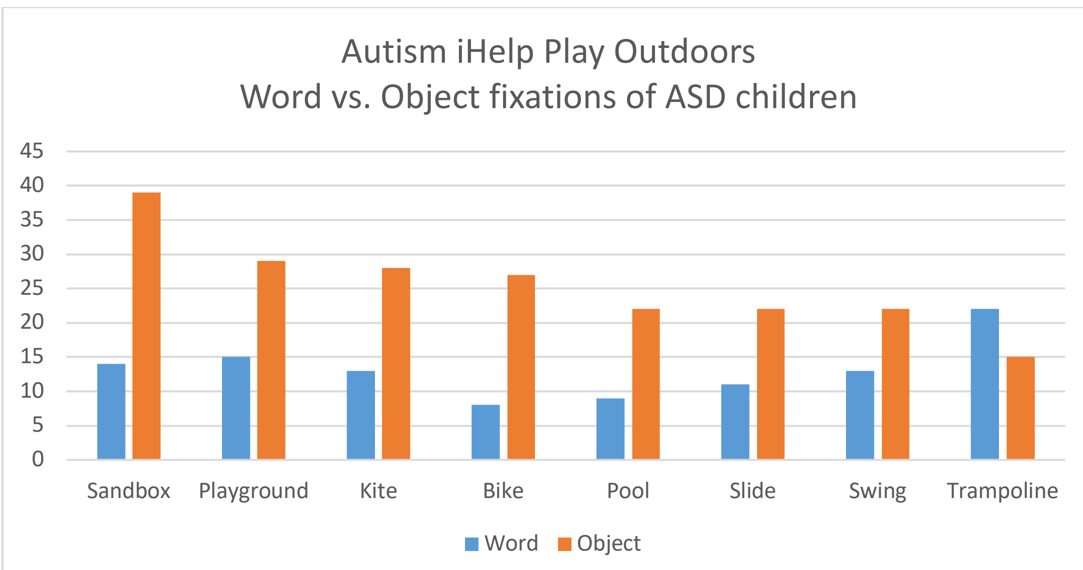


Figure 7-10 Object vs. Word Fixations for Outdoors

The object with the highest number of fixations was 'sandbox'. The fixations on 'pool' 'slide' and 'swing' were exactly the same while the lowest number of fixations on an object was 'trampoline'. However, the highest fixations on a word was for 'trampoline'. The word with the lowest number of fixations was 'bike' as presented in Table 7-14.

Table 7-14 Outdoors scene fixations

Name	Object	Word
Sandbox	39	14
Playground	29	15
Kite	28	13
Bike	27	8
Pool	22	9
Slide	22	11
Swing	22	13
Trampoline	15	22

The reason for the higher fixations on the word "trampoline" was because two of the children with ASD – Child 2 and Child 3 - fixated more intently on the word "trampoline" compared to the other words displayed in the Outdoors section as presented in Table 7-15.

Table 7-15 Fixations per child with ASD

Word	Child 1	Child 2	Child 3	Child 4	Child 5	Child 6
Bike	1	3	2	1	0	1
Kite	2	3	7	0	0	1
Playground	0	5	3	2	0	5
Pool	1	4	2	0	2	0
Sandbox	4	0	1	9	0	0
Slide	0	7	2	0	1	1
Swing	2	3	2	3	1	2
Trampoline	1	9	7	1	1	3

<u>Autism iHelp Play Toy Fixations:</u>

The third and final section of the Autism iHelp Play app was the Toy section. The number of fixations on the words and objects are presented in Figure 7-11. Five children with ASD took part in the Toy section of the app.

The majority of fixations were on the objects rather than words. The biggest difference between fixations was seen with ‘doll’, ‘train’, and ‘books’. The least difference in fixations was for ‘teddy’ and ‘ball’.

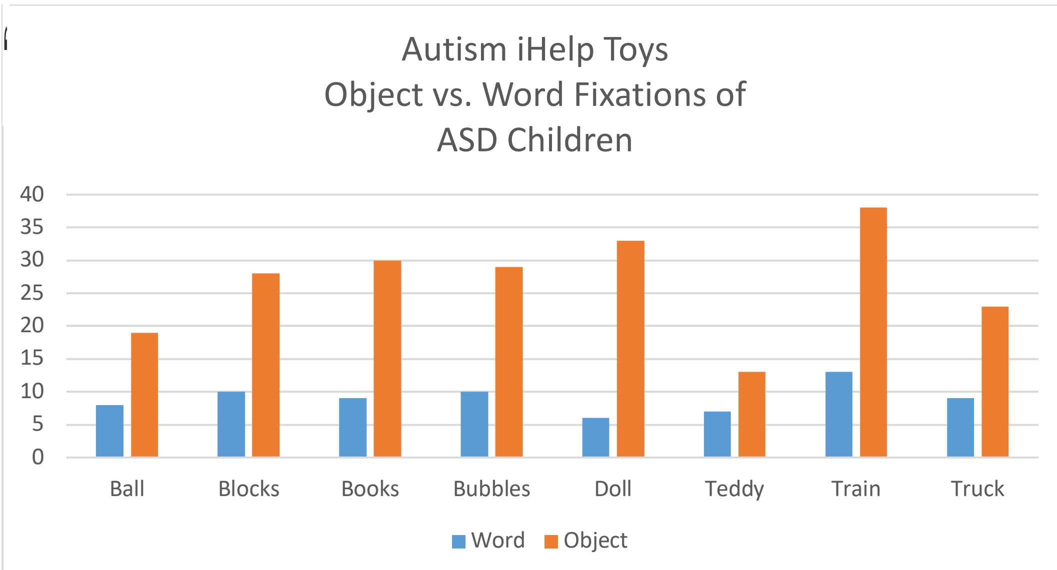


Figure 7-11 Object vs Word Fixations for Toys

Figure 7-11 provides the object with the highest number of fixations namely ‘train” and the least number of fixations namely ‘teddy’. The word with the highest number of fixations was also ‘train’. ‘Bubbles’ and ‘blocks’ had the exact same number of fixations. The word with the least fixations was ‘doll’.

For the Toy section the majority of fixations were focused on the objects rather than the words, similar to the other two sections.

Results of the Autism iHelp Play App

As demonstrated in Figure 7-12 most of the fixations were on the objects presented in the Autism iHelp Play app with the exception of one word: “trampoline. ‘ The fixations for ‘trampoline ‘were higher for the word than the object. As mentioned, two of the children with ASD had greater fixations compared to the other children thus increasing the number of fixations on the word ‘trampoline ‘.

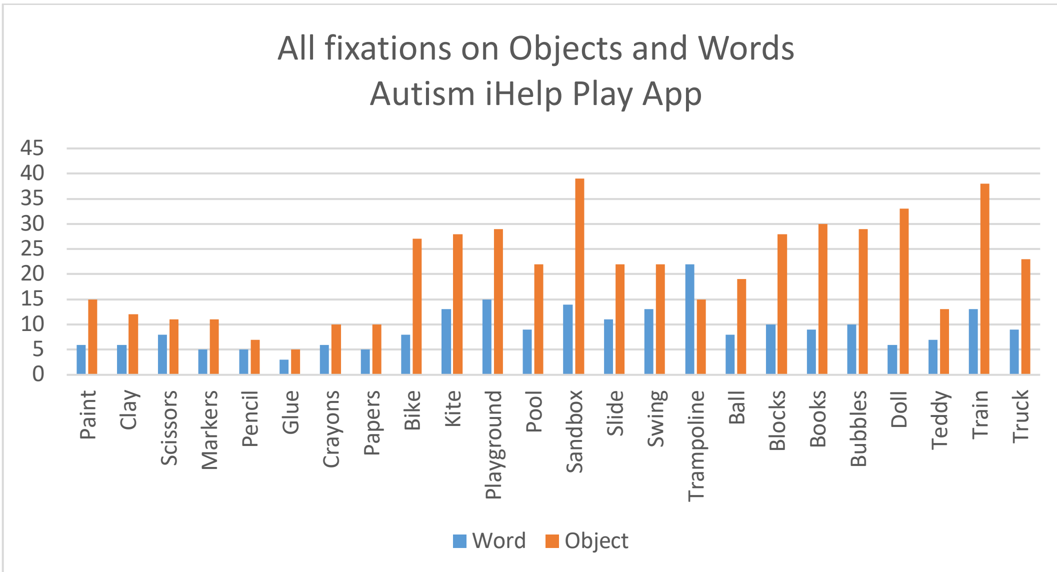


Figure 7-12 Total fixations for Autism iHelp Play

Having examined the fixation on words and objects entirely for the Autism iHelp Play, the inference can be made that the greatest focus for children with ASD was placed on objects rather than words. The only exception was for the word ‘trampoline’ where the fixations were higher on the word than on the object itself.

Figure 7-13 displays the words that had fixations above the median. These words were: ‘kite, playground, pool, sandbox, slide, swing, trampoline, blocks, books, bubbles, train’ and ‘truck’.

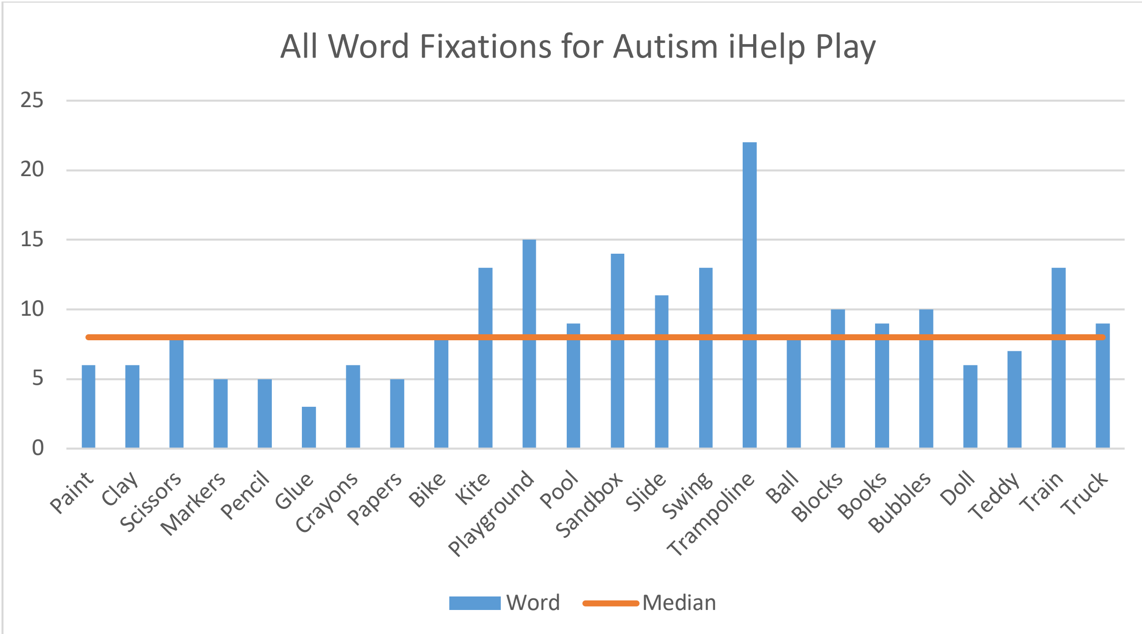


Figure 7-13 Word Fixations for Autism iHelp Play

In total there were 24 words displayed in all sections of the Autism iHelp Play app of which twelve of these words were above the median as seen in Figure 7-14.

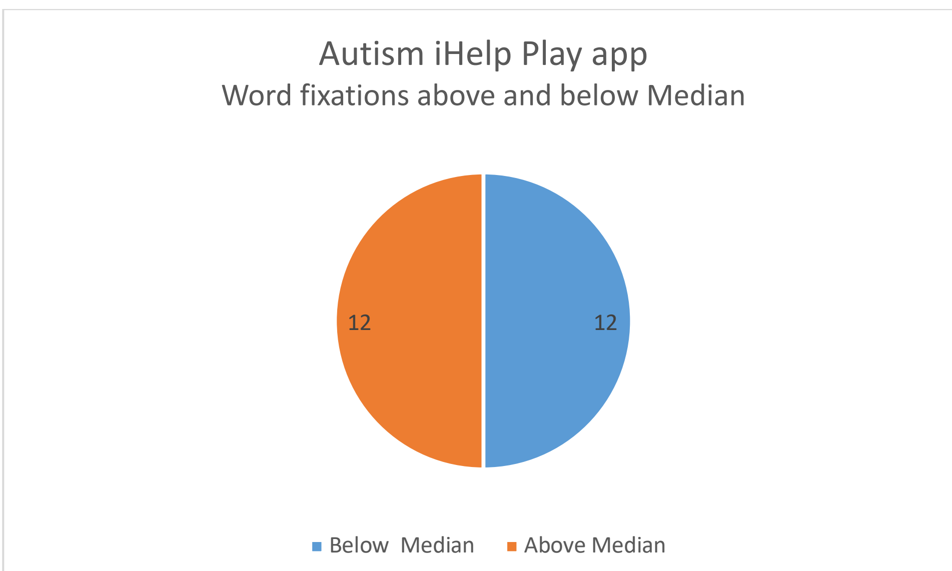


Figure 7-14 Word fixations above and below median

The equal number of fixations on words and objects seen in Figure 7-15 could indicate that vocabulary learning can be improved upon for children with ASD interacting with the Autism iHelp Play app. Implementing multimedia design guidelines could benefit the design of this app to help children with ASD focus on all the words presented with their relating objects.

Results of the Puzzingo App

The Puzzingo app is discussed in detail in Section 6.4.4.7 and claims to appeal specifically to children with ASD and children in need of speech therapy. The activities of this vocabulary app include puzzle building, where objects are matched to their corresponding shape. Each time an object is selected and dragged to its shape the object's name is pronounced and the child can read the name of the object. This app did not teach letters but only words relating to a specific theme. Six children with ASD interacted with the Puzzingo app and their fixation data used to create graphs and tables.

Figure 7-15 provides the number of fixations on objects compared to words. As is evident, the highest number of fixations on objects were on "bucket" and "shovel" and the least but equal number of fixations for objects were on: "exhaust" and "front wheel". The word with the highest number of fixations was "ice cooler". The words: "beach ball, driver's seat, exhaust" and Puzzingo had no fixations.

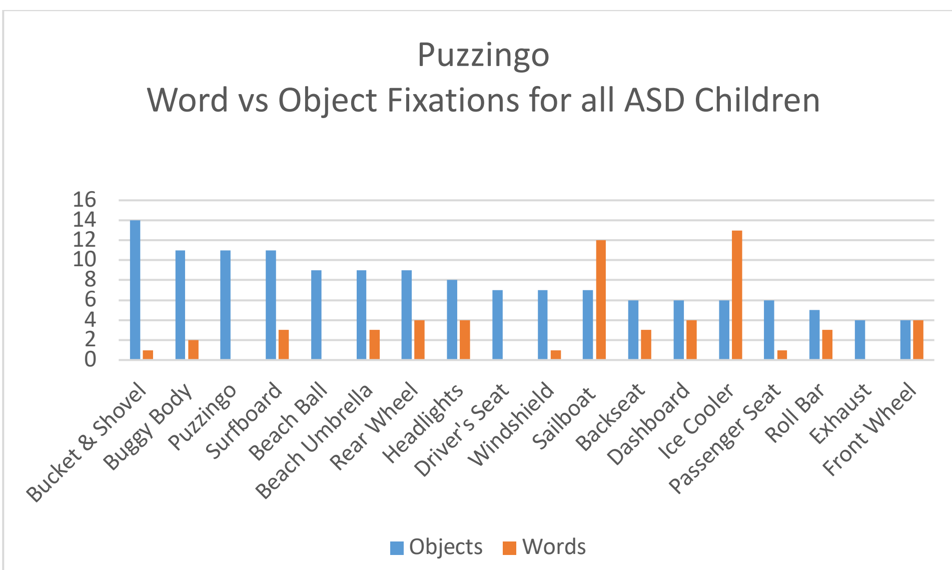


Figure 7-15 Puzzingo Word and Object Fixations

The majority of fixations were on the objects compared to the words with a few exceptions.

Findings of the Puzzingo App

Certain words presented in the Puzzingo App had fixations above the median as presented in Figure 7-16. Word fixations above the median included: dashboard, front wheel, headlights, ice cooler, rear wheel and sailboat. A number of the words did not have any fixations, these words were: "beach ball, driver's seat, exhaust", and Puzzingo the clown. The majority focus for this app was on objects rather than words with a few exceptions.

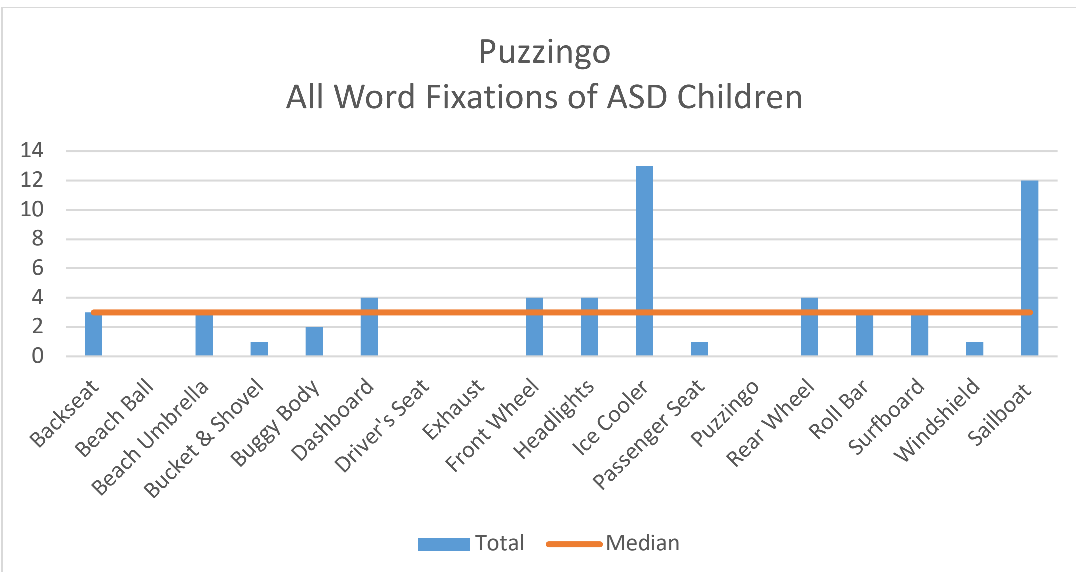


Figure 7-16 Word fixations for Puzzingo

A total of nineteen words were displayed in Puzzingo's Beach Buggy section, which was researched for the study. Six of the nineteen words were above the median as presented in Figure 7-17.

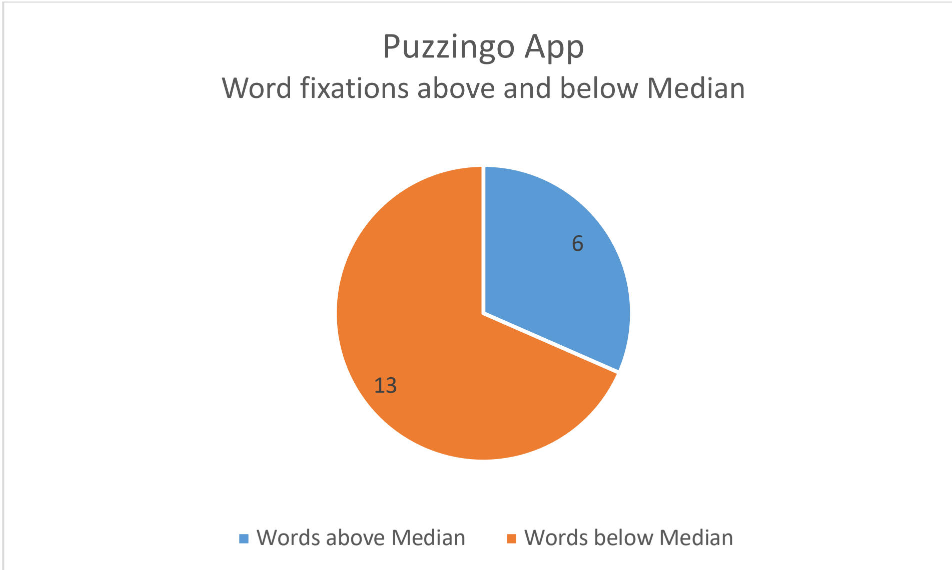


Figure 7-17 Word fixations above and below median

The object fixations were greater than the fixations on words for the Puzzingo app. A number of words did not present any fixations which could be an indication that the words did not attract the children's attention. This could result in Puzzingo not being as effective at teaching vocabulary to children with ASD. The rather significant difference between fixations above and below the median demonstrates that multimedia design guidelines could benefit this app for it to be more effective at language learning.

Results of the Starfall ABC App

The Starfall ABC app (discussed in Section 6.4.4.6) incorporated letters and words into the design of the app. Various vocabulary learning options were available for the children to choose from such as different versions of the alphabet song, phonics using hand signals or sign language, and choosing any letter of the alphabet. The fixations for the letter A and letter B of the Starfall ABC app were studied. Each of the lessons presented in the Starfall ABC app commenced with teaching the letter first, in both upper and lower case, and then progressed to words starting with the specific letter being taught (see Section 6.4.4.6).

THE LETTER A

Figure 7-18 provides information on the fixations for the letter ‘A’. These fixations were identified as follows – the fixations on the letter ‘A’ or ‘a’, then the fixations on words including the letter ‘a’ and finally the fixations on the objects that started with the letter ‘A’.

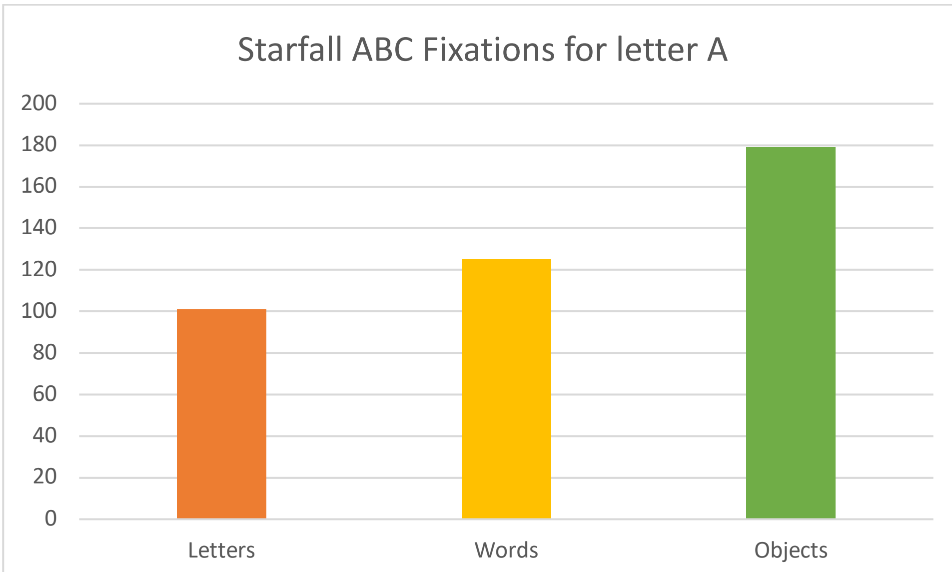


Figure 7-18 Fixations for the Letter A

As presented in Figure 7-18 the fixations on words were greater than the fixation on letters, although the highest number of fixations were on objects. However, it is of vital importance to note that the Starfall ABC app included both letters and words where the other vocabulary apps only included words. For the lesson teaching about the letter A, the fixations for the letter ‘A’ upper and lower case were counted.

When the fixations for both letters and words were combined a different perspective was gained as demonstrated in Figure 7-19.

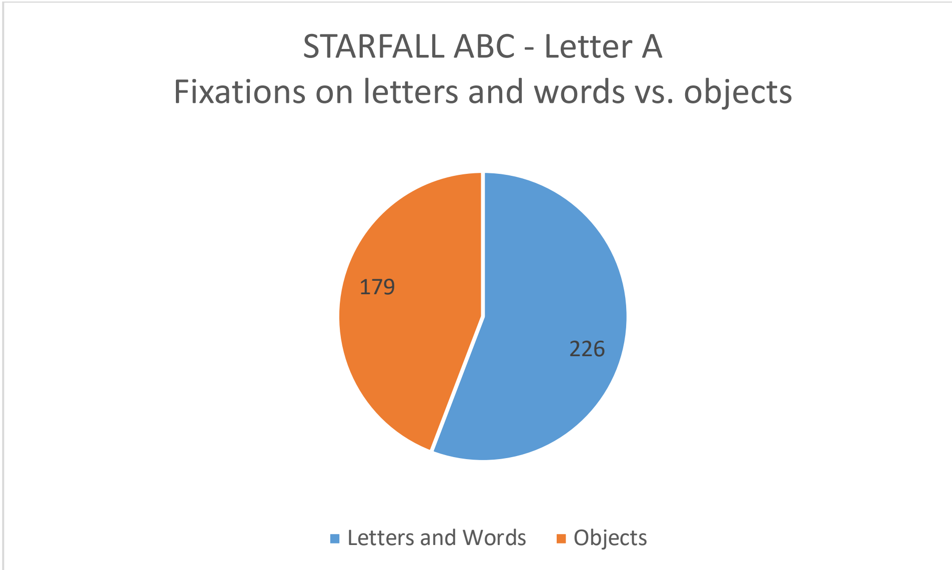


Figure 7-19 Fixations for A

When both the letters and words were combined, the bar graph indicated that the most fixations occurred on the letters and words rather than the objects for the Starfall ABC app. In total there were 226 fixations on the letters and words displayed in this app and 179 fixations on objects. From these results, it is evident that the design of Starfall ABC for the letter A directs the children with ASD's attention. More focus is placed on the letters and words being taught and less focus on the objects.

THE LETTER B

For the letter B the highest number of fixations were on the words, and the second highest on the objects. Letters had the least number of fixations as seen in Figure 7-20.

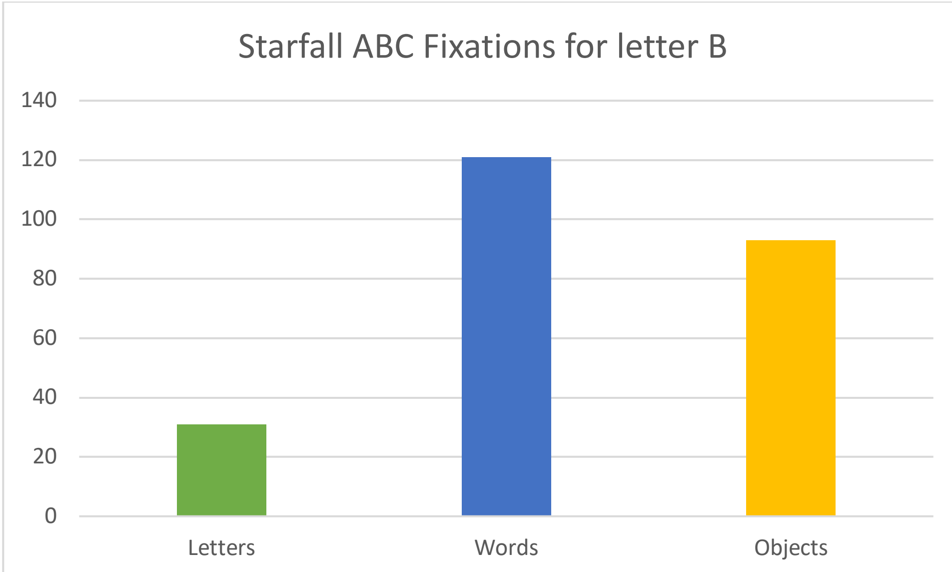


Figure 7-20 Fixations for the Letter B

It is interesting to note that the word fixations were significantly higher than the fixations on the letters, while the difference between words and object fixations were not extremely different.

When combining both letter and word fixations to compare the results against the object fixations a significant difference is seen as displayed in Figure 7-21.

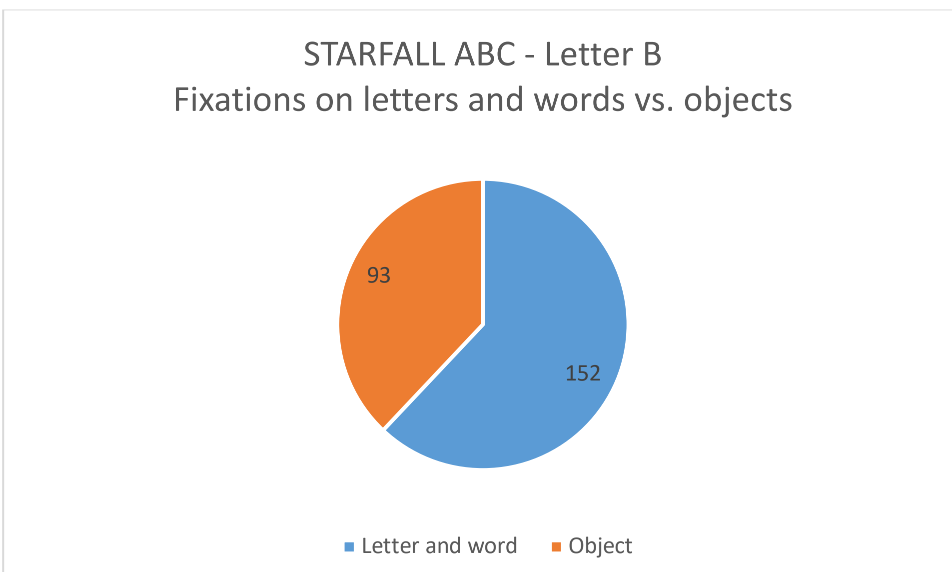


Figure 7-21 Fixations for B

The letter B had a significant number of fixations on letters and words compared to the object fixations.

Findings of the Starfall ABC App

The results from the data of the eye tracking for the Starfall ABC app indicated that the most fixations occurred on the combination of letter and words rather than on objects.

In Figure 7-22 the number of fixations for the letter A and B are provided.

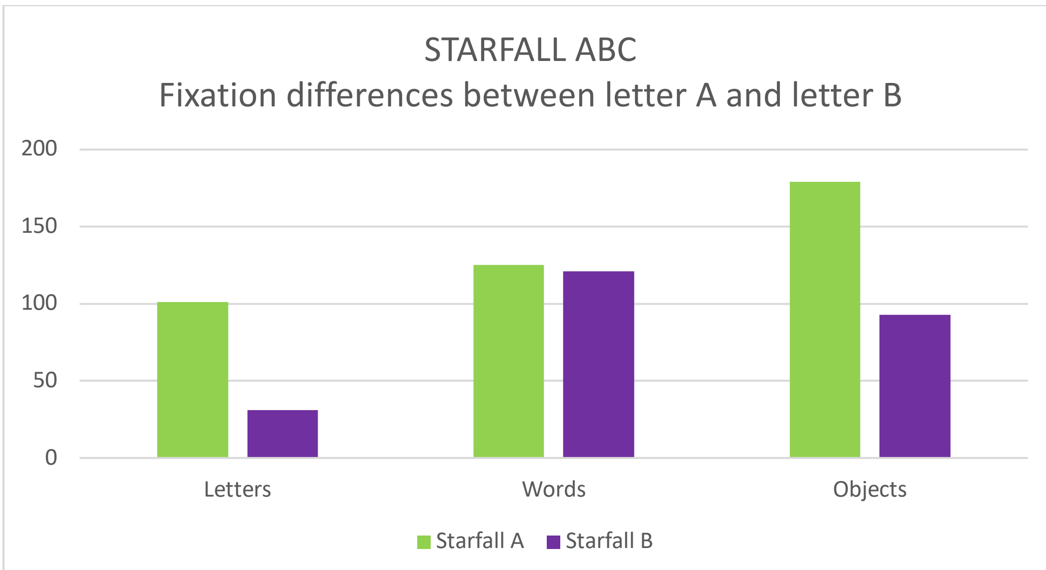


Figure 7-22 Fixation comparisons between A and B

Greater fixations occurred for the <u>letter</u> A than the letter B. The reason for this occurrence is unclear and needs to be investigated further. The fixations on <u>words</u> for both A and B were comparable. A possible explanation for this could be that children with ASD are better at visual processing and learning sight words. A large difference in fixations was seen between the <u>objects</u> presented by letter A compared to letter B, further research is needed to determine the cause.

The Starfall ABC app is the only app out of the three final vocabulary apps that presented more fixations on vocabulary than on objects as seen in Figure 7-23.

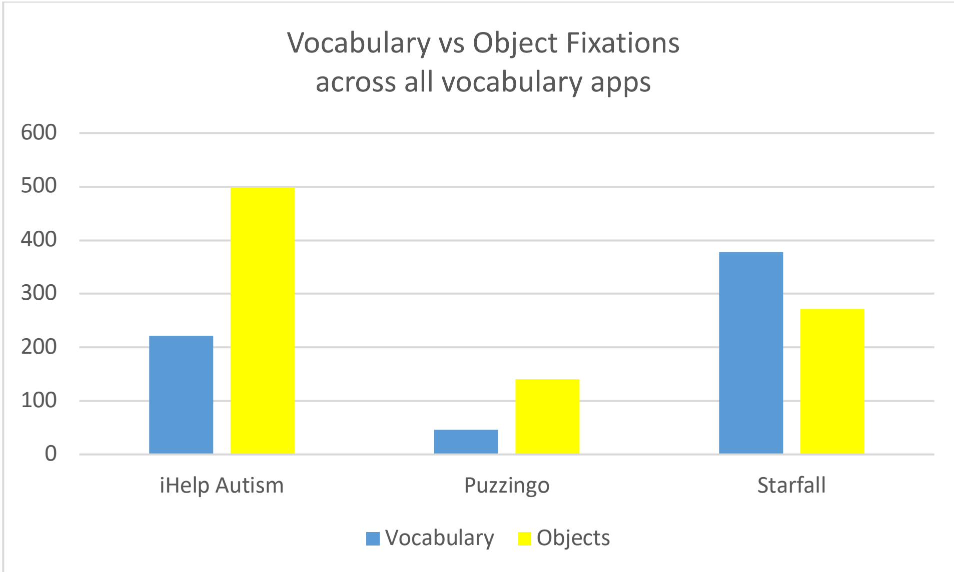


Figure 7-23 Fixations across all vocabulary apps

The large number of fixations for the Starfall app indicated that this vocabulary app contributed most to vocabulary learning for children with ASD.

The multimedia design guidelines regarding attracting attention to the letter or word being taught are displayed in Table 7-16.

Table 7-16 Visual guidelines

MULTIMEDIA DESIGN GUIDELINES
Teach the letter in lower and uppercase
Teach words that begin with the letter being taught
Place emphasis on the letter being taught by making it a different colour in a word
Use colour sparingly by using the same colour in different shades
Use a photo when teaching a word for the first time e.g. a photo of an apple and the word apple
Use lines to box in objects being taught thereby creating a focal point
Ensure that all the objects used in the design are related to the letter/being taught

7.3.4.2 *Vocabulary Apps Summary*

The eye tracking results from the interactions of the children with ASD with the final three vocabulary apps were analysed. The findings showed that Starfall ABC triggered the most fixations on words compared to Autism iHelp Play and Puzzingo apps. The combination of fixations on letters and words resulted in Starfall ABC being an outstanding app to assist in early language learning for children with ASD. A careful and thorough analysis of Starfall

ABC ensured that an effective final artefact was produced. The analyses that took place involved: the identification of multimedia learning principles; the identification of graphic design elements and principles and the identification of auditory and visual stimuli features of the Starfall ABC app compared to the other two vocabulary apps. The purpose was to ensure that the design objectives of the artefact were met and to meet the evaluation criteria of this phase namely the effectiveness and consistency of the artefact.

In the next section the multimedia learning principles are identified.

7.3.4.3 *Multimedia Learning Guidelines*

The multimedia learning checklist (see Appendix G) was created in a similar fashion to the educational checklist utilised by the educational specialist. The three different ways of processing information and their related principles as discussed in Section 3-13 were **extraneous processing** (involving the coherence, signalling, redundancy, spatial contiguity and temporal contiguity principles), **essential processing** (involving the segmenting, pre-training, and modality principles although the pre-training principle was not used in this research study since the chosen vocabulary apps were not linked to any curriculum related teaching that the children with ASD might have received at the school involved in the research study) and lastly, **generative processing involving** (the multimedia, personalisation, voice and image principles). The purpose of the evaluation was to identify multimedia learning principles presented in each of the vocabulary apps.

7.3.4.4 *Results of Multimedia Learning Principles*

The results of the evaluations for extraneous processing and its related principles for the Autism iHelp Play, Puzzingo and Starfall ABC apps are presented in Figure 7-24.

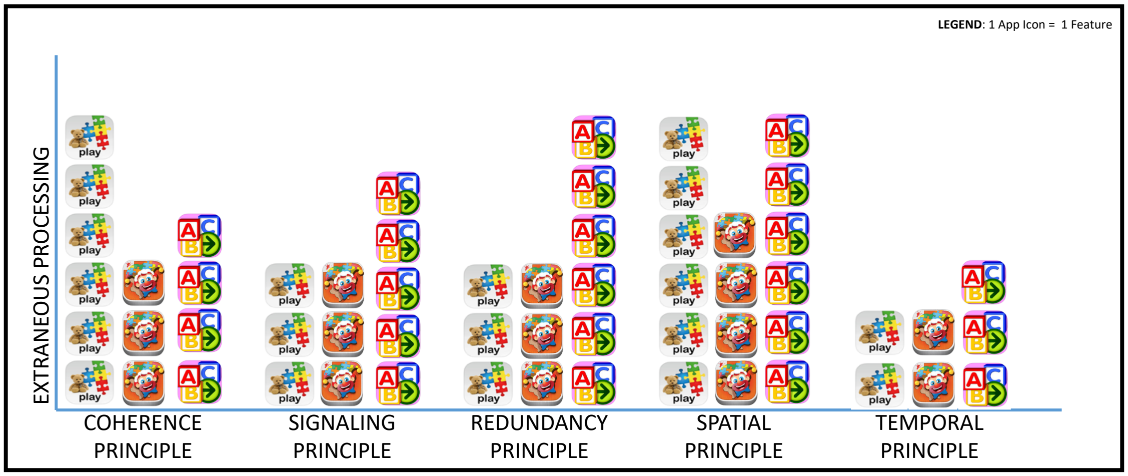


Figure 7-24 Extraneous Processing features

EXTRANEOUS PROCESSING

Coherence Principle

As is evident in Figure 7-24 the coherence principle was adhered to the most by the Autism iPlay app presenting six features with no irrelevant information, sounds or pictures. The Starfall ABC app had second highest score with a total of four features, containing irrelevant sounds and music. Puzzingo scored the lowest with three features including irrelevant pictures, sounds and music.

The multimedia design guidelines identified for vocabulary apps for the Coherence Principle are presented in Table 7-17.

Table 7-17 Identified Coherence Principles

MULTIMEDIA DESIGN GUIDELINES
Only include relevant information
Only include relevant sounds
Only include relevant music
Only include relevant pictures or objects

Signalling Principle

The signalling principle was most evident in the Starfall ABC app with five features namely cues to direct the child's attention, vocal emphasis on key words, signals were used sparingly with an organised design, only containing essential material. The Autism iHelp Play app and Puzzingo app scored the same with three features each. Puzzingo did have cues to direct the child's attention and these were used sparingly while the Autism iHelp play did not include any cues. Both Autism iHelp Play and Puzzingo placed vocal emphasis on key words. The Autism iHelp Play app had an organised design with only essential material while Puzzingo did not. Additional objects were placed in the design which could result in information overload for children. The most common signalling principles used for multimedia design guidelines are presented in Table 7-18.

Table 7-18 Identified Signalling Principles

MULTIMEDIA DESIGN GUIDELINES
Include cues to direct the child's attention
Place vocal emphasis on key words
Ensure that the design is organised
Only include essential material

Redundancy Principle

For the redundancy principle, Starfall ABC had six features which were the most features of all three apps for this principle. Graphics and narration, narrated animation with concurrent on-screen captions, visual scanning between text and pictures and little mental effort was needed for incoming information since short sentences were used. The short sentences were placed near the letters, words or objects they described.

Once again, the Autism iHelp Play and Puzzingo scored the same, each with three features. The difference between the two apps was that the Autism iHelp Play app caused the child to expend little mental effort for incoming information while the opposite was true for the Puzzingo app. The design for Puzzingo was busy resulting in significant attention and mental effort being spent on incoming information. Both apps included graphics and narration, the Autism iHelp Play app did not contain any animations while

Puzzingo had animations with concurrent on-screen captions. The multimedia design guidelines identified for the Redundancy principle are displayed in Table 7-19.

Table 7-19 Identified Redundancy Principles

MULTIMEDIA DESIGN GUIDELINES
Include graphics with narration
Include animations with narration with text all appearing the same time
The graphics and text must be easy to understand
Ensure that sentences are short

Spatial Contiguity Principle

For the spatial contiguity principle, the Autism iHelp Play and Starfall ABC apps both included six features. Both apps had corresponding words and pictures placed close together, with the relevant words close to the object. The design was uncomplicated and the objects comprehensible without words.

The Puzzingo app included four features of this principle. The pictures appeared complicated and not fully understandable for children with special needs. However, there were corresponding words and pictures placed near each other making use of integration design. The spatial contiguity principle delivered multimedia design guidelines as presented in Table 7-20.

Table 7-20 Identified Spatial Contiguity Principles

MULTIMEDIA DESIGN GUIDELINES
Place corresponding words and graphics close together
Make the design uncomplicated
Ensure the graphics are understandable without words
Ensure that sentences are short

Temporal Contiguity Principle

Two different features of this principle were identified for the Autism iHelp Play and Puzzingo apps and three for Starfall ABC. The one feature presented in all three apps was that the corresponding word was placed near the corresponding picture in a consistent manner. For the Autism iHelp Play and Starfall ABC apps the child was in control of the app however, the Puzzingo app was under system control. The activities for Puzzingo required that the shapes had to be matched with the related objects and were presented persistently until the activity ended. Starfall ABC and Puzzingo ensured that the narration was heard at the same time the animation took place. The multimedia design guidelines identified from the spatial contiguity principle are presented in Table 7-21.

Table 7-21 Identified Temporal Contiguity Principles

MULTIMEDIA DESIGN GUIDELINES
Corresponding words and graphics should be presented at the same time
The narration must be heard at the same time the animation plays
The activities must be under the control of the learner

Next the essential processing features of the three vocabulary apps are discussed.

ESSENTIAL PROCESSING

Figure 7-25 provides the results for the Essential Processing Evaluation.

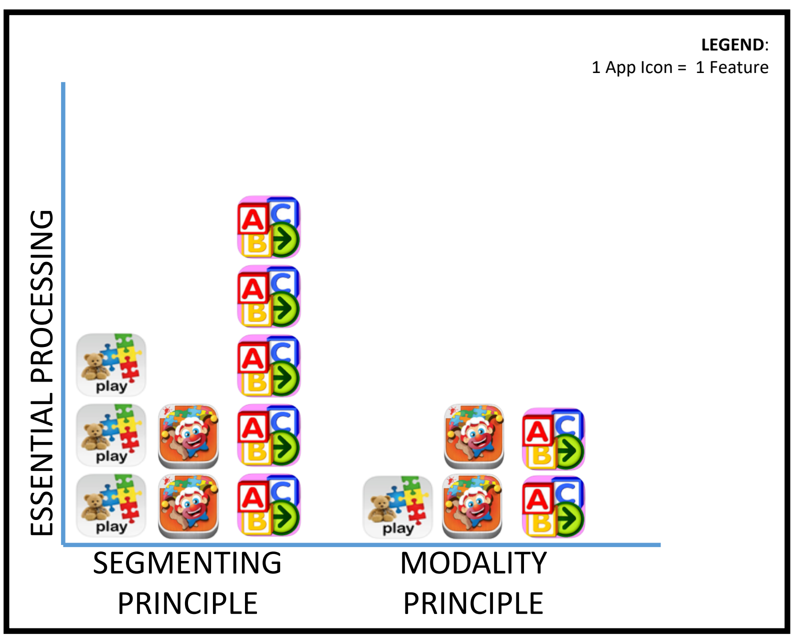


Figure 7-25 Essential processing features

Segmenting Principle

The Starfall ABC app had the most features for this principle integrating five features. These features included: presenting the lesson in user-paced segments with adequately paced narrated animation; the lessons were separated according to each letter of the alphabet; the child could choose which letter he or she would like to learn; clear signals were provided such as a next arrow to continue to the next letter of the alphabet. The Autism iHelp Play app included three features for this principle. Presenting the lesson at a pace that suits the child, with different images and words presented sequentially and controlled by the child. Puzzingo only had two features in total specifically that the lesson had adequately paced, narrated animation with signals to continue after each section. The identified multimedia design guidelines are presented in Table 7-22.

Table 7-22 Identified Segmenting Principles

MULTIMEDIA DESIGN GUIDELINES
Present lessons in segments that are user-paced
Lessons must be divided into smaller parts and presented sequentially
The learner must control advancement from one part of the lesson to the other
Provide arrows for the learner to advance to the next lesson or go back to the previous lesson
The narration must be adequately paced
The animations must be adequately paced

Modality Principle

The Starfall ABC app and Puzzingo both included two features of this principle namely pictures and spoken words as well as animations with narrations. Autism iHelp Play had one feature namely pictures with spoken words. The guidelines identified are presented in Table 7-23.

Table 7-23 Identified Modality Principles

MULTIMEDIA DESIGN GUIDELINES
Present graphics with spoken words
Include animations with narration

Next the generative processing features of the vocabulary apps are described.

GENERATIVE PROCESSING

Figure 7-26 provides the features of each vocabulary app relating to generative processing.

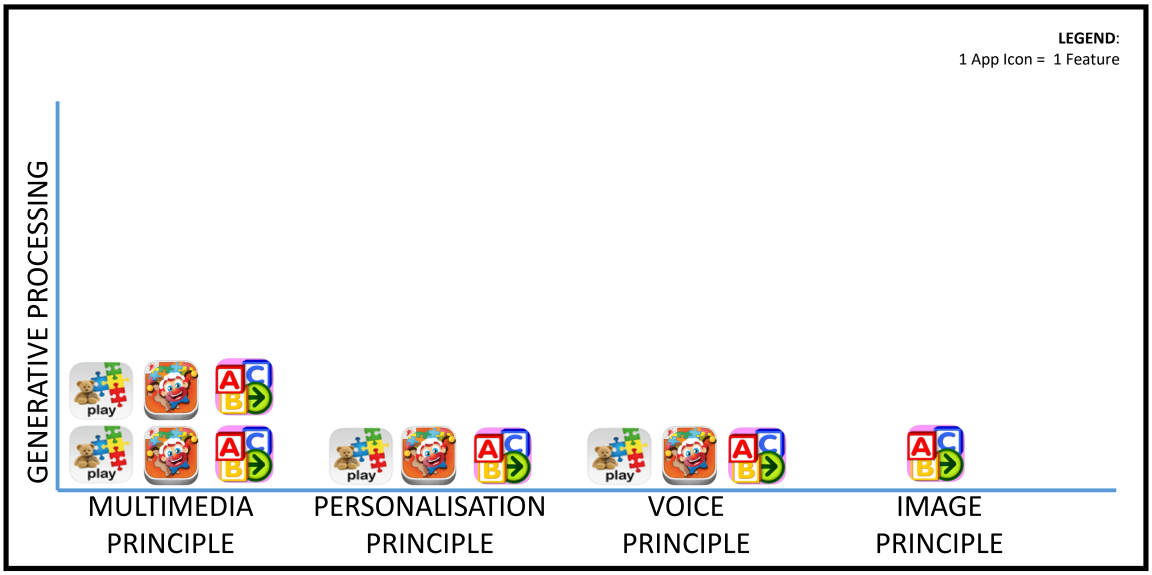


Figure 7-26 Generative processing features

<u>Multimedia Principle</u>

All three vocabulary apps have two identical features for this principle. These features were: pictures with words and the words corresponded with the pictures. Table 7-24 present the identified guidelines.

Table 7-24 Identified Multimedia Principles

MULTIMEDIA DESIGN GUIDELINES
Present graphics with words
Ensure that the words correspond with the graphics

Personalisation Principle

All three vocabulary apps included the feature where the narration was presented in a conversational style and was not machine fabricated. The identified guideline is displayed in Table 7-25.

Table 7-25 Identified Personalisation Principle

MULTIMEDIA DESIGN GUIDELINE
Present narration in a conversational style

Voice Principle

For all three vocabulary apps the narration was vocalised in a human voice and the guideline presented in Table 7-26.

Table 7-26 Identified Voice Principle

MULTIMEDIA DESIGN GUIDELINE
Present narration in a human voice

Image Principle:

Only Starfall ABC included an image of the speaker. However, this image was not consistent with each letter of the alphabet and would differ in race and ethnicity and age. The guidelines identified are presented in Table 7-27.

Table 7-27 Identified Image Principle

MULTIMEDIA DESIGN GUIDELINES
Show a person talking when narration takes place
The person doing the narration must not be there the entire time
The ethnicity of the person narrating must differ within the lesson or activity
The race of the person narrating must differ within the lesson or activity
The age of the person narrating must differ within the lesson or activity

7.3.4.5 *Findings of Multimedia Learning Principles*

Figure 7-27 provides an overall view of the number of multimedia learning features presented in all three vocabulary apps.

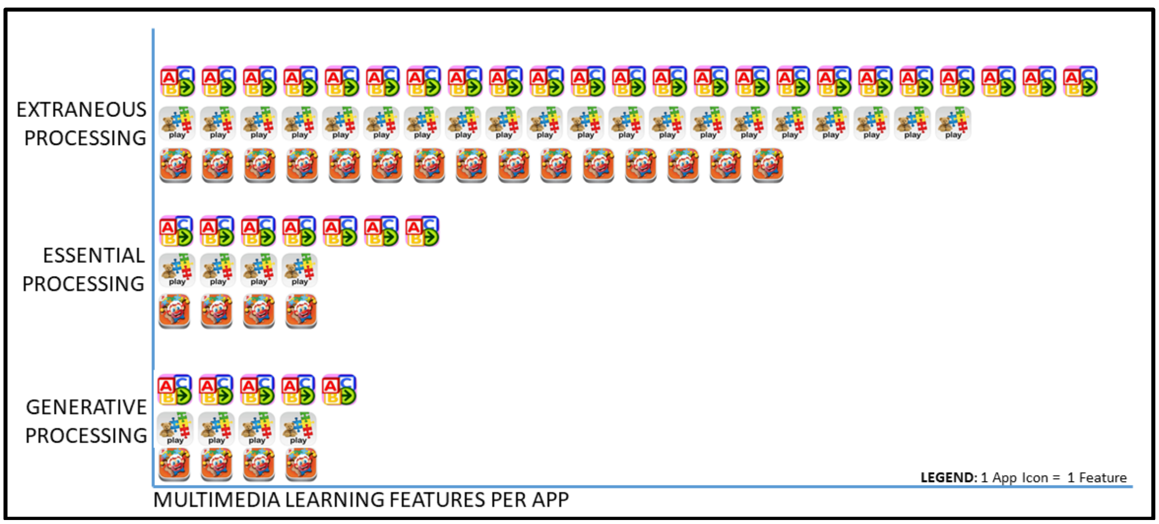


Figure 7-27 Multimedia Learning Features per App

As evident in Figure 7-27 Starfall ABC had the most features related to multimedia learning of which 23 features were linked to extraneous processing, seven features to essential processing and five features to generative processing. A total of 35 multimedia learning features were present in the Starfall ABC app.

The app with the second most features of multimedia learning was Autism iHelp Play, with twenty extraneous processing features, four essential and generative processing features resulting in a total of 28 features.

The app with the least number of features was the Puzzingo app with a total of 23 features, fifteen features for extraneous processing, four for essential processing and four for generative processing.

The vocabulary app that contributed most to multimedia learning was Starfall ABC. This finding validates the finding from the previous section, namely that Starfall ABC promoted and contributed effectively to early language learning for children with ASD. These findings resulted in the creation of an effective, robust artefact with a high level of fidelity.

7.3.4.6 *THE AUTISM iHELP PLAY APP*

EXTRANEOUS PROCESSING

Coherence Principle

The features of the Coherence principle were all met. No irrelevant words, pictures, sounds or music were presented and no nonessential words or symbols were displayed.

Signalling Principle

Not all the features of the signalling principle were presented for this app. The features that were identified included vocal emphasis on key words, the design was organised and only essential material provided. However, there were no cues to direct the learner’s attention to essential material. No outline sentence was introduced at the start of the lesson, nor were any headings keyed to the outline. Pointer words guiding the progress of the lesson were missing as well as any signals to guide the lesson.

Redundancy Principle

For this principle only certain features were identified. Nowhere in the app were there only graphics or only narration or only printed text, but rather graphics and narration. There also was no narrated animation with concurrent on-screen captions containing the same words. Visual scanning took place between the pictures and the on-screen text as was made evident with the eye tracking results. Little mental effort was exerted to compare the incoming print and spoken text since this app was very basic with a photo of an object and its name. There weren't any captions only single words that were placed close to the object they described. The spoken text was not presented before the printed text but simultaneously with it. There were no verbal sections without graphics.

Spatial Contiguity Principle

The features found in the spatial contiguity principle were that the corresponding words and pictures were presented near each other. The diagram was fully understandable without words. In the case of the Autism iHelp Play app there weren't any diagrams but only photo images of an object and its name. The material was presented in an uncomplicated manner. There was specific word and picture dominated space but the graphics were not in a different place than the text but the most relevant words were close to the corresponding graphics.

Temporal Contiguity Principle

For the temporal contiguity principle the features identified were that the corresponding words and pictures were presented at the same time. The narration was presented at the same time that the animation was presented. There were no short or long segments in the lesson where the words and pictures were presented successively. The lesson was under the control of the learner and not the system.

ESSENTIAL PROCESSING

Segmenting Principle

This principle is based on the multimedia lesson provided by the app and were identified and described as follows: The multimedia lesson was presented in user-paced segments and not continuously. The animation was adequately paced in the multimedia lesson and broken into parts that were presented sequentially. Moving from one part of the lesson to the next was under the learner's control. However, there were no arrows to indicate that the learner had to continue to the next segment.

Modality Principle

The features for this principle included pictures and spoken words that were presented, there were not only picture and printed words. There were no narrated or captioned animation in this app.

GENERATIVE PROCESSING

Multimedia Principle

The multimedia features presented for this app included having pictures with words and the words corresponded with the pictures. There were never only words or only pictures in this app.

Personalization Principle

The narrated words were presented in a conversational style.

Voice Principle

The narration was spoken in a human voice.

Image Principle

There was no image of the speaker.

7.3.4.7 *The Puzzingo App*

EXTRANEOUS PROCESSING

Coherence Principle

Only certain features of the coherence principle were presented in the Puzzingo app. There were no interesting but irrelevant words but there were interesting but irrelevant pictures, sounds and music. There were no unneeded words or symbols.

Signalling Principle

Not all the features presented for this principle were identified in the Puzzingo app. The learner's attention was directed to the essential material. There was no outline sentence to start the lesson. No headings were provided nor were they keyed to the outline. There was vocal emphasis on key words but no pointers were provided. The signals in the app were used sparingly. The design was not organised and did not only have the essential material.

Redundancy Principle

The features identified for this app relating to the redundancy principle was that there never was only graphics or only narration or only printed text. Graphics and narration were presented. The narrated animation had concurrent on-screen captions containing the same words. Visual scanning took place between the pictures and on-screen text to a limited degree as made evident by the eye tracking results. The learner had to expend mental effort to compare incoming streams of printed and spoken text since the layout was very busy. There were no captions presented in this app. The spoken text was presented before the printed text. There were no verbal sections with no graphics.

Spatial Contiguity Principle

The features identified for this principle were that the corresponding words and pictures were presented near each other. However, the diagram was not fully understandable without words and some of the children asked for help. There was word and picture dominated space with the relevant word next to the corresponding illustration. The graphics were not in a different place to the text.

Temporal Contiguity Principle

Only certain features were identified for this principle. The corresponding words and pictures were presented at the same time. Although the learner did not hear the narration at the same time he or she saw the animation. The words and pictures were not successive in any part of the app. The lesson was under the control of the learner and not the system.

ESSENTIAL PROCESSING

Segmenting Principle

For the segmenting principle the features identified were that the lesson was presented continuously and not in user paced segments. The multimedia lesson had adequately paced narrated animation. However the lesson was not broken into parts and presented sequentially and the learner could not control the movement from one part of the lesson to the next. There was an arrow to indicate to the learner to continue after each segment had been completed.

Modality Principle

There were pictures and spoken words in this app as well as narrated animations. The animations were not captioned and there were not only pictures and printed words.

GENERATIVE PROCESSING

Multimedia Principle

The multimedia features presented for this app included having pictures with words and the words corresponded with the pictures. There were never only words or only pictures in this app but a combination of both.

Personalisation Principle

The narrated words were presented in a conversational style.

Voice Principle

The narration was spoken in a human voice.

Image Principle

There was no image of the speaker.

7.3.4.8 *The Starfall ABC App*

<u>EXTRANEOUS PROCESSING</u>

<u>Coherence Principle</u>

For this principle the app presented no interesting but irrelevant words or pictures. There were interesting but irrelevant sounds and music. However, no nonessential words or symbols were displayed.

<u>Signalling Principle</u>

There were cues that directed the learner's attention to the essential material. Although there were no outline sentences to start the lesson nor any headings. Vocal emphasis was placed on the key words but no pointer words were used. Signals were used sparingly and the design was organised. Only essential material was presented.

<u>Redundancy Principle</u>

Features identified for this principle in the Starfall ABC app was that there was never only graphics or only narration or only printed text. There was graphics and narration presented in the app, the narrated animation had concurrent on-screen captions containing the same words. Visual scanning took place between the pictures and on-screen text as made evident by the eye tracking. The learner expended little mental effort to compare incoming streams of printed and spoken text. The captions were shortened to a few words and placed next to the part of the graphics they described. The spoken text was not presented before the printed text. There were never only verbal sections without any accompanying graphics in this app.

<u>Spatial Contiguity Principle</u>

The corresponding words and pictures were presented near each other. The diagram was fully understandable without words and the material uncomplicated. There was word and picture dominated space with the relevant words close to the corresponding illustration. The graphics were never in a different place to the text.

Temporal Contiguity Principle

The corresponding words and pictures were presented at the same time. The learner heard the narration at the same time the as the animation was seen. There were short segments in the lesson where the words and pictures were presented successively. The lesson was under the control of the learner and not the system.

ESSENTIAL PROCESSING

Segmenting Principle

The multimedia lesson was presented in user-paced segments and not continuously. The narrated animation was adequately paced. The lessons were broken into parts and presented sequentially. The movement from one part of the lesson to the other was under the learner's control with each segment having an arrow indicating that the learner could continue to the next segment.

Modality Principle

There were pictures and spoken words, not only pictures with printed words. Narrated and captioned animations were presented in the Starfall ABC app.

GENERATIVE PROCESSING

Multimedia Principle

The multimedia features presented for this app included having pictures with words and the words corresponded with the pictures. There were never only words or only pictures in this app but a combination of both.

Personalisation Principle

The narrated words were presented in a conversational style.

Voice Principle

The narration was spoken in a human voice.

Image Principle

In some of the lessons there were images of the speaker as well as in some of the alphabet songs.

Having carefully identified all the features of the three vocabulary apps with the help of the designed multimedia checklists the next section identify the graphic design guidelines presented in the vocabulary apps.

7.3.4.9 *Graphic Design Guidelines*

A checklist (Appendix H) was created for the identification of graphic design features for each of the vocabulary apps. The creation of the graphic design checklist included the features of the design elements and the design principles as manifested by O'Connor (2014) The design elements and principles explained in Section 4.4 are presented as follows.

Design elements consist of:

- colour,
- light-dark contrast,
- line,
- direction,
- shapes,
- size,
- texture, and
- typography

The design principles are:

- simplicity and complexity,
- unity and variety,
- rhythm and movement,
- balance – symmetry and asymmetry,

- contrast,
- compositional technique, and
- realism and abstraction.

Each of the features of the graphic design elements and principles provided by O'Connor (2014) were converted into a checklist by converting the design elements and principles and their associated features into dichotomous questions. The yes or no answers to the questions helped establish which of the graphic design features were present in each vocabulary app.

RESULTS

<u>Graphic design features – Autism iHelp Play</u>

The image of a train as presented in the Autism iHelp Play app is shown in Figure 7-28.

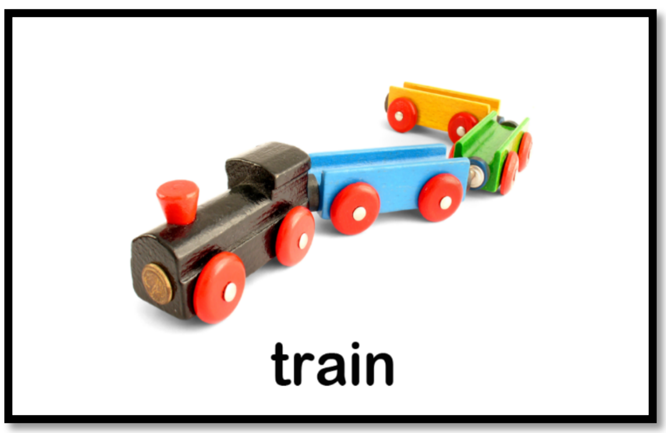


Figure 7-28 Train photo in Autis iHelp Play

ELEMENTS

Colour: The images used were multi-coloured with contrasting colours.

Light-Dark Contrast: The light-dark contrast was seen by the colourful train against a white background.

Line: No lines were used in the design.

Direction: The train was in a curved position, leading the focus from the front of the train to the back.

Shapes: Different shapes were used such as rectangles for the carriages, a type of oblong shape for the chimney and circles for the wheels.

Size: A variation in the size of the elements was used to create perspective. The front locomotive appeared the largest and the carriages grew smaller and smaller.

Texture: There were no variations in texture. A wooden texture was used for the entire train.

Typography: The typography was purely functional and used to communicate information.

PRINCIPLES OF DESIGN

Simplicity-Complexity: The design draws attention to specific elements in this instance the train. There is no visual clutter or lots of detail. There is unity among the elements, colours, and shapes. The elements have the same textures, size and shapes. Different colours and shapes are observed in the design.

Unity-Variety: There is unity among the elements and the shapes although different colours and shapes are used.

Rhythm-Movement: There is no sense of movement or excitement but there is a sense of calmness and tranquillity since the image is static. The shapes and textures are repeated in the image.

Balance: Symmetry and Asymmetry: The design provides symmetry and balance with the train arranged in a diagonal manner.

Contrast: The train perspective is from large to small providing a depth perspective. There is colour contrast with cold and warm colours used for the train.

Compositional Technique: The rule of thirds can be seen in this composition with the position of the first part (the locomotive) of the train. Some of the elements are dominant such as the locomotive and some less dominant in this case the last carriage, giving the image a depth perspective. There is a visual path drawing attention from the front of the train to the back. Bright objects can be identified such as the yellow carriage of the train and the red wheels. The object is in contrast to its surroundings – the colourful train against a white background. There is positive and negative space – the positive space being the space the train occupies and the negative space the white area around the train.

Realism-Abstraction: The image of the train is a photorealistic representation.

<u>Graphic design features – Puzzingo</u>

A screenshot of the beach buggy word learning activity is presented in Figure 7-29.

Figure 7-29 Puzzingo

ELEMENTS

Colour: A multi-coloured design was used for this app including contrasting colours.

Light-Dark Contrast: Large variations in tonal chords can be observed such as seen in the colour blue which has very light to very dark shades.

Line: The lines used in the design are freeform making use of thick and thin lines that are different colours.

Direction: The general direction of the design is to draw attention to horizontal as well as diagonal.

Shapes: Different shapes were used for the design.

Size: There were different sized elements presented in the design.

Texture: Different textures were not used in the design.

Typography: The typography used reinforced the theme, was functional and communicated information.

PRINCIPLES OF DESIGN

Simplicity-Complexity: The design draws attention to specific elements such as the beach buggy. There is visual clutter and a lot of detail in the design with all the objects surrounding the beach buggy.

Unity-Variety: Differences among elements are visible with the variation of colours, shapes and lines.

Rhythm-Movement: A sense of excitement is present in the layout. The theme shows the beach and a clown ready to go on vacation.

Balance: Symmetry and Asymmetry: The design is asymmetrical with a rotational arrangement of objects. The beach buggy is the focal point and the objects are placed around the beach buggy.

Contrast: There are large and small objects as well as light and dark objects presented in the image. Thick and thin lines are used in the design as well as contrasting colours.

Compositional Technique: The Rule of Thirds was incorporated into the design with the sailboat and cooler box drawing attention on the left side of the image. Certain elements were more dominant than others, like the beach buggy, but the sun and the mountain in the background were less dominant. Bright objects were observed in the design namely the surfboard in bright green, the orange cooler box, and the red and white umbrella. The shapes were in contrast to their surroundings because they were black and the rest of the picture in colour. There was negative space as made evident by the black shapes that represented the shapes that had to be matched with their full colour objects.

Realism-Abstraction: The design was a realistic but simplified representation of a beach buggy and vacation items.

Graphic design features – Starfall ABC

The Starfall ABC app consisted of different layouts and designs for each letter of the alphabet. For this research study the letters A, B, and C were examined in detail. With the graphic design checklist, a single design layout was chosen from each of the letters as displayed in Figure 7-30. This was done so that a generalised evaluation could be made of the design features presented in the Starfall ABC app.

Figure 7-30 Starfall ABC Design Layouts

ELEMENTS

Colour: All three of the images were multi-coloured. The image of the apple was considered to be full colour because it had a photo of an apple. The photo of the apple consists of a number of colours such as white, brown, and black rendering it multi-coloured. There were contrasting colours in all three images. The apple image had a bright green arrow in contrast to the different shades of red. The image of the boy had the letter b in blue while the background was different hues of yellow. The image of the cow was green, yellow and brown which are contrasting colours.

Light-Dark Contrast: A large range of light to dark colours were demonstrated in each of the images. Different shades of red were visible in the apple image. The image of the boy ranged from the light colour of white to the dark colour black. In the image of the cow light and dark contrast could be seen in the letters and the photo of the cow.

Line: The lines visible in all three images were thick and thin straight lines. Although the vertical lines used in the cow image were jagged.

Direction: The direction of the lines was horizontal and vertical in all three of the images.

Shapes: No universally recognised shapes were used in the images.

Size: There is some visible variation of size within the images. In the image of the boy the text appears large in comparison with the boy. This is not the case for the apple or cow image.

Texture: The texture did vary from image to image. No texture was visible in the image of the boy. However, there was texture in the apple image seen in the skin of the apple. The image of the cow had visible texture in the wooden beams enclosing the cow as well as the texture if the cows hide.

Typography: In all three images the font used was the same, having a functional purpose in order to communicate information.

PRINCIPLES OF DESIGN

Simplicity-Complexity: The design of all three images draws attention to specific elements with the image. No visual clutter is visible and the images are not detailed.

Unity-Variety: Unity in colour and line is evident in all three images. Each image uses a colour in different shades and the colours do vary. The lines used in the images are similar in design.

Rhythm-Movement: A sense of calmness is experienced in all of three images since the images are static.

Balance: Symmetry and Asymmetry: The image with the apple is symmetrical in that the apple is similar to the letter 'a' and they are placed next to each other. From a design perspective they can be seen as mirror images because they have the same shape. The arrangement is horizontal from left to right moving from the letter a to the image of the apple.

In the image of the boy the design is asymmetrical since the picture of the boy is positioned below the word 'boy' and the sizes differ. The text appears large in comparison with the boy. A rotational arrangement appears in the image which starts at the word boy moving to the picture of the boy and ending at the sentence 'I am a boy'.

The image of the cow is asymmetrical with the letter 'c' next to the cow's but no letter on the other side resulting in the image appearing out of balance. There seems to be a diagonal arrangement from the letter 'c' to the cow's nose to the 'next' arrow.

Contrast: There is no contrast in size for the apple image but there is in light and dark. The darker colours in the letter 'a' and the apple are in contrast to the light background colour. The colour of the 'back' arrow is in contrast to the rest of the colours used in the design.

A contrast in size is visible for the image with the boy. The word 'boy' appears larger in comparison with the picture of the boy. Further there is a visible difference in the contrast in colours such as blue and yellow, black and white.

No contrast in size can be seen in the image with the cow, although contrast can be seen in the use of the colours yellow and green, also, the overall brown colour of the photo of the cow compared to the green background the photo is positioned on.

Compositional Technique: Neither the Golden Mean nor the Rule of Thirds was used in the image with the apple. The letter 'a' and the image of the apple draw equal attention. A visual path runs horizontally from left to right. The only bright object was the 'back' arrow. The letter 'a' and the apple were in contrast to the light background. The positive space is where the letter 'a' and the apple occupied space in the image and the negative space can be seen around these two objects as well as inside the letter 'a'.

For the image with the boy the rule of thirds was not observed by the position of the boy in the layout. The word 'boy' dominated more space in the design than any of the other objects. The visual path appears to be in the shape of a 'c'. The focus starts with the word 'boy' and then moves to the image of the boy and then the sentence 'I am a boy' ending at the 'next' arrow. The bright objects can be seen as the letter 'b' where the focus is drawn to 'b' and the boy's cap. These objects are in contrast with the rest of the design colours used in the image. The word boy is also in contrast with the rest of the image since it is big and bold and centred drawing attention to the word. The positive space is where the boy is placed as well as the word 'boy' in the image. The negative space is the yellow area where no images are as, well as the gaps in the letters filled with yellow.

The rule of thirds was applied as can be observed by the position of the letter 'c' in the design, the letter 'c' makes one third, then the cows head the other third, and the fence the other third. The photo of the cow is dominant in this image while the background behind the cow becomes less dominant. A visual path appears from the letter 'c' moving to the cow's head and then to the word 'cow', ending at the 'next' arrow. Bright objects appear such as the letter 'c'. The cow photo is in contrast with the green background as mentioned earlier. There is positive space where the photo of the cow is placed and the negative space can be seen between the jagged lines.

Realism-Abstraction: The image with the apple has a photorealistic apple in it as well as basic almost childlike letter 'a'.

A realistic and simplified representation of a boy can be seen in the second image with the boy.

In the image with the cow a photorealistic representation of a cow can be seen..

FINDINGS

In this section the findings of the graphic design elements and principles are presented for each of the vocabulary apps used in the study. Figure 7-31 displays the elements of design presented in each of the vocabulary apps.

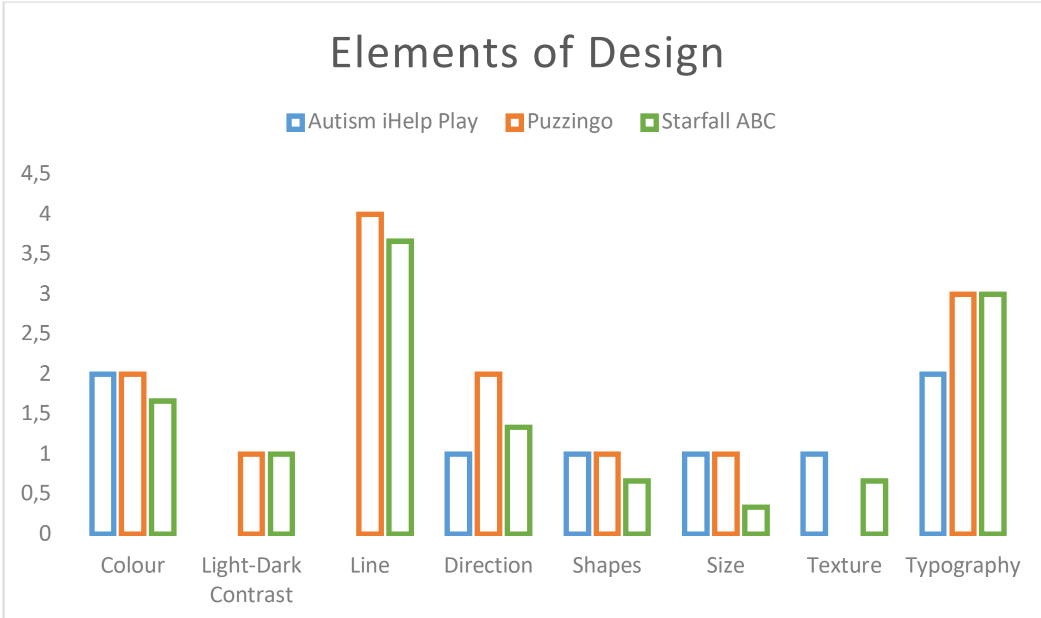


Figure 7-31 Elements of Design

The Autism iHelp Play app always used the same layout, specifically a photo of an object placed in the exact centre of the screen layout. For the Puzzingo app the same layout was used throughout the Beach Buggy Scene with the exception of different objects that were added one by one until the picture was completed as a whole. However, the Starfall ABC app had different layouts for each letter of the alphabet thereby including variety into its design.

<u>Colour</u>

With regards to colour the Autism iHelp Play app and Puzzingo both used multi-coloured and contrasting colours. While the Starfall ABC app had variations in its design, ranging from monochromatic (one colour) to full colour designs in the form of photos and coloured drawings which at times included contrasting colours, although these colours were consistent throughout the different lessons in which the letter or word was taught Table 7-28.

Table 7-28 Identified colour guidelines

MULTIMEDIA DESIGN GUIDELINES
Colour should be used in a consistent manner from one lesson to the next
Colour can range from one colour with different tones to full colour
Full colour photos and then full colour drawings relating to each other should be incorporated
Contrasting colours can be used to draw attention to the letter or word being taught

Light-Dark Contrast

Light-dark contrast was present in both the Puzzingo and Starfall ABC apps. Both these apps incorporated major tonal chords ranging from light to dark for the same colour. The Autism iHelp Play app did not include any tonal chords in its design. Table 7-29 provides the guideline identified for light-dark contrast.

Table 7-29 Identified light-dark contrast guidelines

MULTIMEDIA DESIGN GUIDELINES
Light-dark contrast can be incorporated to draw attention to a letter or word
Tonal chords should be used to direct the child's focus

Line:

The Puzzingo App incorporated many of the features relating to lines in design. This app's design layout included lines that separated the words and objects from the picture. Starfall ABC also incorporated coloured lines in the design except these lines were used to create divisional lines between the image/object and the text, directing attention to the letter or word being taught. No lines were used in the design of the Autism iHelp Play app. The guideline identified from the line feature is displayed in Table 7-30.

Table 7-30 Identified Line guideline

MULTIMEDIA DESIGN GUIDELINE
Lines can be used to separate letters or words guiding the child's attention

Direction

The design layout included direction to draw attention to specific areas in both the Puzzingo and Starfall apps. Direction was also incorporated in the Autism iHelp Play app but to a much lesser extent. The design layout was very basic for the Autism iHelp Play app only containing photos that were placed in the middle of the layout with the related word positioned below the photo. Table 7-31 presents the identified guideline.

Table 7-31 Identified Direction guideline

MULTIMEDIA DESIGN GUIDELINE
Create a layout that incorporates direction leading the child's attention to the letter or word being taught

Shape

There are various shapes that are universally recognised in the design of both the Puzzingo and Autism iHelp Play apps. Shapes are also used in the Starfall ABC app although there are also instances where photos were included for example a bear or an alligator. In the Autism iHelp Play only photos were exclusively e used although basic shapes could be recognised in some of the photos. For example, the rectangular shapes of the carriages of the train or the cylindrical shape of the glue. The guideline identified for shape is displayed in Table 7-32.

Table 7-32 Identified Shape guideline

MULTIMEDIA DESIGN GUIDELINE
Shapes can be used to enhance the learning of a letter or word

Size

There were variations in size in some of the elements used in the design of the vocabulary apps. For most of the instances the variations in size were used to create perspective or the illusion of depth within the layout. Size played a role in the Starfall ABC app when teaching upper and lowercase letters. Uppercase letters were bigger than the lowercase letters. The size guideline is presented in Table 7-33.

Table 7-33 Identified Size guideline

MULTIMEDIA DESIGN GUIDELINE
Size can be used to distinguish between upper and lowercase letters

Texture:

Texture is found in some of the pictures used in the Autism iHelp Play and Starfall apps exhibited in the photos. A wood texture was seen in the photo of the train and in the photo of the sandbox for the Autism iHelp Play app. For the Starfall ABC app texture was seen in the photo of the astronaut and the gravel on the moon surface and the fur of the bear. No texture was used in the design for Puzzingo only coloured line drawings shaded in different colours. For texture the identified guideline is proposed in Table 7-34.

Table 7-34 Identified Texture guideline

MULTIMEDIA DESIGN GUIDELINE
Texture can be used to help the child relate the object to the word being taught

Typography

The typography in all three vocabulary apps were functional and used to communicate information. The font used in Puzzingo reinforced the theme with the cartoonlike appearance. Starfall ABC's font also reinforced the theme by using a font that related to school when teaching children the alphabet. In addition, Starfall ABC used fonts to direct the child's attention to the letter or word being taught. The guidelines identified for typography are shown in Table 7-35.

Table 7-35 Identified Typography guideline

MULTIMEDIA DESIGN GUIDELINES
Typography can be used to represent a specific theme
Typography can be used to place emphasis on a letter or word

Next the evaluation of the principles of design will be discussed as presented in Figure 7-32.

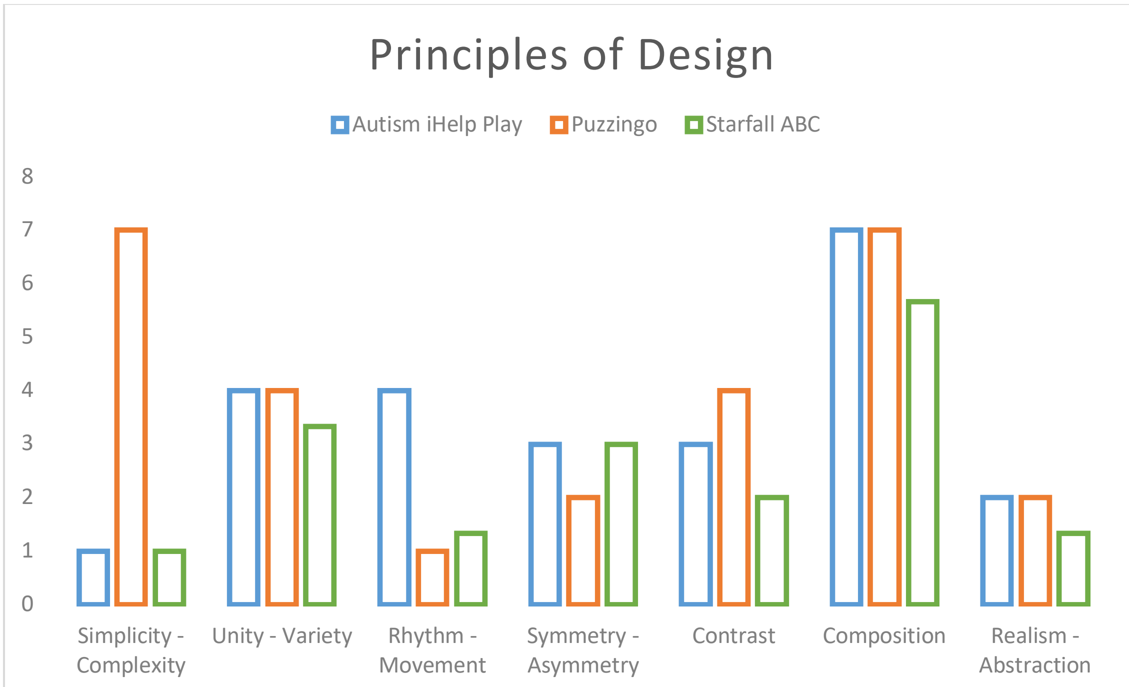


Figure 7-32 Principles of Design

Simplicity-Complexity

The Puzzingo app was the most complex with the design including plenty of detail and a busy layout. While the Autism iHelp Play and Starfall apps design was used to draw attention to the specific words or letters being taught incorporating a clean, uncluttered and organised design layout. Table 7-36 presents the identified guideline.

Table 7-36 Simplicity-Complexity guideline

MULTIMEDIA DESIGN GUIDELINES
Incorporate a clean, uncluttered and organised design layout

Unity-Variety

There were large differences in colours, shapes and lines for all three vocabulary apps resulting in a variety in the design layout of the apps. The guideline for unity-variety is provided in Table 7-37.

Table 7-37 Unity-Variety guideline

MULTIMEDIA DESIGN GUIDELINES
Variety in the layout design maintains focus

Rhythm-Movement

Puzzingo's design brought about the most excitement and stimulation with its busy vacation theme presented in the Beach Buggy section. Both Autism iHelp Play and Starfall ABC incorporated serenity in their design. However, certain of the themes for Starfall ABC produced a sense of movement for example the astronaut design. Furthermore, letters and words were animated, vibrating to attract the child's attention. The Table 7-38 presents the guideline identified.

Table 7-38 Rhythm-Movement Guideline

MULTIMEDIA DESIGN GUIDELINES
Animations can be used to draw attention to the letter or word being taught
Animate the letter or word being taught

Symmetry-Asymmetry

An asymmetrical design layout was used for Puzzingo with a rotational arrangement of objects positioned around the main object. The design layout of the Autism iHelp Play app placed the image at the centre of the layout creating direct focus on the object and word being taught. No additional objects were placed on either side of the main object. The word describing the image was centred and positioned at the bottom of the object. Starfall ABC included both asymmetrical and symmetrical layouts differing from letter to letter creating a variety in the design. The symmetrical and asymmetrical layouts encouraged the child to focus on the letter or word. Table 7-39 presents the identified guideline.

Table 7-39 -Symmetry- Asymmetry guideline

MULTIMEDIA DESIGN GUIDELINES
Asymmetrical and symmetrical design layout can be used to draw attention to the letter or word being taught

Contrast

All three vocabulary apps made use of contrast in their design to either place emphasis on a certain part of the design or to draw attention to an object, letter or word. This was achieved by incorporating contrasting colours into the design or making use of thick and thin lines within the design. The guideline identified is presented in Table 7-40.

Table 7-40 Contrast guideline

MULTIMEDIA DESIGN GUIDELINES
Contrast is colours and thickness of lines can be used to place emphasis on letters and words

Compositional Technique

Compositional technique was incorporated to a lesser extent in the Autism iHelp Play app. Each object and word being taught was centred. Occupying positive space where the object was positioned and negative space as the white background surrounding the objects.

Puzzingo's design incorporated various compositional techniques in the design, such as the rule of thirds and the golden mean. Some of the objects also appeared larger than other to create a depth perspective.

Starfall ABC also made use of various compositional techniques varying in each lesson. Each variation in compositional technique was used to create a focal point on a letter or word. The guideline identified is presented in Table 7-41.

Table 7-41 Compositional Technique guideline

MULTIMEDIA DESIGN GUIDELINES
Composition can be used to create a focal point where attention is drawn to the letter or word being taught

<u>Realism-Abstraction</u>

Autism iHelp Play only included photographs in its design, while Starfall ABC would use a combination of photographs and coloured line drawings resulting in association. Puzzingo only made use of cartoons and coloured line drawings. Table 7-42 displays the identified guideline.

Table 7-42 Realism-Abstraction guideline

MULTIMEDIA DESIGN GUIDELINES
Progress from photos to coloured drawings to black and white line drawings of the same object so that association can take place

The identified multimedia design guidelines for this section were used for the creation of the final artefact. The next section identifies sensory guidelines likewise contributing to the final artefact.

7.3.4.10 *Sensory Guidelines*

In order to identify the sensory guidelines, the tactile and auditory features incorporated in the three vocabulary apps were examined. Video recordings of the children with ASD interacting with the vocabulary apps were analysed. These video recordings were video coded and the tactile and auditory responses noted. For this section specifically, sensory memory involved the responses of: the auditory senses such as listening or saying; tactile senses involving tapping, swiping or dragging and visual senses such as recognising within a vocabulary app. According to theory, as discussed in Section 3.8, all three memories are involved namely sensory, working and long-term. Where sensory memory involves visual, auditory and tactile, working memory involves selecting, organising, matching and connecting and long-term memory involves integrating and retrieving. These activities are mentioned because they prompt tactile and auditory responses.

The sensory responses required from each of the vocabulary apps are discussed further.

Autism iHelp Play

The results of the sensory stimuli determined for the Autism iHelp Play app are presented in Table 7-43.

Table 7-43 Sensory Features of Autism iHelp Play App

Autism iHelp Play App	Memory
Helps children to recognise words.	Sensory/Visual
Allows the child to select the word	Working
Allows saying and signing of word	Sensory/Auditory
Has narration	Sensory/Auditory
Has graphics	Sensory/Visual
Has text	Sensory/Visual
Has selecting activities	Working
Integrates what was learnt into activities	Long Term
Retrieves previous lesson info into present activities	Long Term
Allows for learning through play	Sensory/Tactile
Involves memory to identify objects	Working
Has visual stimulus	Sensory/Visual
Has auditory stimulus	Sensory/Auditory
Has tactile stimulus	Sensory/Tactile
Allows actions to be initiated	Sensory/Tactile
Has various movements i.e. tapping, swiping, poking	Sensory/Tactile
Allows learner to identify objects	Working
Allows for decisions to be made utilising prior knowledge	Working
Action and reaction	Working

As is evident in Table 7-43 sensory memory appears to be mostly integrated in this Autism iHelp Play app, although working memory as well as long term memory were integrated but to a lesser extent.

The following features were identified in the Puzzingo app as displayed in Table 7-44.

Table 7-44 Features of Puzzingo App

Puzzingo App	Features
Helps children to recognise words.	Sensory/Visual
Allows matching word to print	Working
Allows the child to select the word	Working
Has narration	Sensory/Auditory
Has sounds	Sensory/Auditory
Has music	Sensory/Auditory
Has text	Sensory/Visual
Has graphics	Sensory/Visual
Has manipulatives	Sensory/Tactile
Has selecting activities	Working
Has connecting activities	Working
Has organising activities	Working
Allows for learning through play	Sensory/Tactile
Involves memory to identify objects	Working
Has visual stimulus	Sensory/Visual
Has auditory stimulus	Sensory/Auditory
Has tactile stimulus	Sensory/Tactile
Allows actions to be initiated	Sensory/Tactile
Has various movements i.e. tapping swiping, poking	Sensory/Tactile
Allows learner to identify objects	Working
Action and reaction	Working

For the Puzzingo app only two memories were incorporated namely sensory and working memory. Sensory memory appears to be used the most, followed closely by working memory. Long term memory was not expended during any of the activities.

Starfall ABC portrayed the following features as displayed in Table 7-45.

Table 7-45 Features of Starfall ABC App

Starfall ABC App	Features
Helps children to recognise words.	Sensory/Visual
Allows matching word to print	Working
Allows the child to select the word	Working
Allows saying and signing of word	Sensory/Auditory
Displays word in different contexts	Long term
Has narration	Sensory/Auditory
Has sounds	Sensory/Auditory
Has music	Sensory/Auditory
Has text	Sensory/Visual

Has graphics	Sensory/Visual
Has manipulatives	Sensory/Tactile
Has selecting activities	Working
Has connecting activities	Working
Has organising activities	Working
Integrates what was learnt into activities	Long term
Retrieves previous lesson info into present activities	Long term
Allows for learning through play	Sensory/Tactile
Involves memory to identify objects	Working
Has visual stimulus	Sensory/Visual
Has auditory stimulus	Sensory/Auditory
Has tactile stimulus	Sensory/Tactile
Allows actions to be initiated	Sensory/Tactile
Has various movements i.e. tapping swiping, poking	Sensory/Tactile
Allows learner to identify objects	Working
Allows exploration	Working
Allows decision making	Long Term
Action and reaction	Working

For the Starfall ABC app all three memories were utilised when a child with ASD interacted with the app. Sensory memory was utilised most followed by working memory. Long term memory was incorporated the most for all three vocabulary apps.

With this information, the multimedia design guidelines were created as presented in Table 7-46.

Table 7-46 Sensory guidelines

MULTIMEDIA DESIGN GUIDELINES
Include activities where the word has to be identified and selected (decision-making)
Include activities where the narrated letter/word must be matched to the printed letter/word
Include activities where the letters have to be organised in a certain way e.g. to spell a word
Include previous lessons into present lessons
Include visual, auditory and tactile stimuli relevant to the letter or word being taught
Include various tactile responses such as tapping, swiping, dragging
Allow for actions to lead to responses i.e. action and reaction
Provide opportunities for the letter/word to be pronounced or signed using sign language
Present the letter/word in different contexts
Provide opportunities for exploring

These identified multimedia design guidelines contributed to the final artefact.

TACTILE RESULTS

The initial video recordings of the children with ASD interacting with the chosen vocabulary apps were used for the video coding. The video coding included annotations of any tactile responses such as tapping, swiping, dragging and poking that occurred during the interactions with the vocabulary apps. The purpose of this activity was to identify the tactile responses required of each of the vocabulary apps.

Each tactile response was annotated and different tiers were created in ELAN for each tactile response namely tapping, swiping and dragging. An additional tier was created and named 'other' to accommodate tactile activities that weren't typical, where the child with ASD reacted differently to the expected response.

Once every tactile response was identified and noted in ELAN the data was transferred to Excel and converted to graphs.

The tactile responses for each of the chosen vocabulary apps was annotated in ELAN. The results of the number of tactile responses are presented for each vocabulary app, of which the tactile responses for Autism iHelp Play are discussed first.

Autism iHelp Play Tactile Responses

The tactile responses for the Autism iHelp Play included taps and swipes and are displayed in Figure 7-33.

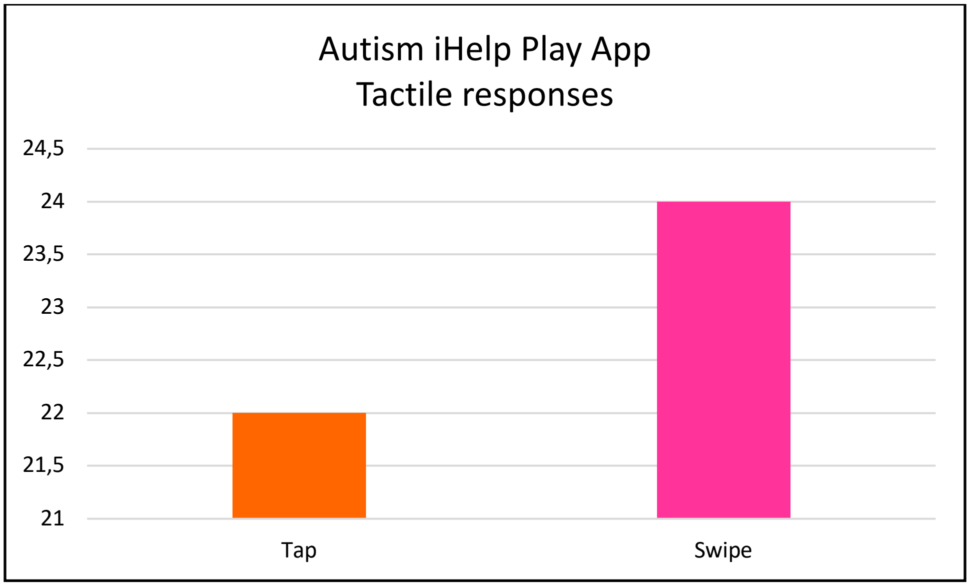


Figure 7-33 Autism iHelp Play - Tactile Responses

The major tactile response for the Autism iHelp Play app was for the swipe action. Swiping took place to transition from one image to the next. The tap response was used when playing games and a word or image had to be selected.

Puzzingo Tactile Responses

The tactile responses for the Puzzingo app included dragging, tapping and swiping among others. Other responses also included tactile responses from the children with ASD when they were unsure what was expected of them by the activity presented. The tactile responses for Puzzingo can be seen in Figure 7-34.

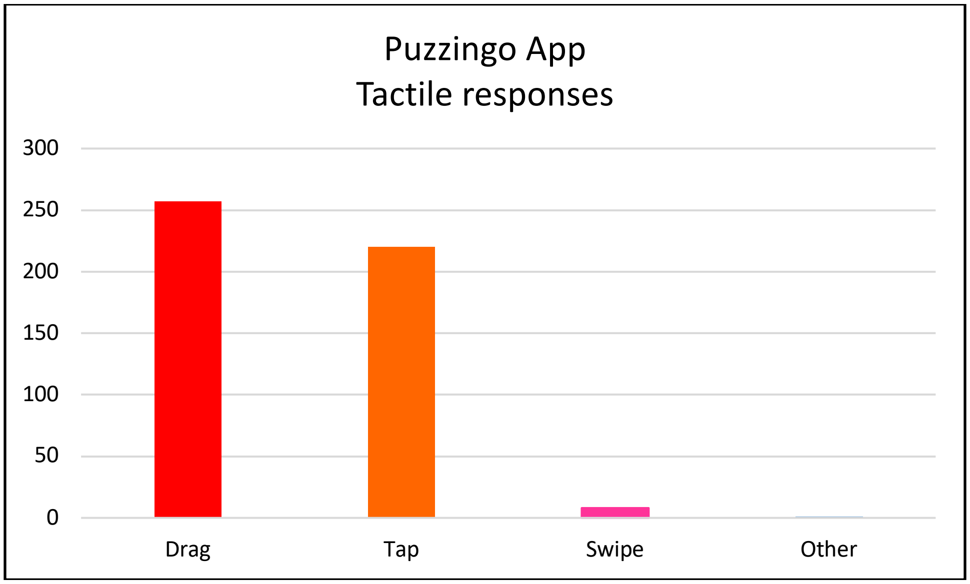


Figure 7-34 Puzzingo - Tactile Responses

The most notable tactile response for the Puzzingo app was dragging since the main activity was to match the object to its shape by dragging the object to its correct shape. The second highest tactile response was tapping. Tapping as tactile response was done at the end of each activity when a short game was awarded for completing the activity. Swiping and other tactile responses occurred the least for this vocabulary app.

Starfall ABC Tactile Responses

For the Starfall ABC app there were two tactile responses namely dragging and tapping. The tactile responses for Starfall ABC are displayed in Figure 7-35.

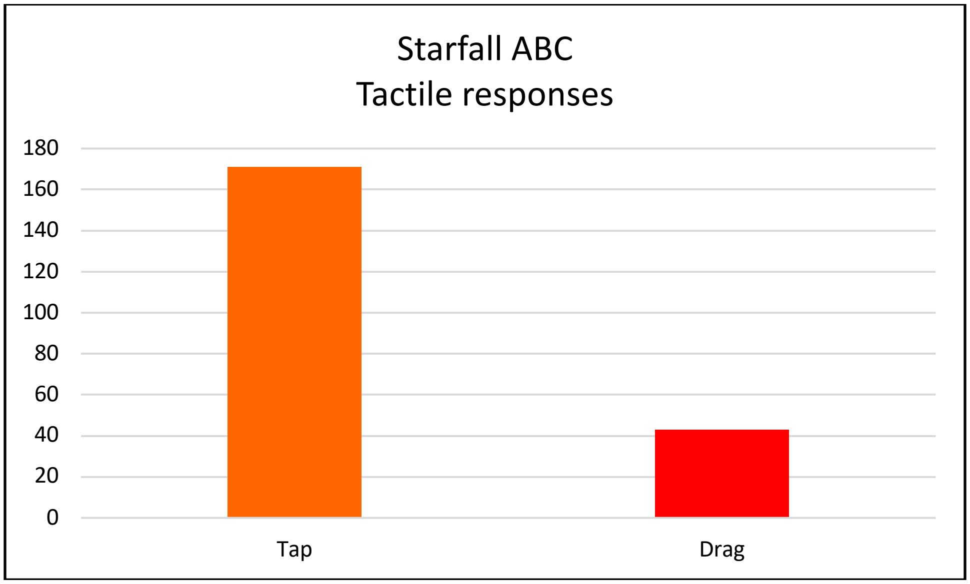


Figure 7-35 Starfall ABC - Tactile Responses

Tapping on the 'next' arrow was the tactile response most used allowing progression from one part of the lesson to the next.. Dragging as tactile response had the lowest count and was included in the reward activities once the entire lesson was completed. The dragging response for example would be required to spell a word relevant to the letter that was taught.

7.3.4.11 *Findings of Tactile responses*

The tactile responses required for each of the vocabulary apps played an important role in early language learning development. Too many tactile responses could result in the child with ASD's attention being diverted from the letter or word being taught to reacting to the activity.

Figure 7-36 displays the number of tactile responses that occurred for each vocabulary app.

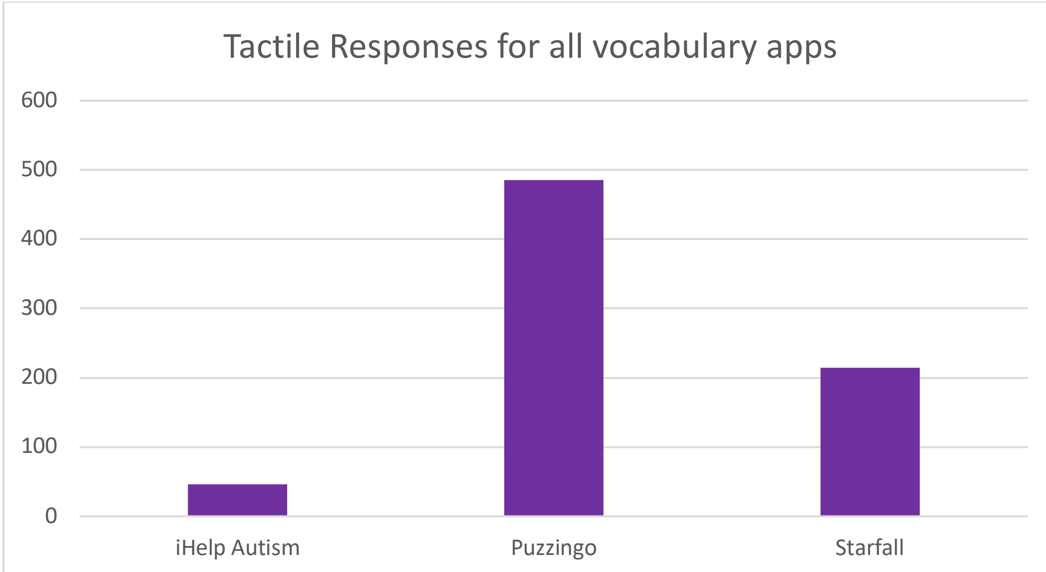


Figure 7-36 Tactile responses for all Vocabulary Apps

The Puzzingo app had the highest total of tactile responses, more than double the total for the Starfall ABC app. The Autism iHelp Play app had the least amount of tactile responses. As mentioned previously, if the vocabulary app triggered numerous tactile responses attention to words and letters was diminished. The opposite was also true, focused and relevant tactile responses can increase attention to words and letters presented in the vocabulary apps.

A comparison of the number of fixations and the number of tactile responses were made across all three vocabulary apps as displayed in Figure 7-37.

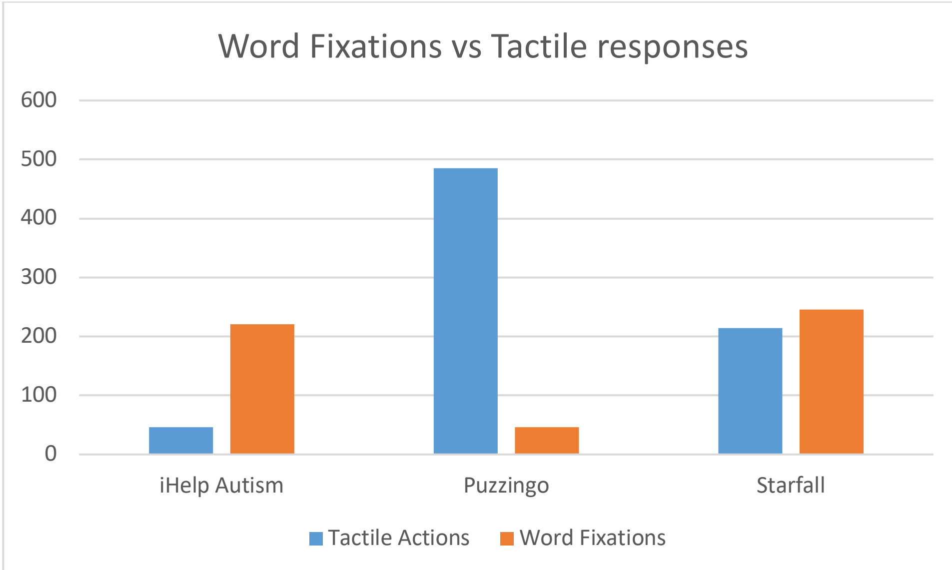


Figure 7-37 Word fixations and tactile responses

The Starfall ABC app had almost equal counts of fixations on words compared to tactile responses. These almost equivalent counts of visual and tactile responses suggest that a balance was achieved and that no sensory overload took place. The balanced sensory responses prevented over or under stimulation of the children with ASD. The evidence suggests that Starfall ABC contributes to language learning relating to the tactile responses.

The multimedia design guidelines identified are presented in Table 7-47.

Table 7-47 Tactile guidelines

MULTIMEDIA DESIGN GUIDELINES
Ensure that tactile responses focus attention on the letter/word being taught
Ensure that tactile responses are related to the letter/word being taught
Ensure that the tactile response results in an auditory response as well e.g. when the child taps on the image of apple, the app must say apple
Only incorporate tactile responses that draw attention and are relevant to the letter/word being taught
Provide an opportunity for the child to write the letter/ word being taught
Allow the child to match the articulated letter to the printed letter
Allow the child to match the articulated word to the object
Allow activities where the child can select the letter/word among other letters/words
Allow activities where the child can organise letters/words in a specific order
Allow the child to recall letters/words from previous lessons in activities

Conclusion of tactile responses for all vocabulary apps

The Puzzingo app had the greatest variety of tactile responses of all three vocabulary apps. Too much tactile activities can result in the child with ASD becoming overstimulated and not focusing on the letter or word being taught as mentioned by the speech therapists. The Autism iHelp Play and Starfall ABC apps both only had two types of tactile responses. Autism iHelp Play included tapping and swiping while Starfall ABC included tapping and dragging as tactile responses.

AUDITORY RESULTS

Similar to the previous section, the initial video recordings of the children with ASD interacting with the selected vocabulary apps were chosen for video coding. The careful reviewing of the interactions identified auditory responses from the vocabulary apps.

In order to determine the auditory qualities of the vocabulary apps, tiers were created to annotate the sounds made. For the Autism iHelp Play and Puzzingo apps two tiers were created. The first tier was for identifying sounds that were relevant to the object being taught, referring to the object's name. The second tier was named 'other' for sounds not relevant to the word being taught. Every auditory response produced by the vocabulary apps was annotated. Once each sound was annotated in ELAN the data was exported to Excel and converted to graphs.

The auditory responses that were annotated in ELAN for the vocabulary apps included sounds including pronouncing a letter or object name that was taught and other sounds. The other sounds would include clapping, shouting, a car horn or any sounds that were not conducive to learning. The recommendations made by the speech therapists regarding sounds was taken into consideration when annotations were made of the sounds played in the vocabulary apps.

The auditory responses for each vocabulary app are described as follows:

Autism iHelp Play Auditory Responses

The Autism iHelp Play app had a minimum of auditory responses. In Figure 7-38 the auditory responses for the Autism iHelp Play app are shown.

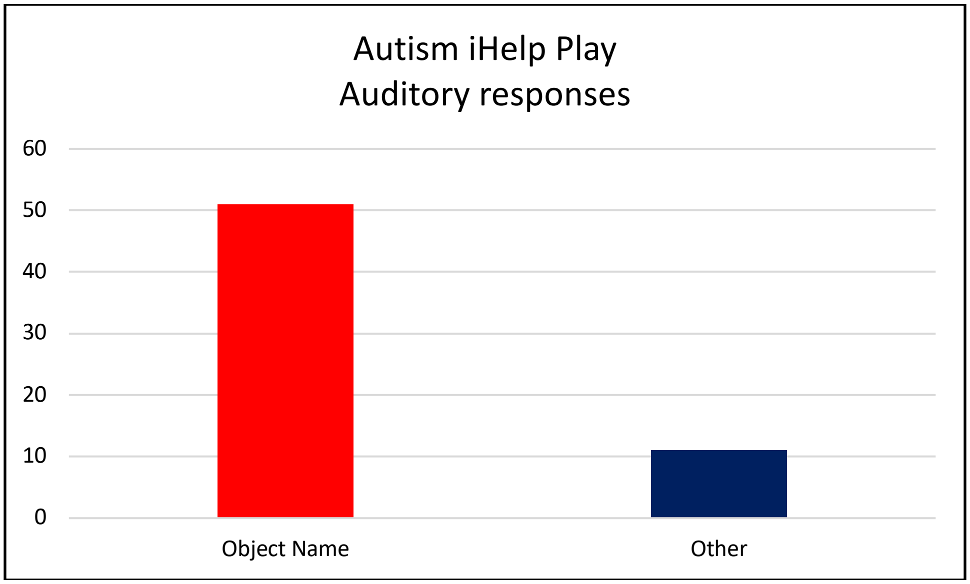


Figure 7-38 Autism iHelp Play - Auditory Responses

Irrelevant sounds were minimal for the Autism iHelp Play app while the articulation of object names was high. For children with ASD that are auditory learners, this vocabulary app is advantageous for auditory learning.

The next section discusses the auditory responses for the Puzzingo app.

Puzzingo Auditory Responses

The Puzzingo app had several different sounds as evident in the high **dark blue** column in Figure 7-39.

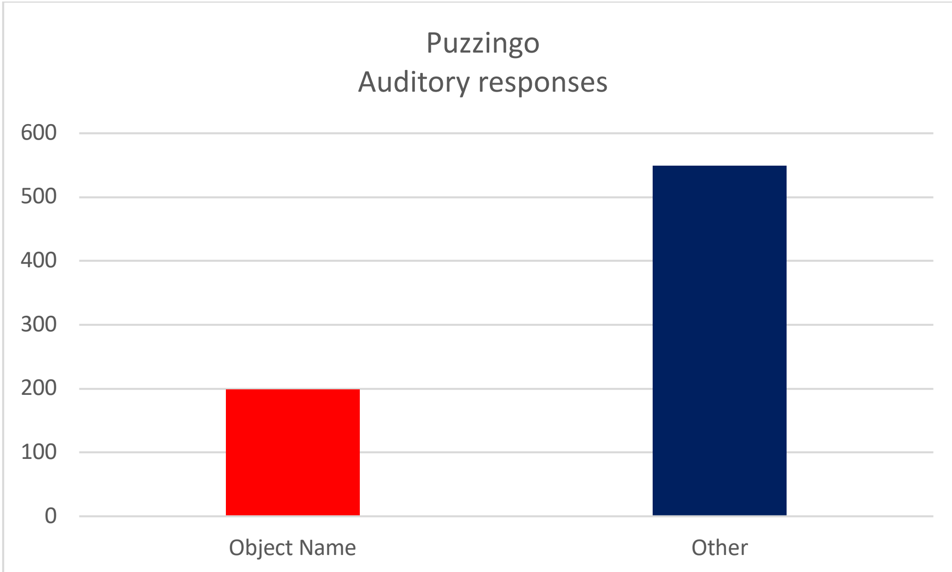


Figure 7-39 Puzzingo - Auditory Responses

Figure 7-39 indicates that the highest sounds were irrelevant sounds and the articulation of object names was the lowest for Puzzingo. The high number of auditory responses can result in sensory overload for some children with ASD. The high count of irrelevant auditory responses compared to the articulating of object names can also result in an adverse effect for vocabulary learning for children with ASD.

Starfall ABC Auditory Responses

The auditory responses for the Starfall ABC app included the pronunciation of letters, words and objects. Figure 7-40 provides the details of all the auditory responses presented in this vocabulary app.

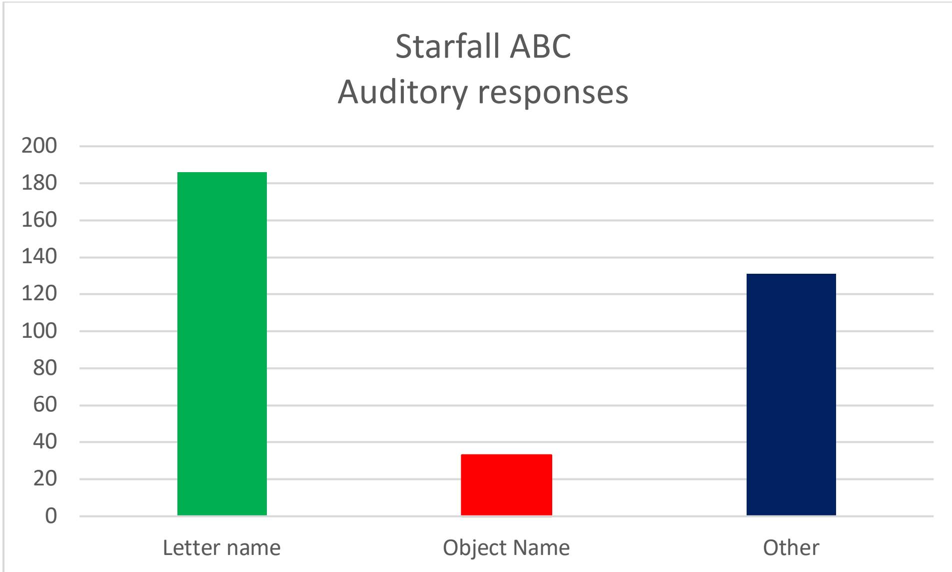


Figure 7-40 Starfall ABC - Auditory Responses

Letter pronunciation had the highest auditory responses for the Starfall ABC app followed by sounds that were irrelevant. The least amount of auditory responses was related to object names. In terms of learning, the pronunciation of letters and words make this vocabulary app effective for language learning.

The multimedia design guidelines identified are presented in Table 7-48.

Table 7-48 Auditory guidelines

MULTIMEDIA DESIGN GUIDELINES
Ensure that the letters/words being taught are articulated often
Ensure that the letter/word is articulated when touched
Ensure that object names are articulated
Incorporate phonics to introduce the letter being taught
Repeat letters phonically numerous times in the lesson
Include verbalised sentences that include the letter being taught
Animations must include the articulation of the letter/word being taught
Supplementary sounds must be limited and used to attract attention to the letter/word being taught
Minimise irrelevant sounds
Include music that is relevant to the letter/word being taught

These identified multimedia design guidelines were added to the final artefact.

7.3.4.12 *Findings of auditory responses for all vocabulary apps*

The number of auditory responses for all the chosen vocabulary apps are provided in Figure 7-41, providing an overall view of the auditory responses for each vocabulary app.

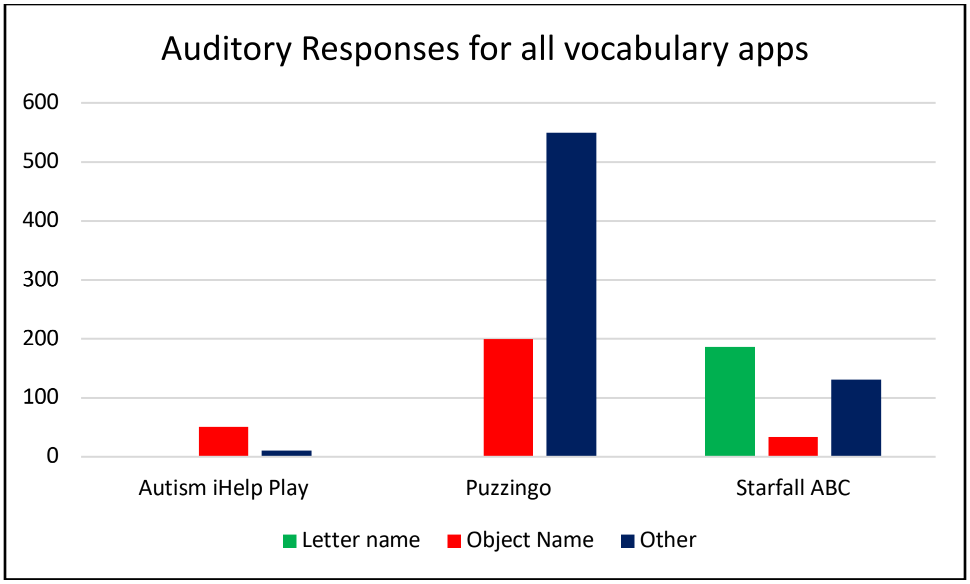


Figure 7-41 Auditory responses for all Vocabulary apps

The vocabulary app with the highest count of auditory responses was Puzzingo. Puzzingo included many sounds that were irrelevant and did not promote language learning. The Starfall ABC app had the second highest count of auditory responses that included the pronunciation of letters, words and objects and these were more numerous than any other auditory responses. Therefore, the deduction can be made that Starfall ABC contributed to language learning in children with ASD. The Autism iHelp Play app had the lowest count of auditory responses although the pronunciation of object names was more numerous than irrelevant sounds for this app, leading to the conclusion that the Autism iHelp Play app likewise contributed positively to language learning in children with ASD.

Both Starfall ABC and Autism iHelp play had higher counts of auditory sounds promoting language learning compared to the irrelevant sounds heard in Puzzingo.

7.3.4.13 *Findings of Auditory Responses*

The number of auditory responses in each of the vocabulary apps is displayed in Figure 7-42.

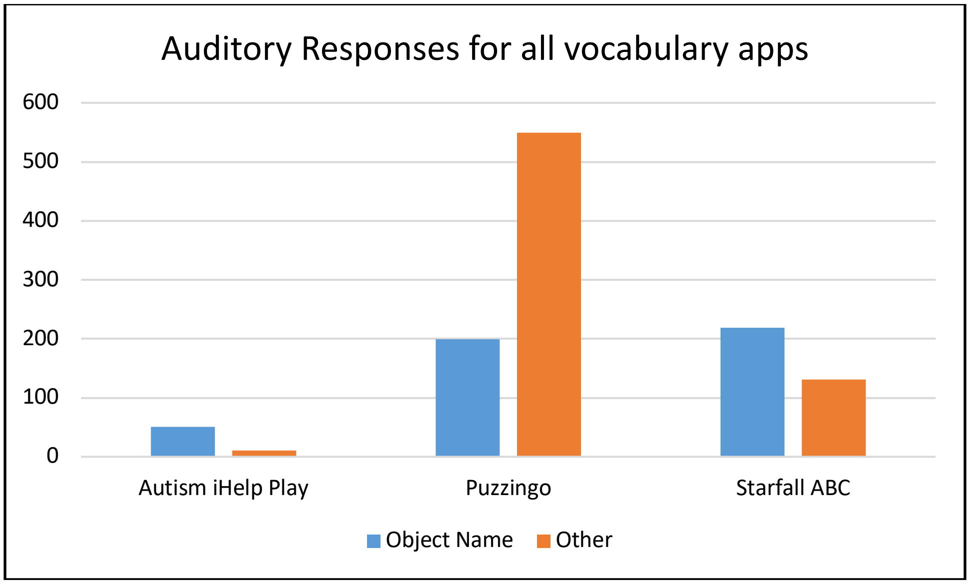


Figure 7-42 Auditory responses for all Vocabulary Apps

For the Starfall ABC app the number of letter and object articulations were calculated together since both contributed to language learning. This was done so that the difference could be seen between sounds that contributed to learning (letter, word and object articulation) and sounds that distracted attention (other – irrelevant sounds).

The vocabulary app that contributed most to learning when considering the auditory responses was the Starfall ABC app followed by the Autism iHelp Play app. The Autism iHelp Play app included limited auditory responses that contributed towards language learning. The Puzzingo app had many irrelevant auditory sounds that could be distracting for children with ASD.

Next, Figure 7-43 compares the number of auditory responses to the number of fixations on words in order to detect whether there were any significant differences between the visual and auditory stimuli.

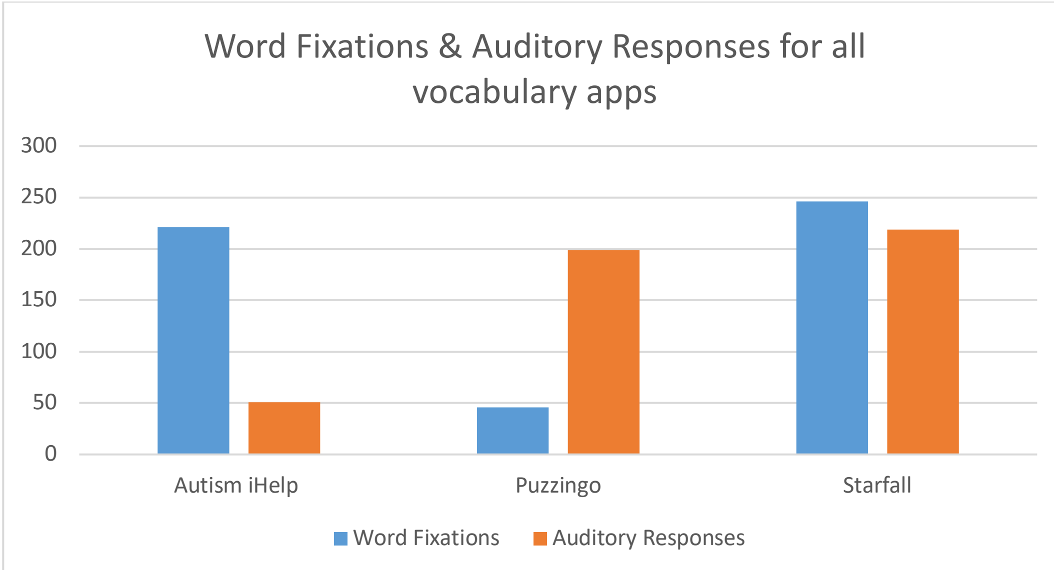


Figure 7-43 Comparison of Fixations and Auditory responses

The Starfall ABC app had almost uniform visual and auditory responses with greater fixations on letters and words than the auditory responses to the letters and words played. Large differences in visual and auditory responses were evident for both the Autism iHelp Play and Puzzingo apps.

Since both the auditory and tactile responses for the Starfall ABC app were almost equal, the evidence suggests that this vocabulary app contributes positively to language learning for children with ASD. Considering the evidence presented in the previous sections, figure 7-44 provides an overall picture of each of the vocabulary apps visual, tactile and auditory responses.

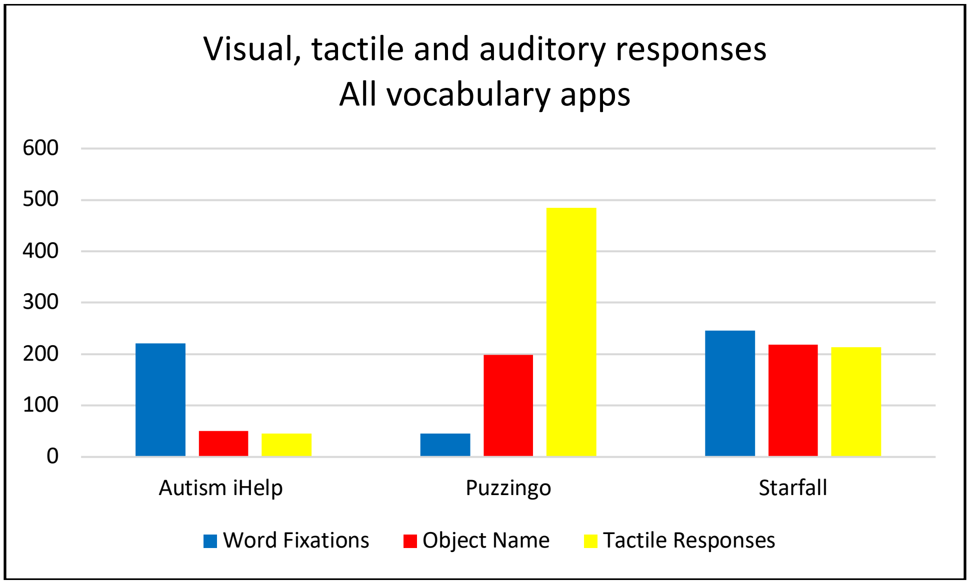


Figure 7-44 All sensory responses of vocabulary apps

The vocabulary app that performed the best in terms of visual, tactile, and auditory responses was Starfall ABC. The assumption can be made that sensory memory is adequately utilised allowing learning to take place through all three senses: visual, auditory and tactile. Therefore, the conclusion can be made that Starfall ABC effectively contributes to language learning in children with ASD performing the best of all three vocabulary apps.

The second app that contributed to learning language for children with ASD was the Autism iHelp Play app. The children with ASD had a high count of word fixations for this app. However, the auditory and tactile responses were moderate in comparison to the word fixations. Consequentially, inadequate sensory stimuli for the visual, tactile and auditory senses takes place. This may have a negative influence on language learning for children with ASD that are auditory or tactile learners.

The vocabulary app that contributed the least to language learning in children with ASD according to the evidence presented was Puzzingo. The tactile responses were very high in comparison to the auditory and visual responses and were considered ineffective for language learning because of the minimal fixations on words.

The accrual of multimedia design guidelines after each evaluation from Phase Two to Phase Four assisted with the creation of the final artefact which is discussed next.

7.4 Final Artefact

The consolidation of multimedia design guidelines from the initial artefact of Phase Two, the intermediate artefact of Phase Three and the multimedia design guidelines identified in Phase Four developed the artefact into an effective and robust final artefact.

The initial artefact of Phase Two identified initial multimedia design guidelines from the results of the interviews with the speech therapists (see Section 6.4.4.2). In addition, the validated design objectives facilitated the creation of the initial artefact.

In Phase Three particularly, the educational guidelines were identified with the help of an educational specialist. The educational guidelines were identified from the educational theories presented in the conceptual framework (see Section 4.7). The educational value of all three vocabulary apps were ascertained. The vocabulary app with the highest educational value was identified by the educational specialist as Starfall ABC. Special attention was awarded to the educational features of Starfall ABC, specifically the features that weren't present in the other two vocabulary apps. Once all the features were identified they were converted into multimedia design guidelines.

For Phase Four, eye tracking took place while the children with ASD interacted with the three chosen vocabulary apps. The app with the highest number of fixations on letters and words was identified as Starfall ABC. Next, the identification of multimedia learning principles occurred whereby all the features that contributed positively towards learning in all three the vocabulary apps were identified. This was done with the help of checklists to determine whether the finding of Phase Two were correct. The findings of multimedia learning also indicated that Starfall ABC was the most effective vocabulary app assisting early language learning in children with ASD. The multimedia learning principles present in Starfall ABC were identified, consolidated and transformed into guidelines.

Also, for Phase Four, the graphic design features of Starfall ABC were identified with the help of checklists. The acknowledged graphic design features were transformed into multimedia design guidelines.

Furthermore, sensory guidelines were identified in Phase Four for Starfall ABC to ensure that all the design objectives were met. This was achieved through video coding.

The consolidation of artefacts leading to the final artefact is presented in Table 7-49.

Table 7-49 Final Artefact

DESIGN OBJECTIVES	FINAL ARTEFACT
Educational values	1. Provide various examples of the letter or word being taught 2. Incorporate short lessons with themes 3. Follow a specific routine when teaching a letter or word 4. Provide guidance, helping the child recognise letters or words 5. Provide opportunities for the child to select and say or sign a letter/word 6. Present the letter or word in a repetitive and consistent manner 7. Display the letter or word in different contexts 8. Allow associations to be made between words and objects 9. Only include information relevant to the lesson 10. Only include essential material 11. Use short sentences 12. Lessons must be designed in user-paced segments that are small and presented sequentially 13. The lesson must be under the control of the child
Emphasis on letters and words being taught	1. Teach the letter in lower- and uppercase 2. Teach words that begin with the letter being taught 3. Teach a letter/word and then provide opportunities to identify the letter/word 4. Include opportunities for sentence building 5. Include repetition 6. Include a variety of games such as puzzles, join the dots and writing the letter/word with fingers 7. Allow association of word and object 8. Include animated letter/word activities 9. Ensure that the letters/words are pronounced when touched 10. Actions relating to the letter/word must take place when the letter/word is tapped (tactile stimulus). 11. Include visual, auditory and tactile activities relevant to the letter or word being taught 12. Provide opportunities for exploring different letters/words according to preference

Activate sensory, working and long-term memory	1. Action and reaction events must occur relating to the letter/word being taught 2. Allow decision making activities concerning the letters/words that were taught 3. Include levels of difficulty allowing the child to progress from easy to difficult 4. Provide activities where the letter/word has to be identified and selected (decision-making) 5. Provide activities where the narrated letter/word must be matched to the printed letter/word 6. Provide activities where the letter/word have to be organised in a certain way e.g. to spell a word or make a sentence 7. Allow the child to recall letters/words from previous lessons in activities
Sensitivity towards sensory stimuli	**TACTILE** 1. Touch, tap, swipe actions must result in the word/letter being articulated 2. Accommodate sensitivity to touch 3. Accommodate fine motor difficulties 4. Include various tactile activities such as tapping, swiping, dragging 5. Ensure that tactile activity focuses attention on the letter/word being taught 6. Ensure that tactile activities are related to the letter/word being taught 7. Ensure that the tactile activity results in an auditory response e.g. when the child taps on the image of apple the word apple must be articulated 8. Only incorporate tactile activities that draw attention and are relevant to the letter/word being taught 9. Provide an opportunity for the child to write the letter/ word being taught 10. Allow the child to match the articulated letter to the printed letter 11. Allow the child to match the articulated word to the object 12. Tactile activities should not be overstimulating or irrelevant
	ANIMATIONS 1. Incorporate limited movements when using animations 2. Animations should focus the child's attention on the letter/word 3. Animations must have narration with text at the same time 4. Animations must include the articulation of the letter/word being taught 5. Animations must be adequately paced 6. Animate the letter or word being taught
	SOUNDS 1. Provide narration of the letter or word being taught 2. Sounds must be purposeful and relevant 3. Include phonetics/phonics to introduce the letter being taught

	4. Include positive reinforcement 5. Sounds must direct the child's attention to the letter/word being taught 6. Music must promote the letter/word being taught 7. Music must be relevant to the letter/word being taught 8. Place vocal emphasis on key letters/words 9. Narration must be adequately paced 10. Spoken words must occur with printed words 11. Narration must be in a conversational style articulated in a human voice 12. Show a person speaking when narration occurs and when the narration stops the person can disappear 13. The person narrating must differ in ethnicity, race, gender and age relevant to the target group 14. Ensure that the letters/words being taught are articulated often 15. Ensure that the letter/word is articulated when touched 16. Ensure that object names are articulated 17. Repeat articulation of letters/words numerous times 18. Include verbalised sentences that include the letter being taught 19. Supplementary sounds must be limited and used to attract attention to the letter/word being taught 20. Minimise irrelevant sounds
Graphic Design	1. Do not include abstract images or objects 2. Objects in the design must progress from photos to coloured drawings to black-and-white line drawings 3. An object must be placed as close as possible to the word being taught 4. When using colour incorporate shades of the same colour 5. Colour must attract the child's attention to the letter/word 6. Colour must be used in a consistent manner from one lesson to the next 7. Colour can range from one colour with different tones to full colour photos or line drawings used conservatively 8. Contrasting colours can be used to draw attention to the letter/word 9. Light/dark contrast can be incorporated to draw attention to a letter/word 10. Tonal chords can be used to direct attention 11. Use a photo of an object when teaching a word for the first time 12. Use lines to create a focal point to the letter/word being taught 13. Present the letter/word in different contexts 14. Line can be used to separate letters/words guiding the child's attention 15. Variation in line thickness can be used to place emphasis on letters/words 16. Ensure that all objects in the design relate to the letter/word being taught

	17. Pictures must be relevant to the letter or word being taught 18. Include cues to direct the child's attention to the letter/word 19. The picture must be easy to understand if there are no words 20. Place corresponding words and objects close to each other 21. Words and objects must be presented at the same time 22. Provide arrows for the child to go back to the previous lesson or forward to the next lesson 23. The design layout should be arranged to direct the child's attention to the letter/word 24. The design layout should be clean, uncluttered and organised 25. The composition must create a focal point to draw attention to a letter/word 26. The design layout can be asymmetrical or symmetrical to draw attention to a letter/word 27. Include variation in the design layout to maintain attention and focus 28. Shapes can be used to enhance the learning of a letter/word 29. Differing sizes of letters/words/objects can help the child distinguish 30. Incorporate texture to teach the word on different surfaces 31. Typography can be used to represent a specific theme but must me readable 32. Typography can be used to place emphasis on a letter/word

The final artefact resulted in the conclusion of the DSRM study. Addressing the problem, namely a lack of validated multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD.

The final artefact successfully addressed the design objectives by including multimedia design guidelines that:

- enhance educational value;
- emphasise letters and words being taught;
- create sensory awareness;
- activate sensory, working and long-term memory;
- guide graphic design layout and composition specifically for children with ASD.

7.5 Conclusion

In this chapter the results and findings of Phase One and Phase Two of the DSRM contributed to Phase Three and Phase Four. The identified problem with the design objectives to address the problem were validated by the speech therapists. The initial vocabulary apps were identified and chosen, based on the recommendations by the speech therapists. The final three apps for the study were chosen based on the preferences of the children with ASD that took part in the study. An educational specialist assisted in the identification of the vocabulary app with the highest educational value, leading to educational guidelines. Multimedia learning, sensory and graphic design guidelines were identified through checklists all of which conclusively resulted in a final robust artefact.

The final chapter of this thesis, presented next, provides an overview of the research. Revisiting the research questions, reflecting on the findings and providing areas of future academic and practical research.

8 CHAPTER EIGHT - SUMMARY, DISCUSSIONS, LIMITATIONS AND RECOMMENDATIONS

8.1 Focus of Chapter

In this final chapter the research questions guiding the research are revisited briefly. In addition, a summary of the research design is provided, followed by a description of the four phases of the Design Science Research Model and the creation of the final artefact. A reflection on the findings is provided, discussing the delineations and assumptions of the research study and ending with a few closing thoughts.

8.2 Research Questions

In order to create effective and robust multimedia design guidelines for vocabulary apps, assisting early language learning in children with ASD, the research was guided by four research questions.

8.2.1 *First sub-research question answered*

The first sub-research question was:

What are the educational qualities of an effective vocabulary app?

To answer this research question, the four learning theories presented in the conceptual framework (see Chapter Four) were judiciously studied. Figure 8-1 presents the diagrammatic representation of the conceptual framework.

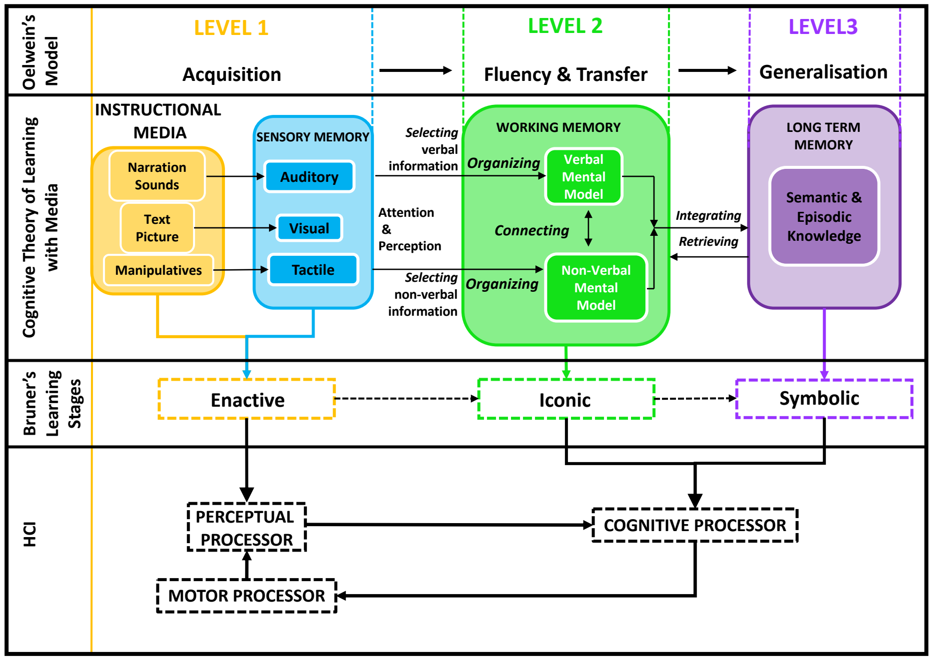


Figure 8-1 Conceptual Framework

The learning theories were amalgamated as follows:

The process was started with a methodology introduced by Oelwein (Broun, 2004) (Broun, 2004; Oelwein, 1995)relating to teaching children with ASD to read. Oelwein's methodology included three stages of learning namely: the acquisition, fluency and transfer, and generalisation stages.

Next the cognitive theory of learning with media (Moreno, 2006) was incorporated. This comprehensive theory encompasses diverse and varied instructional technologies involving the three senses –auditory, visual and tactile - for learning with technology. These three senses are important to consider for children with ASD learning early language since some children are visual and others auditory learners. Active learning takes place when the learner utilises a number of cognitive processes to understand the information presented to him or her. The cognitive processes involved in meaningful learning entail selecting information that is relevant; arranging the information into coherent representations; and integrating the information into existing knowledge.

Following the cognitive theory of learning with media in the conceptual framework, Bruner's three stages of learning are presented. This theory explains that children progress through three stages of learning namely:

- The ***enactive stage*** where children begin to develop understanding through actively manipulating objects.
- The ***iconic stage*** where children are able to make mental images of something and no longer need to have the physical object in front of them.
- The ***symbolic stage*** where children use abstract ideas to represent the world and are able to use symbols and symbolic systems and to think critically (Smidt, 2011).

The final learning theory involves Human Computer Interaction which includes an interactive process whereby information is processed to achieve set objectives. Various processors are involved in HCI specifically the perceptual, cognitive and motor processors. Information is transferred from the perceptual processor to the cognitive processor and finally to the motor processor where actions are executed (Jacko, 2012).

These learning theories assisted in the creation of checklists utilised by an educational specialist. The results from the expert provided the identification of important educational qualities to create an effective vocabulary app. Additional qualities were identified from Phase Two to Phase Four of the DSRM where the final artefact was developed as presented in Table 8-1.

Table 8-1 Educational qualities

EDUCATIONAL QUALITIES OF AN EFFECTIVE VOCABULARY APP	
1.	Provide various examples of the letter or word being taught
2.	Incorporate short lessons with themes
3.	Follow a specific routine when teaching a letter or word
4.	Provide guidance, helping the child recognise letters or words
5.	Provide opportunities for the child to select and say or sign a letter/word
6.	Present the letter or word in a repetitive and consistent manner
7.	Display the letter or word in different contexts
8.	Allow associations to be made between words and objects
9.	Only include information relevant to the lesson
10.	Only include essential material
11.	Use short sentences

12.	Lessons must be designed in user-paced segments that are small and presented sequentially
13.	The lesson must be under the control of the child

8.2.2 *Second sub-research question answered*

The second sub research question was:

How are different memories activated in vocabulary apps?

The different memories referred to in the study are: The **sensory memory**, where every sensation or stimulus namely taste, touch, vision, smell and hearing is recorded. Sensory memory also filters unimportant stimuli that can become overwhelming so preventing an overload in working or long-term memory (Hudmon, 2006). **Working memory** stores transitory information from the sensory memory that may be required later. Attention is awarded to a specific task and the information retained concerning the task (Fougnie, 2008). **Long-term memory** stores copious amounts of information up to a lifetime. This allows taking the required information out of the working memory and storing the information in a more secure environment that has less stimuli that cause interferences or disturbances (Brady et al., 2008).

These different memories assist with language learning and are activated as shown in Table 8-2.

Table 8-2 Memory activation

ACTIVATING SENSORY, WORKING AND LONG-TERM MEMORY IN A VOCABULARY APP	
1.	Action and reaction events must occur relating to the letter/word being taught
2.	Allow decision making activities concerning the letters/words that were taught
3.	Include levels of difficulty allowing the child to progress from easy to difficult
4.	Provide activities where the letter/word has to be identified and selected (decision-making)
5.	Provide activities where the narrated letter/word must be matched to the printed letter/word
6.	Provide activities where the letter/word have to be organised in a certain way e.g. to spell a word or make a sentence
7.	Allow the child to recall letters/words from previous lessons in activities

8.2.3 *Third sub-research question answered*

The third sub-research question was:

How is emphasis placed on letters and words used in a vocabulary app?

To answer this research question eye tracking was incorporated. The children with ASD were given the opportunity to interact with three vocabulary apps they had inadvertently chosen. The interactions with the apps were recorded and the video recordings were analysed by means of video coding. Each fixation on letters (if the vocabulary app taught letters) and words was calculated to determine which of the three vocabulary apps contributed most to language learning. The app that was identified as the most effective for early language learning for children with ASD was Starfall ABC. This app was further analysed with the help of checklists to determine which aspects place emphasis on letters and words being taught. The results are presented in Table 8-3.

Table 8-3 Emphasis on letters and words

PLACING EMPHASIS ON LETTERS AND WORDS BEING TAUGHT IN A VOCABULARY APP
1. Teach the letter in lower- and uppercase 2. Teach words that begin with the letter being taught 3. Teach a letter/word and then provide opportunities to identify the letter/word 4. Include opportunities for sentence building 5. Include repetition 6. Include a variety of games such as puzzles, join the dots, writing the letter/word with fingers 7. Allow association of word and object 8. Include animated letter/word activities 9. Ensure that the letters/words are pronounced when touched 10. Actions relating to the letter/word must take place when the letter/word is tapped (tactile stimulus). 11. Include visual, auditory and tactile activities relevant to the letter or word being taught 12. Provide opportunities for exploring different letters/words according to preference

8.2.4 *Main research question answered*

The main research question was:

Which multimedia design guidelines for vocabulary apps assist early language learning in children with Autism Spectrum Disorder?

The answer to the main research question was provided with the help of the DSRM. Multimedia design guidelines which were identified for various aspects of a vocabulary app. These aspects included multimedia design guidelines:

1. To enhance the educational value of vocabulary apps
2. To place effective emphasis on letters and words being taught by the vocabulary app
3. How to activate sensory, working and long-term memory for children with ASD interacting with a vocabulary app
4. Being sensitive to the sensory stimuli incorporated into a vocabulary app
5. Determining which graphic design elements and principles are most applicable in contributing towards effective language learning in children with ASD.

The identified multimedia design guidelines are presented in Figure 8-2.

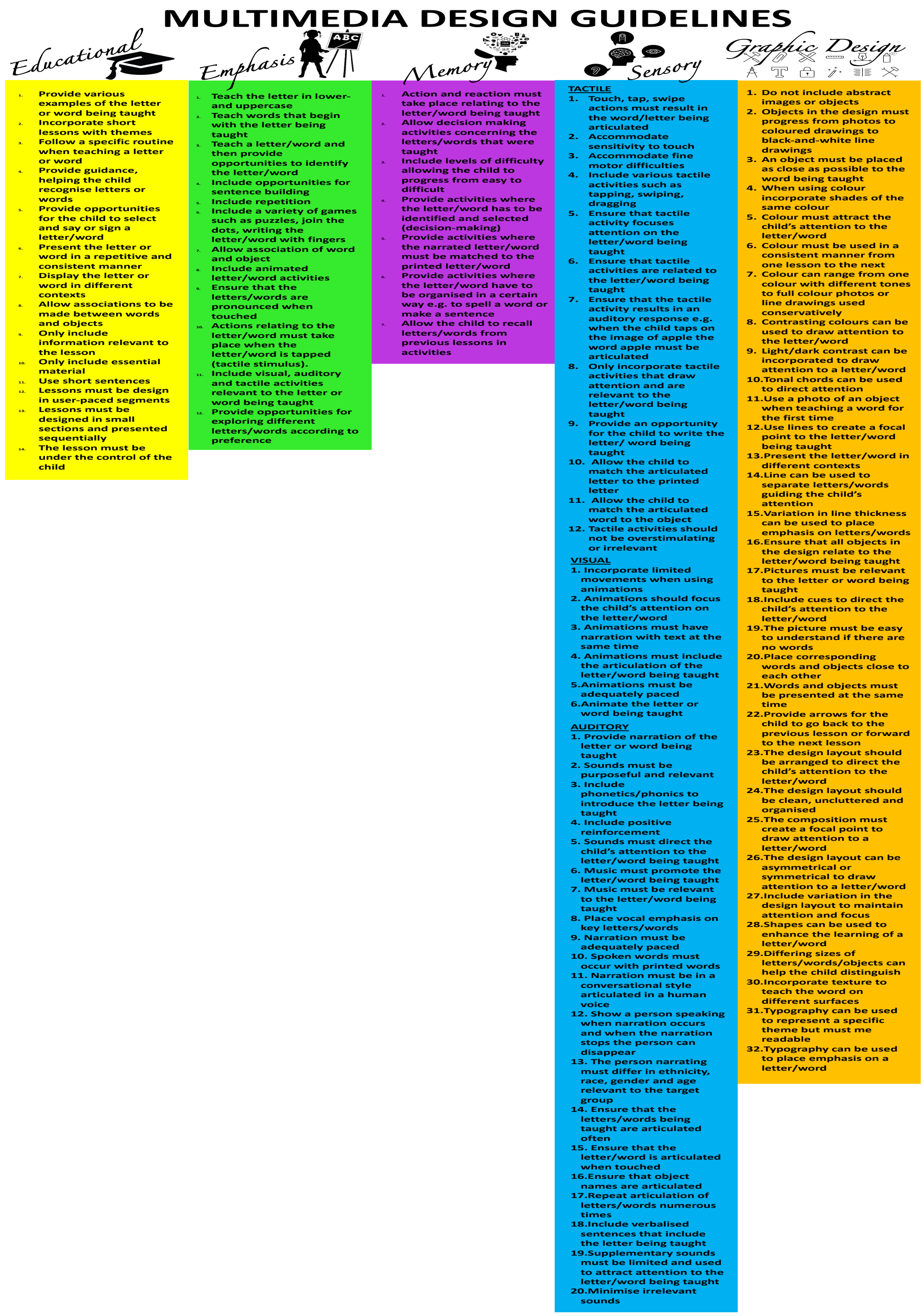


Figure 8-2 Multimedia Design Guidelines

These identified multimedia design guidelines were confirmed throughout the various phases of the DSRM, thereby verifying the fidelity of the guidelines rendering them robust. Also, the design objectives were met that addressed the identified problem thereby validating the multimedia design guidelines further. The various guidelines identified from expert opinions, eye tracking and checklists culminated into multimedia design guidelines which, if implemented into vocabulary apps, would effectively assist early language learning in children with ASD.

8.3 Summary of Research Design

This section provides a brief overview of the research process implemented in the research study. The research process involved different phases of the Design Science Research Model (DSRM) and are discussed as follows.

8.3.1 *The Phases of the DSRM*

The four phases of the DSRM model used for this research study addressed the research questions and are briefly discussed in the paragraphs following.

Phase One of the DSRM

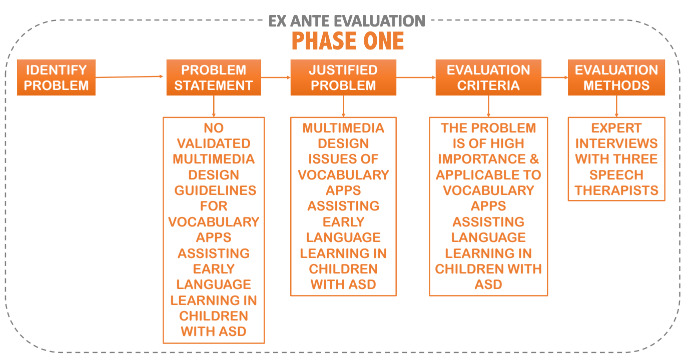


Figure 8-3 DSRM Phase One

The specific research problem identified was that there were no validated multimedia design guidelines for vocabulary apps assisting early language learning in children with ASD as seen in Figure 8-3. A small number of vocabulary apps are designed based on rigorous research incorporating valid multimedia design guidelines. Mostly vocabulary apps are designed according to the preferences of the app developers. Colours are used as pleased; animations and sounds are added with little consideration that they may cause overstimulation of the senses in children with ASD. The identified problem was validated by the expert opinions of speech therapists.

Phase Two of the DSRM

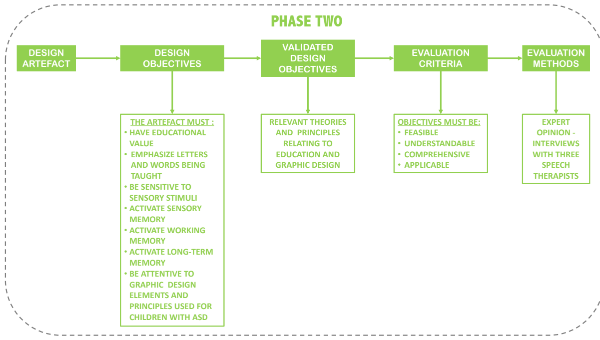


Figure 8-4 DSRM Phase Two

This phase presented in Figure 8-4 involved the identification of design objectives for the creation of the initial artefact providing multimedia design guidelines for vocabulary apps for children with ASD. The design objectives were validated by relevant theories and literature as well as the expert opinions of the speech therapists. Educational theories were included from the conceptual framework. The validation ensured that the artefact was feasible, understandable, comprehensive and applicable.

In addition, the five initial vocabulary apps were identified for the children with ASD to interact with.

Phase Three of the DSRM

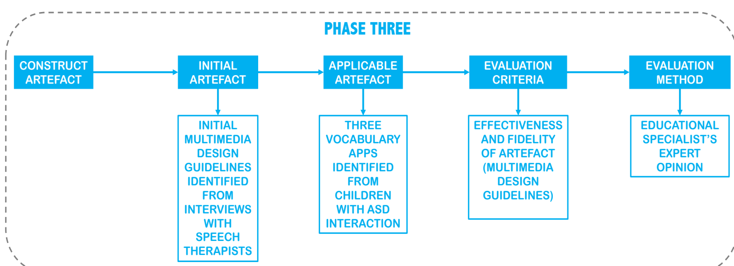


Figure 8-5 DSRM Phase Three

The purpose of the third phase of the DSRM was to attain the expert opinion of an educational specialist regarding the educational value of the identified vocabulary apps.

The interviews with the three speech therapists conducted in the previous phase resulted in the creation of the initial artefact. The children with ASD were given the opportunity to interact with the five chosen vocabulary apps identified in the previous phase. Their interactions were video recorded and the top three vocabulary apps they spent the most time interacting with were chosen. By allowing the children with ASD to inadvertently choose which apps they preferred, these apps were thoroughly evaluated in the study. The expert opinion of an educational specialist ensured the robustness and fidelity of the artefact. The educational value of each of the chosen vocabulary apps was determined by the educational specialist with the help of a checklist incorporating the features of each of the learning theories of the conceptual framework namely Oelwein's Methodology, the Cognitive Theory of Learning with Media, Bruner's Learning Stages and Human Computer Interaction. The expert opinion of the educational specialist resulted in the creation of the intermediate artefact. In addition, once the results of the checklists were analysed the vocabulary app that contributed most to language learning was identified. The identified app was Starfall ABC and this app was meticulously examined for the creation of the final artefact.

Phase Four of the DSRM

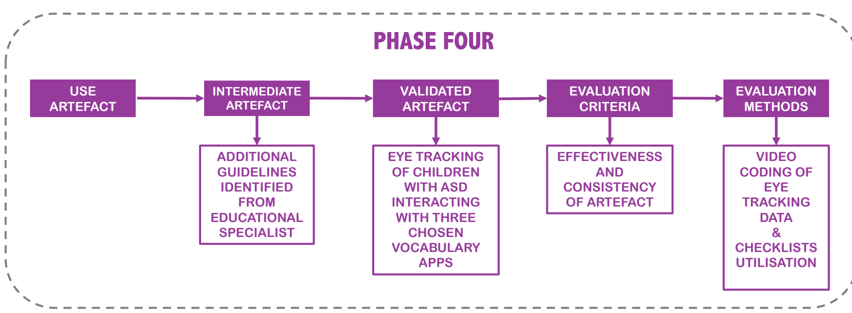


Figure 8-6 DSRM Phase Four

The final phase of the DSRM resulted in the culmination of multimedia design guidelines from the initial and intermediate artefact to create the final artefact. This phase served to ultimately show that the artefact was both applicable and useful in practice. The children with ASD were given a second opportunity to interact with the final three chosen vocabulary apps, only this time eye tracking was involved. Eye tracking was incorporated to determine the number of fixations on letters, words and objects for each of the three chosen vocabulary apps. In addition, the vocabulary app that prompted the highest number of fixations on letters and words, namely Starfall ABC, was identified thereby validating the intermediate artefact.

Also, for this phase the multimedia learning, graphic design and auditory and tactile guidelines of the Starfall ABC app were identified through the administration of checklists identifying relevant features. Two different procedures were involved in the evaluation, specifically video coding annotating the number of fixations and the utilisation of checklists.

The culmination of multimedia design guidelines from the various phases were associated with the design objectives of Phase Two. This efficiently addressed the identified problem of Phase One thus resulting in a robust final artefact demonstrated to be effective.

8.4 Reflection on Findings

In not only identifying the vocabulary app that contributed most to early language learning for children with ASD, but also recognising the multimedia design guidelines that effectively contributed to language learning, various aspects seemed to play a role in a vocabulary apps success. These aspects included the educational contribution made by the app; the manner in which emphasis was placed on letters and words taught in the app; the activities that activate sensory, working and long-term memory; the degree of sensory stimuli integrated in the app; and lastly the design layout of the app.

The learning theories presented in the conceptual framework underpinned the educational importance expected for vocabulary apps. The various stages of learning identified in the conceptual framework provided guidance regarding the utilisation of the sensory, working and long-term memory.

Eye tracking provided insight into the properties that attract the child with ASD's attention to letters and words, helping to gain awareness of how to place emphasis on letters and words being taught by a vocabulary app.

The examining and understanding of graphic design elements and principles assisted in designing the layout of a vocabulary app optimised for children with ASD.

These considerations helped contribute to the identification of effective multimedia guidelines that can be incorporated into the design of vocabulary apps to assist children with ASD in early language learning.

8.5 Contributions of Knowledge

The contributions made by the research study occur on various levels specifically practical, theoretical and methodological.

8.5.1 *Practical Contribution*

The multimedia design guidelines developed during this study, as depicted in Figure 8.2, can help app developers, speech therapists, teachers and parents.

App Developers

By implementing the multimedia design guidelines offered, a greater chance exists for language learning to take place effectively for children with ASD. The multimedia design guidelines take a holistic approach to effective language learning by involving sensory, working and long-term memory in the design of the vocabulary app encouraging learning.

App developers that are determined to develop vocabulary apps that will effectively contribute to early language learning in children with ASD will accomplish a lot by implementing these multimedia design guidelines.

Speech Therapists

The multimedia design guidelines can be presented as suggestions for speech therapists searching for vocabulary apps that effectively contribute to early language learning in children with ASD. The guidelines may also be effective for patients who do not have ASD but need to relearn language.

Teachers

Similarly, teachers making use of mobile devices in their classrooms to teach vocabulary can utilise the multimedia design guidelines to select an effective vocabulary app.

Parents

Many parents are searching the internet and app stores for vocabulary apps that would be guaranteed to help their child or children to learn language effectively. The surplus apps claiming to teach early language have led to disappointment. The reason is that the apps entertain the child rather than teach language. Parents can identify vocabulary apps that will be effective for language learning by incorporating the multimedia design guidelines into their choice criteria when choosing an app.

Vocabulary apps that fulfil all or most of the multimedia design guidelines mentioned in this research study will positively contribute to early language learning, specifically for young typically developing children just starting to learn language or children with language difficulties such as children with ASD.

An additional contribution was the method used to include eye tracking in the study. Most eye tracking studies utilise a head mount to record fixations and saccades. This could not take place for this study since the school requested it not be done. In order to be able to implement eye tracking, the eye tracking equipment was positioned in an unobtrusive manner on a 19.5-inch screen yielding valuable data. Two screens were used and the vocabulary apps mirrored on both screens so that if something went wrong the eye tracking specialist could take over. The three chosen vocabulary apps were downloaded and played through an emulator titled Leapdroid. This allowed the children with ASD to interact with the vocabulary apps in the same manner they would with a tablet. If they quit the app, which is often the case as stated by the speech therapists, the eye tracking specialist can reopen the app on her computer since both screens were under her control.

This allowed the child to continue interacting with the app until enough data was collected.

8.5.2 *Theoretical Contribution*

This research study will contribute to scholarly literatures with a main focus on language and vocabulary development in children with language learning difficulties, such as children with ASD. Effective ways of teaching language to children with ASD has been a focal point for many research studies. By taking heed of the identified multimedia design guidelines further studies can be implemented relating to the multimedia design of technologies for children with ASD.

Specific to this research study, various learning theories were incorporated into the conceptual framework which included the engagement of sensory, working and long-term memory. The engagement of these different memories provides a greater prospect for learning language successfully.

8.5.3 *Methodological Contribution*

The unique and novel application of DSR with the specific model of Sonneberg and vom Burke (2012) in Section 5.5.4 where mixed methods were applied as part of the data collection and analysis in the various phases of the development of the artefact, as was illustrated in Figure 5-1, allowed for a unique way of using mixed methods within a DSR process model and provide something which was not found in previous PhDs in education studies before.

8.6 Recommendations

Considering the results of the research study, recommendations can be made for teaching practices, the design of vocabulary apps and the choice of vocabulary apps for language learning in children with ASD.

8.6.1 *Teaching Practice Recommendations*

Speech therapists and special education teachers alike are involved in fostering language learning in young children with ASD. The understanding of the forms and sounds of letters and words and making associations between words and objects are development opportunities for children with ASD. Ample opportunity should be provided to actively engage in language learning as children with ASD are comfortable with the use of technology. This is even more so when the technology has been proven to be effective in increasing academic interest (Hourcade et al., 2012; Neely et al., 2013).

Therefore, the identified multimedia design guidelines can improve language learning when incorporated into vocabulary apps. Exposing children with ASD to well-designed vocabulary apps that incorporate the identified and proven multimedia design guidelines can result in an increased interest in language learning.

Given the fact that there is a multitude of educational apps available, speech therapists and teachers need to be well informed about the properties that make vocabulary apps effective for early language learning. Opportunities can be created whereby the children with ASD can engage with technology activating sensory, working and long-term memory resulting in learning taking place in such a manner that the child is unaware that he or she is learning.

8.6.2 *Vocabulary App Design Recommendations*

The multimedia design guidelines presented in this study support and assist early language learning for children with ASD. The application of the multimedia design guidelines in the design of vocabulary apps can provide an assurance that a positive contribution for effective language learning will take place. Greater attention needs to be paid to the design of vocabulary apps used to promote language learning in children with ASD. The multimedia design guidelines, when incorporated into the design of vocabulary apps, will allow language learning involving multiple intelligences to take place (Gardner, 2011).

The multimedia learning guidelines addresses extraneous, essential and generative processing that takes place when both words and pictures are used to encourage learning (Mayer, 2009). The implementation of the multimedia design guidelines will prevent cognitive overload in children with ASD since there will be no overstimulating material, designs or animations that may cause confusion. In addition, the instructional goal of language learning will be achieved by the manner in which the vocabulary app is designed. The design will not be demanding or complex for the child with ASD, allowing for improved processing of received information. The vocabulary app will be designed in a way to improve understanding of letters and words, by keeping the children with ASD motivated to engage in the app through intellectual activities that are well organised. The integration of previous lessons into present lessons will provide a sense of accomplishment and advancement in language learning and activate long-term memory.

8.7 Delineations and Assumptions of the Research Study

The limitations identified for the research study were:

- The research sample size was small, initially starting with 14 children and tapering down to seven children with ASD.
- Only three vocabulary apps were used in the study. More vocabulary apps could provide additional guidelines in other areas.

8.8 The Way Forward

Areas identified that could benefit from further research are:

- Determining the effectiveness of the identified multimedia design guidelines incorporated in a vocabulary app assisting early language learning for children with ASD.
- Researching a greater number of vocabulary apps to identify how language learning takes place within vocabulary apps designed for children with ASD.

- Identification of parents and caregivers needs' relating to vocabulary apps assisting early language learning for children with ASD.

8.9 Closing Thoughts

As mentioned at the beginning of this thesis, there is a great need for the design of effective vocabulary apps that assist early language learning in children with ASD. Improved language learning will not only result in improved communication between parent and child, caregiver and child or teacher and child but result in an improved quality of life. The results of the study offered effective multimedia design guidelines for the design of vocabulary apps that could help children with ASD learn language more proficiently. The study also accentuated the need to design vocabulary apps supported by research.

To deliver a vocabulary app that positively contributes to language learning for children with ASD an awareness needs to be created among app developers. Numerous educational apps have been developed but only a few effectively result in actual language learning. Many vocabulary apps support entertainment and revenue production rather than actual language learning. The implementation of the identified multimedia design guidelines presented in this study could change the stigma attached to educational apps claiming to assist with early language learning for young children with ASD.

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10 APPENDIX A – SPEECH THERAPIST CONSENT LETTER

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Speech Therapist Information and Consent Form

Dear Speech Therapist,

I am a student studying through the University of Pretoria. I am currently enrolled for my PhD at the Faculty of Education, the Department of Science, Maths and Technology Education. I have to complete my research and write my thesis to fulfil the requirements expected of me. I would like to ask you whether you will be willing to participate in this research.
The topic of my research is: **A Multimedia Design Framework for Autism Spectrum Disorder Language Acquisition Apps.** Technology plays an essential role in education and the use of tablets to help educate children with Autism Spectrum Disorder has been considered a breakthrough for many researchers. Previous research has shown that the applications (apps) on tablets can be customised to suit specific needs of the ASD child, encouraging interactivity and advance knowledge and skills.

It is vital that the apps designed for language development do actually develop language. These language apps must be designed to advance the learner's language development and not act as a hindrance because of bad design. Insufficient research has been found on the multimedia design principles that promote language development.

The research will include interviews, observations and eye-tracking. The research will be done by me, the researcher. If you agree to participate, you will be interviewed about language development apps for ASD children. The interview will take place at a venue and time that will suit you, but it may not interfere with school activities or teaching time and will not take longer than two hours in total. The interview will be voice recorded and transcribed for data collection purposes.

I would also like to observe the interaction of the ASD child with language development apps that have been decided upon by you. Please would you be present at all times helping and guiding the child if necessary during observations and the eye-tracking activity. These observations will be conducted during your choice of language related teaching time, and my role will remain objective and non-participatory during this process. Informed parental consent and the child's assent will be adhered to. The observations will be video/voice recorded and transcribed for analytic purposes. Only my supervisor and I will have access to this information. No facial features will be recorded whatsoever.

Further along in the research the ASD child will participate in an eye-tracking activity while interacting with a language development app on a computer screen that has an eye-tracking device attached to it. This device will be unobtrusive and will track the child's eye movements on the screen of the computer while he or she interacts with the language development app. Quantitative data is collected about the eye movements that are later statistically analysed by an eye-tracking specialist. No facial features will be recorded whatsoever and no harm will be done to the children's eyes at all. This is done in order to analyse the effectiveness of the app design. When the eye-tracking takes place I will kindly request that you as speech therapist be present at all times for the reassurance and well-being of the children taking part in the research.

You do not have to participate in this research if you do not want to, and you will not be penalised in any way if you decide not to take part. If you decide to participate, but you change your mind later, you can withdraw your participation at any time.

Your identity will be protected. Only my supervisor and I will know your real name, as a pseudonym will be used during data collection and analysis. Your school will not be identified either. The information you give will only be used for academic purposes. In my research report and in any other academic communication, your pseudonym will be used and no other identifying information will be given. Collected data will be in my possession and my supervisor's and will be locked up for safety and confidentiality purposes. After completion of the study, the material will be stored at the university's Science Mathematics and Technology Education Department according to the policy requirements.

If you agree to take part in this research, please fill in the consent form provided below. The research will take place at a venue and time that will suit you and the school. If you have any questions, do not hesitate to contact my supervisor or me at the numbers given below, or via Email.

Kind regards,

Researcher
Ilse de Bruin
Tel: 072 151 7131
E-mail: ilsedebruin1@gmail.com

Supervisor
Dr Ronel Callaghan
Tel: 012 420 5521
Email: ronel.callaghan@up.ac.za

SPEECH THERAPIST CONSENT FORM

I ____ agree that I will participate in the interviews, observations and eye tracking activities for the research:

A Multimedia Design Framework for Autism Spectrum Disorder Language Acquisition Apps

I understand that the participation is voluntary, and confidential, and that the research will not harm me or any child. I agree that the activities may be video/voice recorded for data collection purposes and that the researcher will ensure that my identity will be protected through-out the process.

SIGNED

Speech therapist name: ______________________________ Signature______________________

Date ______________________

Researcher: ______________________________ Signature______________________

Date ______________________

Supervisor: ______________________________ Signature______________________

Date ______________________

11 APPENDIX B – PRINCIPAL CONSENT LETTER

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear Principal,

I am a student studying through the University of Pretoria. I am currently enrolled for my PhD at the Faculty of Education, the Department of Science, Maths and Technology Education. I have to complete my research and write my thesis to fulfil the requirements expected of me. I would like to ask you whether you will be willing to participate in this research.
The topic of my research is: **Multimedia design principles for mobile application development that support early language development in Autism Spectrum Disorder children.** Technology plays an essential role in education and the use of tablets to help educate children with Autism Spectrum Disorder has been considered a breakthrough for many researchers. Previous research has shown that the applications (apps) on tablets can be customised to suit specific needs of the ASD child, encouraging interactivity and advance knowledge and skills.

It is vital that the apps designed for language development do actually develop language. These language apps must be designed to advance the learner's language development and not act as a hindrance because of bad design. Insufficient research has been found on the multimedia design principles that promote language development.

The research will include interviews, observations and eye-tracking. The research will be done by me, the researcher. If you agree that your school may participate, the speech therapists suggested by you will be interviewed about language development apps used for ASD children. The interview will take place at a venue and time that will suit you and the speech therapists, but will not interfere with school activities or teaching time and will not take longer than two hours in total. The interview will be recorded and transcribed for data collection purposes.

I would also like to observe the interaction of the ASD child with language development apps that have been decided upon by the speech therapists and me In addition the child will be given an opportunity to choose which language development apps he or she would like to interact with on a tablet. This interaction will be video recorded and none of the children's facial features will be shown. The observations will be videotaped and transcribed for analytic purposes. The speech therapists will be present at all times helping and guiding the child if necessary. These observations will be conducted during the speech therapists choice of language related teaching time, and my role will remain objective and non-participatory during this process. Informed parental consent and the child's assent will be adhered to. Only my supervisor and I will have access to this information.

Further along in the research with your consent ASD children will be recommended by the speech therapists to participate in an eye-tracking activity. The child will participate in an eye-tracking activity while interacting with a language development app on a computer screen that has an eye-tracking device attached to it. This device will be unobtrusive and will track the child's eye movements on the screen of the computer while he or she interacts with the language development app. Quantitative data is collected about the eye movements that are later statistically analysed by eye-tracking specialist. This is done in order to analyse the effectiveness of the app design. No facial features will be recorded whatsoever and no harm will be done to the children's eyes at all. This is done in order to analyse the effectiveness of the app design. When the eye-tracking takes place I will kindly request that the speech therapist be present at all times for the reassurance and well-being of the children.

Your school does not have to participate in this research if you do not want it to, and the school will not be penalised in any way if you decide that the school may not take part. If you decide that the school may participate, but you change your mind later, you can withdraw the school's participation at any time.

Your identity and the schools identity will be protected. Only my supervisor and I will know your real name, as a pseudonym will be used during data collection and analysis, and your school will not be identified. The information your school gives will only be used for academic purposes. In my research report and in any other academic communication, your pseudonym will be used and no other identifying information will be given. Videotapes that have any faces on them will be graphically manipulated so that none of the participants will be identifiable. Collected data will be in my possession and my supervisor's and will be locked up for safety and confidentiality purposes. After completion of the study, the material will be stored at the university's Science Mathematics and Technology Education Department according to the policy requirements.

If you agree that your school may take part in this research, please fill in the consent form provided below. The research will take place at a venue and time that will suit you and the school. If you have any questions, do not hesitate to contact my supervisor or me at the numbers given below, or via Email.

Kind regards,

Researcher
Ilse de Bruin
Tel: 072 151 7131
E-mail: ilsedebruin1@gmail.com

Supervisor
Dr Ronel Callaghan
Tel: 012 420 5521
Email: ronel.callaghan@up.ac.za

12 APPENDIX C – PARENT/GUARDIAN CONSENT LETTER

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear Parent/Guardian,

I am a student studying through the University of Pretoria. I am currently enrolled for my PhD at the Faculty of Education, the Department of Science, Maths and Technology Education. I have to complete my research and write my thesis to fulfil the requirements expected of me. I would like to ask you whether you will be willing to let your child participate in this research.

The topic of my research is: **Multimedia design principles for mobile application development that support early language acquisition in Autism Spectrum Disorder children.** Technology plays an essential role in education and the use of tablets to help educate children with Autism Spectrum Disorder has been considered a breakthrough for many researchers. Previous research has shown that the applications (apps) on tablets can be customised to suit specific needs of the ASD child, encouraging interactivity and advance knowledge and skills.

It is vital that the apps designed for language development do actually develop language for young ASD children. These language apps must be designed to advance the learner's language development and not act as a hindrance because of bad design. Insufficient research has been found on the multimedia design principles that promote language development for ASD children.

The research will include observations and eye-tracking. The observations will be done by me the researcher, in a non-participatory manner observing your child's interaction with the app. In addition your child will be given an opportunity to choose which language development apps he or she would like to interact with on a tablet. This interaction will be video recorded and none of your child's facial features will be shown. The observations will be videotaped and transcribed for analytic purposes. The speech therapist and your child will be discussing and interacting with the language development apps. Anonymity will be of high priority.

Similarly with your consent your child will participate in an eye-tracking activity while interacting with a language development app on a computer screen that has an eye-tracking device attached to it. This device will be unobtrusive and will track your child's eye movements on the screen of the computer while he or she interacts with the chosen language development app. No facial features will be recorded whatsoever. This is done in order to analyse the effectiveness of the app design. When the eye-tracking takes place your child's speech therapist will be present at all times.

If you agree that you child may participate, the research will take place at a venue and time that will suit the school and speech therapists involved. This research may not interfere with school activities or teaching time. The observations will be voice recorded and transcribed for data collection purposes.

You do not have to let your child participate in this research if you do not want to, and your child will not be penalised in any way if you decide that he/she may not take part. If you do decide to let your child participate, but you change your mind later, your child can withdraw his/her participation at any time.

Also, I would like to ask if you would be willing to provide me with the names of apps you use at home to help develop your child's language. This information will be used to further explore the effectiveness of language development apps.

Your child's identity will be protected. Only my supervisor and I will know your child's real name, a pseudonym will be used during data collection and analysis, and your child's school will not be identified. The information gained from your child's participation will only be used for academic purposes. Collected data will be in my possession and my supervisor's and will be locked up for safety and confidential purposes. After completion of the study, the material will be stored at the university's Science Mathematics and Technology Education Department according to the policy requirements.

If you agree that your child may take part in this research, please fill in the consent form provided. If you have any questions, do not hesitate to contact my supervisor or me at the numbers given below, or via Email.

Kind regards,

Researcher
Ilse de Bruin
Tel: 072 151 7131
Email: ilsedebruin1@gmail.com

Supervisor
Dr Ronel Callaghan
Tel: 012 420 5521
Email: ronel.callaghan@up.ac.za

13 APPENDIX D – ETHICS FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **SM 15/08/02**
DEGREE AND PROJECT	PhD (CIE) Multimedia guidelines for vocabulary Apps assisting early language learning in children with Autism Spectrum Disorder
INVESTIGATOR	Ms Ilse de Bruin
DEPARTMENT	Science, Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	11 August 2016
DATE OF CLEARANCE CERTIFICATE	05 October 2017

CHAIRPERSON OF ETHICS COMMITTEE: Prof Liesel Ebersöhn

CC Ms Bronwynne Swarts
Dr Ronel Callaghan

This Ethics Clearance Certificate should be read in conjunction with the Integrated Declaration Form (D08) which specifies details regarding:

- Compliance with approved research protocol,
- No significant changes,
- Informed consent/assent,
- Adverse experience or undue risk,
- Registered title, and
- Data storage requirements.

14 APPENDIX E – INTERVIEW QUESTIONS FOR SPEECH THERAPISTS

Interview Questions

1. How do you go about choosing an app for language development?
2. What are the key features you look at when choosing an app?
3. What aspects interest you in a language development app?
4. What type of approach to the design of an app are you interested in?
5. What aspects frustrate you about these apps?
6. What aspects of these chosen apps frustrate the learners?
7. What would you add to language development apps to make them more effective?
8. What aspects of an app direct the learner's attention?
9. Do you find apps beneficial to language development?
10. What type of graphics do you look for when choosing an app?
11. Do you choose apps that guide the learner along? Explain.
12. Do the learners get distracted with extraneous material? Explain.
13. Do you prefer graphics and narration or only graphics? Explain.
14. How do you introduce the app to the learner?
15. Do you familiarise the learner with the learning material related to the app? How?
16. What level of difficulty do you make use of when choosing an app?
17. Does the level of difficulty increase as the learner progresses?
18. What type of time constraint do you incorporate for example one long session or many short sessions when using an app?
19. How are the app's controlled by the learner or the app or the specialist?
20. How does the learner get introduced to the main concepts?
21. How does a typical session with an app commence?
22. Do you first teach the learners and then they interact with apps? Explain.
23. Do the learners get to choose which language development app they would like to interact with?
24. Are these apps pre-chosen by you or a higher authority?
25. Can learners identify their own app they prefer to learn language with?
26. How is the learning material chosen?
27. Do you choose apps that combine picture and words? Explain.
28. How does learning take place for children with ASD?
29. What language do you decide on for an app?
30. Do you use the apps for learners that are hearing impaired?
31. With what type of learner are apps most effective e.g. high functioning etc.?
32. What type of conversational style do you prefer to be used in an app?
33. How must the narration take place in the app for the learners?
34. Are the learners beginners with apps?
35. Do you prefer that there is a conversation taking place between the learner and app?
36. If there is a voice with the app how must it sound?
37. How do ethnicity, race and gender play a role in a voice used in an app?
38. How do you feel about on-screen characters?
39. How do the learners interact with on-screen characters?
40. What is your opinion about a character guiding the learner in the app?

15 APPENDIX F – EDUCATIONAL SPECIALIST CHECKLIST

The Oelwein method (Broun, 2004, p. 38) consists of various stages of learning:

1. The ***Acquisition stage*** where the child is learning to recognise words.
2. The ***Fluency stage*** where the child recognises the word with some degree of consistency, recognising the word more often than not.
3. The ***Transfer stage*** where the child recognises the word printed on different surfaces, in different contexts, and with different fonts.
4. The ***Generalisation stage*** where the child recognises the word in any context.

Oelwein's Methodology	Yes	No
Acquisition: does the app help the learner to recognise words		
Does the app allow the child to match a word to a printed word		
Does the app allow the child to select the word		
Does the app allow the child to say or sign the word		
Fluency: does the app help the child recognise a specific word with some degree of consistency		
Transfer: does the app display the specific word on different surfaces		
Does the app display the specific word in different contexts		
Does the app display the specific word in different fonts		
Generalisation: does the app help the child recognise the word in different contexts		

How does this app allow for each of these phases (or not?)

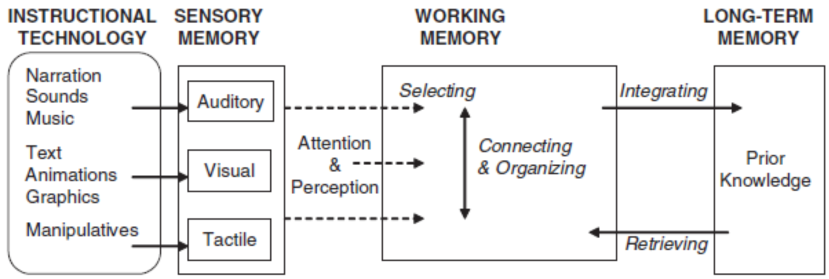

Fig. 1. A cognitive theory of learning with media. Instructional media consist of verbal explanations (in speech or writing) or nonverbal information (e.g. visual, auditory, or tactile representations) entering the learner's sensory memory. Learners then perceive and attend to the multiple information sources within their working memory, the limited capacity and duration of which demands that they select only a few pieces of information at any one time for further processing. Working-memory limitations also force learners to make decisions about how to connect selected pieces of information with each other and how to organize and integrate this information with their prior knowledge. These processes are guided by information retrieved from long-term memory or by external guidance.

Cognitive Theory of Multimedia Learning	**YES**	**NO**
Sensory Memory Auditory: Is there narration		
Sensory Memory Auditory: Are there sounds		
Sensory Memory Auditory: Is there music		
Sensory Memory Visual: Is there text		
Sensory Memory Visual: Are there animations		
Sensory Memory Visual: Are there graphics		
Sensory Memory Tactile: Are there manipulatives		
Working Memory: Does the app have selecting activities		
Working Memory: Does the app have connecting activities		
Working Memory: Does the app have organising activities		
Long-Term Memory: Does the app integrate what was learnt into activities		
Long-Term Memory: Does the app retrieve previous lessons/activities in present lesson/activities		

How does this app allow for each of these memories (or not?)

16 APPENDIX G – MULTIMEDIA LEARNING CHECKLIST

Checklist Matrix

APP:		
EXTRANEOUS PROCESSING		
YES	**NO**	**COHERENCE PRINCIPLE**
		CP1: Are there interesting but irrelevant words?
		CP2: Are there interesting but irrelevant pictures?
		CP3: Are there interesting but irrelevant sounds?
		CP4: Is there interesting but irrelevant music?
		CP5: Are there unneeded/nonessential words?
		CP6: Are there unneeded/nonessential symbols?
		SIGNALING PRINCIPLE
		SP1: Are there cues to direct the learner's attention to the essential material?
		SP2: Is there an outline sentence at the start of the lesson?
		SP3: Are there headings keyed to the outline?
		SP4: Is there vocal emphasis on key words?
		SP5: Are there pointer words i.e. first, second, third?
		SP6: Are the signals used sparingly?
		SP6: Is the design disorganised?
		SP7: Is there extraneous material?
		SP8: Are there headings?
		REDUNDANCY PRINCIPLE
		RP1: Are there only graphics?
		RP2: Is there only narration?
		RP3: Is there only printed text?
		RP4: Is there graphics and narration?
		RP5: Does the narrated animation have concurrent on-screen captions that contain the same words?
		RP6: Does visual scanning between pictures and on-screen text takes place?
		RP7: Must the learner expend mental effort to compare incoming streams of printed and spoken text?
		RP8: Are the captions shortened to a few words?
		RP9: Are the captions placed next to the part of graphics they describe?
		RP10: Is the spoken text presented before the printed text?
		RP11: Are there no graphics but the verbal sections are short?
		SPATIAL CONTIGUITY PRINCIPLE
		SCP1: Are the corresponding words and pictures presented near each other?
		SCP2: Is the learner familiar with the material
		SCP3: Is the diagram not fully understandable without words?
		SCP4: Is the material complex?
		SCP5: Is there word dominated space?
		SCP6: Is there picture dominated space?
		SCP7: Is there separation design i.e. graphics is in a different place than the text?
		SCP8: Is there integration design i.e. most relevant words close to corresponding illustration?
		TEMPORAL CONTIGUITY PRINCIPLE
		TCP1: Are the corresponding words and pictures presented at the same time?

		TCP2: Does the learner hear the narration the same time he/she sees the animation?
		TCP3: Are there short segments in the lesson where the words and pictures are successively?
		TCP4: Are there long segments in the lesson where the words and pictures are successively?
		TCP5: Is the lesson under the control of the learner?
		TCP6: Is the lesson under system control?
ESSENTIAL PROCESSING		
		SEGMENTING PRINCIPLE:
		SP1: Is the multimedia lesson presented in user-paced segments?
		SP2: Is the multimedia lesson presented continuously?
		SP3: Is the multimedia lesson fast paced narrated animation?
		SP4: Is the multimedia lesson broken in parts and presented sequentially?
		SP5: Can the learner control the movement from one part of the lesson to the next?
		SP6: After each segment is there an arrow to continue?
		PRE-TRAINING PRINCIPLE:
		PTP1: Do the learners know the names and characteristics of the main concepts?
		PTP2: Is the multimedia lesson complex for the learner?
		PTP3: Does the learner learn the name of each component first?
		PTP4: Does the learner have appropriate prior knowledge?
		PTP5: Did the learner learn the names and components before the multimedia lesson?
		MODALITY PRINCIPLE:
		MP1: Are there pictures and spoken words?
		MP2: Are there only pictures and printed words?
		MP3: Are there narrated animations?
		MP4: Are there captioned animations?
GENERATIVE PROCESSING		
		MULTIMEDIA PRINCIPLE:
		MP1: Are there only words?
		MP2: Are there pictures only?
		MP3: Are there pictures with the words?
		MP4: Do the words correspond with the pictures?
		PERSONALIZATION, VOICE, AND IMAGE PRINCIPLES
		Personalization Principle
		PP1: Are the narrated words in a conversational style?
		PP2: Are the narrated words in a formal style?
		Voice Principle
		VP1: Is the narration spoken in a human voice?
		VP2: Is the narration spoken in a machine voice?
		Image Principle
		IP1: Is there an image of the speaker?

17 APPENDIX H – ELEMENTS AND PRINCIPLES OF DESIGN CHECKLIST

VISUAL ELEMENTS OF DESIGN	Autism iHelp		Starfall ABC		Puzzingo	
	YES	NO	YES	NO	YES	NO
COLOUR:						
Monochromatic (one colour)						
Multi-coloured						
Monotone (one colour different hues)						
Contrasting colour						
LIGHT-DARK CONTRAST:						
Major tonal chords (large range of variations – very light to darker)						
Minor tonal chords (small range of colours around specific tones)						
LINE:						
Straight						
Freeform						
Thick						
Thin						
Coloured						
Opaque						
DIRECTION:						
Vertical						
Horizontal						
Diagonal						
Curved						
SHAPES: different shapes that are universally recognised						
SIZE: variation of size of elements within an image						
TEXTURE:						
Atmosphere						
Ambience						
TYPOGRAPHY:						
Reinforces theme						
Convey meaning/information						
COMPOSITIONAL PRINCIPLES OF DESIGN						
SIMPLICITY - COMPLEXITY						
Lack of visual clutter						
Draws attention to specific elements						
Visual Clutter						
Lots of detail						
UNITY - VARIETY						
Commonality among elements						
Unifying/similarity of colours						
Unifying/similarity of shapes						
Unifying/similarity of lines						
Differences among elements						
Varying/different colours						
Varying/different shapes						
Varying/different lines						
RHYTHM - MOVEMENT						

Sense of movement						
Sense of excitement						
Sense of calmness						
Sense of tranquillity						
Repeated lines						
Repeated shapes						
Repeated textures						
BALANCE: SYMMETRY - ASYMMETRY						
Arrangement of elements						
Mirror images						
Rotational arrangement						
Diagonal arrangement						
CONTRAST						
Large - Small						
Light - dark						
Thick – thin line						
Colour contrast: cold – warm/complementary						
Variation in direction						
COMPOSITIONAL TECHNIQUE						
Golden rule						
Rule of thirds						
Visual hierarchy						
Some elements are more dominant/significant						
Some elements are less dominant/significant						
Visual path (draws attention from one element to another)						
Bright objects						
Moving object						
Object/s in contrast to surroundings						
Positive - negative space						
REALISM - ABSTRACTION						
Photorealistic						
Realistic representation						
Abstract						
Simplified representation (eg line drawings)						