DEVELOPMENT OF A HAPTICALLY ENHANCED DIGITAL APPLICATION MAGICSPELLS DESIGNED TO AID IN VOCABULARY ACQUISITION FOR LEARNERS WITH DYSLEXIA

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DEDICATION

This dissertation is dedicated to my grandchildren, Case and Leia, whose struggle with learning to read and write offer the driving force behind this research. I also want to acknowledge my son, Justin, and younger brother Michael, who initially fostered, in me, a desire to teach, to learn everything I can about dyslexia, and to seek out ways to support and enhance the education of learners with dyslexia.

ABSTRACT

Coker, Laurie A., *Development of a haptically enhanced digital application MagicSpells designed to aid in vocabulary acquisition for learners with dyslexia.* Doctor of Education (Instructional Systems Design and Technology), May 2022, Sam Houston State University, Huntsville, Texas.

This developmental research aims to (1) examine the developmental processes of the application called MagicSpells, a haptically-enhanced, digital, vocabulary acquisition application design for learners with dyslexia, and (2) investigate the structure and design of the application, and (3) analyze the results of the reviews and usability tests associated with the application. After the creator initially designed the app, the development evolved from concept to initial prototype. Participants in its developmental process include computer programmers, a haptic-touch technology CEO, dyslexia tutors, and dyslexia intervention specialists. The research participants are learners (ages 6-10) with dyslexia, who are native English language speakers, in grades one through five. This study was conducted in six phases: (1) reviewing literatures that cover dyslexia and reading, multisensory input, tools for learning to read/treatment, memory and the senses, educational, developmental research, and methods and approaches in developmental research, as a means to formulate and use fundamental design principles in the application, (2) developing the prototype MagicSpells application that adopts formulated design principals, (3) follow the development processes, (4) conducting expert reviews and usability tests of the application, (5) revising and updating the application through the repetitive expert reviews and usability tests, and (6) clarifying the implications of developmental research. The developed application is expected to demonstrate an

approach to retaining and recognizing vocabulary in a digital format that includes innovative haptic technology.

KEYWORDS: Dyslexia; Application; Haptics; Multisensory; Developmental research; Vocabulary acquisition; Memory; Digital design principles

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PREFACE

Long before the study for this dissertation took place, from paper to the first viable version of the app, I consulted countless experts. Initial experts for the development and design of MagicSpells included students, programmers, a haptic-touch technology CEO associated with the Tanvas company; dyslexia tutors familiar with the Wilson Method for teaching learners with dyslexia; dyslexia intervention specialists informally interviewed by me; and programmers in India developing the app remotely. From the inception of the original app, these formative evaluations, guided by unofficial information gathering, aided in the development.

The first step in this developmental process began with the design of MagicSpells on sheets of copy paper in 2012, followed by preliminary efforts to find a coder/programmer to produce the first functioning prototype. Early attempts failed to produce a working prototype because the necessary technology for including a touch element did not exist. To set MagicSpells apart from other vocabulary acquisition apps, the inclusion of haptic touch is vital. A chance meet-up with an unrelated company led me to an online search and the discovery of Tanvas, a then-burgeoning start-up company. Using the "contact us" feature on the website led to a meeting with a CEO from Tanvas, which proved quite promising and helpful. This meeting put a device in my hand and the tools necessary to begin the development process rigorously. Funding then became a primary obstacle.

Since November 2019, I have worked closely with programmers in India. Since they do not have a device on which they can pilot iterations, they must rely on feedback and direction from me. Over the past 15 months, we worked closely to create a quality

product, and I pay for their services on my own – in payments. We began with an initial contract that I paid in full. However, because of persistent efforts and challenges, I continue to send periodic payments as I can. The programmers completed a non-disclosure agreement (NDA) as the first step. They established the core app feature groundwork, including a dictionary, word banks, drawing tools, clipart, record and playback features, and both text-to-speech and speech to text capabilities.

To effectively do what is expected for learners with dyslexia, this application needed to engage as many senses as possible. Until now, digital apps only provided for interaction with sight and sound. Adding touch was a game-changer. Many aspects of the app were easy to program, so I was told. Still, the haptic inclusion proved quite challenging because of the distance between the programmers and the device. One of the most challenging issues arose when the programmers discovered a coding "language" problem. The Tanvas coding language required the programmers to create a translator (or bridge of sorts) so that the code language used to develop MagicSpells could connect to and communicate with the TanvasTouch® code language. This consumed time and required conversation between Tanvas programmers and the programmers in India via email and online meetings through Google Meet. Another issue arose when the main Tanvas programmer moved to a different company, leaving the programmers in India with gaps in information they worked through over additional weeks.

Eventually, with the assistance of the original Tanvas contact, the programmers worked through the coding issues and managed a solid link to the haptic feature. Again, with the programmers working remotely and without a haptic-enabled device, it was necessary to have multiple meetings where I tested the app's features and reported back to

the programmers. Using Anydesk (an online, remote computer access software), I gave the programmers control of the device and app. Notably, the first time I felt the letters, it was singularly exciting. What should have felt like a smooth screen, surprisingly, felt as if I rubbed my fingertip over sandpaper.

Early versions (Figure 5) of the app did not include background choices, were limited by color choices, and had issues with the voice-to-text feature. These basic features were developed as the programmers learned how to code for the touch aspect and connect to the Tanvas haptic code. These initial versions were not acceptable for this study because the game-changing element of the design lies in the ability for users to feel the letters on the screen, which programmers could not add until the subsequent versions (Figures 5, 6, and 7).

TABLE OF CONTENTS

Page

DEDICATION iii

ABSTRACT iv

ACKNOWLEDGEMENTS vi

PREFACE vii

TABLE OF CONTENTS x

LIST OF TABLES xiii

LIST OF FIGURES xiv

CHAPTER I: INTRODUCTION 1

Statement of Problem and Research Questions 4

Research Questions 6

Rationale and Significance of the Study 6

Tanvas Technology 8

Key Definitions 10

CHAPTER II: LITERATURE REVIEW 12

Dyslexia and Reading 13

Multisensory Input 16

Tools for Learning to Read/Treatments 21

Memory and the Senses 25

Design Principles of Multimedia Learning 27

Summary – Dyslexia, Multisensory Learning, and the Senses 29

Educational Developmental Research 31

Types of Developmental Research 32
Approaches in Developmental Research 36
Summary – Developmental Research Method Literature Review 40
CHAPTER III: METHODS 42
MagicSpells 42
Research Design 46
Materials 55
Participant Selection 60
Data Collection 62
Summary 64
CHAPTER IV: RESULTS 65
Introduction 65
Participants 66
Emerging Themes 80
Exploration of Research Questions 86
CHAPTER V: DISCUSSION AND CONCLUSION 97
Introduction 97
Discussion 98
Limitations 109
Future Research 111
Conclusion 112
REFERENCES 115
APPENDIX A 127

APPENDIX B 131
APPENDIX C 134
APPENDIX D 136
APPENDIX E 139
APPENDIX F 141
APPENDIX G 142
APPENDIX H 143
APPENDIX J 144
APPENDIX K 148
APPENDIX L 149
APPENDIX M 150
VITA 151

LIST OF TABLES

Table **Page**

1 Participant Demographic Information 67

2 Pre-Trial Survey Results 68

3 Post-Trial Survey Results 69

4 Emerging Themes 80

LIST OF FIGURES

Figure **Page**

1 MagicSpells App Homepage 3

2 TanvasTouch® Programmer Package 4

3 Mayer's 12 Principles of Multimedia Design 28

4 Mimo/TanvasTouch® Device and Equipment 57

5 MagicSpells Early Version 1 57

6 MagicSpells Updated Version 2 58

7 MagicSpells Updated Version 3 58

8 In-app Assessment 59

9 Primary Office Space for MagicSpells Trial 61

10 Secondary Office Space for MagicSpells Trial 61

11 Results of Pre-Trial Survey 85

12 Results of Post-Trial Survey 85

CHAPTER I

Introduction

The ability to read at a subconscious level is ordinary for many; however, persons with dyslexia do not experience a natural transition between oral and written language. Learning to read comes naturally to many youngsters, but for others, learning to read is not only difficult; it can be agonizing (Krause, 2015; Lyon, et al., 2003; Seidenberg, 2013). A frustrating phenomenon regarding these learners lies in the fact that they are articulate and seem to have "normal" cognitive abilities, and yet, they struggle to spell, read, and write (Krause, 2015). Despite every effort to read, a significant portion of the world's population does not experience a smooth transition between the oral and written word (Krause, 2015). These individuals have difficulty with speed and accuracy of word decoding (Lyon, et al., 2003) and children and adults who display this incongruity of intellectual ability and reading performance are said to have developmental dyslexia as per the 2003 definition (Krause, 2015; Lyon, et al., 2003). Even beyond developmental vocabulary, learners rely more on difficult subject-specific words as they progress in school.

Moreover, as learners with dyslexia enter into upper grades and higher education - ill-prepared for the rigors of the reading and writing skills necessary for success - there is an even greater need to go beyond reliance on accessibility tools (Kirby et al., 2008; Lyon, et al., 2003; Stevens, 2011). The study of dyslexic and non-dyslexic students in higher education revealed that reading ability differences between groups were strongest for word reading and reading history (Seigal, 2006). This is unsurprising, given that the learners' word reading component supports current theories and definitions of dyslexia,

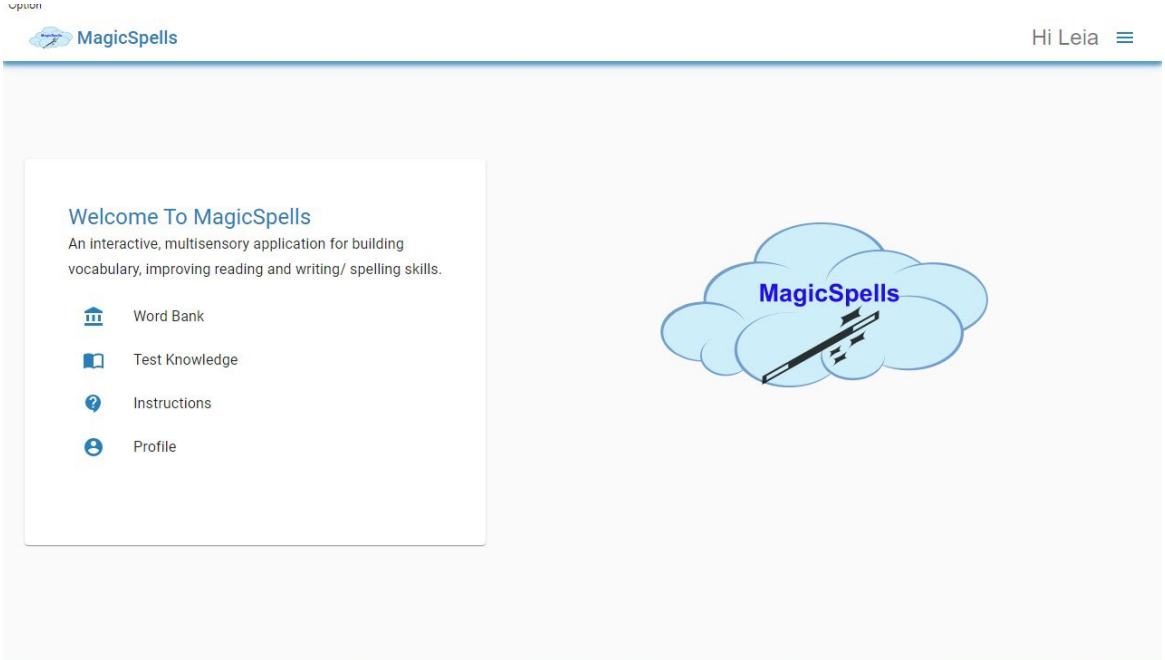
and their record reflects the participants' sense that they have long suffered from reading difficulties (Kirby et al., 2008). Dyslexia Center of Utah (2019) points out that the occurrence of dyslexia in males and females is almost even, and roughly one in five, or 15-20% of the population, has a language-based learning disability. Developmental dyslexia can begin sporadically due to an alteration in brain development, but in most cases, it arises from a genetic mutation that runs in families (Galabruda, 2005; Gerliŏ & Jaušovec,1999).

A study from the American Educational Research Association revealed startling facts about how low reading skills affect graduation rates – the most surprising to many is that low reading skills cause more students to drop out of school before receiving a diploma than poverty (Stevens, 2011). Notably, students who cannot read on grade level by 3rd grade are four times less likely to graduate by age 19 than children who read proficiently by that time (Hernandez, 2011). That said, many students have not or will not be allowed to move through school on-level with peers. It is vital to encourage them to increase vocabulary and word acquisition across subjects and grade levels to best facilitate success at any level. If we mean to support learners in upper-grades, higher education and beyond, timely and scaffolded vocabulary acquisition, beginning as early as possible, using a multisensory, haptic touch enhanced digital application can narrow the gaps and widen opportunities.

A developmental dissertation is in order to explore an app called MagicSpells, which I initially designed in 2012 (Figure 1).

Figure 1

MagicSpells App Homepage



A key feature of the design - direct, digital haptic (touch) technology - was not available until 2017, when my inquiries led me to a company called Tanvas (www.tanvas.co). Tanvas creators have provided their innovative hardware equipped with the MagicSpells app for my research study. Because of limited funding and local programmers, I located and worked with a small team of programmers in Chandigarh, India, to develop the app. We placed the prototype version of the software on the TanvasTouch® device for use in this study. Figure 2 shows an image of the TanvasTouch® device. I hope that MagicSpells, a digital app with the addition of a digital sense of touch through Tanvas haptics, will impact the acquisition of vocabulary for people with dyslexia, thereby improving writing and reading skills. Learning challenging words from the earliest levels and acquiring the necessary academic language should take precedence for persons with dyslexia, particularly since reading ability

affects all subjects in academia and beyond. Developing vocabulary at an early age and continuing as the learner progresses through school will allow students with dyslexia to learn required words and allow them the opportunity to reach and stay on grade level with their peers. Even older learners and adults will benefit from continued word attainment, but this study will focus on younger learners, because these struggling learners are at the crux of academic need and currently the application is set up for elementary-level vocabulary acquisition.

Figure 2

TanvasTouch® Programmer Package

Statement of Problem and Research Questions

Reading is fundamental (McNamara, 1966). Teachers and parents have repeated this phrase to learners for decades. Reading is at the core of almost everything we learn, including mathematics. Learners who have dyslexia often struggle from the beginning to keep up with their peers in reading and, also, writing. Lagging behind peers can cause

self-esteem and behavioral problems as well. Dyslexia Center of Utah (2019) reports that 70-80% of persons with poor reading skills likely have dyslexia. More clearly, on average, about one in five students - 15-20% of the overall population - has some form of language-based learning disability. While it was often misidentified in the past, dyslexia is the most common of language-based learning disabilities (Dyslexia Center of Utah, 2019). Some might argue that dyslexia is just a label and that phonetic instruction, with drill and practice, is the only way to learn to read; however, this is not the case.

Learning tools, like the phonetic instruction mentioned above, differ from accessibility tools (Baazeem & Al-Khalifa, 2015). Accessibility refers to making something obtainable or attainable, whereas learning means acquiring knowledge or skills through experience or instruction (Baazeem & Al-Khalifa, 2015; Kulkarni, 2019). With the advent and inclusion of technology in education, accessibility tools have taken some of the fear and torment out of the task. Still, these tools do not actually teach spelling, vocabulary, reading, and writing. They only provide access. The engagement of multiple senses best supports memory and retention, and until now, digital tools only include sight and sound. Haptic technology, while not new, thanks to research and dedication, can now bring the sense of touch to digital learning experiences. With this state-of-the-art innovation, a person with dyslexia of any age can build vocabulary and improve reading and writing by adding touch to sight and sound. Using a specially designed app and TanvasTouch® technology, learners can interact with words using sight, sound, and touch. Richey and Klein (2005) explain the need to work from the foundation of research questions rather than from hypotheses. They stress the need to identify limitations in the potential study. Research questions should support the

exploration of developmental research in a way that examines the evolution of the educational tool.

Research Questions

1. How can the developmental research process lead to a quality product that best meets the needs of all stakeholders - in particular, learners with dyslexia who struggle to stay on level with peers in reading and writing?
2. Can the exploration and employment of the principles of design, development, and evaluation aid in creating workable and effective features of the MagicSpells application?
3. How can analysis of the reviews and results of the usability tests help to improve on the MagicSpells app and lead to future iterations of the application?

These research questions guided every aspect of this developmental dissertation and were in play prior to the initiation of the first version of the MagicSpells app. They serve as guides for the analysis of expert feedback as the app evolves. Furthermore, these questions support the rationale and significance of the study, which follows.

Rationale and Significance of the Study

The learning of vocabulary used for thought and communication is incomprehensibly significant and multifaceted - although it typically happens naturally, beginning from birth (Kuhl, 2010). However, for a portion of the population who are learners with dyslexia, vocabulary acquisition can be perplexing and elusive (Seidenberg, 2013). Dyslexic learners currently have access to accessibility tools like text-to-speech and speech-to-text, font, and color scheme variations. Still, these are basic and limited

when it comes to acquiring new skills. Technology affords many tools for struggling readers and writers, but I propose a means to support learning new vocabulary. Accessibility tools are aids and do not actually teach language, reading, or writing. There are benefits to audiobooks, for example, but reading on one's own can improve both academics and self-confidence (Pajares & Johnson, 1994). Through the natural acquisition of words, learners with dyslexia can find more success in recognizing, retaining, and reading necessary words. As a result, these learners can develop the vocabulary required for reading and writing success. The focus of my dissertation is the study of the effectiveness of multisensory (sight, sound, and touch) digital technology (MagicSpells) aimed at building vocabulary skills, improving reading and writing, and fostering positive self-esteem.

Studies have explored multisensory instruction – including sight, sound, and touch in vocabulary instruction – for struggling readers (Krause, 2015; Malatesha, et al., 2002; LD Online, 2019; Oakland, et al., 1998; Shams & Seitz, 2018). However, the digital realm has been limited to audio and visual interactions until recently. Technology integration has streamlined education in many ways. Still, persons with dyslexia mainly reap the benefits of support tools, which differ significantly from instruction leading to recognition and retention of vocabulary. Developmental and design-based research on new innovative, haptic-enhanced tools can shed light on the effectiveness of haptic-enhanced digital technology. A tool that can put multisensory learning at a learner's fingertips with a single device can be a game-changer. Adding touch to the sight and sound in a digital format promises an effective and efficient learning experience for learners with dyslexia.

It is important to note that learning tools differ from accessibility tools. Speech-to-text, text-to-speech, font variations, color overlays, and audiobooks provide means for accessing information. On the other hand, learning means acquiring knowledge through experience or instruction – skills and knowledge that last in memory. With the inclusion of technology in education, accessibility tools have taken some of the fear and torment out of reading and writing tasks. However, these tools do not actually teach spelling, vocabulary, reading, or writing. They only provide access. The sights and sounds that technology affords make learning more accessible, but like pen and paper before keyboards, far more can be gained through the employment of other senses in the digital experience. Our memories come by engaging a variety of senses in our daily lives (Lawson, et al., 2015; Quak, 2015). Memory includes sensory, short-term, and long-term retention of information. Digital devices typically involve only sight and sound – users see and hear what is happening on the screen. While not new, haptic technology, thanks to research and dedication, can now bring the sense of touch to digital learning experiences, making an otherwise smooth screen feel like it is textured. For this study, we enlisted learners between the ages of 6 and 10. Covid-19 made it necessary to conduct a few aspects of the study remotely, such as recruitment and initial parental contacts, since the original school setting became unavailable. However, participants could test the app in person, and all essential hardware was cleaned and sanitized following necessary protocols.

Tanvas Technology

With a mission to connect people to the digital world through touch, Tanvas has created TanvasTouch® that utilized surface haptics to add a new dimension to digital

technology, putting touch where it belongs – at the tip of the fingers. Regardless of advances in graphics and sound, touchscreens are little more than a window into untouchable realms. TanvasTouch® adds a realistic sense of touch, allowing developers to create dynamic textures easily felt with the swipe of a finger. Using electrostatics, Tanvas controls friction to create virtual touch – and the applications are endless. Users can feel the edge of keys, the snap of a toggle switch, the swipe of a turned page, the elements of a game, and even the shape of letters. Tanvas promises to elevate the user experience through its touchable canvas. There is an infinite number of holistic and integrated experiences through programmable software that adds textures and feelings to smooth, physical surfaces (About, 2020).

TanvasTouch® surface haptics offers programmable textures and haptic effects that work with the swipe of fingers on touchscreens, trackpads, and physical surfaces. Notably, it is the screen designed by Tanvas that allows the user to experience the sense of touch. Programmers in India have been and continue working to create the MagicSpells app and add the TanvasTouch® technology to create crisp edges and rich textures - that range from smooth to gritty - on smooth physical surfaces, which happens between the finger and any touch-enabled surface (About, 2020). Once engaged, the learner can feel critical letters, words, and drawings in various textures as they interact with vocabulary in the device.

Working with Greg Topel, Tanvas' chief business officer, I acquired one touch-enhanced tablet and mini-computer. Topel, also a person with dyslexia, learned about the MagicSpells app in 2017 after I found and completed a survey on the Tanvas website. He approached me with the desire to help me and others. While the hardware I acquired is

not the newest version of the haptic-enabled system, it allowed programmers to create and install the MagicSpells app with all the original design features. Topel also provided access to the necessary code and tech support to ensure that the first full-prototype version of MagicSpells presents a usable, effective tool for developmental research in vocabulary acquisition for persons with dyslexia.

Key Definitions

Dolch Words - also known as sight words, account for between 50-75% of all vocabulary found in grade school reading material.

Dyslexia - a learning disorder that involves difficulty learning to read or interpret words, letters, and other symbols but does not affect general intelligence.

Grapheme - the smallest meaningful contrastive unit in a writing system.

Haptic-Enhanced – refers to TanvasTouch® technology with a user to opportunity feel a texture on a smooth tablet screen.

Onset and Rime - the initial phonological unit of any word (e.g., c in cat) and the term "rime" refers to the string of letters that follow, usually a vowel and final consonants (e.g., at in cat). Not all words have onsets.

Phoneme - any perceptually distinct units of sound in a specified language that distinguish one word from another, such as p, b, d, and t in the English words pad, pat, bad, and bat. Simply put, phonemes are oral, and the smallest parts of words and letters are written and are the most essential parts of written words.

Trigger Words – words that the Davis Dyslexia Program deem problematic and frustrating to learners with dyslexia.

Visuomotor Skills - when vision and movement work together to produce actions. Visuomotor integration depends on efficient control of eye movements, adequate vision, and the ability to plan the motor act and carry out the required motor skill.

CHAPTER II

Literature Review

A literature review for this developmental research study explores the acquisition of vocabulary for learners with dyslexia and the effectiveness of multisensory instruction concerning memory, particularly the inclusion of the touch to basic digital features in the app called MagicSpells. Currently, digital devices provide sight and auditory feedback and interaction. According to Bara et al. (2007), haptic exploration improves children's reading level in letter knowledge and initial phoneme identification beyond what they can accomplish with visual exploration only (Bara et al., 2007; Lawson et al., 2015). Bara et al. (2007) note that haptic exploration increases letter knowledge and phonemic awareness. Touch makes the link between letters and sounds more precise, improving decoding skills. The multisensory methods stressing vision, hearing, and haptics can provide a suitable solution. Learners can make unique connections between the other behaviors involved in reading and spelling, allowing the child to retain, simultaneously, the visual representation of the letter and the movement necessary for producing it in writing (Bara et al., 2007; Bryant & Bradley, 1985).

Lawson et al. (2015) report that verbal and visual processes are involved in acquiring and storing information perceived by touch, at least during the haptic encoding of information like letters and words. Clear cognizance of a specific sound is gained only when its connection with a particular letter is formed. Because haptic exploration improved letter knowledge, phonemic awareness came more easily, and presumably, multisensory training will work for remediation of reading difficulties and the prevention of these difficulties (Bara et al., 2007; Lawson et al., 2015). In particular, memory

associated with the addition of touch technology plays an essential role in retaining and recognizing letters and essential words (Lawson et al., 2015). Additionally, it is crucial to examine developmental research and the benefits of using such analysis to create practical tools for learners with dyslexia.

Dyslexia and Reading

Dyslexia refers to the inability to perform accurate or fluent word reading (incorrect reading of single words aloud) and spelling disability of sound-to-letter correspondence (Layes et al., 2019). Anthony et al. (2002) report that children's sensitivity to words, syllables, rhymes, onset and rimes, and phonemes represent a single underlying phonological ability. They reveal that children can express awareness of linguistic units at lower levels of linguistic complexity (e.g., words or syllables) before they can communicate an understanding of linguistic units at higher levels of linguistic complexity (e.g., phonemes). As such, this pattern reflects the developmental course of a unidimensional phonological aptitude, specifically phonological awareness. According to Bruck (1992), the processes of phonological awareness (for example, counting the number of syllables or phonemes) are closely associated with a person's reading and spelling ability and in their knowledge of the correlation between spelling and sounds. Anthony et al. (2002) also lend contrasting evidence from examining factor analytic findings, suggesting that understanding onset-rime, syllables, and phonemes represents corresponding underlying ability. Phonological awareness provides a foundation for early learning and dyslexic lack the ability to make these necessary phonological connections.

Moreover, analyses of within-group variability indicate that dyslexics' phoneme awareness skills show little development as a function of age or reading level; however,

dyslexics' awareness of onsets and rimes develops with reading skill (Bruck, 1992; Kilpatrick, 2016). We can gauge phonological awareness by undertakings requiring recognition or maneuvering of onsets, rimes, vowels, or codas - most of which can be more than one phoneme long - holding that tasks concerning sub-syllabic units necessitate conscious awareness to reflect on the corresponding units of sound. In contrast, tasks that comprise syllables or words may reflect sensitivity to acoustic qualities of speech (Anthony et al., 2002). Ostensibly, learners with dyslexia demonstrate and inability to recognize or maneuver the basic core elements of words and language.

Nevertheless, excellent readers' phoneme awareness increases as a function of reading skill, although onset awareness does not - indicating that even the youngest children have mastered this skill (Bruck, 1992; Layes et al., 2019). Notably, dyslexic children show poorer mindfulness of the onset-rime distinction than reading- or age-matched subjects. These early-stage learners with dyslexia often require more effective instruction and strategies to read and spell because of their difficulties using sound-letter correspondence rules (Bruck, 1992; Kilpatrick, 2016; Krashen, 2001; Layes et al., 2019). Kilpatrick (2016) further notes that phonemic awareness falls under phonological awareness and is necessary for competent reading. While word awareness, rhyme awareness, syllable awareness and alliteration, and initial sound awareness provide the foundation for phonemic awareness alone, these more specific physiological skills do not result in skilled reading (Kilpatrick, 2016). Therefore, it is safe to say that learners who demonstrate these skills can still show reading difficulties because of a lack of phonemic awareness. For clarity, Kilpatrick (2016) defines phonics as that which deals with printed language - the letters and the various sounds represented by those letters - and is a

strategy for sounding out words (academic skill), and phonemic awareness relates to the spoken word, having nothing directly to do with letters. As such, phonemic awareness is a mental/linguistic skill. It is essential to point out that some researchers believe in a broader developmental conceptualization of phonological sensitivity (Anthony et al., 2002; Krashen (2001). Theirs suggests a vital continuity between lower levels of phonological sensitivity (e.g., rhyme detection) and higher levels of phonological sensitivity (e.g., phonemic awareness) (Anthony et al., 2002). Krashen (2001) tells us that it is not unusual for many learners to exhibit poor phonemic awareness, regardless of an average to above-average IQ. Reading involves more than decoding graphemes and phonemes – skilled readers need accuracy and speed, leading to reading comprehension (Layes et al., 2019; Ouellette, 2006). Learners with dyslexia lack the clear phonemic awareness and have limited ability to decode language.

Dyslexia was first thought of as word blindness. However, a pioneer in the study of dyslexia, Samuel Torrey Orton, believed that the issue lay in visual perception and visual memory (Orton, 1925; Siegel, 2006). The vast majority of children and adults with reading disabilities, including dyslexia, have marked difficulties when asked to rapidly name the most familiar visual symbols and stimuli in the language: letters, numbers, colors, and simple objects (Wolf et al., 2000). Research devoted to a phonological core deficit aside, dyslexic children show impairment in several other domains, most notably in cognitive abilities specifically related to memory and attention (Beneventi et al., 2009). Benítez-Burraco (2010) reports that dyslexia is a cognitive disorder involving reduced reading proficiency. He adds that it is typically comorbid with other issues that have as a distinctive feature a deficit in the ability to learn and acquire specific skills. Additionally,

Benítez-Burraco (2010) asserts that dyslexia is often coupled with a particular disorder of language, speech sounds, or Attention Deficit Hyperactivity Disorder, but rarely with a lack of cognitive ability. Often, children with dyslexia demonstrate comorbidity in multiple areas – attention, cognition, and retention, for example.

Many studies demonstrate that a large proportion of children (always more than 50%) who are most at risk for reading failure can learn at roughly regular rates in early elementary school by applying the best of what is known right now about reading instruction (Ouellette, 2006; Seidenberg, 2013; Tønnessen & Uppstad, 2015; Torgesen, 2000; Wolf, et al. 2000). Recent research of university students with dyslexia has shown persistent deficits in written word recognition (Colé, et al., 2014). While many of these learners go on to earn degrees, many others do not, and little is known on how these readers manage the rigorous exposure to written language necessary to obtain a university degree (Colé et al., 2014). Students noted that their difficulties were long-standing and had been experienced already in elementary school and feel that earlier intervention might have made a difference as they moved forward (Colé et al., 2014).. The students seemed to compensate via additional time for examinations, access to dyslexia tutors, and information technology support (Olofsson et al., 2012). Ideally, struggling readers could avoid undue stress by learning to read well, recognizing necessary vocabulary, and writing without relying on accessibility tools.

Multisensory Input

Multisensory learning encompasses the use of visual, auditory, and kinesthetic-tactile routes in the brain as a means to enhance a learner's memory and the learning of written language, creating consistent links between the visual-auditory and kinesthetic-

tactile routes to assist in learning to read, write, and spell (LD Online, 2019; Quak et al., 2015; Shams & Seitz, 2008). Instruction that employs a unisensory stimulus method does not engage multisensory educational devices ideal for learning. On the other hand, multisensory-training protocols can imitate the natural settings for learning new things and are more effective when teaching new skills (Shams & Seitz, 2008). Multisensory processing refers to the interaction of signals arriving approximately simultaneously from various sensory modalities, and in this, novel multisensory associations can develop rapidly (Quak et al., 2015; Shams & Seitz, 2008). Multisensory teaching is a vital aspect of instruction for a person with dyslexia. For reading instruction to be successful for students with dyslexia, it should be explicit, direct, cumulative, intensive, and focused on the structure of language. Analytic instruction presents the whole and teaches how to break it down into parts (LD Online, 2019). Bara et al. (2007) revealed that visual and haptic exploration of letters (HVAM), when compared to only visual exploration of letters (VAM), performance in the letter recognition task and the initial phoneme identification task. Moreover, they point out that pseudo-word decoding scores improved more after HVAM training than after VAM training, demonstrating that visuo-haptic exploration enables the children to increase performance on letter knowledge and initial phoneme awareness and allows for better decoding skills.

Traditionally, perception was viewed as a modular function, particularly identifying different sensory modalities as working as separate and independent processes (Shams & Seitz, 2008). However, according to Shams and Seitz (2008) new and substantial findings refuted this belief system. Through decades of thorough exploration, a considerable agreement has formed about the features of effective vocabulary

instruction. It should present both definitional and contextual information, provide encounters with words in multiple contexts, and engage students' active processing of word meanings (McKeown, 2019). People with dyslexia who learn about reading and spelling through auditory, tactile, kinesthetic, and visual activities recognize, retain, and retrieve information more efficiently (Dyslexia Center of Utah, 2019; McKeown, 2019; Shams & Seitz, 2008). In part, learners can accomplish this by simultaneously using multiple senses, including auditory, visual, and tactile/haptic. In this way, a dyslexic learner is taught to see the letter A, say its name and sound, and write it in the air—all at the same time (Bara et al., 2007). It is important to note that in the case of vision, all the object's dimensions are perceived quasi-simultaneously. However, the haptic modality requires exploration by the learner to process letters in a more sequential and, therefore, in a more analytical way, which does not come naturally to learners with dyslexia when letters are presented visually only (Bara et al., 2007). The use of multisensory input is thought to enhance memory storage and retrieval. Beyond reading and writing, multisensory approaches show promise for use with math, demonstrating that the learning benefit is an overarching phenomenon. Multisensory input gives students the advantage of learning alphabetic patterns and words through the engagement of all learning modalities (McKeown, 2019; LD Online, 2019; *Reading Programs That Work*, 2018; Shams & Seitz, 2008). Their chronological age controls systematically outperformed dyslexic university students in reading tasks, confirming written word recognition skills deficits. Colé et al. (2014) point out that early childhood intervention that includes tactile, sight, and auditory aspects is wise. If a child learns something while engaging more than a single sense, the information is more likely to stay with them in short and long-term

memory. Multisensory instruction encourages children to tap into how they learn to read in a way that fosters contentment when learning, allowing them to make connections and form memories (Bara et al., 2007; Colé et al., 2014; McKeown, 2019; *Reading Programs That Work*, 2018; Shams & Seitz, 2008)

True multisensory methods (including vision, hearing, and touch) offer an appropriate answer to vocabulary acquisition (Malatesha, et al., 2002). These methods could potentially assist learners in connecting the different activities involved in reading and spelling, allowing a learner to retain the visual image of the letter and the movement necessary for writing it (Bara et al., 2007; Bryant & Bradley, 1985). It is important to note that haptic exploration requires learners to process letters more sequentially in a more analytical way. Therefore, haptic inclusion is more promising than visual learning alone (Bara et al., 2007). Tracing and imagination offer simple and effective learning strategies that can easily be implemented into instructional designs and are supported by research (Paas & Van Merriënboer, 2020). Meaningfully, information entering through multiple processing channels helps bypass the inadequate processing capabilities of each track, and the effects associated with tracing, and tracing then imagining, on intrinsic motivation for learning has shown positive results (Paas & Van Merriënboer, 2020). As such, more data can be processed when spread between multiple senses and is better retained (Shams & Seitz, 2008). Multisensory, controlled language programs, including synthetic and analytic instruction, should include a presentation of the parts of the language and then teach how the parts work together to form a whole to learn vocabulary (Quak et al., 2015). Visuomotor memory ability can affect written language recognition (decoding abilities) and influence written language production, and this movement

supports the visual representation of letters and may favor encoding and recall (Layes et al., 2019).

Moreover, multisensory instruction allows persons with dyslexia to use a broader range of means to show what they have learned, and the multimedia approach improves achievement over the standard methods. The more attributes of a medium used, the greater the learning (Gerlič & Jaušovec, 1999; Morin, 2020). Attention, memory, and multisensory processing are fundamentally interwoven, and working memory is multisensory. It must be considered to achieve a genuine understanding of how functional memory processes maintain and manipulate information (Quak et al., 2015). The multisensory (notably haptic) features create engaging activities that improve recall and retention of vocabulary learned and give the child a mental and physical impression of letter shapes, preparing them for writing (Paas & Van Merriënboer, 2020). One can only hope that students make it past high school to attend college. Once they do, the idea is that they continue to learn the vocabulary necessary in being competitive with their peers beyond higher education and training. Multisensory processes are methodical, consecutive, categorical, and straightforward in instructing and utilizing visual, auditory, kinesthetic, and tactile senses for teaching reading (Malatesha Joshi et al., 2002). Until recently, the option of including more than sight and sound instruction on digital devices did not exist. Willis and Willis (2020) report that the more ways we work to learn something, the more memory pathways we build, and at younger ages, brains are still growing, and learners are ripe for new knowledge. An app like MagicSpells presents the opportunity to play off the brain's plasticity and, through multisensory input, improve vocabulary learning.

Tools for Learning to Read/Treatments

The reading of single words, while seemingly uncomplex, involves multiple levels of representation, in particular, visual representations of letter shape, orthographic representations of letter identity and order of letters and their phonological representations of the word's pronunciation, and semantic representations of its meaning (Fischer-Baum et al., 2017; Quak et al., 2015; Seidenberg, 2013). While this appears simple, it can prove challenging to some. The top learning approaches for teaching persons with dyslexia are the Orton-Gillingham, which uses sight, sound, touch, and movement; the Wilson reading system, which use a "sound-tapping" system; the Barton Reading Program, which includes color-coded letter tiles to connect sound to letters (Morin, 2020); and the Davis learning approach which uses brain-focus activities and clay to promote the learning of words Of these, the two leading vocabulary learning approaches are the Orton–Gillingham Approach- a teaching design to help struggling readers by explicitly teaching the connections between letters and sounds and The Wilson Reading System (WRS) - an instructional program that uses the rigid structure of the Orton–Gillingham Approach – where most vocabulary acquisition is based (Malatesha Joshi et al., 2002; Morin, 2020).

Tools for accessibility have increased by leaps and bounds over the past several years (Baazeem & Al-Khalifa, 2015). With technology advancements moving along rapidly, the doors of education are wide open for diverse learners, even if gaps still exist (Baazeem & Al-Khalifa, 2015). Metaphorically speaking, too often, technology for people with dyslexia works more like a prop – providing a means for differently-abled learners to access education. However, the better option is to provide a way for struggling

readers to learn to read, write, and recognize the vocabulary necessary for self-directed learning. It is generally understood that "Digital technology, has a potential for transforming education, has been a major theme of research and development work for a long time" (Säljö, 2010, p.54). A 2003 study by Newell et al., as reported by Doyle (2019), revealed that the advantage of a multisensory approach could be seen when assessments demonstrated that after instruction included touch, only 65% of the responses were correct. Only 72% of the responses were accurate with sight, but when instruction included both sight and touch, answers were 85% correct. While dyslexia is something people struggle with for life, technology and strategy use can make language-based activities more manageable and less stressful.

Furthermore, behaviors such as writing, calculating, gaming, beginning and retaining social relationships, and many others are coordinated through digital interaction for a considerable proportion of the young and not-so-young generations (Doyle, 2019), making a multisensory vocabulary learning program promising. For an extended time now, developers have designed and launched "Playful Learning" websites for children intent on providing these learners a happy learning experience (Alhussayen et al., 2015). Fun, however, should not be age-specific, and learning necessary skills for success begins with early reading and writing skills and continues throughout a person's education and career. Beck and McKeown (2007) believe that direct and rich instruction better prepares people with dyslexia to recognize and retain vocabulary. Rich instruction includes explaining word meanings in student-friendly language, providing multiple examples and multiple contexts, and requiring students to process words acutely by identifying and explaining appropriate and inappropriate uses and situations and creating multiple

contexts. This rich instruction makes up the critical goals of the MagicSpells app and is the primary rationale behind this study proposal.

Alphabetic Phonics

As its name implies, Alphabetic Phonics stresses the essential characteristics of the English alphabet, especially phonology and letter sequence. The primary emphasis lies in teaching phonic skills for reading and spelling. The program began in the mid-1960s at Texas Scottish Rite Hospital and has expanded to several teacher training centers and numerous school districts across the United States (Oakland et al., 1998). Dyslexia is not a one size fits all term. There is uncertainty when delineating the difference between dyslexic and non-dyslexic, and the line is skewed and controversial. There is no dispute about the reality of dyslexia, just that identifying persons with dyslexia is subjective (Siegel, 2006). De Jong and van der Leij (2003) note a clear difference between the onset and persistence of deficits in phonological awareness and rapid naming in dyslexic children. Whereas multiple definitions of the term" decoding" exist, focusing on the concept of a "translation" from writing to speech (Tønnessen & Uppstad, 2015). With the English alphabet, each letter (grapheme) should connect with a sound (phoneme); more simply put, decoding necessitates the facility to differentiate and identify the individual phonemes in the spoken stream of speech (Ouellette, 2006; Tønnessen & Uppstad, 2015), making phonemic awareness necessary to vocabulary acquisition. Further, given that a "translation" is to be made from speech, vision is also an essential condition for decoding, and there are additional conditions necessary by definition.

Vocabulary development includes increasing and cultivating phonological representations to the lexicon and storing and elaborating the associated semantic knowledge. A wide variety of information is required about each word to support vocabulary mastery and academic learning (McKeown, 2019; Ouellette, 2006). Willis (2006) feels that with repeated practice, our working memories imprint as permanent neuronal circuits of axons and dendrites available for activation and recall when required. When recalled often, the brain's neuronal circuits undoubtedly develop because of their repeated activation. Hebb (1949) asserts that neuron cells that fire together wire together. Shams and Seitz (2008) argue that multisensory-training protocols, over unisensory protocols, work beneficially to approximate natural settings where learning happens, thus producing more significant and more efficient learning. Tools that engage multiple senses and require interaction, like MagicSpells, encourage repetition and multisensory interaction, promoting brain growth. Whereas teachers might engage students with manipulatives and some word interaction, MagicSpells' premise is to create a sensory-rich, stimulating environment for building more robust, long-term memory connections with each letter as it forms a word and for retention. Much like an exercised muscle, memory circuits become more efficient and easier to access and activate (Willis & Willis, 2020). Doyle (2019) notes that individual senses provide supplementary retrieval cues for data and shape a more comprehensive experience of a concept or an idea. Since multisensory learning allows for multiple ways of experiencing something, it is an ideal way to learn. Gross and fine motor exploration of letters has an exceptionally constructive impact on their recognition, which may benefit young learners with reading and spelling disabilities (Layes et al., 2019). Additionally, Layes et al. (2019) cite

Longcamp et al. (2004) as supporting movements, like tracing and handwriting letters, as directly linked to learning to read since children can access their perceptual-motor system and recognize the letter through memory.

Memory and the Senses

Numerous experiences trigger the memory, and touch is conceivably the most intimate of the senses involved in memory (Pan, 2019). While the sense of touch has previously been underestimated in terms of memory, humans notably form comprehensive and robust long-term memory representations for an extraordinary number of their haptic experiences, even when there is no effort to remember (Hutmacher & Kuhbandner, 2018). When we hold or graze something, we are as physically close to it as possible, and at that moment, dedicated skin cells transport an abundance of data, including texture, to the brain (Pan, 2019). Furthermore, Hutmacher and Kuhbandner (2018) explain that representations explored through the sense of touch and stored by persons for the long-term are retained as a natural product of haptic perception, which gives credence to the inclusion of a tactile feature in the digital realm of acquisition of new vocabulary. If a person learns something using multiple senses, the information is more likely to impact and stay with them, and these engaging activities result in better memory of the concept (Morin, 2020). Lawson et al. (2015) suggest that evidence demonstrates that verbal and visual processes also acquire and store information perceived by touch, at least during the haptic encoding of less familiar objects. Information is better retained by incorporating multiple stimuli and senses as one interacts with vocabulary (Doyle, 2019; Morin, 2020). Being able to hear, see and touch when interacting with letters and words make the experience more meaningful and

notably, more memorable (Lawson et al., 2015). Doyle (2019) and Morin (2020) assert that multisensory learning directly links to memory and retention, so when learners listen to, see, and feel letters and words, they are more likely to remember them. Adding a touch feature in a digital realm can serve to enhance the learning experience for learners with dyslexia, particularly given the brain's plasticity.

Past research indicated that the brain at birth never changed or grew and instead, the grey matter died throughout one's life; however, studies now reveal that the brain's plasticity allows it to reshape and reorganize the networks of dendrite-neuron connections in reaction to the augmented or diminished use of these neuropathways throughout one's life (Gerliš & Jaušovec, 1999, Willis, 2006). Instances of this brain plasticity are noticeable when people repetitively practice behaviors controlled by portions of their visual, motor, sensory, or coordination systems for particular learned activities (Gerliš & Jaušovec, 1999; Willis, 2006). After birth, the young brain has periodic growth spurts increasing gray matter and connections reaching a maximum density at about age 11. Still, this growth can continue if the person continues to practice skills and activities (Willis, 2006) – this is similar to learning a language in that without practice, the skills are lost. Doyle (2019) reveals that recent findings demonstrate that the human senses cooperate with each other – adding that when two or more senses are employed simultaneously, learning and memory heighten. Given the brains plasticity, engaging in repetitive behaviors involving multiple senses can work to embed information into memory and provide for better retention.

With the repeated engagement of various senses, students will have increased opportunities to pull up all those related pieces of data from their multiple storage areas

in response to a single cue, i.e., the words that might otherwise elude them. This cross-referencing of data strengthens the information into something we learn rather than just memorized and can store in long-term memory because serial rehearsal adds to improved retention (Beneventi et al., 2009; Willis, 2006). Willis (2006) adds that multiple stimulations mean better memory, leading to an assumption that an app like MagicSpells can provide sensory variety and diversity in interactions with words that will aid in remembering and identifying them. Dyslexic children struggle but do not seem to have impairments in verbal working memory in at least one study (De Jong & van der Leij, 2003). Mediation for reading proves successful when the exploration of letters is made by the haptic faculty and visual faculty. As such, visuo-haptic exploration enables the children to increase performance on letter knowledge and initial phoneme awareness and then allow for better decoding skills (Bara et al., 2007). By initiating Mayer's principles of multimedia design, which will be outlined in the next section, as a vital element of the design processes, creators have a better chance of successfully meeting the needs of target learners.

Design Principles of Multimedia Learning

Digital learning presents challenges, and Mayer (2009) suggests particular principles of multimedia learning design. Practical digital learning tools necessitate multimedia design features that support and do not overwhelm learners (Mayer, 2009). Figure 3 outlines the 12 principles of multimedia learning considered for developing the MagicSpells app and its efficacy for learners with dyslexia. These principles provide support for the core features of the MagicSpells app. In addition to following the theories for multisensory learning, using these basic principles of design, as set forth by Mayer,

the programmers and I worked to make MagicSpells an operational and successful learning tool for persons with dyslexia.

Figure 3

Mayer's 12 Principles of Multimedia Design

Adapted from Mayer's 12 Principles of Multimedia Design	
1. Coherence Principle Learners learn best when superfluous words, pictures, and media are excluded. It is crucial to limit the content to only essential information.	7. Pre-Timing Pre-Training Principle Markedly, this Principle stresses providing learners with either a brief review of previously-learned content or providing them with the necessary terms.
2. Signaling Principle It is best to engage learners by highlighting important information by adding visual cues such as arrows, bolding essential words, or circling important images to draw attention.	8. Modality Principle Learners learn better when presented with simple graphics and narration instead of animation and text. Pairing animation with text may visually over-stimulate learners and inhibit their retention.
3. Redundancy Principle This Principle refers to having closed captioning and voice narration of a text next to each other. Use either text or voice narration but not both to avoid cognitive overload. Although, learners with dyslexia (and other special needs) may engage better with text and voice narration.	9. Multimedia Principle This Principle tresses that learners learn better when presented with words and pictures at the same time. Introducing students with visual and text-based representations of the content meets the needs of all learning styles.
4. Spatial Contiguity Principle Notably, learners learn best when corresponding words and images are near each other on the screen, allowing students to direct their attention to one central focal point.	10. Personalization Principle Information should be presented to learners in conversational, age-appropriate tone and language.
5. Temporal Contiguity Principle Related to the spatial contiguity principle, this Principle asserts that it is best to present information at the same time rather than successively.	11. Voice Principle The voice principle also relates to narrative tone and emphasizes the importance of using a human voice rather than an automated one.
6. Segmenting Principle Learners learn best when working at their own pace. This Principle focuses on the idea that multimedia lessons should be presented in user-paced sections rather than one continuous lesson.	12. Image Principle People do not necessarily learn better from a multimedia lesson when the speaker's image appears on the screen.

Note. Adapted from Mayer, R. E. (2009). Multimedia learning (2nd ed.). Cambridge, England: Cambridge University Press and used with permission (APPENDIX M).

Merrill (2002) suggests that quality digital learning tools must promote efficient, effective, and engaging learning. His five basic principles of design state that learning is promoted when learners are engaged in solving real-world problems when existing knowledge [and skill] is activated as a foundation for new knowledge [and skill] when new knowledge is demonstrated to the learner, when the learner applies new knowledge,

and finally when new knowledge is integrated into the learner's world. Using both theories posed by Mayer and Merrill as baselines for exploring and developing the MagicSpells app, I examined and will continue to examine features that will best meet the needs of learners with dyslexia. Ultimately, there is a benefit in exploring the app using a developmental approach.

Summary – Dyslexia, Multisensory Learning, and the Senses

This literature review provides the foundation for the current study. In addition to examining characteristics of dyslexia, the importance of multisensory learning, and the importance of the senses in memory, it demonstrates a gap in the literature concerning multisensory digital applications that provide haptic enhancements for learners with dyslexia. The literature supports the premise that effective multisensory educational products should assist persons with dyslexia in acquiring vocabulary. The Orton-Gillingham, Wilson, Davis, and Barton programs for teaching learners with dyslexia support the multisensory aspect of quality and practical instruction. It is important to note that the literature reveals that the processes of phonological awareness closely align with a person's reading and spelling abilities and in the awareness of the correlation between spelling and sounds. Any multisensory processing that connects with the interaction of simultaneous signals arriving from a variety of sensory modalities supports unique, quickly developed multisensory associations. Furthermore, children with dyslexia demonstrate inferior mindfulness of the onset-rime distinction compared to non-dyslexic peers, requiring keener and more effective instructional strategies to assist them in learning to read and spell.

There is limited research into the effectiveness of digital tools in helping learners with dyslexia acquire new vocabulary and remember, recognize, and retain new words. Holding new words (or information) in long-term memory can prove challenging. While recent research explores the brain's plasticity, we need to discover more about long-term memory retention and the senses, particularly touch, when it comes to digital format for learning new words. A key takeaway is the concept that by engaging multiple senses, new information is more likely to impact the learner and allow remembering and recalling. Multiple sense engagement activities result in improved memory of the information being taught.

Until now, and with recent innovations in touch technology, the potential for a multisensory engagement in a digital format has been non-existent, except for the use of dual (sight and sound) senses. Mayer's 12 Principles of Multimedia Design (shown above) can serve as a basis for exploration and can aid in creating and developing an educational tool that incorporates a haptic feature. Because little is known about the inclusion of haptics – actually feeling something on a smooth screen - developmental research is necessary to ensure that the educational product supports the user and does so in a way that follows Mayer's principles.

The literature review supports the need for multisensory cutting-edge technologies and processes to help learners with dyslexia acquire new vocabulary and articulate the target users' needs. It demonstrates the core needs of learners with dyslexia and reveals current efforts made to assist them in learning to read and write. The literature stresses the need for reading instruction that is clear, precise, accumulative, and concentrated on the structure of language in a way that supports both long-term memory

and the idea that appealing to multiple senses makes remembering, recognizing, and retaining information more easily facilitated. The use of multisensory tools – like clay, sandpaper, and other manipulatives – has proven successful in many face-to-face, hands-on tutoring, and teaching experiences. I have identified a gap in the literature for additional research in the area of digitally-based tools that provide multisensory elements for learners with dyslexia.

The literature also highlights the process of developing a design for digital platforms that supports word acquisition for learners with dyslexia – encouraging limiting distractions for these learners, which markedly should provide directed guidance for designers looking to develop an educational product. Using developmental design approaches, I looked to discover the preeminent means for creating the most effective digital product in a way that no other or previous devices provide. This design effort is best served by using a developmental research approach to examine the app's features and helps provide important feedback at various critical stages in the design and development process. As such, an exploration of developmental approaches follows.

Educational Developmental Research

Technology integration and advancements have led to adaptations of research methods and approaches in gathering and analyzing data. In education, developmental research comes from the need to explore and understand the purpose, focus, and techniques of developmental research itself, as well as the need to cultivate the processes and products that lead to the empirical description of a teachable longitudinal development (Lijnse, 1995; Miller, 2017). Richey et al. (2004) suggest that

developmental research methods not only expand the empirical methodologies in education fields but also provide substance.

Sanders (1981) contends that developmental research is appropriate to those specific innovative, undefined procedures that researchers find challenging to examine through conventional research methods. In the field of education, looking directly at interventions that can determine desirable results is best. Therefore, the term developmental research is used to refer to any small-scale educational product development supported through research, design, development, testing, and revision. According to Plomp (2000), developmental research reduces the uncertainty of educational design decisions while producing concrete recommendations for effectual improvement by analyzing general design principles, resulting in the stimulation of professional development within the scope of stakeholder needs. We can liken developmental research in education to design-based research. It is characterized as an interdisciplinary research approach conducted "in the field" that serves practical and theoretical construction purposes (Richey, 1994; Richey et al., 2004). It can include tangible or intangible products/designs for which research questions are formulated. Notably, a developmental research dissertation involves designing, developing, and drafting and a willingness to trust in the process of testing and revising. Moving forward, additional phases of the study will be carried out in a natural educational setting (Reimann, 2010; Richey, 1994; Richey et al., 2004).

Types of Developmental Research

Initially, Richey (1994) identified three basic types of development research: the description or analysis of a product or program design; the development and evaluation

of a product, program, or design; the description or analysis of a product or program utilization and impact evaluation. However, Richey et al. (2004) have now narrowed developmental research to two types: Type I and Type II – the first for developing instructional systems or products and the second for conducting instructional development in response to questions, as a means to generate new instructional models in instructional systems and learning environments. They also note that "the two types vary in terms of the extent to which the conclusions resulting from the research are generalizable or contextually specific" (p.23). Furthermore, keeping in mind the end goal of improved learning, developmental research is a pragmatic approach that looks at knowledge grounded in data systematically derived from the practice, which offers a way to test theory previously only hypothesized (Richey & Klein, 2005). Also, they note that developmental research provides a means to establish novel procedures, techniques, and tools founded upon a systematic analysis of particular circumstances.

Furthermore, while the term development has many connotations, an appropriate explanation in terms of instructional design is that it is the method of interpreting and making design specifications into operational physical form, or in simpler terms, producing materials for education (Seels & Richey, 1994). Research is the story of the usability and effectiveness of these products (Richey et al., 2004). Research for developmental purposes lends itself to the immediate solution of practical problems, clearly making it similar to other methodologies such as action research (Richey et al., 2004). Plomp (2000) describes developmental research from an engineer's approach, in line with tackling a problem, designing and making a product, and testing the product's

effectiveness, which could be a course, a piece of instruction, or a multimedia product. However, it does not have to be tangible.

Developmental Research is a problem-oriented, interdisciplinary research methodology that reduces the uncertainty of particular design decisions to generate concrete recommendations for quality improvement by testing general design principles and stimulating professional development (Plomp, 2000; Plomp et al., 2010). In the simplest terms, developmental research is research related to the scientific need to make or develop something and see if it works and coincides with needs (Plomp, 2000). Notably, developmental researchers accumulate knowledge in a continuing research study, allowing time for reviewing and modifying interventions to best meet the needs of stakeholders (Gravemeijer, 1994; Guzman, n.d.). In developmental research, acquisition of knowledge is the primary concern, and making sense of what is going on is more important than predicting what will happen (Gravemeijer, 1994). Ideally, developmental-style research seeks to identify context-specific findings and determine their relevance for use in alternate instructional situations and settings - while also identifying novel principles of design, development, and evaluation to meet the needs of all stakeholders, but most notable target users (Richey et al., 2004).

More than anything, developmental research is directed at concluding whether, through specific interventions, anticipated results can be attained, and if so, under what circumstances (Sanders, 1981). Plomp et al. (2010) state, "The key focus in all scientific research is the search for 'understanding' or for 'knowing' to contribute to the body of knowledge or a theory in the domain of research" (p.10). In a clear sense, developmental research is a no-nonsense type of research that presents a means for testing a theory that

has only previously been posited and allows for an opportunity to validate a practice previously perpetuated through unchallenged tradition (Richey & Klein, 2005). Also, it is a way to establish new procedures, techniques, and tools based upon a methodical analysis of specific cases (Richey et al., 2004). Such research methods respond to emergent features of students' situations and emergent behaviors in response to activities driven in developing the intervention and development of the theory (The Design-based Research Collective, 2003). Too often, research associated with education takes place far removed from classroom settings and relies on inorganic experiences. Barab and Squire (2004) emphasize that quality developmental, design-based research "occurs in the buzzing, blooming confusion of real-life= settings where most learning occurs" (p.4). To take advantage of natural educational settings, before the trial of instructional activities in the classroom, the developer works to imagine how the teaching-learning process progresses; it is on these thought experiments that the instructional design is founded, and it is the developmental process itself that has to bolster the theory (Barab & Squire, 2004; Gravemeijer, 1994; Herrington et al., 2011). Developmental research lends itself to built-in reliability, enabling checkpoints that support researchers in redefining and reflecting on their research as it evolves (Kennedy-Clark, 2013). These checkpoints allow for modification and improvement at various developmental stages. Amiel and Reeves (2008) feel that the educational researchers' role is to limit the investigation of the educational processes and instead focus primarily on the educational direction and goals that best benefit stakeholders. Developmental research studies seek to enlighten designers and researchers about a particular practice model (Kelly, 2004; Sanders, 1981). Learning and design and the use of an innovative piece of software or specific learning

environment can precipitate a mechanism for intelligent human participation in the creation of educational systems and practices compatible with the reality of social evolution (Kelly, 2004; Sanders, 1981). Ultimately, according to Kortland and Klaassen (2010), for developmental research in education, there is a recurrent process of small-scale in-depth development and evaluation of the design and product, at a content-specific level, of excellent teaching-learning sequences. They report an aim to produce validation of the inner workings of these sequences - supported by observation and experimentation rather than theory.

Approaches in Developmental Research

Developmental research aims to use the scientific methods of organized observation and analysis, including experimentation, to guide and create desirable uses and outcomes (Sanders, 1981). Teachers often find it difficult to implement innovative learning designs because inorganic settings, where the learning innovation has been established, are nothing akin to the demands and constraints of the actual classroom (Reimann, 2010). When creating a product, whether it is an application, a lesson plan, a course, or other tangible or intangible things, developmental research allows researchers to test the effectiveness with natural learners and teachers (Plomp, 2000; Reimann, 2010). Moreover, developmental research provides viable means for intelligent human participation in the design of various educational forms consistent with the reality of community advancement (Sanders, 1981).

The word developmental implies a gradual evolution of growth and change (AECT, 2020). However, developmental research perceives development as the process of converting a design into a complete instructional product (AECT, 2020). AECT (2020)

agrees with Richey and Klein (2005) that the approach disregards planning and production as core approaches to instructional development with a design involving determining core requirements and development as the process of producing instructional material (AECT, 2020). Nonetheless, the researchers agree that the evaluation approach to developmental research traditionally served as a needs assessment and a follow-up analysis method (AECT, 2020). Richey and Klein (2005) note that evaluations are undertaken during the early stages of development to assess the validity of a product or program. Therefore, evaluation and validation are employed in developmental research to determine the validity and suitability of a particular product, such as software-based upon students' educational needs (Richey & Klein, 2005). Richey and Klein (2005) and Lee et al., (2017) agree that the research method employed in developmental research defines the subsequent instructional design and development phase. Accordingly, researchers must reach a consensus with experts before implementing a project, product, or program (Richey & Klein, 2005). This consensus approach makes the evaluation and validation of the critical methods of developmental research more valuable.

Nevertheless, accounting for contextual variables might challenge developmental design (Lee et al., 2017). As part of the process, programs must be run regardless of the errors involved in the design. Accordingly, validation must also apply some cross-sectional studies with testing between stages to verify the credibility and suitability of a program, for instance, a lesson scheduling program (Lee et al., 2017).

Van den Akker and Nieveen (2017) argue that design research links practicing teachers to external researchers. Teachers may determine the outcomes of a developmental research project because they are directly involved in the implementation

process (Van den Akker & Nieveen, 2017). Bakker (2018) agrees that an essential aspect of developmental research is the outcomes and not the research design process. Accordingly, Van den Akker and Nieveen (2017) substantiate that a research design process is only declared successful after the program serves the intended purpose. Nonetheless, Van den Akker and Nieveen's (2017) study does not highlight how researchers implement an instructional program. The study does not involve a follow-up or cross-sectional study approach to vividly confirm the relationship between teachers and external researchers in developmental research. Vogt et al. (2011) assert that the design of a curriculum is done to fulfill the needs of students; therefore, students are the primary influencers of curriculum design. Their involvement in design research should be acknowledged regardless of being passive stakeholders in developmental research. The methodologies in developmental research facilitate the study of innovative tools, models, and processes so that stakeholders can successfully predict the effectiveness and address the pressing problems in education (Richey et al., 2004). Effective tools must go through realistic testing beyond designers and programmers.

Plomp, et al. (2010) asserts that developmental research should take place in a real-world setting and that studies should adopt three distinct stages of research – preliminary research, prototyping, and assessment to provide a systematic evaluation of each phase. Multiple research methodologies are often used in developmental research studies, mainly when the project contains different phases (Richey & Klein, 2005). Through the use of surveys, observations, interviews, and student products, researchers should adapt and adjust and be prepared to take on the role of designer, advisor, and facilitator without losing sight of being a researcher (Plomp et al, 2010). Furthermore,

Kennedy-Clark (2013) notes that using varied data methods gathered from diverse expert groups, completing micro-phases with checkpoints, and working with adaptable designs allows the researchers to improve and modify their research projects. As a result, to better understand the problem and improve outcomes researchers should look at methodical and cooperative approaches.

Educational researchers should use more systematic and collaborative methods of the investigation, allowing for research that will make apparent differences for stakeholders (Amiel & Reeves, 2008). Furthermore, this approach requires an understanding of technology and technique as part of the process instead of merely gathering artifacts, an unwavering desire, and concern for the values and principles that guide educational research, particularly involving technology (Amiel & Reeves, 2008). Richey and Klein (2005) begin their description of the first developmental research as the need to focus the research problem on a particular aspect of the design, or development, instead of focusing on one specific variable that impacts learning.

Ideally, developing and designing interventions should be built upon in-depth exploration to provide the best vehicle for change. Gilgun and Sands (2012) define challenging educational environments as interactive contexts in which individuals live their lives over time and where there is a need for intervention, and these situations require qualitative methods, such as in-depth unstructured interviews, observations, and case record reviews to study the problem. It is recommended that to best prepare for studying the issue, research should learn about which previous interventions have worked or not worked (Gilgun & Sands, 2012). The next step is to conduct a small sample study, with careful evaluation of this pilot, and then an application of the results to any

reformulation of the problematic situations and of the interventions that the pilot has evidence for, and then execution of the intervention on more significant samples (Gilgun & Sands, 2012). As per Markauskaite et al. (2011), data acquisition and analysis should progressively move through multiple testing cycles and design application and function. Kelly (2004) claims that for some, these developmental research studies can advance our knowledge base, serve as an incubator for original research techniques, advance stakeholders' skills in designing learning environments, and perhaps can lead to better instrumentation. Mixed-method approaches offer boundless possibilities for enriching instruction and producing theory for practitioner-oriented fields, particularly in technology-based education and learning environments (Stahl, et al., 2019).

Summary – Developmental Research Method Literature Review

Current literature supports using a developmental research approach to educational product design. It suggests that developmental design research methods increase the pragmatic procedures for product design in education fields and provide groundwork and substance. To address the need for digitally-based, multisensory tools, I utilize educational development research, using Richey's (1994) suggestion for developmental research – specifically, the description or analysis of a product design; the development and evaluation of this product; and the description or analysis of a product or program utilization and impact evaluation. I used the notion that the conclusions resulting from the research are generalizable or contextually specific to learners with dyslexia. Furthermore, I wanted to produce validation of the inner workings of the developmental sequences - supported by observation and trialing rather than through theory alone and to conduct this research in organic settings with the users who can most

benefit from the final product. Unlike design-based research, which follows a design idea through development and into a completed prototype, developmental research looks at educational design theory and how to apply this theory to the development of an educational tool. Developmental research emphasizes the end stakeholders and the instructional design process, providing a robust means for exploring educational design theory and creating quality educational tools or programs.

CHAPTER III

Methods

In this developmental research, I used a mixed-method study to explore and the developmental process in the use, programming, and improvement of the MagicSpells app, specifically designed to assist learners with dyslexia in the acquisition of vocabulary. While no statistical analysis of quantitative data took place, comparisons between some questions on the pre-trial survey and the post-trail survey came to light. Additionally, the quantitative data serve to augment qualitative data and to guide interview questions and support necessary modifications to the app. The entire developmental process began long before the current study and culminated into a face-to-face trial with target stakeholders as participants. With this study, I sought to gather participant feedback and to apply these findings to the continued development and design of the app.

MagicSpells

My passion for discovering a way to help people with dyslexia began decades before I started my doctoral program. Having come from a long line of people with dyslexia, my interest in assisting people with dyslexia acquire vocabulary, and read and write, comes deeply rooted in history, experience, and personal trials. I define "acquisition" as identifying, recognizing, reading, and writing new vocabulary. While I read at an early age, my spelling and ability to complete math problems, especiall y word problems, then and now take a toll on my grades and my self-esteem. A significant number of my family members and former students struggle to read and write well. As a third grader, I helped my younger brother acquire vocabulary and learn to read using letters cut from sandpaper, sound effects, and repetition. Both of my grandchildren have

dyslexia, as do their parents. Because of this history and my desire to help my grandson and now my granddaughter learn to read and write, I am driven to make a difference.

Dyslexic learners currently have access to accessibility tools like text-to-speech and speech-to-text, and font and color scheme variations. Technology affords many trappings for struggling readers and writers. However, I contend that accessibility tools work as learning aids, but they do not teach vocabulary, reading, or writing. I propose a means to support life-long learning. Through the digitally enhanced acquisition of words, dyslexic learners will find more success in recognizing, retaining, and reading necessary words. As a result, these learners can potentially develop the essential vocabulary for literacy success. The focus of my developmental dissertation was to develop a practical application supporting the use of multi-sensory (sight, sound, and touch) digital technology (MagicSpells) aimed at building vocabulary skills and improving reading and writing and fostering positive self-esteem.

Imagined initially in 2012, MagicSpells is a digitally-based, multisensory application that uses sight, sound, and touch to assist learners with dyslexia in acquiring new vocabulary. At that time, I scratched images of my design on printer paper and began looking for someone who could program it. One of my students from the high school's "Girls That Code" club developed a simple version of the app, but she could not figure out how to add a touch element. Unfortunately, I learned I was ahead of the time, and I could not locate the haptic feature or a programmer who could add it and produce the app. Technology caught up with me before enrolling in the Instructional Systems Design and Technology program at Sam Houston State University in 2017, and I learned about TanvasTouch®. This innovative, haptic design can change the way learners use

digital devices to learn vocabulary. With the support of a representative from the Tanvas company, I acquired one haptic-enabled set of hardware on which we installed MagicSpells. In November of 2019, I enlisted two programmers in India. Since then, we have been involved in creating the app's core, adding the haptic features, and refining the app over time.

It is essential to note that the TanvasTouch® elements have limits that resulted in exceptions and changes to the original design, at least for now. The TanvasTouch® engine and unique screen are still, in many ways, in the development stage too. For now, the hardware provides enough haptic feedback to complete the study. Future innovations from Tanvas will allow continued advancement and development of the MagicSpells application.

MagicSpells App Description

MagicSpells was installed on hardware equipped with the TanvasTouch® screen and includes the following elements:

- word banks - Learners selected or added a word from the word banks. (For this study, a preset word list will be used.)
- read and spell the word – the learner says and records the word and spells the word one letter at a time for later playback
- listen to word and definition – Learners choose from a list of definitions of the word and listen to and can remove any desired definition
- record and play back a definition – leaners create and record for playback, a definition of their own

- record and play speech – Learners used buttons to navigate and say and record definitions, letters, words, and sentences (with playback)
- choose a touch texture – Learners chose from various textures to give a sense of touch to finger movement on the screen (to be fine-tuned)
- create the word - the user builds the word; this is less like tracing letters and more like forming or shaping letters. Learners created each letter in the word and then feel each separate letter as well as the entire word (This will include haptic feedback in the future).
- the users create an image representing the sentence by drawing or using the clipart feature (or both)
- assessment mode for each word – unscramble the word, match the definition to work, and guess the text/image by speech or writing, find the correct text by hearing the text audio, and visual identification
- some sort of culminating game/activity at the end of each cluster of, say, 10-15 words to demonstrate recognition and retention

Because dyslexic learners have difficulty associating letter shapes with sounds, an intervention like MagicSpells - based on integrating visuomotor skills and letter-sound associations - can support letter representation and formation and increase reading, decoding, and spelling abilities (Layes et al., 2019). The break between connecting letter shapes with sound reflects a problem in establishing and retrieving sound-visual configuration associations. MagicSpells creates a connection between seeing each letter as it is formed and feeling the shape of the letter on the touch screen. The completed word and the audio, visual, and haptic features can solidify the information in the learner's memory for future recall. Conceptually, by adding the auditory feature alongside

sight and touch, the app will provide an interactive and multisensory experience for learners to engage with words. It is essential for students learning to read to actively process the information as they interact with words - manipulating ideas around words to extend and deepen knowledge of the word, its uses, and its connections to other words and situations (McKeown, 2019). Multisensory tools for learners with dyslexia have yet to include digital devices beyond the inclusion of sight and sound. With the advent of innovative TanvasTouch®, MagicSpells stands poised to deliver a product platform that provides sound, sight, and touch features in a digital format for vocabulary acquisition, thus providing a viable tool for target users. Using developmental research can best explore a digital vocabulary acquisition application that best meets target stakeholders' needs.

Research Design

A developmental research project can utilize multiple research methodologies and designs, with different designs being used for different project phases. Using organic settings with target participants can enhance the credibility of the research. As is expected, changes in research plans and procedures can and did come from unanticipated events - like the COVID lockdown, availability of multiple devices, the failure of the original device to work, availability of office space, and other challenges typical in other types of research. Such is the case that led to this study.

For the MagicSpells trial with target participants, specifically learners with dyslexia, critical design and development processes were explicated using case study methods – including surveys, interviews, videos and photographs, and observations. The results of the study feedback were used to gather data and document the processes

employed as wells as the conditions under which they are employed, with the ultimate goal of discovering the usability of the MagicSpells app and the quality of its elements and features.

Purpose of the Study and Research Questions

While learners with dyslexia have access to tools that assist in the educational process, learning new vocabulary to help them stay on level with peers can prove quite elusive. Indeed, there is no substitution for reading, recognizing, and retaining new words. Armed with a better vocabulary, learners with dyslexia should see improved reading and writing skills. An app aimed at increasing word recognition and retention has the potential to be a game-changer, and using developmental research approaches is the best means for designing, creating, and fine-tuning a viable working educational tool. The MagicSpells app was designed to provide a multisensory environment where learners could interact with new words using sight, sound, and touch. The following research questions were used to guide this study:

1: How can the developmental research process lead to a quality product that best meets the needs of all stakeholders- in particular, learners with dyslexia who struggle to stay on level with peers in reading and writing?

2: Can the exploration and employment of the principles of design, development, and evaluation aid in creating workable and compelling features of the MagicSpells application?

3: How can analysis and the results of the reviews and usability tests help to improve the MagicSpells app and lead to future iterations of the application?

Developmental Research

I used a qualitative exploration to address these research questions to analyze participants' feedback. Feedback came from learners with dyslexia between the ages of 6 and 10, in the first through the fifth grades. Specifically, I sought feedback regarding the usability of the MagicSpells and its features. Quantitative survey data gathered served to make possible comparisons and gauge the users' responses to the usability and functionality of the app. Markedly, during recruitment, one participant, independently diagnosed with dyslexia and with parents with dyslexia, was allowed to participate in the study, even though learners his age and grade were not originally recruited. Vogt et al. (2011) point out that the design of education materials (in this case, an app) is done to fulfill the needs of learners, and as such, students should be the chief influencers of educational app design.

In addition to qualitative data, quantitative data was gathered, revealing commonalities and averages in participant responses. Following Van den Akker et al. (2010), this research study focused on the design processes set in a realistic setting for education as a collective effort to understand and improve the MagicSpells app. I applied design theories simultaneously with field testing and the evaluation of previous consecutive prototypes, culminating in the study conducted for this dissertation. Simply put, the primary developmental theory utilizes three essential elements, 1. design/develop, 2. implement/try-out, and 3. evaluate (formative) in a cyclical manner (Van den Akker et al., 2010).

Pre-study Protocol

In addition to examining learning theories and relevant literature, I consulted experts – including dyslexia tutors and specialists, emerging readers, special education teachers, and academics - early in the design process and throughout the entire experience. Staying true to developmental theorists, I worked to take the app through several versions (Figures 5, 6, and 7), including two early designs created for a smartphone that lacked the haptic feature. In an effort to create the best possible product, it became necessary to conduct informal field-testing. Using feedback from dyslexia specialists, tutors, and persons with dyslexia and referring to several dyslexia program standards, I determined the key elements to include in MagicSpells. However, it became necessary to try out and have others interact with the app. As each version of MagicSpells came to fruition, I found it recurrently necessary and helpful to have others try MagicSpells and offer critiques. My cohort-mate and her daughters played with the early versions of the app and later with a few subsequent ones. Their feedback then led to updates to the app's non-haptic elements. I shared one version with a special education counselor, who could feel the haptic feature, and she, too, shared her opinion. I also had my granddaughter, who is a person with dyslexia (age 8 at the time and again at ages 9 and 10), try the app, and she offered her opinion and suggestions.

I shared the 10th version of the app with an eight-year-old boy, who, while not a learner with dyslexia, spent two hours trying the app and its features with his mother. Aside from my granddaughter, this young man was the first child to play with the haptically-enhanced version of the app. His excitement spurred me on, and the 11th version had several suggested modifications. I again shared the app with my cohort-mate

and an elementary teacher and gained more feedback, leading to the 13th edition of the app, which became the prototype for the current study. Importantly, since I have the only haptically-enhanced device with the app installed, allowing individuals to use it fell to those with whom I could connect in person. However, anyone with a computer could review other app features, and this feedback proved equally valuable to the developmental process.

With these pre-study interactions, MagicSpells could evolve organically into a fully-operational app. It took 11 versions for me to finally feel confident enough to put MagicSpells into the hands of target users and their parents to solicit their feedback. Ultimately, in the present study, the prototype came about through continuous interaction with experts, pilot studies, and trial and error – following the same recurrent developmental approach.

Study Protocol

General procedures were used for all of the participants and included:

(a) the completion of a pre-trial survey - Notably, the pre-trial survey was initially created to gather participants' feelings about reading, writing, and technology. A few items did, in the end, allow for some simple comparisons.

(b) training of participating parents and each child on the TanvasTouch® equipment and the MagicSpells app

(c) vocabulary intervention using the MagicSpells app for participants through collaboration between the children, parents, and researcher

(d) completion of the MagicSpells Follow-up Developmental Design Survey – the survey questions were used to garner feedback about each feature of the MagicSpells application and participants reactions to them

(e) interviewing of students and participating parents to obtain feedback regarding the app's features, usefulness, and engagement.

In order to accommodate participants from a variety of schools, it was necessary to locate and utilize private office space that included a desk and at least two chairs. I acquired two separate office spaces, which allowed for privacy and easy sanitation and cleaning between participants. Participants' parents traveled to the locations to participate in the study.

After I trained participants and their parents to use the app, they felt comfortable with the hardware and application, and they then worked with the MagicSpells application to choose and practice a minimum of five words. I instructed them to use all the tools and features, including the participants' choice of assessment – definition matching and word scramble. At the end of each session, totaling nearly two hours per participant, and after cleaning and sanitation, the equipment was transferred to the next student. In addition to the TanvasTouch® enabled screen, a keyboard, a mouse, and a NUC minicomputer were provided for the study. The video and pictures did not include any identifying elements or features of participants, and their information, responses, and interactions were kept confidential.

Each learner worked with a specific bank of words. (choosing a minimum of five words) for the duration of the intervention and completed the in-app assessment at the end of the intervention. The app assessments offer a review ("hint") feature as part of the

instructional process to further support recognition and retention. Participants, parents, and I chose the words for use during the intervention to provide the most realistic experience possible. The app provides banks of age and grade-level appropriate Dolch (Appendix A) and trigger words (Appendix B) from which participants can choose. Additionally, the parent often selected the word list so that the participant would not automatically choose words they already knew.

Participants were chosen because they are learners with dyslexia, who are native English speakers between the ages of 7 and 10 and who are in the second through the fifth grades. There were seven learners who fit the specified criteria, with the exception of one participant who was younger – age 6, but still met all other criteria. I included this participant because he had been independently diagnosed with dyslexia, and his parents are adults with dyslexia. Because of the availability of only one haptic-enhanced device, each learner was scheduled for the trial based on space and equipment availability. A nearly two-hour time slot was allocated for learners and adults to become familiar with and try out the MagicSpells app and its tools, features, and functions. There was a fifteen-minute interval between each participant to allow time for sanitizing and clean up. Additionally, I took pictures and short videos of learners typing, drawing, creating – audio - speech to text and visuals - drawings, letter formations, word creation. Participant defining characteristics such as faces were not visible on the camera; only their actions were recorded.

Offices for the trial were secured where participants could try the app with limited distractions. Figures 8 and 9 show the trial settings and set-ups that allowed for both participants' and parents' interaction. With current Covid-related concerns, it was

necessary to acquire these private office spaces and to follow all necessary sanitizing and cleaning protocols. Masks were used at parent or participant request. I arrived early to prepare the space and set up the Mimo/TanvasTouch® device, and ensure all equipment functioned as expected. Water and snacks (nuts, trail mix, and breakfast bars) were provided.

I gave step-by-step instructions to both the participants and parents for using the app. The app does contain in-app instructions that can be read or listened to, but in the interest of time, I chose to walk each participant and parent through the process. Instructions on how to use the MagicSpells app took place in the allotted timeslot where the participant, one parent, and I interacted. I stayed in the room to photograph and video the study and for support. Because a unique piece of hardware is required, I remained on hand for troubleshooting any technical issues that arose. The tablet's built-in microphone and speaker were used for recording and playback. Also, the equipment set-up included a wireless external keyboard and wireless mouse. Because the equipment was used by all participants, after each session, I practiced strict cleaning and sanitizing protocols to ensure that the exchange of participants and equipment followed current safety standards. Individual interviews took place in person. These follow-up responses were taken down by hand.

Parents and participants sat side-by-side and familiarized themselves with the features of the app. Under my instructions, each participant/parent pair completed all activities for each of the five words. These activities included:

1. Choose a word
2. Say and spell the word (recorded)

3. Listen to the definition(s)

4. Record their own definition

5. Choose a background for the canvas

6. Choose a font color

7. Draw the word on screen

8. Create a sentence using the word (speak the sentence and record)

9. Create an illustration (using the draw and/or clipart feature)

10. Click the haptic-feedback page (hear the word, spelling, definition and sentence), and FEEL the word

11. Complete one of the two in-app assessments, after they completed a minimum of five words.

During this time, I observed and took photographs and short videos. When questions arose, I was there to help. At the end of the trial, the participants completed the MagicSpells Follow-up Developmental Design Survey (Appendix D), administered after the trial. This data was used to gather feedback about the app's usability and its features. Additionally, I used the second survey questions as interview questions to follow up on the Likert responses, in particular, extreme responses (Appendix E) - to encourage elaboration on Likert-scale choices that were either wholly positive (score of 4) or wholly negative (score of 1).

Ethics in Research

Before the research began, authorization for human subject research with minors was obtained through Sam Houston State University. Parental consent and student assent were obtained for all student participants on the day of the trial. Copies of the parental

consent form and participant assent forms were emailed to parents prior to the study. Since I used a cellphone camera to capture the participants as they completed the intervention, I obtained permission for photos and video footage. No faces or identifying features appeared in the photos. Furthermore, I informed parents that I would only identify participants by participant numbers and destroy all documentation and photographs after five years.

Materials

The materials for this study included a TanvasTouch®-enabled tablet display and a mini-computer with the MagicSpells app installed (Figure 4). Additionally, I provided each participant with a keyboard and a mouse, and each participant used the internal mic and speaker for the recording and playback features. I used my cellphone to record and take pictures. MagicSpells was chosen as the intervention for this study because I designed it specifically to help children with dyslexia accomplish the following educational goals: (1) improve letter identification, (2) improve word formation and identification, (3) improve word acquisition and retention, (4) improve spelling, (5) improve writing, and (6) improve receptive and expressive language.

The application provides a simple "canvas" and various digital tools where learners can interact with the letters and words in a way that uses sights, sounds, and touch, providing a multisensory experience. It has an extensive word bank and a way for the user to add words and definitions. The simple, uncluttered view allows the learner to focus on the word in a multisensory way that enhances memory. Within the canvas, learners choose words, listen, repeat, record definitions, craft letters and words with haptics included, speak or type sentences, and create an illustration representing the word. The app uses

auditory playback of the student's voice to reinforce vocabulary development. Once participants viewed the word and received the auditory prompt, the student verbalized, recorded, played back, and listened to their saying of letters, the word, and sentence throughout the process and for review before moving on to the next word in the series. In the case where learners were extremely soft-spoken or shy, parents were encouraged to speak definitions and occasionally sentences for playback. These elements were saved and revisited for review as needed. After completing a set bank of words, a game-style assessment tested retention, recognition, spelling, and use.

TanvasTouch® adds a haptic interaction that enhances the sound and sight features typical of digital learning. The tablet is equipped with a touch-enhanced screen that allows the user to feel various textures as he or she slides fingers across and around the screen. Notably, for this study, the programmers and I had settled on a single "feel" texture because they programmed the touch feature without access to the device. A toolbar within the app allows users to pick digital brush size, color, selection tool, clipart, images, and backgrounds. Learners also chose from a set of backgrounds – sand, clouds, pebbles, water, brick, plushy, and others – as well as the system voice for playing instructions and definitions. In the prototype version, textures and voice are limited, and access to these provided valuable feedback from learner participants and their parents for future versions of the application.

Conceptually, MagicSpells is designed to increase the vocabulary of dyslexic learners. In the app, the learners can add and remove definitions of the words. They can also record and playback their voices, use speech to text to add sentences and definitions, use the keyboard to type sentences. Currently, the app has a word scramble and match

word/definition assessment (Figure 8). However, programmers will add matching and sentence creation assessments when possible. For the trial, programmers populated the word bank with specific Dolch and Trigger (Appendix A) words. The word list for the intervention was individualized to each participant from a preset bank of words. The assessment section includes the same set of words chosen during the intervention.

Figure 4

Mimo/TanvasTouch® Device and Equipment

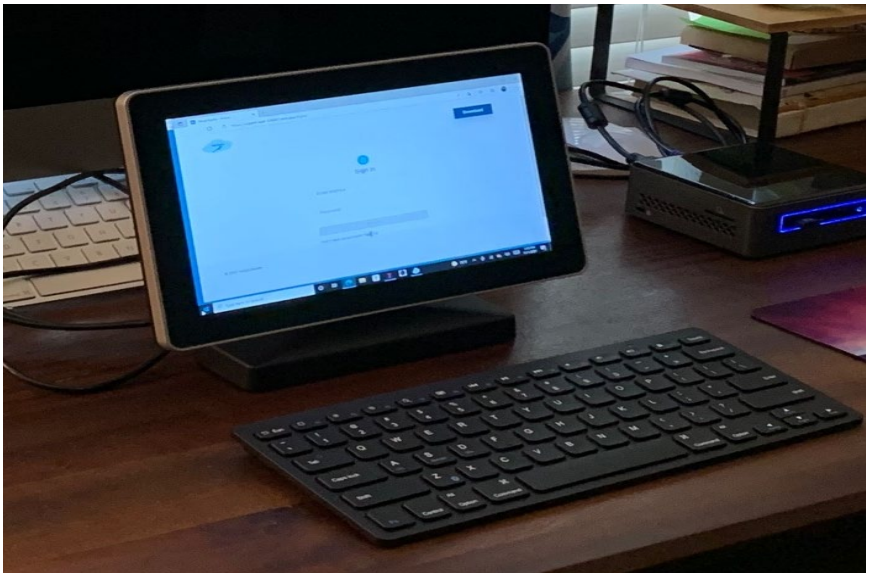


Figure 5

MagicSpells Early Version 1

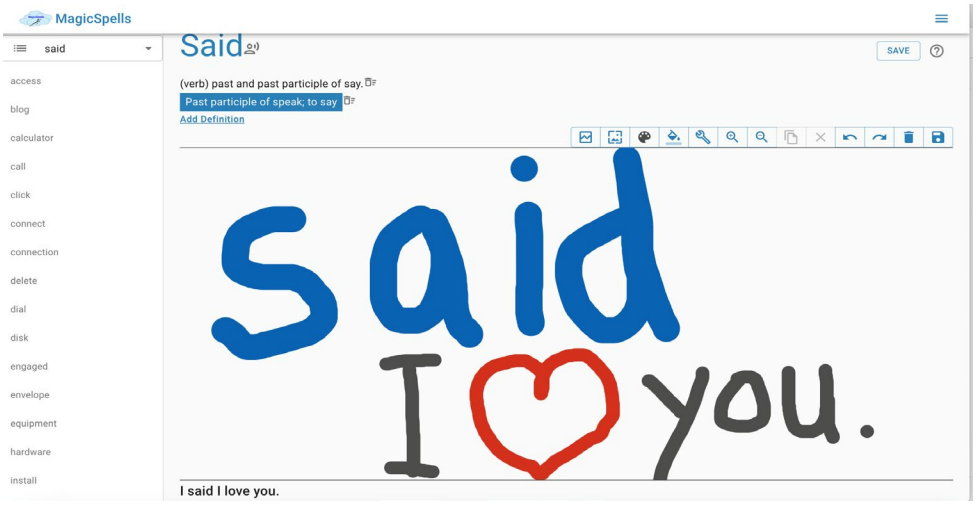


Figure 6

MagicSpells Updated Version 2

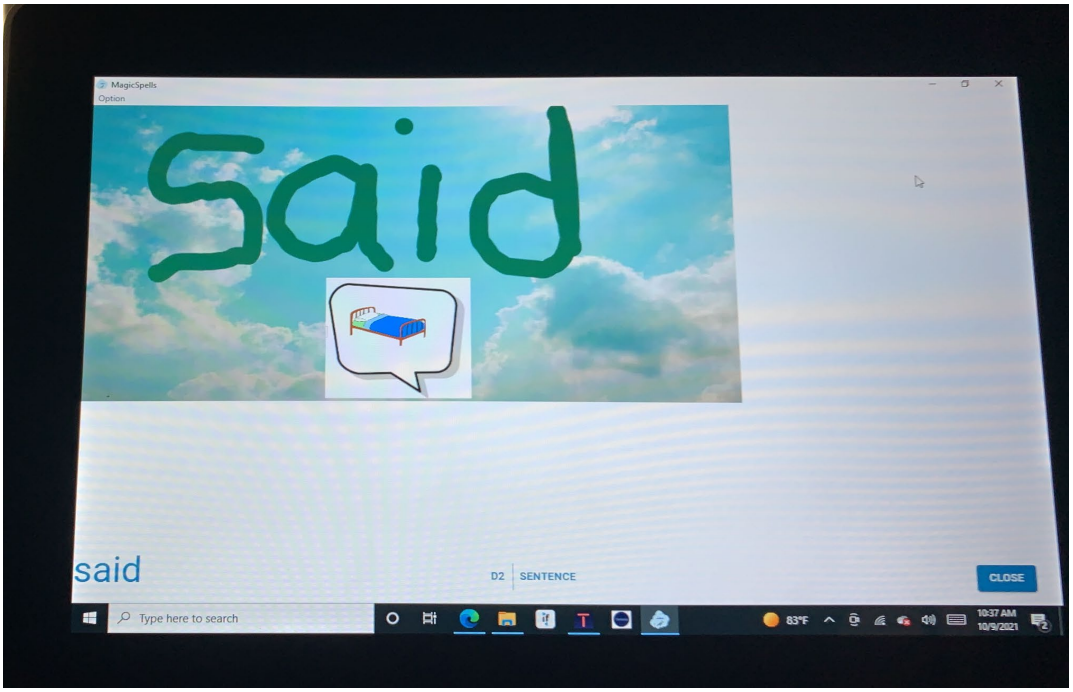


Figure 7

MagicSpells Updated Version 3

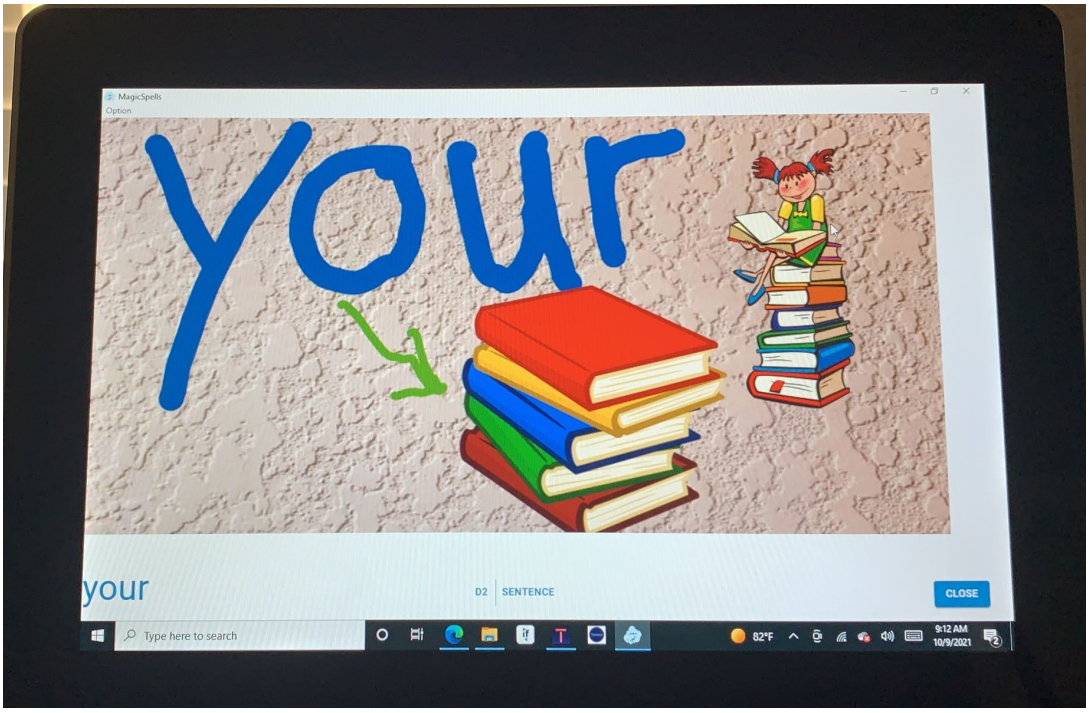
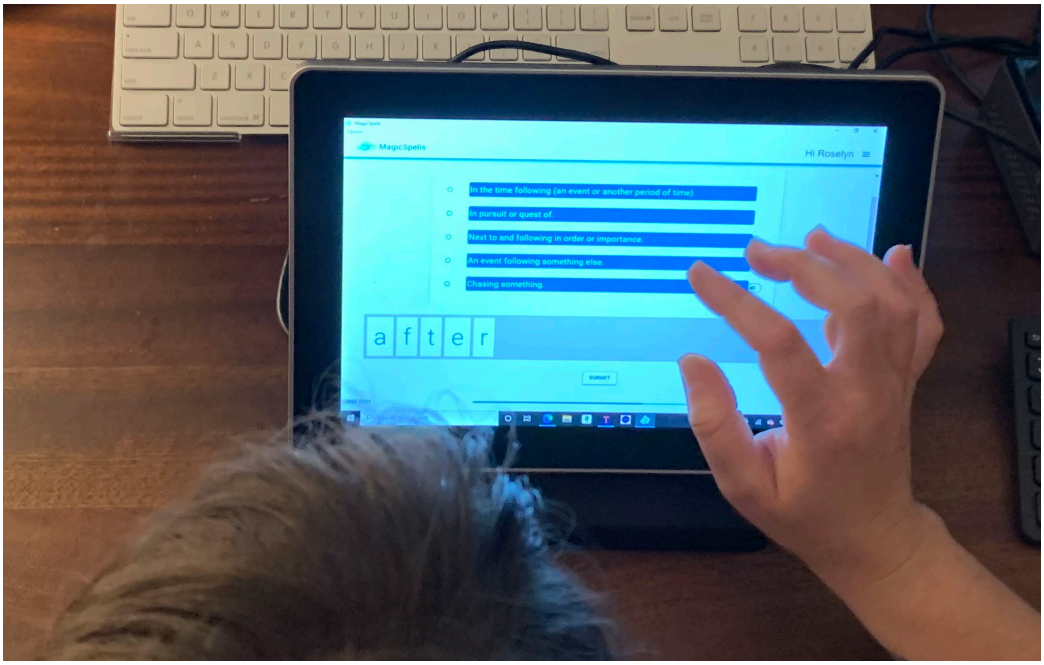


Figure 8

In-app Assessment



During this time, I observed and took photographs and short videos. When questions arose, I was there to help. At the end of the trial, the participants completed the MagicSpells Follow-up Developmental Design Survey (Appendix D), administered after the trial. This data was used to gather feedback about the app's usability and its features. Additionally, I used the second survey questions as interview questions to follow up on the Likert responses, in particular, extreme responses (Appendix E) - to encourage elaboration on Likert-scale choices that were either wholly positive (score of 4) or wholly negative (score of 1).

After the trial, I interviewed students and parents to gauge their satisfaction with using the technology and the MagicSpells app and how they felt the technology-based, touch-enhanced instruction compared to traditional dyslexia intervention. Interviews were recorded as notes and were obtained during the trial. I gathered information as a

means to conduct the systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet the criteria of internal consistency and effectiveness (Richey, 1994). For this study, Likert scales and a standardized survey-based interview approach were used when gathering and interpreting the data to develop the app in subsequent iterations. Additionally, interviews measured the informants' satisfaction with using technology, the MagicSpells app, and how they felt the touch-enabled, technology-enhanced instruction compared to traditional instruction, among other features.

Participant Selection

Since the objective of a purposive sample (a type of nonrandom sampling) is to produce a group that can be logically assumed to represent the population, a purposive sample was used for this study (Lavrakas, 2008). I needed to have native English-speaking learners who have been diagnosed with dyslexia and who are in grades 1 through 5, and recruitment was geared toward this population. Recruitment took place in a charter school in the Austin, Texas, area and via a dyslexia support group on Facebook.

Participants for the study were recruited in two different ways. A representative from the central Texas charter school attached my recruitment letter (Appendix F) to the school newsletter emailed to all the parents. The parents contacted me via email, and I sent them an informative PowerPoint presentation (Appendix H). Then the parents signed up their child on a schedule posted on the website Sign-up Genius (Appendix G). Furthermore, I recruited participants from a dyslexia support group on Facebook. Parents agreed to bring their child to the trial sites and to stay and help their child participate in the trial. All participants live in the Austin area and drove to the study site.

Figure 9

Primary Office Space for MagicSpells Trial

Figure 10

Secondary Office Space for MagicSpells Trial

Data Collection

Likert data was collected via in-person assessments crafted by me to create a baseline for future exploration of the application's usability and efficacy. Interviews, using survey responses, were used to collect more details and specific data on reaction/feedback responses. The type of data collected varied along with the phases, with the current study being the final stage for now. Data contributing to contextual understanding were emphasized in earlier stages of the developmental process, while data on prototype characteristics and user reactions were explicitly collected for this study. Surveys, interviews, observations, and photos and videos were gathered from all participants for this study.

Data Collection Procedures

I specifically designed the MagicSpells Post-Trial Follow-up Developmental Design Survey to garner feedback from study participants about the usability of the MagicSpells app and its features. Two 4-point Likert scales were used to gather information before and after the trial. The Likert scale allowed for self-reported participant ratings for satisfaction, ease of use, and ease of finding information, where participants rate the features and app on a scale of 1-4. I chose a 4-point scale to force a response beyond neutral. I initially created a Pre-Trial Survey just to gauge learners' attitudes regarding reading, writing, and spelling. Administration of the first survey took place before the trial, and at that time, I gathered basic demographic information including race, school type, gender, age, and grade. After each participant finished the trial and completed the second survey, I used questions from the survey to ask learners to

elaborate on their responses – particularly on extreme responses on either end of the 4-point Likert scale.

Survey Data Analysis

Survey research offers a valuable and genuine approach to research that helps to describe and explore variables necessary for app improvement. In the case of this study, feedback provided by the surveys was vital to the developmental process for the MagicSpells app. Two surveys were used for this study. The first was a pre-trial survey designed solely to acquire basic participants' attitudes regarding reading, writing, spelling, and technology in education. During this survey, I also gathered basic demographic information. The follow-up, post-trial survey reduced the uncertainty of educational design decisions while producing concrete recommendations for effective development through the evaluation of general design principles (Plomp, 2000).

Interview Data Analysis

I developed data-driven codes to reduce raw information into smaller units using the emerging themes from the interview questions responses. The Likert scale survey responses allowed me to ask specific questions and write down replies. Since I worked with children, answers were often simple – single words and short phrases that were surprisingly similar, but notably, quite helpful. Additionally, the follow-up questions allowed for clarity and gave credence for using a 4-point over a 5-point Likert Scale.

Overall Analysis

Data from the Likert surveys was entered into an Excel spreadsheet, and graphs were created. This data was then incorporated with the interview responses to explore reactions to the survey questions and look for commonalities. Interview/elaborated

responses were thoroughly examined and like terms and responses were recorded and coded as themes emerged. During the analysis, each theme was discussed in detail with a committee member and cohort mate. Even though the pre-survey was initially intended as a tool to gather basic participant information regarding reading, writing and technology, and demographics, a few comparisons materialized between the pre and post-surveys. These comparisons and the final data and results were discussed and used to improve, modify, and update the version used in the study.

Summary

Data gathering took place over three days and consisted of surveys, the trial of the MagicSpells app, and interview questions. Seven elementary-aged learners with dyslexia participated with one parent each. Feedback from the current study results, coupled with all aspects of the developmental approach, serve to guide subsequent versions of the MagicSpells app. A thorough exploration of the results is necessary to understand the impact of developmental research on the design of an educational application.

CHAPTER IV

Results

Introduction

The current study is this final step (for now) in the developmental process. It specifically uses target participants to try the app and offer criticism, which provides the relevant feedback to create the next version of MagicSpells as a viable, user-friendly application specifically for learners with dyslexia. The design and development of this educational app were conducted to fulfill the needs of students with dyslexia, who are the primary stakeholders when considering curriculum design specific to their needs (Vogt, et al., 2011). Their involvement in design research should be acknowledged regardless of being passive stakeholders in developmental research. It is this study and their feedback that will guide the working prototype of MagicSpells to offer to parents, learners, and educational institutions. However, in line with developmental research theories, it will likely go through multiple iterations, even after the first full version is made available, and it will continue to evolve. As Richey et al. (2004) attest, developmental research works to assist in the creation and improvement of instructional systems or products and for piloting instructional development, as a means to generate improved instructional models, and that was the goal of this dissertation experience.

First, the participants are identified, and then the results of the surveys are revealed and explored. Subsequently, individual survey responses and supporting interview questions are analyzed in detail, followed by an exploration of the research questions. Participant learners with dyslexia struggle to read and write, and at the core of these reading and writing skills is vocabulary acquisition. By increasing vocabulary and

supporting reading and writing skills, MagicSpells can play a major role in achieving this goal. Quantitative data was used to compute usability metrics for comfort and satisfaction ratings. Qualitative data was used to compile and provide insights about the efforts taken by participants, problems experienced, and answers that they provided in the surveys and during post-test interviews.

Participants

The participants in this study have been diagnosed as learners with dyslexia. They are between the ages of 6 and 10 years of age, in other words, first through fifth grade, who either attend public, charter, or homeschool in the Central Texas area. Four of the seven participants attend a small charter school, two attend public elementary schools, and one participant is homeschooled. The charter school learners were recruited through the school's weekly newsletter, and the remaining participants were recruited via online dyslexia support groups – specifically on Facebook. Participants consisted of six females and one male. To maintain confidentiality, participants were given pseudonyms and a participant number which were included on all documents. For the purpose of this study, participant numbers were used in the presentation of the data and results.

All participants were selected based on the following criteria: (1) they had been identified with a language-based disability, specifically dyslexia, (2) their teachers/parents indicated their need for vocabulary development, (3) student age and or grade level, (4) and the learners were English-as-a-first language speakers. Second language learners would be problematic because dyslexia would first have to be diagnosed in the learner's primary language. Any difficulty in second language acquisition could not be related to typical second-language acquisition learning

issues. Participants were specifically identified as those who showed delays in expressive and receptive vocabulary, which focused on the identified intervention, MagicSpells, the multisensory digital vocabulary acquisition app.

Table 1

Participant Demographic Information

Participant	Gender	Race	School	Age	Grade
1	F	Hispanic	Charter	8	3
2	F	Mixed-race	Public	9	4
3	M	White	Charter	6*	1
4	F	White	Homeschool	9	4
5	F	Black	Charter	9	4
6	F	White	Charter	10	5
7	F	White	Charter	10	5

Note. *Participant 3 was included in the study despite his age because he was independently diagnosed as a learner with dyslexia and both of his parents are adults with dyslexia.

As Richey et al. (2004) point out, developmental research explores the usability and effectiveness of an educational product. Notably, developmental research allows researchers to test the effectiveness with target learners and teachers (Plomp, 2000; Reimann, 2010), which theoretically guides this study and supports the research questions. Table 2 shows learner responses to questions and averages for the pre-trial survey, which was used to gather simple reactions of participants to reading, writing, and technology. It was not originally designed or included to garner feedback on the MagicSpells application. These results were used to explore research questions and to

provide support for in-depth, question-by-question analysis and examination. For this Likert-guided survey, 4 signified the most positive response, while 1 signified the most negative response.

Table 2

Pre-Trial Survey Results

Participant	**One**	**Two**	**Three**	**Four**	**Five**	**Six**	**Seven**	**Average**
Q1- How do you feel about reading?	3	2	3	2	3	3	1	2.43
Q2 - How do you feel about being read to?	4	4	4	4	4	4	4	4.00
Q3- How do you feel about writing?	1	1	3	1	2	3	1	1.71
Q4 – How do you feel about spelling?	3	1	4	3	2.5	3	1	2.50
Q5 - How easy is it for you to learn vocabulary?	3	2	2	4	3.5	3	1	2.64
Q6 – How comfortable are you using a tablet?	3	4	3.5	4	4	4	4	3.79
Q7- How do you feel about using a tablet to learn vocabulary?	3	4	3	3	3	4	4	3.43

Continued

Participant	One	Two	Three	Four	Five	Six	Seven	Average
Q8 – Do you find it easier to learn using technology?	3	1	4	4	4	4	4	3.43

Using the results of the post-trial survey (Appendix D) and follow-up questions (interviews Appendix E), Table 3 shows participant responses and averages. Responses are explored more in depth in question-by-question analysis later in this chapter and comparisons are made between the pre-trial responses (where applicable) in this analysis too. A second Instructional Systems Design and Technology doctoral candidate assisted in the analysis of the data and in the creation of the tables and charts.

Table 3

Post-Trial Survey Results

Participant	One	Two	Three	Four	Five	Six	Seven	Average
Q1- How easy was it to learn vocabulary with the MagicSpells app?	3	3	4	4	4	4	2	3.43
Q2 - How comfortable are you using a tablet to learn words?	4	4	4	3	4	4	4	3.86
Q3- How do you feel about the usability of the MagicSpells app?	3	3	4	3	3	4	1	3.00

Continued

Participant	One	Two	Three	Four	Five	Six	Seven	Average
Q4 - Do you find it easier to learn words using the app?	4	4	4	4	4	4	4	4.00
Q5 - How do you feel about the definitions provided?	3	3	4	3	3	4	2	3.14
Q6 - How did you feel using the speech-to-text feature of the app?	4	1	4	4	4	4	2	3.29
Q7- Did you find it easy to use the touchscreen feature of the app when using the app?	3	4	1.5	4	4	4	3	3.50
Q8 - How do you feel about the record feature in the app?	4	2	4	3	3	4	3	3.29
Q9 - How do you feel about the playback feature?	2	4	4	4	2	4	2	3.14
How do you feel about recording and playing back your voice?	2	2	3	3	4	4	3	3.00

Continued

Participant	One	Two	Three	Four	Five	Six	Seven	Average
Q11 - How do you feel about the clipart feature?	3	3	3.5	4	4	4	4	3.64
Q12 - How do you feel about the toolbars and menus in the app?	3	1	3	4	3.5	4	1	2.64
Q13 - How do you feel about "feeling" the letters of the word?	3	3	4	4	4	4	4	3.71
Q14 - How do you feel about the in-app assessments (tests)?	2	4	4	3	2	4	2	2.86
Q15 – How likely are you to use the MagicSpells app to learn new vocabulary?	4	4	4	3	4	4	3	3.71

The following questions demonstrate and explore user responses to using the app, and each is examined thoroughly with the research questions in mind. They represent both numerical and qualitative data, but the study emphasizes surveys and interview questions and the resulting feedback for further developing the MagicSpells app. No triangulation of the data took place and statistical analysis did not occur because there were no post or pre-tests and the quantitative data collected served only as a guide to

support the qualitative data. There could not be an identified significant difference between pre-trial and post-trial results, but basic comparisons were made when I discovered that comparison demonstrated differences in participant's attitudes about learning vocabulary and using an app to learn new words after the intervention.

Questions and Participant Survey Responses

Question 1. How easy was it to learn vocabulary with the MagicSpells app?

Most of the participants responded positively to this question, with participants three, four, five, and six responding with a 4 on the Likert scale; participants one and two responding with a 3 on the scale and participant seven responding with a 2. When interviewed about responses to this question, participant seven admitted she "always has trouble learning new words" but that this was "more fun than spelling lists." It seems important to note that on the Pre-trial Survey (Appendix D), on the Likert scale, when asked how easy it is for them to learn vocabulary, the average score was 2.64. However, after using the MagicSpells app, the average score improved to 3.43, which shows a marked increase in positive attitude toward learning in with this technology.

While neither response directly supports the current study research questions, the response shows promise that learners with dyslexia will stay on task to learn vocabulary with the app. It also reveals the usability of the application in its current version. Additionally, the Likert results demonstrated a high likelihood of learners using technology and this app to learn new words, with all participants responding with a 4. Most users mentioned fun and were exceptionally responsive to the touch feature of the app.

Question 2. How comfortable are you using a tablet to learn words?

Participant four answered with a 3 on the Likert scale, while all other participants responded with a 4. The consensus from the participants was positive. Participant four chose a 3 on this question, but she said it was "very" comfortable when asked about it. She noted issues with non-responsive or glitching elements. In the pre-trial survey, seven out of seven participants affirmed that they feel comfortable and like using a tablet for learning, which carried through after using the app on the tablet as evidenced on the post-trial survey resulting average of 3.86. Notably, participant seven does not like learning vocabulary in any educational setting. Six participants expressed that they would use the app for its intended purpose. The feedback on glitches allows programmers to address the problem and improve the next version.

Question 3. How do you feel about the usability of the MagicSpells app?

Concerning the app's overall usability, participants one, two, four, and five all answered with a 3, while participants three and six marked a 4. However, participant seven responded with a 1. Participant seven said that she "got confused" and that the "buttons needed to be bigger." It is important to note that participants one through four completed the trial before noon on a weekend, and participants five, six, and seven completed their trials after 5 PM, on a weekday, after school. Participant seven completed her trial just before her dinner time and became fixated on that at times. Still, the feedback helped me and the programmers create larger font and fewer distractions in the definition section of the app.

Question 4. Do you find it easier to learn words using the app?

All participants responded with a 4 on this, even participant seven, who struggled to stay focused. Participant six said, "I think it will help me." Participant four said, "I am not sure, but I think it would help." The consensus on this question was that the app would help, and consensus supports progress toward a more effective and usable app (Richey & Klein, 2005). In response to this question, five of the participants' parents wanted to purchase the app and device now or as soon as it is made available – positive news indeed.

Question 5. How do you feel about the definitions provided?

The participants one, two, four, and five all answered 4 on the scale for this question. Participants three and six answered with a 3 and seven with a 2. Participants one, three, four, six, and seven all felt that some words had too many definitions. All parents and four participants noted that some of the definitions had the word in the definition and would make the assessment for some words easy. Participant seven found coming up with definitions difficult and did not like "so many definitions." Participants one and four also noticed the "answers were given" in some cases during assessment and that it was challenging to come up with their own definitions. This question and participant response support developmental research as it addresses the usability and effectiveness of MagicSpells (Richey et al., 2004) and provides feedback that will lead to improvements within the app.

Question 6. How did you feel using the speech-to-text feature of the app?

Participants one and two (responded with a 1) and seven (marked 2 as her response) all felt like the speech-to-text feature was frustrating. Participant two spoke

extremely softly, and her mother had to repeat her responses. She said she "preferred to type" her responses because "it couldn't always hear" her. Participant seven also said the app could not always hear her. Participant one could be heard clearly, but the recording feature would shut off before she finished what she was saying. She did not become frustrated and figured out how to do it by speaking faster and more clearly, and she said, "I had to get my dad to help." Still, participants three, four, five, and six responded with a 4 on the Likert scale. It is notable that participant six also had to adjust and speak more quickly. Participant four said, "I loved it," and appeared to have no issue recording her voice. Participants three and five both responded that they liked it "okay." One parent suggested adjusting the feature to allow complete user control of the recording start and stop times. The speech-to-text feature presented problems in early versions of the app. While several learners had no issue, the fact that it frustrated two participants led back to the drawing board – as suggested in developmental research – and to a better, less sensitive voice-to-text element.

Question 7. Did you find it easy to use the touchscreen feature of the app when using the app?

Except for participant two, who did not like to record or hear her own voice and who preferred typing on the keyboard, and participants three and seven, who found the letter sliding features frustrating, most enjoyed the touchscreen feature, particularly when feeling the letters on the haptic page. Participant six's mother said, "some of the touch features seemed laggy." Other participants expressed delight at the "feel" of the letter and enjoyed the ease of touch use. During the previous expert reviews of the app, it was discovered that the programmers could only guess at the textures and quality of the haptic

elements because they do not have access to a touch-enabled device and the Tanvas engine. This workaround was to provide the texture with the highest sensory feedback. In the perfect world and with Tanvas programmers working on fine-tuning, multiple textures can be employed. Participant three would have preferred a lighter haptic feel, perhaps "like water" instead of sandpaper. In line with developmental approaches, as time, funding, and programmers allow, additional textures can be added to improve the app to please multiple users and their sensitivity to textures.

Question 8. How do you feel about the record feature in the app?

As noted, participant two preferred to type responses. She was extraordinarily soft-spoken and said, "I'm shy," and that "it couldn't always hear me." She also noted that it was difficult for her to spell out loud. Participant seven claimed the device did not hear her voice, while participant one said she liked to record and hear back her own voice. All participants would have preferred to control the start and stop features for recording. The feedback to this question led to better timing of recordings, as controlled by the user.

Question 9. How do you feel about the playback feature?

Participants one, five, and seven responded with a two on this feature. All three of these participants felt like the device did not always hear them well. However, participant six liked the playback feature very much. Again, participant two preferred typing, which negates the playback feature in some cases. The participants need to record responses for the multisensory features on the haptics page to complement each other. Like the other modifications revealed during this study, we can improve the users' experience by making sure that the playback feature is straightforward and can be played back for each word, spelling, definition, the sentence on both the canvas page and the haptic-enhanced

summary page for each word. Because the developmental research process involves designing, developing, and drafting, the current study's version can be seen as another draft. By trusting in the process of testing and revising, we can move forward to additional phases of reviewing and studying, which will be carried out in a more natural educational setting (Reimann, 2010; Richey, 1994; Richey et al., 2004).

Question 10. How do you feel about recording and playing back your voice?

Except for participant two, who preferred to type, and one and seven, who struggled to be heard, most participants appreciated the record and playback of their own voices. They enjoyed hearing their responses presented on the final haptic/culminating activity page. The participants who responded with a 3 liked the feature when it worked appropriately. All participants preferred their own voices instead of the computer-generated voice used for supplied definitions. With learners' voices recorded, this feature supports Mayer's principle of voice, which states that learners prefer a natural voice rather than a computer-generated speech option.

Question 11. How do you feel about the clipart feature?

Participants four, five, six, and seven all liked the clipart feature in the app and responded with a 4. Participant six said, "it's great. Lots of choices." Participants one and three both responded with the word "good." The parents of participant three and four discovered semi-inappropriate images on at least three occasions. While none were terribly inappropriate, it was noted that free versions of clipart banks need to be thoroughly screened with code to weed out possibly unsuitable images.

Question 12. How do you feel about the toolbars and menus in the app?

Participants one, two, and seven stated that the "toolbar could be bigger." Participant two and her parent agreed that the font could be larger for children, especially on definitions. Most participants agreed that overall font sizes could be larger even on the assessment pages. Participant seven said that the toolbar should be "bigger, and there should be less stuff on the screen." Participant five said "maybe bigger," but managed it well.

Interestingly, one parent liked the large number of color choices (participant six), while another parent (participant one) thought fewer color choices would be better. Of comments on the color and font choices, participant one's father suggested that "perhaps allow for fewer color choices and a smaller default font." In contrast, participant six's parent stated that there are "enough color choices" and that the font overall could be larger.

Question 13. How do you feel about "feeling" the letters of the word?

Touch is the key feature of the app. Tracing and feeling the letters allows the learner a third sensory feedback experience. The touch feature makes the app different from other word learning apps. Participants one and two gave the touch feature a 3 on the Likert scale, while participants three, four, five, six, and seven responded with a 4. When asked about her response to the question, Participant one said, "I loved it!" Furthermore, participant three said, "I like feeling it, but it feels different." He spent a great deal of time rubbing the screen and feeling the letters. Participant seven said, "I think it is cool. Weird." Participant five said, "I loved it. It's cool." Participant four called it "awesome" and said she would "like to see more textures" and "I didn't know computers could do

that." One parent (participant six) described the haptic portion of the app as fun and said, "it had us laughing."

Question 14. How do you feel about the in-app assessments (tests)? (Figure 8)

Participants one and five responded with a 2 on this question, and participant seven responded with a 1. Participant three responded 3 and two, three, and six responded with a 4. Participant three said, "I like the scramble words best, but it didn't always work." The main complaint about this feature was that the letters were sometimes difficult to move/slide in the scramble word section. "I get frustrated that it was hard to work," said participant five. Participant seven said it "was hard, and I need to be read to." A few parents noted that the definition matching assessment had the words in the definition, and children did not have to remember the word, making the assessment too easy.

Question 15. How likely are you to use the MagicSpells app to learn new vocabulary?

On this final question, all participants responded with a 4, except for participants four and seven, who responded with 3. Interestingly, participant four and her parent both said they "loved it!" Participant seven admitted that she did not like trying to learn vocabulary ever. Participant three's parent likes that MagicSpells is "in line with homework." Five out of the seven participants' parents would like to have purchased the device and app the day of the trial. All of these parents wanted to get the device and app. One parent (participant one) asked, "Where can I get one?" Their excitement at the possibilities for their children was nearly palpable, and they asked to be made aware of the availability of a final product.

Emerging Themes

Using a constant comparative method, I broke down the data into themes or categories of issues that were revealed in the surveys and interviews. Using the constant comparison method, highlighted issues underwent content and characterization changes as the data were compared and categorized (in this case into common themes and issues) and issues were revealed and refined through the analytical process (Defining the Constant Comparison, 2012). There were six major themes that emerged from this study: issues with definitions, issues with assessments, issues with toolbar features and menu, issues with recording and playback features, haptic feedback, and over all usability of the MagicSpells app. As noted, these themes are derived from the post-trial survey (Appendix D) and follow-up questions (Appendix E).

Table 4

Emerging Themes

Theme	Description	Significant Statements
Issues with Definitions	The number of definitions provided per word – from one to twenty provided	"So many definitions." "Whoa, too many definitions."
Issues with Assessments	The word scramble and definition matching assessment feature which did not react well to touch Word in definitions	"I get frustrated that it was hard to work."

Continued

Issues Toolbar features & Menus	Side menu and toolbar features, that includes words and tools, color wheel, font choices and other tools necessary to complete each activity	"Toolbar could be bigger." "Perhaps allow for fewer color choices" "Enough color choices."
Issues Voice Recording & Playback	Tools used to record participants responses – words, definitions, and sentences	"It couldn't always hear me." "It would stop recording before I finished."
Haptic Feedback	App page where participants can feel each letter of the word and see and hear their responses	"I loved it!" "I'd like it to feel like water. Softer."
Overall usability of MagicSpells	Participant and parents' response to using the app in the future	"Loved it!" "Where can I buy this?"

Exploration of Emerging Themes

Issues with Definitions. From the onset, providing a quality bank of definitions proved challenging. The heart of MagicSpells is the haptic feature, but learners need to interact with words in meaningful ways to understand and connect - including learning all aspects of the word. Participants noticed that there are countless definitions for some

words, and for others, only one or two. The multiple definitions confused some participants, with many saying there were "too many." After asking for elaboration in this regard, I learned that two main issues were 1.) there are too many definitions for some words, and 2.) the answers to assessments could be found in some of the definitions – negating the need to actually learn the word. They all liked hearing the definitions and removing the ones they did not want. In this vein, having the learner create their own definition after hearing multiple definitions helped, even when creating a definition seemed difficult.

Issues with Assessments. In MagicSpells, the assessments are culminating activities that allow users to test their knowledge of new words but equally important; they reveal where learners need more practice and exposure to certain words. All participants liked the format of the assessments, but there was a glitch that caused the slide-the-letter-to-unscramble-word feature to lag, and the letters did not move easily. This issue caused frustration for several participants and was immediately addressed with programmers. Additionally, the match definitions assessment section - which displays definitions to match with words – revealed the words in some of the definitions, making matching too easy and negating answers. The participants liked the smiley face responses to correct answers, but one did suggest an even bigger fanfare response to correct answers.

Issues with Toolbar Features & Menus. In a touch screen situation with learners who struggle to read, accessibility and operator-friendliness can make or break the usability and effectiveness of the product. The consensus regarding the toolbar was positive - primarily 3s on the Likert scale, except for participant seven, who felt frustrated

by the font size and the toolbar. In that vein, participant comments reveal two areas that need attention. First, the toolbar and font (in all aspects of the site) could be more prominent. Participants one, two, five, and seven said they would like to see a larger toolbar and font. The side menu, definitions, and other fonts within the app could be more prominent as well. Interestingly, participant one suggested that there should be fewer color choices in the app. However, two other participants mentioned that they liked the ability to choose from a wider variety of color choices.

Issues Voice Recording & Playback. The speech-to-text and playback features are critical in multisensory learning. A few participants had issues with speaking loud enough for the device to hear – particularly participant two, who spoke softly. It is vital to address the issue of audio recording sensitivity with the programmers. Another thing the feedback revealed is that the record feature would periodically shut off before the participant could finish saying the words and letters, create their own definition, and then create a sentence. This recording shutdown happened most often with participants one and two. Three participants suggested that the feature be modified to allow the user to start and stop the recording with a tap or mouse click. The playback feature worked flawlessly when the participants could record their voices without a problem.

Haptic Feedback. This feature is the defining element of the MagicSpells app, which sets it apart from other vocabulary and word apps. While all the other features combined work to create a viable learning tool, the TanvasTouch® best supports dyslexia learning theories of multisensory inclusion. Notably, except for participant three, who did not "like the sandpaper" feel of the haptic touch letters, all participants were excited and awed about the ability to feel the letters of the word in the app. It was exciting to see their

surprise and enthusiasm about the touch aspect. Participant three suggested making the feel of water an option. As noted early on, we settled on one texture because the programmers were working without a device or the ability to feel the haptics themselves. Hopefully, future versions will have texture choices. In fact, based on the advancement of the Mimo devices and the TanvasTouch® technology, this is a distinct possibility. The TanvasTouch® device does provide a variety of textures, so once the funding is available, additional, and more finetuned, haptic textures will be added. Participants visibly showed excitement when they felt the letters for the first time and spent several minutes touching the letters. Even the parents joined in touching the screen and feeling the texture of each letter.

Overall usability of MagicSpells. All seven participants enjoyed the app and felt it would help them learn vocabulary. Despite the app's issues, participants loved it, and five out of the seven (and their parents) wanted to purchase the app and device. All participants said they found it easier and more fun to use the MagicSpells app to acquire vocabulary than traditional word lists and trying to memorize. Fun and love were two words repeated during the study. Based on observations, learners stayed focused and eager to use the app despite any hesitation or frustration with the app. While there were calls for some improvement, the app's purpose was proven in that the learners had primarily positive feedback.

Figure 11 shows the researcher's average responses to pre-trial questions to gauge learners' attitudes toward reading, writing, spelling, vocabulary study, and the use of technology. The original intent of this survey was purely informational; however, a few

comparisons could be made with questions from the post-trial survey, in particular in the area of technology use and the desire to learn new words.

Figure 11

Results of Pre-Trial Survey

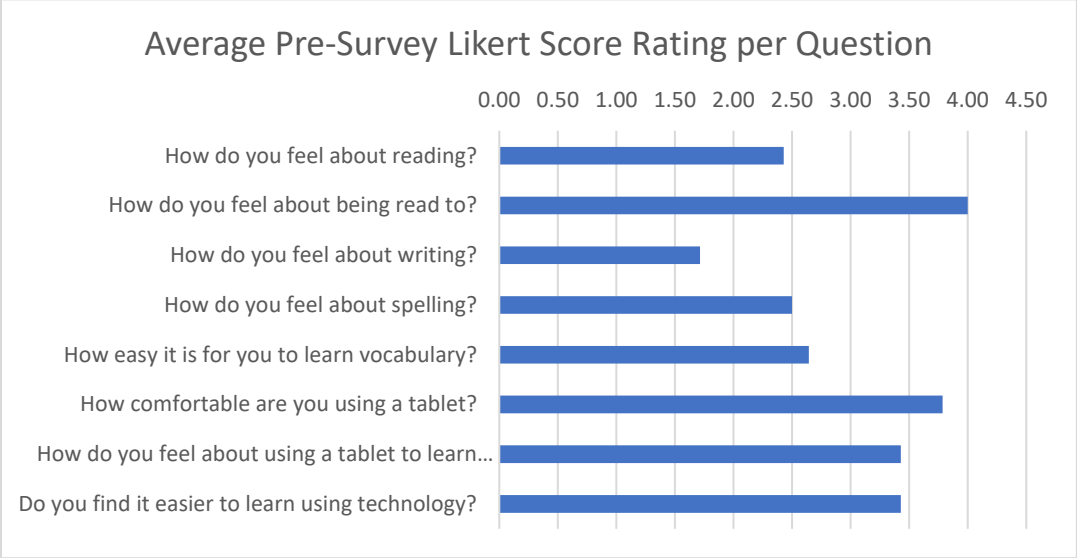
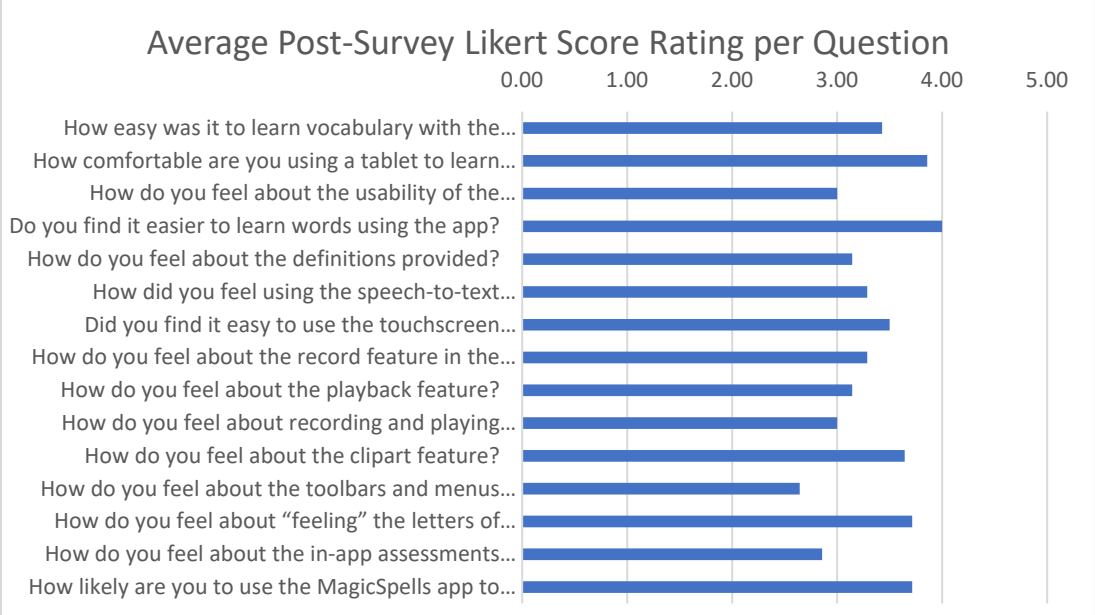


Figure 12

Results of Post-Trial Survey



Exploration of Research Questions

Using the data collected and analyzed above and previous steps in the developmental process, I answered my research questions and, more importantly, gathered usable feedback for adapting and modifying the MagicSpells app. The developmental process allows for impact evaluations through feedback from stakeholders who try the application and provide valuable information, which serves to improve the design and implementation of the product for the subsequent participants. At this point, it seems important to point out that the Pre-Trial Survey (Appendix D) was not originally intended to be addressed as part of the overall results. I meant to use it only in the revelation of demographic information and to gather simple user data to better understand participant experiences and feelings regarding reading, writing, and technology. That it provided some simple comparisons proved to be a bonus to its use.

Research Question 1

RQ1: How can the developmental research process lead to a quality product that best meets the needs of all stakeholders - in particular, learners with dyslexia who struggle to stay on level with peers in reading and writing?

The developmental approach in this study served not only to guide the design from inception but also to predict interest in the product and support the application's relevance for learners with dyslexia. The more authentic the research setting and experience, the more genuine the research results (Plomp, 2000). The developmental research process allowed for pre-study feedback from experts over long periods and for trial-and-error efforts to take place and predict interest in the project. Furthermore, developmental research efforts helped ascertain whether or not the research is viewed as

relevant. There was no haptic element in its early stages, but conceptually, it could be explored. Another teacher and I tested the first version of the application. Several iterations were tested out by an 8 (later 9) year-old with dyslexia, and a few changes were made, leading to modifications in features. Each updated version of the app was tested either by me, an expert, or a target user. Even the smallest changes along the way worked to improve the app garnering positive results and improvements.

In line with developmental research and the desired outcome of viable, effective educational products, I ensured that programmers had the basic core features in place. These features included variations in definitions, color choices, font sizes, and clipart features. Additionally, the earlier text-to-speech feature failed to respond to certain voices, particularly children's voices and softer-spoken female voices. This fault could only be discovered through trial with a variety of users. Since the first version, dyslexia specialists, two special education teachers, two early readers, and their parents, and in particular, one nine-year-old with dyslexia have tested subsequent versions. As per the assertion of Lee et al., (2017), MagicSpells, as it evolved, received consensus from various "experts" along the way, and this cross-sectional feedback with consistent testing between stages and modification served to verify the credibility and suitability of the app. Recurrently, the programmers and I worked with, revised, and modified the app based on the feedback of others. At any given time, I consulted one or more learners and experts. It developed into the usable version provided for the current study. In this vein, developmental research allowed me to repeatedly test the effectiveness with experts and with learners and teachers (Plomp, 2000; Reimann, 2010).

The ultimate goal of developmental research is to build a stronger connection between educational product research and the potential remedy for real-world problems. A developmental approach results in cyclical-type research - significantly different from that currently followed by many researchers developing and designing educational tools (Amiel & Reeves, 2008) – and worked to help me produce MagicSpells. As a result, I emphasized an iterative research process to not only evaluate MagicSpells, but so I can systematically and continually refine the app over time (Amiel & Reeves, 2008). Additionally, the in-person study results that support design principles can guide similar research and development endeavors (Amiel & Reeves, 2008).

As dictated by developmental research, it was necessary to see if the application works well and validate all assumptions and research questions. Validation is accomplished by testing with users, and it is one of the most valuable steps in my research process. Amiel and Reeves (2008) support my use of cycles of design and re-design, which allowed for the investigation of critical variables and, more importantly, limitations, which lead to valuable and useful results. One notable takeaway from the trial/study lies in the fact that out of seven participants, five wanted to purchase the device and the app as soon as possible. A user-centered design philosophy sets up a foundation for designing (needs-based), developing, testing, and revising an educational product in developmental research. This foundation has the target user at its core (Plomp, 2000; Reimann, 2010). Each user's feedback leads to adaptations and adjustments to continue the developmental evolution of the application (Plomp, 2000; Reimann, 2010).

The users' attitudes about learning new words improved as they explored the app, as evidenced by the change in Likert scores. When comparisons are made between pre-

trial (questions 5) and post-trial results (question 4), there was a notable difference between the average score (2.64) regarding the use of a tablet to learn vocabulary and the use of a tablet equipped with MagicSpells (4.00) to learn new words. There were high usability scores from participants, which garnered positive feedback about the app, which indicates a successful product. Notably, the touchscreen feedback helped elucidate the participants' preferences and made apparent the different participant preferences which led to making the app usable for other learners with dyslexia. Amiel and Reeves (2008) further point out that not using developmental research negates the value of educational products – like MagicSpells – as tools to support the needs of target learners.

Moreover, Amiel and Reeves (2008) posit that researchers in the field of educational technology, through the use of developmental research, should revert from short-term objectives of their individual projects and recognize the transformational research possibilities that guide the creation of useable educational treatments that support specific needs – like vocabulary acquisition for learners with dyslexia. They expressly state that the "primary responsibility of researchers in the field should be to limit their investigation of means and contemplate educational ends or aims, making them explicit in the process of an investigation" (p. 37), which is precisely what these research results seek to accomplish. The development research results provided invaluable data that led to desired ends – an improved, working educational tool.

Research Question 2

RQ2: Can the exploration and employment of the principles of design, development, and evaluation aid in creating workable and effective features of the MagicSpells application?

Plomp (2000) suggests, developmental research takes an engineer's approach - confronting a particular problem, designing and creating a product, and testing the product's effectiveness in multiple efforts. It is necessary to undertake evaluations during the early stages of development to assess the validity of the application (Richey & Klein, 2005). In the case of MagicSpells, using Mayer's (2009) design principles served to flesh out the most effective format and features. In his guiding constructs, Mayer (2009) specifies 12 principles – most notably, limiting clutter, using natural voices, providing learner interaction, limited distractions, breaking elements into user-paced segments, and providing more organic content. Below, I explore each of the 12 Principles concerning the development of the MagicSpells app.

The Coherence Principle. individuals, learn more effectively when superfluous, distracting material is excluded. Reducing clutter and distractions is particularly important to dyslexic learners. In order to best meet the needs of learners, the design of MagicSpells and its layout required limiting the elements on the pages to only necessary information. I knew we needed words, definitions, a toolbar, record and playback icons, and a canvas on which to create. The original design called for specific features to allow the user to create the most content. Still, there was an issue early on about the definitions. Some words had far too many definitions, and some included the word an example supporting the definition. Study participants did express concern about the number of definitions and the distraction caused by the long list of definitions. We remedied this by

reducing the number of definitions and having users create their own definition of the word for playback. There is also an option to remove any or all definitions, which also reduces clutter. The definitions section was revised and improved upon through the developmental process and especially after the study.

The Signaling Principle - people experience more successful learning when cues point out the organization of the essential material. Signaling is perhaps one of the least focused on principles in creating and developing the MagicSpells app. While users along the way seemed to easily follow the steps in the MagicSpells process, font size and location of links were modified to make ease of use better. A great deal of the content for the app is user-created, requiring no signaling per se. There are links and cues provided when recording, but no "signals" that specifically point, like an arrow, to the links. One early expert suggested arrow buttons next to links, particularly in the assessment section. However, still, I felt that signaling in the case of MagicSpells might cause more distraction than good. It is not out of the question but requires more in-depth exploration.

The Redundancy Principle. People experience more successful learning from graphics and narration than from graphics, narration, and printed text. From the onset, I designed MagicSpells to keep the user at the helm of a good deal of the content. The user creates most "graphics" (clipart and drawn illustrations). In the assessments, a smiley (or if the chosen answer is incorrect – eyes x-ed out face) pops up when the user clicks a response. At the same time, text appears that says "correct" or "try again." The participants in the study like this, and one suggested the addition of more fanfare. Notably, this simplicity makes for less clutter (as in the Coherence Principle).

The Spatial Contiguity Principle. People experience more successful learning when presented with corresponding words and pictures closer to rather than far from each other on the page or screen. Since users create a good deal of the content on the tablet's canvas in MagicSpells and the space is limited by the size of the screen and preset content, the spatial principle is easily followed. Over the app's development, space came to the forefront several times because the device's size limits it. Again, in MagicSpells, the user controls the content beyond the words and definitions. Importantly, on the haptic-enhanced pages, all elements stay close to each other and are linked to touch and voice narration (of the user), which provides sight, sound, and touch stimuli.

The Temporal Contiguity Principle. People experience more successful learning when presented with corresponding words and pictures simultaneously rather than successively – This principle does not necessarily apply to the app since the user creates the narration and the images. However, in the haptic section, the user's narration corresponds with the words, definitions, and sentences as they click on them, thus adhering to the simultaneousness to a degree.

The Segmenting Principle. People experience more successful learning when presented with a multimedia message in user-paced segments rather than as a continuous unit – MagicSpells is almost wholly user-led. From its inception and through the developmental process, the goal has been to make the users responsible for their own learning and provide a self-paced learning program. Users can choose the number of words they want to work through in any given timeframe and when they decide to complete any assessments. Participants in the study had total control – along with a parent – of how they worked through the program.

The Pre-Training Principle. People learn more deeply from a multimedia message when they know the names and characteristics of the main concepts. The MagicSpells app comes with a set of instructions provided with a human narrator that is audible as the users tap on each individual instruction. Icons in the instructions help direct the users to various features in the app, and a clickable tutorial is also provided. The elements came in the original design but were modified after expert reviews and guided by this principle. Originally, though, the instructions were "read" by a computer-generated voice, but this changed because of the voice principle discussed below.

The Modality Principle. People learn more intensely from pictures and spoken words than from pictures and printed words. MagicSpells' original version and design allowed users to use their own voices and draw pictures. However, the sections where users record their voices grew through the developmental process to make the app more personal and more accessible. The illustrating and narrating features are actually the core of the app and offer the means for users to connect personally with the app, the words, and the spelling and definitions of the words.

The Multimedia Principle. People experience more successful learning from words and pictures than words alone. Because of its intended purpose and the app's design, learners create (draw words) and images (illustrate their word/sentence), MagicSpells meets the principle of modality by design. The app allows the user to create the word and matching image encouraging the user to draw on past experiences to make new and, hopefully, lasting connections. In the final step in the app, before users complete assessments, a link sends them to the "haptic" page where they can see, hear,

and feel all their work. This page sets the app apart from other spelling and vocabulary applications.

The Personalization Principle. People experience more successful learning from multimedia presentations when presented with conversational language (rather than formal). This principle does not apply directly to the MagicSpells app, but the fact that users narrate their spelling, definitions, and sentences "personalizes" the experience. As the app developed and experts reviewed it, the programmers and I worked to make as many of the voice elements in the app as natural as possible. Allowing users to record their voices gives an organic, informal feel about the app.

The Voice Principle. People experience more successful learning when narration is presented in a real human voice rather than a machine-generated one. Most early reviews expressed the annoyance of computer-generated narration, and I have always found computer narration irritating. In MagicSpells in the original versions, all voices were computer-generated. Through development, the learner's voices became the main source of narration. Moreover, after additional trial and feedback, I had a colleague record her voice reading each instruction in a casual, informal way. The definitions, for practical reasons, could not all be recorded. However, I realized that having the users create and record their definitions would serve multiple purposes, including adding multisensory experiences and human narration to the definition feature in the app.

The Image Principle. People do not necessarily learn better when the speaker's image is on the screen. There is no speaker other than the learner who narrates words and spelling, definitions, and sentences. – The image principle does not apply to MagicSpells since the app is tablet-based and relies on learners creating many elements.

The exploration through design, development, and evaluation identifies changes that need to be made to make the app more user-friendly and desirable and, ideally, as a result, more effective. In particular, the survey results, questions one, two, five, six, seven, eight, nine, ten, eleven, and twelve directly lead to improvement in the app. Learners clearly defined areas that need attention, and as is required of developmental research, the process is cyclical. Multiple experts, including I, have tested each version, and Mayer's principles guide large sections of the process.

Research Question 3

RQ3: How can analysis of the reviews and results of the usability tests help to improve on the MagicSpells app and lead to future iterations of the application?

The feedback provided by participants allowed me to return to the programmers with user-specific concerns, considerations, and recommendations. When a designer can hear clear-cut ideas and suggestions from target users, it is far easier to return to the app and make necessary changes that might (and did previously) go unnoticed. I specifically wanted to learn about usability and engagement, and with learners and their parents trying out the app, I was able to use their fresh eyes to see aspects of the app that I, as an adult and the designer, could not see especially after self-reviewing so many versions.

The highlight of the results and further examination of feedback and emerging themes aid in understanding the effectiveness of MagicSpells as a functioning, user-friendly tool for learners with dyslexia for acquiring new words. Since a product that uses unisensory stimulus will not engage multisensory learning devices best for learning, the combination of sight, sound, and touch create and meet multisensory-training protocols necessary for learners with dyslexia (Shams & Seitz, 2008). It is also important to imitate

the organic settings and put learners in the driver's seat, per se, making learners in charge of their learning. Participants liked the clipart feature and enjoyed illustrating their sentences/words, supporting Mayer's multimedia principles. They also appreciated the voice recording and playback over the computer-generated voice, and this too speaks to Mayer's principles. The presurvey results indicate that these particular children with dyslexia prefer learning with technology, being read to, and using a tablet. These preferences line up with traditional dyslexia teaching strategies, and as McKeown (2019) points out, they should offer definitional and contextual information, provide encounters with words in multiple contexts, and engage students' active processing of word meanings leading to better retention and recognition of words.

CHAPTER V

Discussion and Conclusion

Introduction

The study reviewed here represents the culmination of years of developmental research. It is important to note that the results of this study serve as one crucial stage of a continual developmental approach meant to support the design, development, and evaluation of the MagicSpells. With this study, I sought not only to identify necessary modifications but also to discern elements of the app that work well and those that challenge users. This data is an integral part of design research because it supports developing creative or innovative educational products directed at chronic educational problems (Plomp et al., 2010) and provides a view of actual participants in natural settings as part of the developmental process. As Plomp et al. (2010) suggest, developmental research is different from conventional instructional design because the iterative cycles are essentially micro-cycles of research conducted to learn more than just how to improve a product. While data analysis may also result in improvement, the ultimate goal is to create a final, user-friendly that best meets the needs of the target audience.

Ultimately, as pointed out in the literature review, developmental design approaches look to follow an educational product or tool from design inception to prototype. Developmental research for education is appropriate when examining unique, indeterminate processes that prove more challenging through conventional research methods (Amiel & Reeves, 2008). MagicSpells, because it is an innovative, digitally-based app, needed to go through a developmental process to ensure that it can do what it

promises and that it engages and appeals to learners with dyslexia. Developmental research follows the scientific methods of organized observation and analysis, including product testing, to drive and create appropriate outcomes and produce the ideal and most useful final product (Sanders, 1981).

Qualitative data collection is a sweeping endeavor that continues throughout the project's life (Basit, 2003). Making sense of qualitative data can be arduous, and it requires a vigorous, intuitive, and creative analysis that includes inductive intellectual reasoning, thought, and conjecture (Basit, 2003). Qualitative analysis is not a matter of numbers, and it helps explain reactions, identify similarities and differences, and provide valuable product evaluation. In reality, qualitative data analysis for this project was not only carried out at the final stages of research but was also indirectly used throughout the process. As a means for gathering valuable feedback, questions and participant responses were examined for common themes. This study represents the culmination of years of effort, and it provides an avenue for improving the app for better meeting learners' needs.

Discussion

Research Question 1

RQ 1: How can the developmental research process lead to a quality product that best meets the needs of all stakeholders- in particular, learners with dyslexia who struggle to stay on level with peers in reading and writing?

Educational technology is not a standardized "intervention" but a wide variation of modalities, tools, and strategies for learning. Therefore, an educational product's efficacy hangs on how well it helps stakeholders achieve the desired instructional goals (Ross et al., 2010). Ross et al. (2010) report that many argue that this is not measurable in a

valuable way. With app design and creation, the most effective means for examining and creating a viable working app is developmental research and approaches. In 1981, Sanders believed that what is needed in education was not a departure from science. However, instead, there should be a revitalization in authentic scientific inquiry, and as such, developmental research approaches point their way to this revitalization. The developmental research process conducted for the current study, which is the culminating component in a long-term developmental design process, began with an idea scribbled on printer paper. The process utilized for development research supports digital educational design theories and promotes a design, create, test, revise and repeat the cycle. The idea for MagicSpells came out of a desire to help learners with dyslexia who often fall behind peers academically because of difficulty processing language. Since MagicSpells began as an unsupported concept, developmental research offered a means for exploring ways to make it work and meet the needs of learners with dyslexia. One in five learners who struggle with reading likely have dyslexia. Reading and writing issues often lead to self-esteem issues and more significant academic problems (Dyslexia Center of Utah, 2019).

Prior to the current study, I spent years following developmental research protocol. The application of Mayer's 12 Principles of Multimedia Design began long before the MagicSpells app version used for the study came to fruition. I enlisted the app programmers in the fall of 2019 and continued to follow the developmental process and approaches. Indirectly, the developmental process began seven years earlier without identifying it as such. Decisively, when developing an educational product, formative evaluation is necessary.

Moreover, it is crucial to find best practices when working with learners, particularly those with dyslexia. Mayer's principles, coupled with the cyclical design development processes, helped create an original and usable prototype. Richey and Klein (2005) explain that it is not surprising for a developmental research project to follow various research methodologies and designs - with different designs or versions used at different stages during development. The MagicSpells app used for this study was the twelfth version, and this study led to a thirteenth version. Whiles concerns about the quality and impact of education technology research have been raised, and the quality of experimental studies over educational interventions have declined, Ross et al. (2010) report that methods typically used for these studies lean strongly towards observations, expert reviews, case studies, and similar qualitative and descriptive approaches.

Ross et al. (2010) suggest integrating technology as a learning tool in classroom instruction and teaching students to become skilled and confident technology users. Both of which ideally require developmental exploration. Using expert reviews to start, followed by observations, surveys, and interviews, the programmers and I worked to take the vision forward. Following my original design, notes, presentations, and images, they have developed most app features thus far, intending to have a working prototype in the spring of 2021, which they did. The greatest challenge came, in a way, because the programmers had to work blindly in terms of the haptics since we have access to only one set of hardware, and it is with me in Texas. Covid and cost prevented risking mailing the hardware back and forth. It was not financially possible to have two sets of hardware. I met with them weekly and have had and used several extremely promising versions of the app. We were able to work through the bugs and ensure that all features were in place at

the time of the study. Once all the features and elements were in place, we installed the working version on the hardware and made it ready for learners to explore.

Every version of the app evolves from a discussion, testing elements, and creating lists of changes and improvements. Weekly, or more often if needed, I met with the programmers via Google Meet, Zoom, or Skype to try out the app's features and brainstorm after testing components in the latest version. This effort was made more accessible with the use of an app called AnyDesk, with which the programmers in India accessed and took control of the TanvasTouch® device desktop. AnyDesk allows the programmers to test aspects of the app, with me working as their fingers to feel. That said, since the programmers cannot "feel" the haptic elements, they relied on me to test and verbalize these features as each version was (and will be) created. When possible, a young learner with dyslexia tried out the app at different stages and gave feedback that helped the programmers troubleshoot age-specific, user-friendliness, and any area or steps that cause undue frustration or problems. Like writing an essay, a new set of eyes can make a huge difference in finding ways to improve. Patience was of utmost importance when working between programmers and me since we have unique skill sets. Terminology, and in this case, accent and language differences, came into play, as can differences in the overall vision for the app prototype. Spelling, idioms, and word use, for example, vary between American and Indian English, with Indian English taking on British English features – such as tire versus tyre, organize versus organise, and many others. It became necessary to spell-check longer written elements within the application.

Developmental researchers do not examine and emphasize unique variables. Instead, they seek to gather information that leads to the design of a product and

subsequent version of the product that best meets user needs. Each step in this process leads to an updated version of MagicSpells, which could only happen as part of the developmental process. Taking what the experts said and then providing a viable app to target users gave me the tool to see if the features were desirable and usable by learners with dyslexia. By going directly to learners with dyslexia and using the developmental research process to cultivate and evaluate the MagicSpells app, I believe I have created and can continue to develop a quality product that best meets the needs of all stakeholders - in particular, learners with dyslexia who strive to stay on level with peers in academics. Participants' feedback to the app's most recent version allowed programmers to finetune a variety of aspects and features, leading to an updated version of the app, ready for use by learners, teachers, tutors, and parents. As Plomp (2000) and Reimann (2010) noted, when developing an educational product, like the MagicSpells app, developmental research allows researchers to test the effectiveness with natural learners and teachers and adapt and modify the app for better usability and efficacy. As Richey et al. (2004) suggest, developmental research methods increase pragmatic practices in educational fields and deliver necessary substance. MagicSpells has seen many versions, but until actual target users in natural settings offered input, the previous versions' results were more theoretically effective than significantly supported. Evaluation research techniques were employed to determine the effectiveness of the resulting product during the design and development project (Richey et al., 2004). As with all evaluation research, various data collection techniques are possible.

Research Question 2

RQ 2: Can the exploration and employment of the principles of design, development, and evaluation aid in creating workable and compelling features of the MagicSpells application?

I previously believed that including lots of "bells and whistles" made for better, more engaging learning tools. As the app developed and I received more formative feedback, this proved true. However, according to Mayer, learners learn more efficiently when extraneous information and images are excluded from the design. Because of its simplistic design and user interaction, MagicSpells does limit extraneous information and allows the user to create most of the data in the app. Additionally, Mayer explains that students learn more effectively interacting in multimedia lessons presented in user-paced sections rather than in one continuous lesson. By adding the multisensory features, particularly the haptic feature, MagicSpells encourages self-paced interaction in various ways, including but not limited to total control of timing and managing of content, voice recording, and playback and feeling the letters of the words. Since learners record their voices, Mayer's voice principle applies – providing the narrative tone Mayer suggests. The speech-to-text and playback elements use an actual human voice rather than an automated one. While an automated voice presents the definitions, the learners record their definitions for playback as they progress and for playback in the haptic and assessment sections of the app.

With his image principle, Mayer suggests that adding images (of the speaker) or extraneous images to a multimedia lesson does not necessarily dictate an improved learning experience. Since the learners create their own images to support their learning

of each word, this aspect of the app also supports learner interaction and pacing. The app's user-directed progression also follows Mayer's Personalization Principle by providing an age-appropriate tone and language for better learning experiences. In this same vein, the Spatial Contiguity Principle states that students learn more efficiently when corresponding words and images are displayed near each other, allowing learners to direct their attention to one central focal point, which happens directly on the haptic page of the app. Spatial congruity is especially notable when the learner can listen to the word, its spelling, the definition and sentence, and most importantly, feel the word in the same space. Because of Mayer's Redundancy Principle - which refers to having side-by-side closed captioning and voice narration of a text coupled with the Voice Principle - instructions for the app were recorded in a natural human voice. According to Mayer, using either text or voice narration prevents learners' cognitive overload. Further, it suggests that learners with dyslexia may engage more effectively in both text and voice narration.

Guided by Mayer's 12 Principles of Design, MagicSpells was reviewed, evaluated, and retested at every step. Changes came to pass as part of the developmental process as programmers modified subsequent versions throughout the process. Each rendition was tried and discussed between the programmers and me. The programmers would troubleshoot issues with the app and make changes and when it came to the haptic, consulted Tanvas programmers, Others - tutors, educators, and professors - were consulted periodically. Then more adaption and modification took place. A research method employed in developmental research defines the subsequent instructional design of a product and its development phases. A consensus must be reached with experts

before a project, product, or program is implemented (Lee et al., 2017; Richey & Klein, 2005), and it is through this process, MagicSpells evolved into the app used for the current study. Through consensus, evaluation and validation of the critical methods of developmental research become more valuable, and these efforts take time and formative evaluation. During the process, experts tried the app, and adaptions were made irrespective of the flaws enmeshed in various stages and versions of the design. Accordingly, validation must also apply to some cross-sectional studies with testing between stages to verify the credibility and suitability of a product. Various experts were consulted in informal settings to design a suitable prototype to share and garner genuine and valuable feedback from target users.

Continuing to use Meyer's Principles of Multimedia Design and methods and approaches in developmental research, I consulted the experts whenever needed and shared the app with others. The current investigation served to gather feedback from target users regarding the usefulness and user-friendliness of the MagicSpells app as a means for learning new vocabulary. I accomplished this primarily by measuring the reactions of these learner participants with interviews and surveys to create a more user-friendly, engaging app and continue the development of the app. Furthermore, a study in a realistic setting was the natural next step in creating the best possible version of the app to help learners with dyslexia acquire new vocabulary. The study demonstrated that adding haptics to the traditional sights and sounds in a digital tool (tablet) improves engagement and can possibly improve vocabulary because it encourages engagement. More than that, the study allowed for the gathering of valuable feedback in the developmental research process, leading to a better version of the MagicSpells app. The

parents' and participants' feedback aided in revising and retooling the application, allowing for continuous improvement and development to best meet learners' needs and drive future app versions for further development.

By letting parents and learners use, explore, and engage with the app, I was able to take their feedback back to programmers to create a more practicable and effective version of the MagicSpells app. Stakeholder input at various stages follows developmental research protocols. This step affords future users a fully operational and vocabulary acquisition app.

I used this experimentation/trial to guide and create desirable uses and outcomes for the app and its features as a method suggested by Sanders (1981). This trial allowed for a more organic and natural use of the app (Reimann, 2010) and for gaining real-world responses in a real-world setting. Ross et al. (2010) ask researchers to reduce efforts to prove the "effectiveness" of a technology-based application. Instead, they state that developmental researchers should focus on rigorous and pertinent mixed-methods studies to clarify which technology applications work best to simplify learning while considering what ways, in which contexts, for whom, and why a product works.

As a follow-up, and this is discussed in the future research section, the efficacy and effectiveness of the app to help learners with dyslexia improve vocabulary should be explored more deeply. To best support quality development, I sought to use actual participants in organic settings and use their feedback to guide changes to the application's internal workings. Ultimately, educational technology, like the MagicSpells app, is not a standardized "intervention," but instead, it fits in an extensive assortment of modalities, tools, and approaches designed to promote learning (Ross et al., 2010).

MagicSpells effectiveness, therefore, depends on how well it helps learners and their teacher, parents, or tutors achieve their desired vocabulary acquisition goals.

Research Question 3

RQ 3: How can analysis of the reviews and results of the usability tests help to improve on the MagicSpells app and lead to future iterations of the application?

This developmental research project focuses on the needs of the primary target groups (learners with dyslexia) and explores the usability of MagicSpells. Before this study could happen and after the design was first conceived, programmers were employed. For many months, version after version of the app was deployed and tested using feedback from various specialists and experts. Consequentially, each subsequent version was improved or modified after consultation (formative evaluation) with experts – dyslexia specialists, literacy professors, and Tanvas programmers, who tried out and offered feedback on the app and through trial and error. Until that is, we developed a fully functional version of the app. There are several benefits that developmental research usability tests allow. These benefits include evidence as to whether participants could complete the required tasks successfully and why they might have struggled, participant satisfaction, suggestions for improvement of usability and satisfaction, and evidence as to the apps' performance overall (U.S. General Service Administration, 2013).

Because learners with dyslexia struggle to make sense of language and research supports multisensory learning, MagicSpells needed to be designed with these learners in mind and with the knowledge that a study should be conducted using natural learners with dyslexia in order to gauge the usability of the app (Plomp, 2000; Reimann, 2010). Testers with dyslexia and their parents suggested useful features and modifications that

resulted in the small-scale restructuring of app features - considered for their benefits to the app's overall usability and functionality (Chin et al., 2021). As part of the overall developmental process, it is common for designers to measure a design's usability—from idea to the final deliverable product - ensuring maximum usability (Chin et al., 2021).

As Chin et al. (2021) point out, research-driven apps like MagicSpells should be developed, paying particular attention to their usability for target learners. Furthermore, traditional usability approaches tend to be limited to metrics involving time to and challenge for completing tasks and user's satisfaction with the app. Conversely, current research suggests reaching further for educational applications by including the additional specific usability criteria for elements like effectiveness, consistency, and reliability – and focusing on academic usability components including motivation, learner control, and feedback (Tahir & Arif, 2016). In this study, usability testing exposed issues and gaps in stakeholders' notion of what a practical, operational, and sufficient product entails (Chin et al., 2021). This data and feedback facilitated design improvement and allowed the fine-tuning of toolbars and definitions. Feedback also leads to the removal of glitches in the assessment section. Developing a mobile app should budget for early and iterative testing to find and fix problems or usability issues, increasing eventual product use and preventing potential data gaps (Richey & Klein, 2005). Because this study took place in a realistic environment with learners with dyslexia and garnered genuine and specific feedback from users, the reviews and usability tests helped improve the MagicSpells app. They did lead to an amended and better-quality iteration of the application. Notably, developmental research suggests a progressive and gradual evolution of a product, which in turn recognizes design development as the process of converting a prototype into a

complete instructional product over time (AECT, 2020). This gradual and continuing evolution guided every step of the MagicSpells app's creation – culminating effectively with the inclusion of a study employing target stakeholders (persons with dyslexia). The programmers adjusted the app at my instruction regarding usability testing and the participants' and parents' recommendations. In the end, the app presented to the participants for this study was the twelfth version of MagicSpells. With the study complete, a thirteenth version has come to fruition, showing promise for providing it to all stakeholders.

Every comment, every suggestion, and the review of all results aided in the transformation of the MagicSpells. Moreover, unexpected issues that took place – observation, casual commentary, and notes scribbled on post-it notes as the study transpired - offered valuable feedback in addition to the feedback solicited by the surveys and interview questions. These organically gathered tidbits worked in conjunction with more formal data to give the programmers specifics for making changes to make the app better. Without this information from target users, we would still rely on my input and experts who are not the intended consumers.

Limitations

Besides the obvious Covid limitations, there were several limitations in this study. Covid protocols and numbers made it more difficult to recruit participants and required more time and effort to ensure safety and cleanliness during the study. The need for native English-speaking learners in particular age and grade ranges limited the number of participants, especially since the participant pool was made smaller by Covid issues. An additional limitation came from travel and time constraints, both for the researcher and

the participants and parents. They all had to travel to private offices to participate in the study. Also, the offices were only available during certain times – office one was weekends only, and office two was only weekday afternoons. Furthermore, distance issues and programmers not having access to the device present limitations in haptic features and caused time delays when cross-code issues occurred between the code used by programmers and the code created to facilitate Tanvas features.

Another limitation that prevented faster design and programming was the lack of funding. It was necessary to fund the programming on my own, and after finding the programmers on a site called "People Per Hour," we moved to email and WhatsApp correspondence to avoid paying extra fees. We agreed on an initial amount ($1000), but as work continued and versions were updated, I continued monthly payments until the app was ready for the study. In the same vein, the initial TanvasTouch® device was given to me at no cost but stopped working, and I looked to purchase one. Fortunately, a second device was donated (I paid for shipping), which was no small feat since, at that time, the Tanvas Company was undergoing staffing changes and Covid related business issues that nearly shut it down.

A marked limitation was that only a single study was conducted. While it garnered valuable data, providing follow-up trials with the same participants could help see if changes based on feedback improved the app as they suggested. Possibly, future trials involving the same participants would prove valuable. Additionally, I believe having all participants complete the trial before noon rather than after school or late evening would have made some difference in attitude and outcome.

Finally, given that males are diagnosed with dyslexia more frequently than females, it seemed ironic that of the seven participants in this study, six were female, and only one was male. He was also the youngest participant. I see this as a limitation to the current study and suggest that subsequent studies include more male participants, at the very least an equal number.

Future Research

In my exploration of developmental research and approaches, I learned the importance of the cyclical design and development process and the importance of using real-world settings and target stakeholders to ensure that the product is the preeminent prototype and will best support the needs of end-users. It has taken a long ten years to take the idea of MagicSpells from pieces of printer paper to a fully-functional, truly multisensory digital application. During this time, I invested my resources, spent hours researching and networking, endured brain and spine surgeries, and faced several other personal setbacks. However, I honestly believe the potential benefits of an app like MagicSpells made this research and the ongoing journey worth every sacrifice. The challenge to see MagicSpells realized drove this dissertation, and seeing it in action brings joy and hope. In addition to continual improvement and enhancement of the app over time, future research should focus on the efficacy of the MagicSpells application and how the inclusion of a haptic feature in the digital realm can assist learners with dyslexia with vocabulary acquisition. The following research questions can guide further research of the application:

Q1 - Can learners between the ages of 6 and 10 in grades first through fifth who are English language speakers, and who have been diagnosed with dyslexia, acquire age-appropriate vocabulary for reading and writing on grade level with peers through the use of newly developed, digital touch haptics?

Q2 - Using a TanvasTouch® enabled device, coupled with audio play, recording, and playback, drawing tools, and clipart images features and equipped with the MagicSpells app, can learners (aged 8-10) with dyslexia learn the grade-level words necessary to read and write on par with peers?

Q3 - With the use of current innovations in haptic touch-screen technology, specifically the TanvasTouch® screen that allows users to "feel" a variety of textures on what appears to be a smooth screen, can persons between the ages of 8 and 10 learn grade-level-appropriate words necessary to read and write on-level with peers?

Q4 - Will an app like MagicSpells and its multisensory, haptically enhanced elements better engage and excite learners in their efforts to acquire more vocabulary?

Furthermore, future research should include modifying the app for learners with dyslexia who speak other languages (word banks in the user's language) and for learners of second languages. The app has the potential to help any learner who looks to improve vocabulary skills.

Conclusion

Using developmental research approaches allowed me to take my design from concept to fruition. It is not enough to imagine that an educational tool will work as designed or expected. Creating the first viable version of the app took research and networking. While more informal research took place initially, it became necessary to

enlist experts and apply design principles. Early on, no technology existed that allowed for the inclusion of the haptic feature in the app. Still, once I discovered TanvasTouch® and Mino monitors, the game changed, and the developmental process began.

Exploring and implementing Mayer's (2009) principles of design made the overall design more user-appealing and assisted in creating various elements of the application. Understanding multisensory learning approaches and the relationship between senses and memory proved extremely assistive. Importantly, applying these principles functioned as part of the overall developmental approach to the educational tool design and assisted in implementing the app. Since MagicSpells appears to be one of a kind in the digital world, it needs to appeal to learners with dyslexia, parents, and educators in the best ways possible.

Developmental research approaches offered a repetitive and cyclical examination of all aspects of MagicSpells. As it evolved to include the instrumental haptic element of the app, I tested various versions over many months. For over two years, periodic meetings and input from experts coupled with routine testing with numerous users helped guide the app's evolution. A single implementation of MagicSpells would not have sufficed to gather ample evidence and feedback and assess its effect on the intended learners. Gathering target users' feedback made an improved and viable version a reality, but the developmental cycle will continue. A typical developmental research study has two or more phases. For MagicSpells, after the first and several subsequent implementations and evaluations, we made changes to further improve its potential to help learners with dyslexia. I expect that learners will offer feedback and suggestions for modifications each time the app is launched and used, and updated versions will follow.

With the study, I sought to prove nothing but rather to improve the MagicSpells app and create the most user-friendly, practical tool possible. The current study's participants were included to best reflect learners with dyslexia and facilitate the creation of an app that engages learners in the acquisition of vocabulary. Readdressing the problem statement, the development process used here served as a means for consultation of experts and engagement of learners with dyslexia to create an app that can potentially lead to vocabulary acquisition and improved reading and writing skills. Grounded in multisensory theory, the MagicSpells app stands poised to provide the inclusion of three sense in a digital format. To that end, the results of this study provide valuable input for revisions to content and elements. Moreover, I used the results to work with programmers to come to the desired end. This study, however, does not represent the end of the developmental research process for the app. Future versions will depend on user feedback and continuous improvement and modification.

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APPENDIX A

Dolch Word List

Pre-Primer	Primer	First Grade	Second Grade	Third Grade
the	he	of	would	if
to	was	his	very	long
and	that	had	your	about
a	she	him	its	got
I	on	her	around	six
you	they	some	don't	never
it	but	as	right	seven
in	at	then	green	eight
said	with	could	their	today
for	all	when	call	myself
up	there	were	sleep	much
look	out	them	five	keep
is	be	ask	wash	try
go	have	an	or	start

we	am	over	before	ten
little	do	just	been	bring
down	did	from	off	drink
can	what	any	cold	only
see	so	how	tell	better
not	get	know	work	hold
one	like	put	first	warm
my	this	take	does	full
me	will	every	goes	done
big	yes	old	write	light
come	went	by	always	pick
blue	are	after	made	hurt
red	now	think	gave	cut
where	no	let	us	kind
jump	came	going	buy	fall
away	ride	walk	those	carry
here	into	again	use	small
help	good	may	fast	own

make	want	stop	pull	show
yellow	too	fly	both	hot
two	pretty	round	sit	far
play	four	give	which	draw
run	saw	once	read	clean
find	well	open	why	grow
three	ran	has	found	together
funny	brown	live	because	shall
	eat	thank	best	laugh
	who		upon	
	new		these	
	must		sing	
	black		wish	
	white		many	
	soon			
	our			
	ate			
	say			

	under			
	please			

APPENDIX B

Trigger/Challenging Words

a	is	do	got
about	was	did	go
after	were	does	goes
again	being	doing	going
ago	been	done	gone
all	because	don't	went
almost	become	doesn't	have
also	became	down	had
always	becoming	each	has
an	becomes	either	having
and	before	else	he
another	between	even	he's
any	but	ever	her
anyhow	by	every	hers
anyway	can	everything	here
as	could	for	him
away	can't	from	his
back	come	full	form
be	came	get	if
am	comes	gets	in
are	coming	getting	into

isn’t	many	otherwise	stand
it	may	our	standing
its	maybe	ours	stands
it’s	me	out	stood
just	mine	over	such
last	more	put	sure
leave	most	puts	take
leaves	much	putting	takes
leaving	my	run	taking
left	neither	ran	took
least	never	running	than
less	no	runs	that
let	none	said	that’s
lets	one	same	I
let’s	nor	see	the
letting	not	saw	their
like	now	seen	theirs
liked	of	sees	them
likes	off	shall	then
liking	on	should	there
low	one	she	there’s
make	onto	she’s	these
made	or	so	they

makes	other	some	they’re
making	others	soon	this
those	over	belief	four
though	us	believe	within
tow	very	which	without
toe	saw	while	under
to	we	who	won’t
too	we’re	who’s	won
too	what	whose	yet
unless	when	why	you
until	where	will	your
up	where’s	would	you’re
upon	whether	with	yours
bow	how		know

Adapted (with permission APPENDIX L) from Davis Dyslexia Association International (1995)

APPENDIX C

Pre-Study Participant Survey

	4	3	2	1
How do you feel about reading?				
How do you feel about being read to?				
How do you feel about writing?				
How do you feel about spelling?				
How easy it is for you to learn vocabulary?				
How comfortable are you using a tablet?				
How do you feel about using a tablet to learn vocabulary?				

Do you find it easier to learn using technology?				

APPENDIX D

MagicSpells Follow-up Developmental Design Survey

	4	3	2	1
How easy was it to learn vocabulary with the MagicSpells app?				
How comfortable are you using a tablet to learn words?				
How do you feel about the usability of the MagicSpells app?				
Do you find it easier to learn words using the app?				
How do you feel about the				

definitions provided?				
How did you feel using the speech-to-text feature of the app?				
Did you find it easy to use the touchscreen feature of the app when using the app?				
How do you feel about the record feature in the app?				
How do you feel about the playback feature?				
How do you feel about recording and playing back your voice?				

How do you feel about the clipart feature?				
How do you feel about the toolbars and menus in the app?				
How do you feel about "feeling" the letters of the word?				
How do you feel about the in-app assessments (tests)?				
How likely are you to use the MagicSpells app to learn new vocabulary?				

APPENDIX E

Follow-up Interview Questions

Explain your response to - How easy was it to learn vocabulary with the MagicSpells app?
Explain your response to - How comfortable are you using a tablet to learn vocabulary?
Explain your response to - How do you feel about usability of the MagicSpells app?
Explain your response to - Do you find it easier to learn words using the app?
Explain your response to - How did you feel using the speech to text feature of the app?
Explain your response to - Did you find it easy to use the touchscreen feature of the app when drawing and using the app?
Explain your response to - How do you feel about the record feature in the app?
Explain your response to - How do you feel about the playback feature?

Explain your response to - How do you feel about recording and playing back your own voice?
Explain your response to - How do you feel about the clipart feature?
Explain your response to - How do you feel about the toolbars and menus in the app?
Explain your response to - How do you feel about being about feeling the word and letters?
Explain your response to - How do you feel about the in-app assessments (tests)?
Explain your response to - How likely are you to use the MagicSpells app to learn new vocabulary?

APPENDIX F

Hello, Wolfpack Parents,

I am a doctoral candidate at Sam Houston State University in the Instructional Systems Design and Technology program. I am looking for elementary learners with dyslexia to spend time using an app I designed to help children with dyslexia learn new vocabulary. This app called MagicSpells combines the use of sight, sound, and touch on a specially designed digital device to engage learners. The main goal of my study is to garner feedback from learners and their parents about the application's usability and multisensory features as part of the design process to produce the best, most effective final version of MagicSpells.

Because of my family's long history with dyslexia, in 2012, I came up with the design for MagicSpells. As a teacher (now retired) and a student (starting 2017), I made it my dissertation focus to take the app from idea to fruition. Advances in technology finally allowed me to add the game-changing touch feature to my design. Dyslexic learners currently have access to accessibility tools like text to speech and speech to text and font and color scheme variations. Technology affords many tools for struggling readers and writers, but I propose a means to support learning. Accessibility tools are aids and do not teach a skill. Through the digitally enhanced acquisition of words, dyslexic learners will recognize, retain, and read necessary words. As a result, these learners will develop the essential vocabulary for reading and writing success. I see benefits beyond learning new words – in academic advancement and improved self-esteem.

Please take advantage of this opportunity to help create what could be a game-changer in vocabulary acquisition for learners with dyslexia. I look forward to sharing MagicSpells with your students.

Thank you,
Laurie Coker

APPENDIX G

SignUpGenius

MagicSpells Trial Participants

MagicSpells Trial

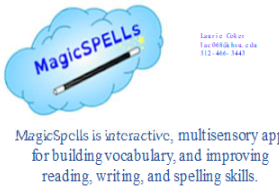
Location: 201 S. Lakeline ,Ste. 103. Cedar Park, TX 78613

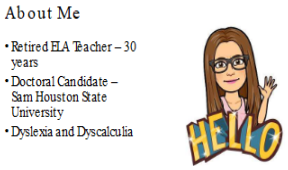
Created By: Laurie Coker

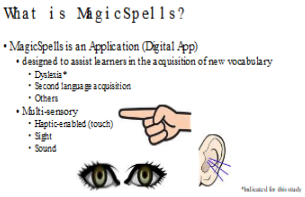
Dates are in mm/dd/yyyy. Times are shown in EST.

10/30/2021 (Sat. 9:00AM - 10:45AM)			
Participate in MagicSpells Trial (1)	Name: **Eduardo Gonzalez**	Email: egonzal528@gmail.com	Phone:
10/30/2021 (Sat. 11:00AM - 12:45PM)			
Participate in MagicSpells Trial (1)	Name: **Angela Hora**	Email: angelaphora99@gmail.com	Phone:
10/30/2021 (Sat. 1:00PM - 2:45AM)			
Participate in MagicSpells Trial (1)	Name: **Shannah West**	Email: mary.immanuel@icloud.com	Phone:
10/31/2021 (Sun. 9:00AM - 10:45AM)			
Participate in MagicSpells Trial (1)	Name: **Angela Rock**	Email: angelarock83@gmail.com	Phone:
10/31/2021 (Sun. 11:00AM - 12:45PM)			
Participate in MagicSpells Trial (1)	Name: **Kiki Fountain**	Email: kikijo13@gmail.com	Phone:
10/31/2021 (Sun. 1:00PM - 2:45PM)			
Participate in MagicSpells Trial (1)	Name:	Email:	Phone:

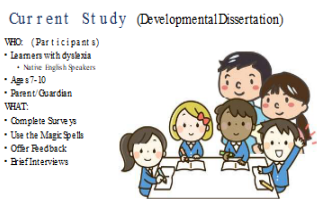
APPENDIX H

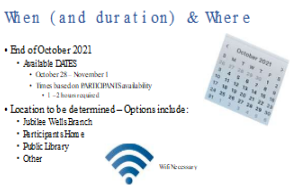

MagicSPELLS
Laurie Coker
312-466-3443
MagicSpells is interactive, multisensory app for building vocabulary, and improving reading, writing, and spelling skills.

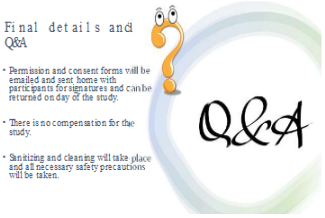

About Me
• Retired ELA Teacher – 30 years
• Doctoral Candidate – Sam Houston State University
• Dyslexia and Dyscalculia
HELLO


What is MagicSpells?
• MagicSpells is an Application (Digital App)
• designed to assist learners in the acquisition of new vocabulary
• Dyslexia*
• Second language acquisition
• Others
• Multi-sensory
• Haptic-enabled (touch)
• Sight
• Sound
*Indicated for this study


History Behind MagicSpells
MagicSPELLS
• Original Design (2012)
• The Haptic Technology – Tanvas
• Doctoral Study & Dissertation – 2017 to Present
• Design and Development – 2019 to Present
• Trial runs with programmers
• Equipment Trials
• Programmers in India
• Role of Study Participants


Current Study (Developmental Dissertation)
WHO: (Participants)
• Learners with dyslexia
• Native English Speakers
• Ages 7-10
• Parent/Guardian
WHAT:
• Complete Surveys
• Use the MagicSpells
• Offer Feedback
• Brief Interviews


When (and duration) & Where
• End of October 2021
• Available DATES
• October 28 - November 1
• Times based on PARTICIPANTS availability
• 1 - 2 hours required
• Location to be determined – Options include:
• Jubilee Wells Branch
• Participants Home
• Public Library
• Other
Wi-fi Necessary


Final details and Q&A
• Permission and consent forms will be emailed and sent home with participants for signatures and can be returned on day of the study.
• There is no compensation for the study.
• Sanitizing and cleaning will take place and all necessary safety precautions will be taken.
Q&A


My Contact INFORMATION
•Laurie Coker
•[redacted]
[redacted]
@

APPENDIX J

Sam Houston State University, Huntsville, TX

PARENT PERMISSION FOR MINOR TO PARTICIPATE IN RESEARCH

DEVELOPMENT OF A HAPTICALLY ENHANCED THE DIGITAL APPLICATION MAGICSPELLS FOR VOCABULARY ACQUISITION FOR LEARNERS WITH DYSLEXIA

Laurie Coker ABD doctoral candidate and faculty advisor Dr. Donggil Song, from the Instructional Systems Design and Technology department at Sam Houston State University (SHSU) are conducting a research study.

Your child was selected as a possible participant in this study because he or she has been diagnosed with dyslexia and is a native English speaker between the ages of 8 and 10.

Your child's participation in this research study is voluntary.

Why is this study being done?

This study is a for a developmental dissertation to assist in the design and development of a haptically-enhanced app called MagicSpells. With this state-of-the-art innovation, a person with dyslexia of any age can build vocabulary and improve reading and writing by adding touch to sight and sound. With MagicSpells, using a specially designed app and TanvasTouch® technology, learners can interact with words through sight, sound, and touch. This study is part of the process for design and development of the MagicSpells and feedback from the study will be use to modify and improve the app.

What will happen if my child takes part in this research study?

If you agree to allow your child to participate in this study, we would ask him/her to:

- Complete a brief pre-study interview

- Complete a survey regarding the use of technology and learning vocabulary
- Complete trial of about 1 hour & 45 minutes using the MagicSpells app
- Complete a post survey and intervention interview – to offer feedback on the intervention experience

How long will my child be in the research study?

Participation will take a total of at most 1 hour - 45 minutes.

Are there any potential risks or discomforts that my child can expect from this study?

- There are no potential risk or discomforts that can be expected from participation in this study.

Are there any potential benefits to my child if he or she participates?

Your child may benefit from the study. Ideally, your child will acquire new vocabulary by participating in the study and will gain self-confidence.

The results of the research may demonstrate how the use of haptics in a digital application can engage learners and assist them in the acquisition of vocabulary and can support the improvement and further development of the MagicSpells app.

Will information about my child's participation be kept confidential?

Any information that is obtained in connection with this study and that can identify your child will remain confidential. It will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of the assignment of participant numbers, thematic coding and destruction of all documents in five years.

What are my and my child's rights if he or she takes part in this study?

- You can choose whether or not you want your child to be in this study, and you may withdraw your permission and discontinue your child's participation at any time.
- Whatever decision you make, there will be no penalty to you or your child, and no loss of benefits to which you or your child were otherwise entitled.
- Your child may refuse to answer any questions that he/she does not want to answer and still remain in the study.
- Your decision whether or not to permit your child to participate will not affect your current or future relations with Sam Houston State University or Jubilee Academy Wells Branch. If you decide to participate, you are free to withdraw at any time without affecting those relationships.

Who can I contact if I have questions about this study?

- **The research team:**

  If you have any questions, comments or concerns about the research, you can talk to the one of the researchers. Please contact:

  PI: Laurie Coker – [redacted]Faculty Chair: Dr. Donggil Song - [redacted]

- **SHSU Office of Research** and **Sponsored Programs (ORSP):**

  If you have questions about your child's rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call Sharla Miles, Research Compliance Administrator at (936) 294-4875 or write to:

  Office of Research and Sponsored Programs

  Institutional Review Board

ATTN: Sharla Miles, CIP

ORSP-SHSU Box 2448

Huntsville, TX 77341-2448

You will be given a copy of this information to keep for your records.

SIGNATURE OF PARENT OR LEGAL GUARDIAN

_____

Name of Child

_____

Name of Parent or Legal Guardian

_____ _____

Signature of Parent or Legal Guardian Date

SIGNATURE OF PERSON OBTAINING CONSENT

_____ _____

Name of Person Obtaining Consent Contact Number

_____ _____

Signature of Person Obtaining Consent Date

APPENDIX K

Sam Houston STATE UNIVERSITY
A Member of The Texas State University System

Date: Sep 29, 2021 1:30:28 PM CDT

TO: Laurie Coker Donggil Song
FROM: SHSU IRB
PROJECT TITLE: Development of a Haptically Enhanced the Digital Application MagicSpells for Vocabulary Acquisition for Learners with Dyslexia
PROTOCOL #: IRB-2021-247
SUBMISSION TYPE: Initial
ACTION: Approved
DECISION DATE: September 29, 2021
EXPIRATION DATE: September 29, 2022
FULL EXPEDITED REVIEW JUSTIFICATION: §46.111 Criteria for IRB approval of research (Subpart A) & §46.404 Research not involving greater than minimal risk (Subpart D)
OPPORTUNITY TO PROVIDE FEEDBACK: To access the survey, click **here**. It only takes 10 minutes of your time and is voluntary. The results will be used internally to make improvements to the IRB application and/or process. Thank you for your time.

Greetings,

The above-referenced submission has been reviewed by the IRB and it has been Approved. This decision expires on September 29, 2022. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

Since Cayuse IRB does not currently possess the ability to provide a "stamp of approval" on any recruitment or consent documentation, it is the strong recommendation of this office to please include the following approval language in the footer of those recruitment and consent documents: IRB-2021-247/September 29, 2021/September 29, 2022.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Modifications: Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please submit a Modification Submission through Cayuse IRB for this procedure.

Incidents: All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please submit an Incident Submission through Cayuse IRB for this procedure. All Department of Health and Human Services and sponsor reporting requirements should also be followed.

Renewals: Based on the risks, this project requires renewal reviews by this committee on an annual basis. Please submit a Renewal Submission through Cayuse IRB for this procedure. Your documentation for renewal must be

APPENDIX L

Coker, Laurie
Sun 11/15/2020 10:53 AM
To: ddai@dyslexia.com

Hello,

I hope you and yours are well. I am a doctoral candidate at Sam Houston State University. The focus of my dissertation is digital interventions for vocabulary acquisition for learners with dyslexia and I wanted to know if it might be possible to use the Davis program list of Trigger words? I will, of course, attribute the list of words appropriately.

Thank you in advance for your consideration. Please let me know if using the word list is acceptable and if it is not, I will move forward.

Cheers,

Laurie Coker BS, BA, MSEd

AM

Abigail Marshall <webmaster@dyslexia.com>
Sun 11/15/2020 2:16 PM
To: Coker, Laurie
Cc: Abigail Marshall <ddai@dyslexia.com>

Yes, that is fine! Thank you for asking.

We hope you will share your dissertation with us when your work is completed, as we definitely would be interested in your findings.

Best wishes,

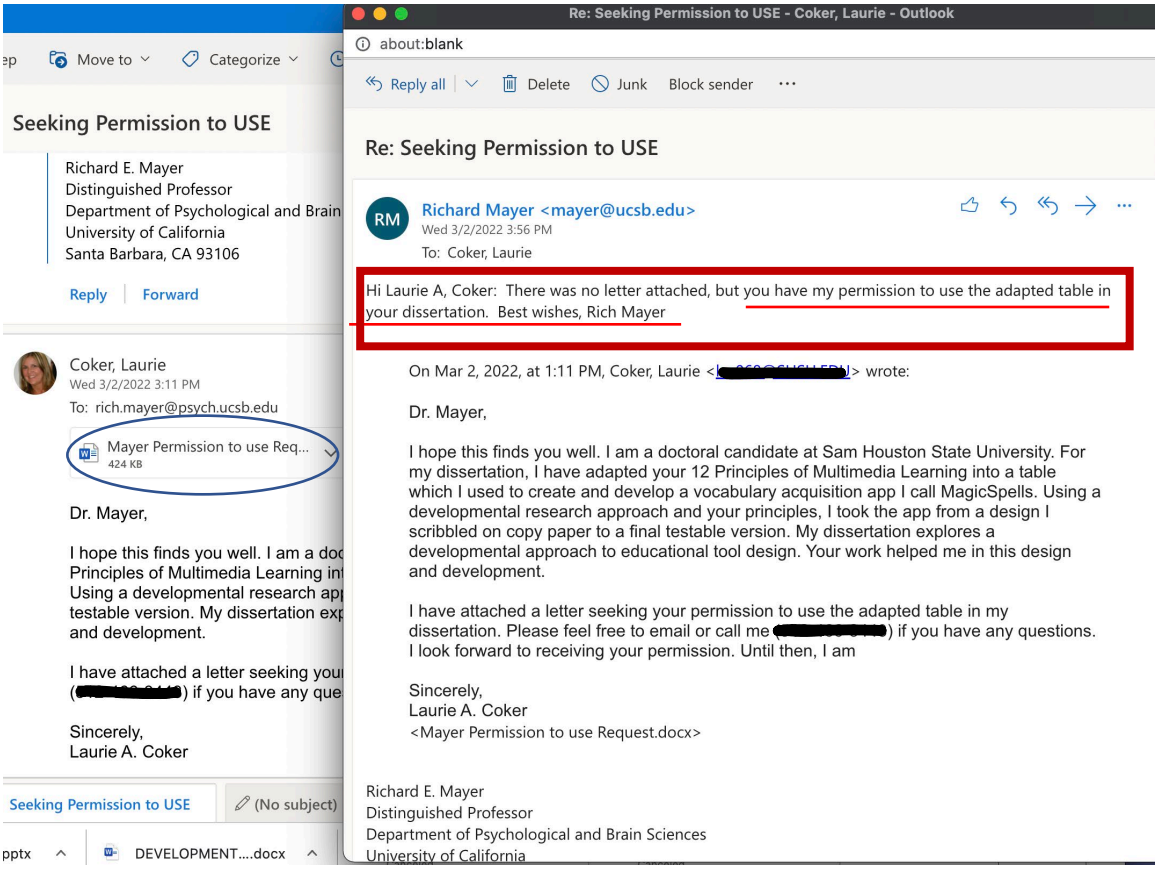
Abigail Marshall
Internet Information Services Director
Davis Dyslexia Association International
www.dyslexia.com

Dyslexia the Gift - www.dyslexia.com

Dyslexia help and information. Effective strength-based solutions, training and referrals from Davis Dyslexia Association International.

www.dyslexia.com

APPENDIX M


Move to
Categorize
Seeking Permission to USE
Richard E. Mayer
Distinguished Professor
Department of Psychological and Brain
University of California
Santa Barbara, CA 93106
Reply
Forward
Coker, Laurie
Wed 3/2/2022 3:11 PM
To: rich.mayer@psych.ucsb.edu
Mayer Permission to use Req...
424 KB
Dr. Mayer,
I hope this finds you well. I am a doc
Principles of Multimedia Learning int
Using a developmental research app
testable version. My dissertation exp
and development.
I have attached a letter seeking you
[redacted]) if you have any que
Sincerely,
Laurie A. Coker
Seeking Permission to USE
(No subject)
pptx
DEVELOPMENT....docx
Re: Seeking Permission to USE - Coker, Laurie - Outlook
about:blank
Reply all
Delete
Junk
Block sender
Re: Seeking Permission to USE
RM
Richard Mayer <mayer@ucsb.edu>
Wed 3/2/2022 3:56 PM
To: Coker, Laurie
Hi Laurie A, Coker: There was no letter attached, but you have my permission to use the adapted table in your dissertation. Best wishes, Rich Mayer
On Mar 2, 2022, at 1:11 PM, Coker, Laurie <[redacted]> wrote:
Dr. Mayer,
I hope this finds you well. I am a doctoral candidate at Sam Houston State University. For my dissertation, I have adapted your 12 Principles of Multimedia Learning into a table which I used to create and develop a vocabulary acquisition app I call MagicSpells. Using a developmental research approach and your principles, I took the app from a design I scribbled on copy paper to a final testable version. My dissertation explores a developmental approach to educational tool design. Your work helped me in this design and development.
I have attached a letter seeking your permission to use the adapted table in my dissertation. Please feel free to email or call me [redacted]) if you have any questions. I look forward to receiving your permission. Until then, I am
Sincerely,
Laurie A. Coker
<Mayer Permission to use Request.docx>
Richard E. Mayer
Distinguished Professor
Department of Psychological and Brain Sciences
University of California

VITA

LAURIE COKER

OBJECTIVE: Seeking a Doctorate of Education in Instructional Systems Design and Technology.

SKILLS

- Experienced educator and curriculum writer
- Experience with web-authoring tools and multimedia software
- Experience with virtual instruction and online course creation
- Proficient with presentation software including Pages and Keynote
- Command of Spanish – speaking, reading and writing
- Proficient with Mac OS X and Microsoft Office
- Experience with online, classroom and distance learning settings
- Knowledge of Experience with Learning Management Systems – including but not limited to Moodle, Google Classroom, Canvas, and Edmodo
- Natural ability for creating innovative, computer-based and virtual training experiences for a variety of learners
- Excellent research and internet skills
- Excellent writer

PROFESSIONAL EXPERIENCE

2019 - 2020 **Adtalem Global Education Inc**. Remote

- Volunteer Researcher and Writer
- Writing lesson plans for VR inclusion
- Researching VR use in vocabulary and language acquisition

- Writing literature reviews and study proposals

1988 - 2018 **Westwood High School, Round Rock ISD** Austin, TX

Educator, Technologist and Curriculum Developer

- Taught English Language Arts Grade 9, 11 & 12
- Taught Creative Writing Grades 10 – 12
- Created curriculum designed for multi-cultural and diverse learners
- Taught Speech Communication Grades 9-12
- Sponsored Student Apprentice Teachers (University of Texas, Concordia University, and

Texas State University)

- Designed & wrote Virtual Online English and Science Courses
- Taught in London as part of a year-long Fulbright Teacher Exchange ages 11-18 (1994-1995)

2013 – 2015 **Longhorn International Tutoring** Austin, TX

Curriculum Writer and Tutor

- Worked within multi-culture and multi-language learning environments
- Tutored English to Chinese students online
- Tutored English in Chinese Summer Camps
- Developed curriculum for English lessons for ages 8 to adult
- Using online meeting program to create interactive, engaging online lessons

2002– 2018 **Journeys Adolescent Services** Las Vegas, NV

Transporter of Troubled Teens to Wilderness and Treatment Facilities

- Safely and Confidentially Chaperone at-risk teens from home or facility to specified location

2000-2001 **Association of Colleges and Universities** Austin, TX

Editor and Lesson Plan Writer

- Edited and contributed to The Next Level – A Writing Guide for College students
- Wrote corresponding lessons for high school teachers to use The Next Level with college bound students

2000 – 2006 **The University of Texas at Austin** Austin, TX

Curriculum and Test Writer – Grant Reader

- Wrote 12th Grade High School Correspondence Course and Credit by Exams
- Created Grade-Level Language Arts Lesson Plans for the UTOPIA Project
- Read and rated grant applications to be considered for funding by UT's UTOPIA Project
- Created Language Arts lesson plans for a variety of departments at the University of Texas

EDUCATION

- 2017 - Present Sam Houston State University

  PhD in Instructional Systems Design and Technology
- 1998 - 1998 The University of Texas at Austin

  Bachelor of Arts English
- 1992 - 1994 The University of Texas at Austin

  Master's in Education – Special Education
    - Kappa Delta Phi Honor Society

- 1984 - 1988 The University of Texas at Austin

  Bachelor of Science in Education - English Major/Communication Minor

  - Teaching Certification – English & Speech

ADDITIONAL PROFESSIONAL ACTIVITIES

- KEYE Silver Apple Award – November 2003
- Texas Council of Teacher of English – Presenter January 2001 & January 2003
- Texas Council of Teachers of English – Language Arts High School Educator of the Year – 2002
- Round Rock ISD Summer Staff Development – Presenter June 2001 & June 2004
- Round Rock ISD – Curriculum Developer – Summers beginning 2005
- HEB Excellence in Education Finalist – 2009
- SXSWedu – Attendee and Presenter – Offering workshops for incorporating virtual and interactive experiences for elementary, secondary and higher education level learners

PROFESSIONAL MEMBERSHIPS & AWARDS

- Fulbright-Hays Education Seminar Abroad to South Africa – July 2007-August 2007
- Fulbright Memorial Fund International Teacher Program to Japan – October 2004
- Fulbright Exchange Teacher to London – August 1994 – July 1995 – Taught English to Grades 6-A Levels