



# **ASHESI UNIVERSITY**

## **INTELLIGENT LEARNING SYSTEMS FOR INCLUSIVE EDUCATION: A FOCUS ON DYSLEXIA**

### **UNDERGRADUATE THESIS**

B.Sc. Computer Science

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**ASHESI UNIVERSITY**

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EDUCATION: A FOCUS ON DYSLEXIA**

**UNDERGRADUATE THESIS**

Thesis submitted to the Department of Computer Science, Ashesi  
University College, in partial fulfillment of the requirements for the award  
of Bachelor of Science degree in Computer Science.

**Naayi Tei-Dornoo**

**2022**



## **Declaration**

I hereby declare that this Undergraduate Thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

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Candidate's Name:

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Date:

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I hereby declare that the preparation and presentation of this Thesis were supervised in accordance with the guidelines on supervision of Theses laid down by Ashesi University.

Supervisor's Signature:

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## **Acknowledgements**

To my supervisor, whose academic advice helped me undertake this project.

## **Abstract**

As children grow, they learn how to read and write. Reading involves recognizing, distinguishing, and understanding words and characters to make sense of a text. By the age of 7, a child should read and understand simple texts. For some people, it is not the case. They struggle to read and write. Reading is fundamental as it is applied everywhere; for instance, a person needs to read road signs to know their current location, read the operating manual for a new device they have bought, and many others. Some people struggle to read and write because of a learning disability called Dyslexia. It makes them unable to identify words and make sense of them. Some people can overcome Dyslexia by third grade, but others struggle even in university. Students are struggling to keep up academically because of this learning disability. This Thesis undertakes research to identify what students with Dyslexia go through and what strategies work best to help them study effectively and at a reasonable pace.

Keywords: *Dyslexia; text-to-speech; speech synthesis; optical character recognition; audiobooks*

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# **Chapter One: Introduction**

## **1.1 Overview of Disability**

A disability is any condition that restricts a person's ability to perform certain activities [1]. Disabilities can affect a person's vision, speech, hearing, learning, thinking, communication, movement, mental health and relationships [1]. A person is classified as disabled when they cannot function as the average human being. For example, a person who uses a wheelchair to move from one place to another is disabled because they cannot walk, which is the normal way for humans to move around. There are many disabilities, such as brain disabilities, vision disabilities, spinal cord disabilities, hearing disabilities, and learning disabilities [2]. One billion people in the world are disabled, 20% of this population live with extreme functional difficulty, 3.2% of the world's population suffers from blindness or vision impairment, 6% are deaf or losing their hearing, 1% move around using wheelchairs, and 2.6% have intellectual disabilities [3]. Eighty million Africans are disabled, including those with physical impairments, congenital disabilities, and mental health conditions, and 5 million are Ghanaians [4, 5]. Disabled people in Ghana face hindrances when it comes to education and healthcare. Most of them end up in poverty, so they beg on the streets for money [6].

## **1.2 Learning Disabilities**

Learning is the constant acquisition of knowledge, skills, and information. Learning takes place in informal education, at school, and in everyday life. Learning is a process where one encounters new information, pays attention to it, applies it, and stores it in their memory [8]. Learning transpires through experience, for instance, learning how to cook, drive, and read. Learning can affect one's attitude and behavior because as a person learns more, their mindsets and behaviors will also change [8]. Academic learning is the attainment of skills by following a curriculum. It is usually done in schools, and

subjects, for example, mathematics, physics, and English, are taught and learned. Academic learning equips learners with theoretical and educational knowledge [9]. Everyone can learn; however, some people struggle to learn because they have cognitive challenges. Such challenges alter the way a person assimilates and synthesizes information. It also affects how one memorizes and processes what they learn [8]. Cognitive challenges include learning disabilities. Learning disabilities are ascribable to genetic abnormalities that affect brain functioning such that the individual develops cognitive challenges that affect their ability to read, write, and do simple mathematics [10]. Learning disabilities are called hidden disabilities because they cannot be detected by looking at the individual but through testing and investigating the individual's intellectual strengths and weaknesses. Learning disabilities can only be managed but not cured totally. They are lifelong disabilities. Dyslexia, Dysgraphia, Dyscalculia, ADHD, and related disorders are the most prevalent learning disabilities globally [7]. Children with learning disabilities are intelligent and may have a higher than average intelligence, but their disability hinders them from reaching their full potential [10].

### **1.3 Dyslexia**

Dyslexia is the most common learning disorder. Dyslexia is a learning disability that makes an individual unable to read, write accurately or spell. People with Dyslexia struggle to make sense of the words they see. Dyslexia is genetic and runs in families; hence an individual who has Dyslexia most likely has other family members who also have it [11]. It could be their mother or father, and their siblings may also have Dyslexia [11]. 9 – 12 % of the world's population suffers from Dyslexia, and 2 – 4 % suffer from it severely [12]. In Ghana, 10% of the population is dyslexic, and 4% suffer from severe Dyslexia [13]. Dyslexic students struggle throughout their academic lives, especially when they do not get help or support. They end up performing poorly because they cannot read. One has to read

instructions to understand the requirements of an assignment or task. Dyslexic people are not unintelligent and incapable of excelling. Many of them are intelligent and hardworking, but they cannot read. There are barely any systems in place in Ghana to accommodate and help them keep up with their mates, and there are not many resources available to help dyslexic students learn. Some teachers get frustrated and beat the students because they intentionally think they are making mistakes [14].

#### **1.4 Aim of Research**

The research aims to answer the question, "Can technological provision be made for children in Ghana with dyslexia so they can access resources to help them learn and read with ease?" and prove the hypothesis that "Children with dyslexia are intelligent and can thrive academically if they are given the appropriate technological resources."

## Chapter Two: Literature Review

### 2.1 Overview of Dyslexia

Dyslexia is a condition that impedes one's ability to write, spell and read. 5 – 12% of children have Dyslexia [20]. People with Dyslexia cannot read at a good pace because they struggle to connect letters with the sounds they make [19]. People with Dyslexia cannot outgrow it. The condition can only be managed with some teaching techniques [15]. Students with Dyslexia are intelligent, but their inability to read and make sense of texts hinders their ability to learn like their peers. Critchley [2010] explains that Dyslexia is a reading impediment and a syndrome that causes delays [16]. People with dyslexia struggle with reading and mathematics, writing, spelling, and learning in general. Dyslexic people have neurological differences that make them think and learn in a certain way because the dyslexic brain has certain features that affect the way a person thinks and learns [18]. Looking at a dyslexic person's brain, it is noticed that the part that processes language does not work well. People with Dyslexia do not see words as ordinary people do; hence the letters in words mix up in their minds, causing confusion; so for instance, if the word is "mat," the dyslexic student will see it as "tam" or "atm" [17]. Children with Dyslexia have normal vision and are equally as smart or even more intelligent than their peers, but their learning impediment prevents them from reaching their full potential [19]. Dyslexia may be mild in some people and severe in others. Adults can have Dyslexia too. Some people do not know they have Dyslexia until they get older [19]. Dyslexia can be detected in non-school-age children if they exhibit symptoms like starting to talk late, difficulty in learning nursery rhymes, and mispronouncing words. In elementary school age, teens and adults, symptoms of Dyslexia include reading below their age level, trouble spelling, trouble sounding out words, slow reading, spelling difficulties, avoidance of reading, difficulty

memorizing what they learn, trouble processing language, and inability to remember sequences [21].

## **2.2 Causes of Dyslexia**

Dyslexia is a hereditary disorder. 49% of parents with dyslexic children have Dyslexia, and 40% of dyslexic children have siblings who also struggle with dyslexia [20]. Brain imaging studies show that dyslexic people have specific disparities in their brains. There is a neural circuit involving regions in the left hemisphere of the brain which is responsible for language and comprehension [21]. There are also some genes linked to language and processing. These genes also affect how the brain communicates. An abnormality in only one gene may cause Dyslexia [20]. Premature birth and exposure to alcohol and drugs during pregnancy can also cause Dyslexia by altering brain development in the fetus [22]. Using Magnetic Resonance Imaging (MRI), researchers could deduce differences between a dyslexic child's brain and the brain of a child with no learning disability. They also discovered that children with Dyslexia experienced improvements in their brain abnormalities with practical training and instruction, proving that Dyslexia can be managed [20].

## **2.3 Effects and Problems Dyslexia Children Face**

Children with Dyslexia have a hard time with visual processing, not because they are blind but because they process visual information like words and shapes slowly. They also have a poor short-term memory system, so they struggle to remember what they learn [18]. Children with Dyslexia have low self-esteem, anxiety, anger, depression, aggression, and these behaviors may lead to problems in the future when they become adults [22]. Dyslexia affects one's vision such that they have difficulty reading and understanding text, hearing so that they struggle or are unable to interpret sounds and attention so that they are unable to focus on each word and read when reading a sentence [33].

Dyslexic students usually understand the concepts taught in class, but they struggle to keep up with studies outside of class. They struggle to read course textbooks and are evaluated the same way as their mates. They have the same preparation time for tests and examinations as their classmates who have no learning disabilities. They write the same examinations as their peers and do not perform well because of their cognitive setbacks [23]. People with Dyslexia have incoherent handwriting, short attention span, poor time management; they have low self-esteem, and general literacy problems [24]. Christopher Byrne [2018] mentions that university staff are skeptical about dyslexic students and fail to give them the support they need. It is hard to believe that someone cannot read, though it is a disability that affects a vast number of students all around the world. There is a gap between dyslexic students' academic performance and non-dyslexic performance [25]. Occasionally, teachers give students a little more time to finish their work, forgetting that the student is not only unable to write clearly, but they cannot read, make sense of words quickly, and manage their time well [25].

#### **2.4 Technologies and Support Available for Dyslexic Students**

Through research and evaluation, technological innovations and inventions have been made to help dyslexic children improve in various areas. In 2010, Goldfus and Gotesman [2010] researched whether dyslexic students could use assistive technologies to learn. They tested two batches of such students: one used text-to-speech software, and the others used computers to learn. They concluded that those that used solely text-to-speech software performed much better than those who used only computers to learn [26]. It can be deduced that people with Dyslexia learn better by hearing and listening. Cerni and Job [2015] also explain that text-to-speech software increases dyslexic students' curiosity and motivation in subject areas [27]. Word prediction software was brought about for people with learning disabilities so that they do not have to go through the stress of spelling words. There is a

downside to word prediction software for people with Dyslexia because they cannot spell, and for the word prediction to work, the user has to spell at least the beginning part of the word so that it can be completed for them. The student also must recognize the correct word in the list of generated possible words before adding it to their work [28]. Depending on the intensity of one's Dyslexia, they may be unable to make out the particular word they are looking for. Word processing, speech support, and spelling help dyslexic students learn. Such software supports the students' independent learning by using text and audio together, hence improving the student's memory [29]. Fonts also affect a dyslexic person's ability to read. Some fonts are difficult for people with Dyslexia to read, for instance, Arial italicized fonts. The most readable fonts for people with Dyslexia are Helvetica, Courier, CMU, and Verdana [32].

Andrea Zingoni et al. [2021] sought to create a method of teaching that was inclusive for dyslexic students. They launched the VRAllexia project, which produced an Artificial intelligence system that evaluated dyslexic students and generated supporting tools to help them learn. The system incorporated testing and assessment means to determine the level of help the student needs, and then generated a solution based on the results and relayed information to teachers on what strategies were best to use to teach the student [30].

Augmentally, a low-cost application for dyslexic students, is available on iOS and Android for students with Dyslexia who cannot afford special tutelage. It uses immersive reading to help improve reading and writing and Optical Character Recognition (OCR) to scan text, transform and display it in a dyslexia-friendly view by changing the font style and size [31]. Microsoft's Immersive Reader gives schools and parents the support to help dyslexic students learn without incurring any costs. The immersive reader is an extension of Microsoft's OneNote software which increases readability on screens. It boosts the child's

confidence by increasing readability, making the child's love for reading develop over time [34].

Researchers sought to design technology to train and improve dyslexic children's spelling. They created a game called DysEggxia, which gives the children exercises to help them learn how to spell words. With this software, they presented exercises that aided in spelling by providing words misspelled or missing a letter to spell correctly. After four weeks, the students who used the DysEggxia application improved their spelling significantly [36].



## **Chapter Three: Methodology**

Dyslexic students struggle to keep up with their mates academically, and this research seeks to find out whether the gap can be bridged between dyslexic students and those with no learning disability. Primary and Secondary research was carried out to acquire necessary data.

### **3.1 Primary Research**

At the Dzorwulu Special School in Dzorwulu, Accra, five dyslexic students participated in this research. They were all Ghanaians and in the fifth grade. The usual age range for fifth graders is 9 – 11 years old, but in this case, their ages ranged from 17 to 33 years old. There were two males and three females.

#### **3.1.1 Observation**

Dyslexia is a disability that makes children unable to read. It also causes stunted growth so that some dyslexic children do not act their age. They are not as socially mature as the rest of their peers, which draws them back in many areas [35]. We find 17, 19, 22, 24, and 33-year-old individuals in the fifth grade. There was no technology available to help them learn. If the provision had been made for them when they were younger, they would have been at a much higher education level. Observation of how they read, spell, identify words and answer math questions was carried out.

#### **3.1.2 Spelling Words**

Each student was asked first to write their full name. They could all spell their names; however, they struggled to spell their names orally. They could write their names because they have memorized how the name looks when written. They have memorized the order of the letters, so they know just what to write when asked. When they were asked to spell their names orally, they all spelled something random which was not close to their name.

After this exercise, each student's name was written on the board, and they were asked to approach the board and circle their first and last names. They struggled to identify their names, but they found their names and circled them after some time. After one student wrote his name on the board, he was asked to pronounce his name. He mentioned the first name correctly, but he mentioned a name that did not correlate with what was on the board for his last name. He mentioned his middle name, which he had not written on the board, instead of his last name, which was on the board. This showed that he had only memorized how to write his name but could not identify the letters involved in writing his name. After the name spelling exercise, students were asked to spell two-letter words.

Student	Word given	How they spelled it	Assistance given	Result
Student 1	in	e	Sounding out letters one by one	The student was able to spell "in"
Student 2	so	o	Sounding out letters one by one	The student was able to spell "so"
Student 3	go	no	Showing the student the letter "g" and sounding it out to him	The student was able to spell "go"
Student 4	do	bo	Differentiating the letter d from b and sounding it out to the student	The student was able to spell "do"
Student 5	is	is	The student did not need extra assistance	The student spelled the word correctly

*Table 3.1.2*

As seen in *Table 3.1.2*, four out of five students struggled to spell the words independently. One girl was asked to spell "in" she wrote "e" because that is what "in" sounded like to her. Dyslexic people struggle to match words with their sounds [19]. The

individual letters were sounded out to her before she could spell the word "in" after some time. Another was asked to spell "so ."She wrote "o" instead of "so" because she could only identify the "o" sound. After the letters were sounded out to her as in "ssss," "oooo," "ssooo," she was able to spell it. As the students wrote on the board, it was seen that their handwritings were sometimes illegible. Dyslexic people, in some cases, have incoherent handwriting [24]. Another student was asked to spell "go ."Before writing something, he thought long and hard, and he wrote "no" instead of "go ."He somehow got the "o" right but not the preceding consonant. After the letter was shown to him and sounded out to him, he could spell "go ."A student was asked to spell "do ."She could not distinguish between "b" and "d ."She wrote "bo" instead of "do" and could not tell the difference after they sounded out to her. After a while, she accepted that they were alphabets with two different sounds. This exercise showed how dyslexic students relate words with their sounds, and it is seen that they can write the correct words when they are sounded out to them.

### 3.1.3 Mathematics



Figure 3.13

*Figure 3.13* shows that five students were given counters to aid in addition and subtraction. With the counters, they were swift when answering questions, and they answered them correctly; however, four out of five could not answer the most straightforward addition questions without using the counters. For a question like  $3 - 1$ , they would still use counters to answer them. One out of the five students was good with mental mathematics. She could perform addition and subtraction without the counters, and she was able to write mathematical equations on the board for her mates to solve. Another one out of the four students got confused when counting at a point because he could not keep track of the numbers. He would lose count and start over. From this test, it can be deduced that dyslexic students tackle and understand mathematics differently.

#### **3.1.4 Writing**

The five students were asked to write the alphabet from A – to Z. They all took a while to write it. Some of them needed help, so they looked at an alphabet chart pasted on the wall as a guide. They wrote from A – Z but not with ease. One of them wrote some of the alphabets backward, for example, “Q” instead of “D” and “O” instead of “C.” Another one of them also wrote the letters correctly, but they overlapped each other.

When they were asked to write down some words during the spelling session, the same incidents occurred. Some wrote some letters backward and had poor handwriting.

#### **3.1.5 Fonts and Readability**

When words were written on the board to be identified, they had more difficulty identifying words written with cursive, a font with letters joined to each other. They took a shorter time to identify words written plainly with no writing style, curls, or curves. They also asked for an increase in font sizes, and after this, they spent less time identifying the words.

#### **3.1.6 Word Identification**

A list of random two, three- and four-letter words were written on the board in this test. Students were given a word to find on the board. The words included “as”, “in” “for”, “fire”, "boy", "girl", and many others. They stared at the words in confusion as they came up to the board. Many words present simultaneously can confuse a dyslexic person [33]. When they got to the board, the letters in the word were sounded out to them, so for instance, when a girl was asked to find the word "is," it was sounded out to her as in "iiii," "sssss" before she figured out the word and circled it. Another girl was asked to find the word "fire ."The word "for" was on the board simultaneously, so it tricked her a bit. She could figure that the word had the letter "f" at the beginning, but she could not deduce the word "fire" until the letters were sounded out to her individually. She still chose "for," and after much explanation, she selected the correct word, "fire ." They all struggled to link the sounds to their respective words until the letters in words were sounded out to them individually. This shows that dyslexic people need technology such as text-to-speech or speech-to-text to help their spelling.

On the next day, they were asked to learn a song. The song was written on the board, and the lyrics were pointed out to them and mentioned one after the other. The lyrics were "Cast your burdens unto Jesus for He cares for you ."They recited the lyrics as they were pointed out to them, then they were taught the tune. Four students could point out the lyrics and sing them by themselves, but one of them could not. She could not differentiate between the words on the board because they looked many to her, and she was confused. After some tutelage and having the words voiced out to her, she was able to read them out and sing the song by herself.

When new words were introduced to them in a song, they were more receptive and learned the words faster. After the song, they could identify the words individually, and some of

them could spell the new words like "cast" and "unto ."They were able to learn new words when presented in the form of a song.

### **3.2 Secondary Research**

Information was gathered from existing research on dyslexic students and the technologies available to them to help them study. This section will compare various research papers based on sample size, focus, technologies, and recommendations.

#### **3.2.1 Comparing Different Software for Learning**

Goldfus and Gotesman [2010] researched what assistive technologies could best help dyslexic students learn. They matched specific assistive technologies to specific problems. For decoding and reading comprehension, text-to-speech was used. Speech to text programs were employed for handwriting directionality. Spell checkers were used for proofreading. This study was carried out to examine how competent assistive technologies are when students with language-related difficulties and Dyslexia use them [26]. The researchers organized an intervention program that lasted for three semesters. Ten students were involved in this experiment, and during each semester, they were presented with texts of different levels. The students were given 1500 beginner-level words with simple sentences during the first semester. They were given 2000 longer intermediate-level words with intermediate-level sentences and more sophisticated vocabulary. This was level two. They moved to level three in the third semester, where they were given 2600 advanced-level texts. Their ability to read level three texts and construe meaning from them was one of the goals of this research activity. Every student was given a computer and headphones. They tested two text to speech software, ReadPlease, and TextAloud. TextAloud was the best option because it read the text to the students in human voices, whereas ReadPlease read the texts in artificial voices, which the students complained about [26]. At the end of the research, the student's grades and reading ability improved. Researchers sent out a

questionnaire to determine which software was most effective, and 96% of the students selected TextAloud [26].

### **3.2.2 Computer Assisted Instruction**

An eight-week experiment was conducted with 48 children to monitor their reading progression. A game called DysEggxia was created by integrating specific spelling exercises. These exercises were made from real spelling errors made by dyslexic people, and the aim was to help the children determine that the words were misspelled and correct them [36]. The researchers also had another set of children playing a word search game on iPads. They found that those who played the DysEggxia game improved their reading skills significantly, while there was a slight improvement in those who played the word search game.

## Chapter Four: Implementation and Results

Dyslexic students need assistance with reading and connecting sounds to words they see. To assist them with this, a web application called DyxLearn was created. DyxLearn is progressive so that the children can use it even when there is no internet connection. It has an Optical Character Recognition (OCR) feature whereby the user can take a photograph of text, transform it into a pdf and have it read to them. DyxLearn also has text to speech features so that based on the user's choice, they can have texts read from the screen to them as their cursor hovers on them.

### 4.1 Implementation of Functionalities

Functionality	Implementation Method	Function
Speech Recognition and Speech Synthesis	Web Speech API	This component converts the user's spoken text to speech and reads out their typed input.
Optical Character Recognition (OCR)	Java Script with the packages: Express, Multer, and Tesseract	The OCR component will capture texts from pictures and convert them to texts.
Audio Books	Link to Loyal Books	Users can access over 7000 storybooks for free
Dyslexia Learning Resources	Upload resources, including worksheets, etc.	Users can access

*Table 4.1*



#### 4.1.1 Speech Recognition and Speech Synthesis

The API deployed to perform this task is the Web Speech API by MDN Docs (Mozilla Developer Network), as shown in Table 4.1. The Web Speech API provides speech recognition and speech synthesis functionality. The user speaks into the device's microphone for speech recognition, and whatever is said gets checked against possible grammar. If the string is recognized, results are returned [37]. Also, this speech recognition functionality makes it possible for dictation. The children can dictate what they want to be written, and it gets done for them.

The Web Speech API has variables that contain an array of strings the application should recognize based on the topic. For instance, an array of names such as

```
Var names = ['Mary', 'Amanda', 'Melody'];
```

```
var clothing = ['pants', 'boots', 'shirt'];
```

can be keyed in so that the speech recognition tool can determine the list of words to choose from before returning an output [37]. Next, the grammar (array of words) is plugged into the speech recognition instance by using a `SpeechRecognition()` constructor and `SpeechGrammarList()` constructor to contain a list of the grammar. The list is updated using the `SpeechGrammarList.addFromString()` method, which accepts the parameters to be added [37]. The Web Speech API has various methods for various functions. It has methods to set the language for recognition, set the number of possible maximum number of word alternatives, and control the capturing of results. A `nomatch` event handles errors that occur when an unrecognizable word is spoken. It returns possible alternatives and a message explaining that there is no such word [37].

Speech synthesis with this API entails assimilating text on a screen and reading it out loud to the user through the device's audio output. A controller called `SpeechSynthesis` works with other interfaces called utterances, the voices that read the text to the user. With this,

the user can change the voices reading the text, regulate the speed and change the pitch of the voice.

#### 4.1.2 Optical Character Recognition (OCR)

JavaScript was used to create an OCR engine (incorporating Express, Multer, and Tesseract packages), allowing users to upload the desired picture of any texts they want to be read to them. The Express package extracts the text from the uploaded image, multer makes it possible to upload an image, and Tesseract outputs the text in pdf format.

#### 4.1.3 Audiobooks

Reading storybooks helps enhance one’s vocabulary. The users can access thousands of audiobooks on Loyal Books, with over 7000 storybooks available. The link to this website will be embedded in the DyxLearn web application.

### 4.2 Functional and Non-Functional Requirements

Functional Requirements	Non-Functional Requirements
The user shall be allowed to create an account and sign in if they already have an account. They shall be allowed to change their password if needed as well.	Usability – The system shall be easy to understand and use by users.
The user shall have access to audiobook resources.	Maintainability – The system shall be updated and maintained as and when necessary.
The system shall have a speech-to-text functionality that allows users to speak and have it typed out.	Availability – The system shall be available for users at all times.
The system shall have a text-to-speech functionality that reads on-screen text to users.	Security – User’s information shall be secure.
The system shall have an Optical Character Recognition functionality that allows users to upload a picture and have the text extracted and read.	Performance – The system shall respond fast to the user's demands (clicking, text-to-speech, and others.)
The system shall grant users access to dyslexia learning tools to learn phonics, the alphabet and learn to read.	Capacity – The system shall be able to handle a large number of users at a time.

Table 4.3

### 4.3 Results

The DyxLearn system gives dyslexic students access to audiobooks, speech synthesis and speech to text functionalities, text-to-speech functionalities, optical character recognition, and dyslexia learning tools.

Functionality	Test	Results
OCR	An image with texts was uploaded	The system extracted the text from the image
Speech-to-text and Speech Synthesis	Words were spoken into the device microphone (testing API methods)	Spoken words were converted to text on the screen, and texts on the screen could be read out to the user
Audio Books	Clicking on the link provided	When the link was clicked, the user was redirected to a site and gained access to many audiobooks.
Dyslexia Learning Resources	Users clicked on available options	Users were able to access worksheets and activities to aid in their learning.

*Table 4.4*

## **Chapter Five: Conclusion**

### **5.1 Summary**

In this research, the question of whether technological provision can be made for children in Ghana with Dyslexia so they can access resources to help them learn and read with ease is answered. A system called DyxLearn was built, incorporating features that best aid dyslexic students with their learning. The DyxLearn web application comprised three components: speech synthesis and speech to text functionality, text-to-speech functionality, dyslexia learning resources, audiobooks, and optical character recognition. Web Speech API was used for speech synthesis and speech to text. JavaScript alongside some packages were used for the OCR aspect of the system. Audiobooks and dyslexia learning resources were also made accessible. The creation of DyxLearn proves the hypothesis that children with Dyslexia are intelligent and can thrive academically if they are given the appropriate technological resources.

### **5.2 Limitations**

It was challenging to find a school that had dyslexic children for observation. Finding a free API to aid with the speech synthesis aspect of the system was also difficult.

### **5.3 Suggestions for Future Work**

DyxLearn is a web application; however, developing it into a native application would make it much better and easier to use. Also, it only focuses on assisting dyslexic students with reading, but not mathematics, so updating the system in the future to add functionalities and updates to help with mathematics would be necessary.

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