Development of a Wearable Device to Improve Assessment and Learning Outcomes of Students with Disabilities

Adebowale Akinfaderin
National Open University of Nigeria Africa Centre of Excellence on Technology Enhanced Learning
akinfaderinadebowale@gmail.com

Yusuf Sahabi Ali
Department of Computer Science
Ahamdu Bello University,
Zaria, Nigeria
sahabi@abu.edu.ng

Ibrahim Abdullahi
Department of Computer Science
Ibrahim Badamasi Babangida University,
Lapai, Niger State, Nigeria

Ndunagu Juliana Ngozi
National Open University of Nigeria. Abuja
jndunagu@noun.edu.ng

S. A Hassan
Department of Computer Science,
Ahmadu Bello University
Zaria, Nigeria
myynzee@gmail.com

Abdulrazaq Abdulrahim
Department of Computer Science,
Ahmadu Bello University
Zaria, Nigeria
aabdulrahim@abu.edu.ng

Usman Mohammed Joda
Department of Information Technology,
Bayero University, Kano
umjoda@gmail.com

***Abstract*—Visually impaired students (VISs) often encounter challenges in traditional classroom settings, particularly in assessment and personalized learning. Ensuring their equal participation in education is crucial. Assistive technologies, including wearables and smartphones, play a pivotal role in promoting equality in education. International initiatives emphasize the importance of disability-friendly technologies and their availability. While more VISs participate in education worldwide, they still face academic, psychological, and social challenges. These issues are exacerbated by the organizational and structural characteristics of higher education environments. Enhancing VISs' learning and participation requires accessible materials and assistive technology (AT). However, there's a notable lack of research on AT for VISs in Africa. This study develops a prototype wearable device to support VISs' assessment and learning outcomes using design-science paradigm. This is achieved through five (5) phases that involve a detailed literature review, prototype development, web application development that will interface with the wearable device, and finally, establishing ethical data guidelines. The research study reveals key wearable features for VISs, personalization potential, ethical considerations, and technical challenges. Wearables can enhance assessment, support personalized learning, and improve VISs' outcomes. Ethical guidelines are essential, considering data privacy. Some of the implications of the research findings include inclusive education, improved learning, AT advancements, ethical use, and policy influence on disability-friendly technologies. This research study is highly significant as it has the potential to enhance educational opportunities, promote inclusivity, and improve VISs' learning outcomes through wearable technology integration in special education programs.**

Keywords—Visually impaired students, Assistive technology, Personalized learning, Prototype, Wearables

I. INTRODUCTION

In the realm of education, the pursuit of knowledge is an endeavor that transcends barriers, limitations, and differences. It is a fundamental right, universally acknowledged, that every individual, regardless of their unique abilities or disabilities, should have equal access to quality education. This concern to ensure equality and equity is evidenced in most of the international initiatives over the past decade, for example the UNESCO-Weidong Group project "Harnessing ICTs for Education 2030" which will, over four years, support participating Member States in harnessing the potential of ICTs to achieve ODS 4 by 2030. Yet, the reality faced by students with disabilities (SWDs) in traditional educational settings has often fallen short of this noble ideal.

Students with disabilities encompass a diverse group of individuals, each navigating their educational journey with distinct needs, challenges, and aspirations. From visual impairments to cognitive disabilities, the educational experiences of students with virtual impairments (SWVIs) have long been characterized by hurdles that extend beyond the curriculum itself. These hurdles encompass physical barriers, communication gaps, and limitations in assessment methods that fail to account for the diverse ways in which SWVIs learn and demonstrate knowledge. Additionally, these challenges limit their learning and achievement in different activities taking place in the traditional classroom settings, particularly when it comes to assessment and personalized learning [1]. Internationally, an increasing number of students with disabilities SWVIs are accessing and actively participating in education. Data from the European Commission for example, indicate that over three quarters of children with disabilities are enrolled in mainstream schools in Portugal, Spain, Ireland and Italy. In the USA, increasing levels of engagement have also been documented, with 65.8% of SWVIs participating substantially, if not fully, within mainstream public school classrooms. While the increasing participation of SWVIs in higher education points to more inclusive education systems, SWVIs still face academic, psychological and social challenges. Some disabilities affect students' capacities to actively engage in coursework, others affect students' abilities to move freely around campus. These types of difficulties are exacerbated in the organizational and structural characteristics of higher education environments e.g., large numbers of students in noisy lecture theatres, buildings with poor accessibility [2].

Disability support services within the educational environment are of utmost importance to SWVIs in promoting a sense of belonging and ensuring the appropriate supports are received [2]. It is essential that SWVIs have access to the same educational opportunities in the society as their peers [1]. Technology is playing a vital role in overcoming these hindrances to actualization of every child's dream.

However, SWVIs are faced with tremendous challenges from the traditional classroom setup in their educational pursuit. They are stigmatized and left to make do with little or no support provided. Their educational journey is often marked by a disconnect between their unique needs and the tools available for assessment and learning. Traditional assessment methods may not accurately capture their abilities, leading to disparities in educational outcomes. Additionally, the challenge of personalizing learning experiences to cater to the diverse needs of SWVIs remains a critical concern. These types of challenges are exacerbated in the organizational and structural characteristics of the traditional learning environments e.g., large numbers of students in noisy lecture theatres, buildings with poor accessibility [2]. The existing gap between traditional education and the potential of wearable technology underscores the need for a solution that can bridge these disparities.

This paper is organized as follows:

Section I present the introduction while in section II a review of the literature is carried out. Section III presents the methodology while section IV present the results and discussion. Finally, section V provide the conclusion of the entire research work.

II. LITERATURE REVIEW

A. Students with Disabilities

In the realm of inclusive education, the education of students with disabilities has garnered significant attention and become a focal point for educational policy, practice, and research. The inclusion of students with disabilities in mainstream educational settings is a reflection of society's commitment to ensuring equal access to education and the fundamental right of all students, regardless of their abilities, to receive quality education. The term "students with disabilities" encompasses a wide range of abilities, needs, and challenges, making it a diverse and dynamic field of study and practice within education.

Students with disabilities form a significant portion of the student population in many educational settings. The term "disabilities" encompasses a wide range of conditions, including but not limited to physical, sensory, cognitive, and emotional impairments. These students often face unique challenges in accessing and benefiting from traditional educational approaches, necessitating tailored strategies and technologies to support their learning.

B. Challenges faced by Students with Disabilities

The inclusion of students with disabilities in mainstream educational settings is a commendable step toward achieving equal access to education. However, educating students with disabilities presents both challenges and opportunities for educators, policymakers, and society at large. These set of students' encounter challenges that hinder their learning and achievement within traditional classroom environments, especially in terms of assessment and personalized learning [3]. Challenges include meeting the diverse needs of students with disabilities, ensuring appropriate support and accommodations, and addressing issues related to social inclusion and stigma. These challenges highlight the necessity of exploring innovative approaches that can overcome these barriers and provide tailored support to meet the unique needs of students with disabilities. One of the most notable interventions in overcoming these barriers is the Assistive technology. Thus, it can be stated that AT is successful and necessary to ensure the inclusion of this population in the classroom [4].

Despite the progress made in inclusive education and assistive technology, students with disabilities continue to encounter numerous challenges in their educational journey. These challenges encompass physical barriers, such as inaccessible infrastructure, as well as attitudinal and societal barriers that perpetuate discrimination and stigmatization. Additionally, there may be a lack of awareness and training among educators in implementing inclusive practices and leveraging assistive technologies effectively

C. Assistive Technology in Education

The World Health Organization (WHO) defines assistive technology as a broad term encompassing systems and services related to the use of assistive products [5]. "Assistive Technology" (hereinafter AT) according to the World Health Organization (WHO), is a generic term that designates all systems and services related to the use of assistive products and the performance of services [6]. Generally, and according to the AT Act of 1998, in the U.S. it is defined as "any item, piece of equipment or system, whether acquired commercially, modified, or customized, that is commonly used to increase, maintain, or improve the functional capabilities of people with disabilities" [7]. Assistive technology encompasses a wide range of tools, devices, software, and strategies designed to enhance the learning experiences and capabilities of individuals with disabilities. For [4], AT has two main purposes: on the one hand, to increase a person's capabilities so that his or her abilities balance out the effects of any disability. And second, to provide an alternative way of approaching a task so that disabilities are compensated. AT encompasses a broad range of devices, software, and tools designed to assist individuals with disabilities in various aspects of learning and daily life. These technologies, including screen readers, speech recognition software, alternative communication devices, and adaptive learning platforms, empower students with disabilities to participate fully in educational activities, fostering an inclusive educational environment.

In the pursuit of equitable education, the role of AT has become increasingly significant. The incorporation of assistive technology in educational settings holds the promise of reducing barriers to access, promoting inclusive learning environments, and leveling the playing field for students with disabilities. AT emphasizes the importance of ensuring equal opportunities for students with disabilities in education and

society as a whole [8]. In other words, Assistive technology (AT) plays a pivotal role in promoting equality in education for students with disabilities. The International Convention on the Rights of People with Disabilities, adopted by the United Nations, further emphasizes the need for research and development of disability-friendly technologies [5]. These initiatives provide the backdrop for incorporating assistive technologies, such as wearables into educational settings to promote equality and equity.

D. Related Works

One of the fundamental components of the United Nations' sustainable development 2030 agenda is quality education. It aims to ensure inclusive and equitable quality education for all. Digital technologies have emerged as an essential tool to achieve this goal [9]. This has resulted in the search for equitable technology by researchers, thereby, increasing the commitment of nations in ensuring the inclusion of students with disabilities in the use of digital technologies most especially, AT in education [8]. Nowadays, technologies have become a knowledge provider, co-creator of information, a mentor, and an assessor [9]. Thus, giving a complete information about the educational performance as well as areas of improvement for all and sundry. There are so many literatures on the use of technology in education most especially from the developed nations [4]. For instance, authors such as [10] studied how specialized technologies contribute to the development of skills that provide stimulation and support to this group of students. For [11] AT is able to fit instantly to a student's level and provide instant feedback for improved learning. In addition, they support students with disabilities in performing tasks or functions that they would otherwise be unable to do [12]. For their part, [13] focused on improvements in academic performance and language development. [14] conducted research on the use of Multimedia Assistive Technology (MAT), finding that these tools improve the performance of university students. [10] reviewed the role of digital technologies in education as well as their challenges. They found out that technologies have open a new vista of life in the educational field where they help improve access and also increase productivity on the side of instructors and students alike. They also identify several challenges such as excessive screen time, lack of qualified instructors to handle these technologies. [15] studied the use and impact of assistive technology for people with visual loss. He found out that such technology enhances the functioning and performance of daily living skills, thereby improves the independent living. [16] carried out a comprehensive review of the use of AI in education. They extract 4,519 publications from 2000 to 2019 which indicates a growing interest in the use of AI in education by the academic community. The challenges encountered as well as future direction were presented. The study is a testament to the ever-growing interest in the use of emerging technologies to improve educational accessibility and learning outcomes. [1] in their study explored the role of assistive technology devices in facilitating the participation and learning of students with visual impairment in higher education institutions in Tanzania. Twenty-one respondents were purposively involved in an open-ended questionnaire survey and semi-structured interview, seventeen of whom were students with visual impairment and four were transcribers. The study found that students with visual impairment were well-acquainted with the meaning of assistive technology. However, their knowledge was limited to the assistive technology devices available at their institution. Most of the students with visual impairment emerged as dependent users of assistive technology devices, who depend on the support of either sighted students or a more skilled person. Based on their findings, they recommend that higher education institutions provide adequate and sustainable funding for assistive technology to ensure that students with visual impairment benefit from the education they get. [4] carried a systematic review of studies regarding the impact of Assistive Technology for the inclusion of students with disabilities. A total of 31 articles that met the inclusion criteria of the review were extracted, out of a total of 216 identified. According to their findings, AT has emerged as a suitable instrument for both accessibility and inclusion of students, as well as for meeting their educational needs during their learning process [17,18]. Barriers such as teacher education, lack of information or accessibility are found. Furthermore, they also found that, with respect to the countries that concentrate the greatest scientific production in this field, mainly in the United States, followed by Brazil and Turkey. This fact enables a reflection on future research in order to know if the country and its context affect the use of these technologies for the inclusion of students. [19] studied the inclusion of people with disabilities amid COVID-19 in the Philippines. Their study examines the laws of the Philippine Government on the provision for the inclusive special education and rights of the said learners, highlights the possible educational interventions to supplement their learning amid the pandemic and offers recommendations for the emergency preparedness legislative policies and services to be responsive to the educational, socio-emotional, and mental health needs of the students with disabilities amid the pandemic. [2] systematically reviewed the impact of assistive technology on educational and psychosocial outcomes for students with disabilities (SWDs) in higher education. The researchers use 26 papers for analysis. They identified four analytic themes; "AT as an enabler of academic engagement"; "barriers to effective AT use can hinder academic engagement"; "the transformative possibilities of AT from a psychological perspective"; and "AT as an enabler of participation". They finally conclude that AT can promote educational, psychological and social benefits for SWD. However, AT users and AT officers must be aware of certain factors, such as inadequate AT training, inadequacies of devices, availability of external support and the challenge of negotiating multiple information sources, can hinder effective AT use and thus restrict engagement in the higher education environment. They also proposed that AT practices should focus on harnessing the potential of mainstream devices as AT for all students, thus facilitating inclusion and reducing stigma.

It is also believed that AT will help foster all-inclusive learning [8]. In this regard, other studies conclude that the potential use of AT for students with disabilities will promote inclusion and decrease stigma [20,21]. From the

aforementioned literatures, it can be clearly seen that AT holds a great potential for the advancement of inclusive learning for those students with disabilities. However, it is evidently clear that there are challenges that include unavailability of AT for the developing nations, which could be attributed to lack of research in this area from these nations. Therefore, it become expedient for this research to conducted so that a prototype AT can be produced locally which holds the potential to be mass-produced for those students with disabilities.

III. METHODOLOGY

The research methodology refers to a set of guidelines, procedures and rules which provide a framework for how to conduct a research study. It includes the phases, rules, patterns, techniques and procedures that arc used to achieve the particular research objectives. The methodology used to conduct this research is presented in this chapter.

A. Research Design

Research design comprises the methods and procedures that guide researchers in conducting their studies from start to finish. [22] defined research design as the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions. This research will involve a mixed-methods approach to address the research questions. In the first phase, we will conduct a thorough review of the existing literature to identify the key features that new wearables should have to best support the assessment and learning outcomes of students with disabilities. This will include a review of current wearable devices used in special education programs, as well as emerging technologies that could be adapted to meet the needs of students with disabilities. In the second phase, we will develop and test prototype wearables that incorporate the key features identified in the literature review. This will involve working closely with educators and students with disabilities to ensure that the prototypes are tailored to their specific needs and preferences. We will conduct usability and feasibility testing to evaluate the effectiveness of the prototypes in supporting the assessment and learning outcomes of students with disabilities.
In the third phase, we develop a web/mobile app that will interface with the wearables to ensure seamless communication. This will ensure that all the needs of the student are always communicated to the appropriate channel.

In the fourth phase, we will examine the ethical considerations related to the collection and use of data generated by wearables in special education settings. We will conduct focus groups and surveys with educators, students, and parents to gather their perspectives on these issues, and develop guidelines for the ethical use of data generated by these technologies.

Figure 1 present the proposed wearable devices that will be used by the students. The device has two buttons that helps the student to accept and reject commands as can be seen from the figure.

Fig. 1. Proposed wearable device

B. System Architecture

The system architecture is the model that conceptually defines the views, structure, and behavior of the system. System architecture in other words is the representation and description of how the system works and communicates with other system components in general. The architecture of the proposed system is presented in figure 2.

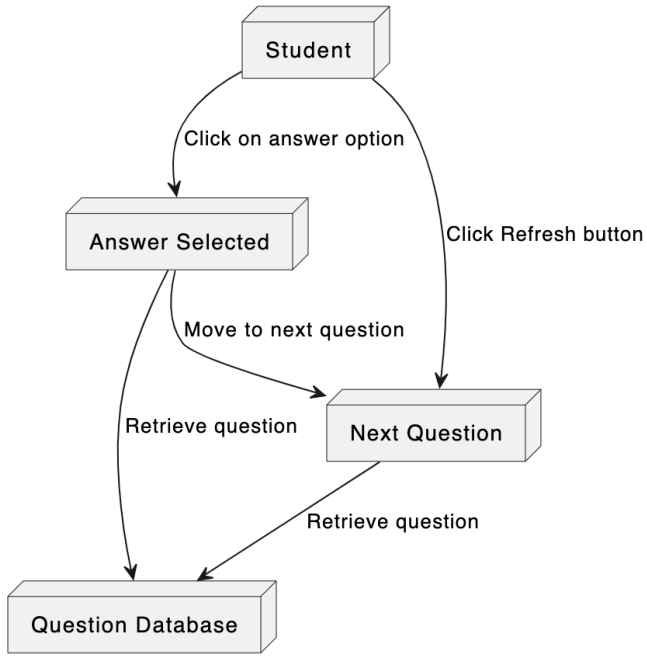

Fig. 2. System architecture

IV. RESULTS AND DISCUSSION

In this section, the results obtained (wearable device) will be presented and the functionality of each component examined. This will be achieved by presenting the screenshots and their functionality.

Instruction Page: This screen reads out the course information and instructions on how to start the examination. Then the user is expected to take two actions here:

- Press the SMOOTH BUTTON two times to start the exam, which will load the next page.
- Listen to the Instruction again by pressing the side button

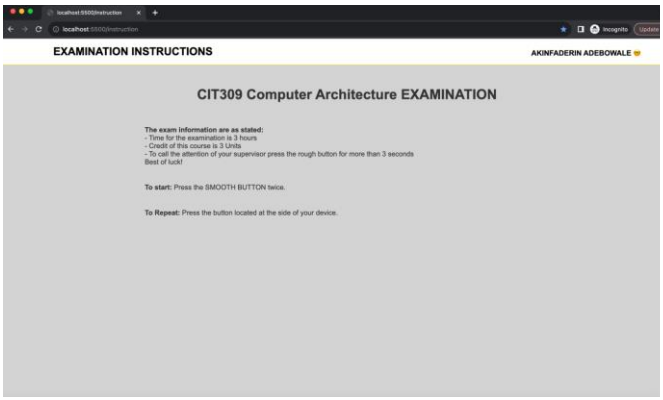

Fig. 3. Instruction page

Question page: This page displays question 1, the question is read out for the student to listen, then the student can use the device to:

- Select preferred answer by pressing the ROUGH button base on the answer position; A: Once B: Twice C: Three Times D:Four Times

And use the SMOOTH button to submit selection, then the system reads out the selected option to allow the student to either confirm selection by Pressing the SMOOTH button again or to retake the question by Pressing the side button.

If the user submits the answer, then the next question is displayed.

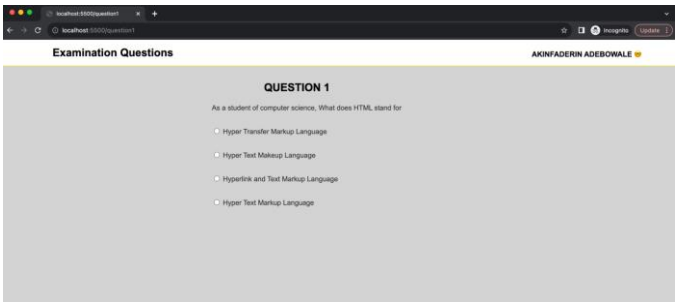

Fig. 4. Question page

Question page: This page displays question 2, after the user must have submitted the answer in question 1. The same process applies as the system reads out the question to the student to listen, then the student can use the device to:

- Select preferred answer by pressing the ROUGH button base on the answer position; A: Once B: Twice C: Three Times D: Four Times

And use the SMOOTH button to submit selection, then the system reads out the selected option to allow the student to either confirm selection by Pressing the SMOOTH button again or to retake the question by Pressing the side button.

The same cycle of events continues until the last question.

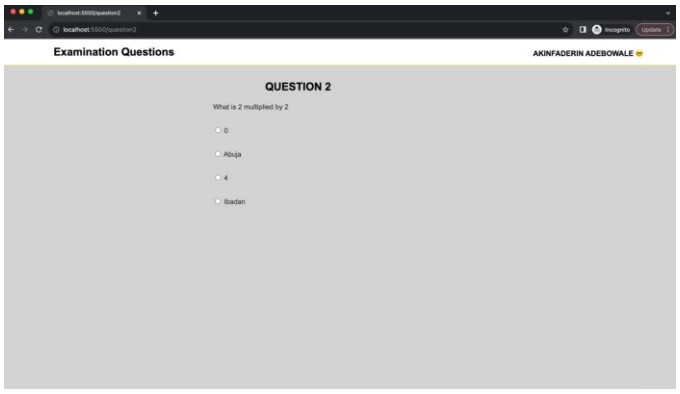

Fig. 5. Question page

Closing page: This is a final page that is displayed to just show that the test is over. It is a sample that is designed specifically for the purpose of presentation of the process flow of the device.

The result obtained in this study is a prototype wearable device (as shown in figure 5) designed for the visually impaired students. It is meant to enhance their learning process and also improve accessibility to assistive technology that will support them in their academic pursuit.

The device developed is cost effective, in the sense that, it is locally produced with some of basic devices. This implies that, it can be mass produced for the benefit of those visually impaired students. The screen reader section of the device provides the students with a clear instruction as well as the questions to answer. These reader is user friendly that it can allow for repetition until the question is crystal clear for the student to proceed and choose an option. Once an option is selected, the student will hear the system reading the selected option. This will allow the visually impaired students to have total control of the examination process which will in turn improve their academic performance.

The buttons on the device vary in terms of their texture (i.e. smooth and coarse) so that the will know which button to press at any point in time. This is an important design aspect that will go a long way in helping the students to navigate the wearable device. Effective system navigation is an important aspect of

any device that determines its success or failure when it is deployed in the field.

Fig. 5. Wearable prototype

A. *Implication of the Results*

The implication of the result of this research study is that it will provide a cost-effective assistive technology that can be mass produced by the stakeholders in order to improve the learning process of the visually impaired students. This is because, when these students gain access to such technology, it will elicit their firm desire to continue their academic pursuit as they will have no fear of being left behind as is the case in the traditional educational system. Some of the major research implications are:

Inclusive Education: The research promotes equality in education by using wearables to support SWDs, fostering inclusivity.

Improved Learning: Personalized learning through wearables enhances SWDs' engagement and academic achievement

AT Advancements: The study informs the development of future assistive technologies, benefiting SWDs and others with similar needs.

Ethical Use: Guidelines ensure responsible data usage, upholding privacy in special education.

Policy Influence: The research aligns with international initiatives, contributing to discussions on disability-friendly technologies.

Future Research: This study inspires further research in technology-supported education for diverse learners

V. CONCLUSION

Students with VI require a variety of AT devices to cater for their learning and mobility needs in addition to enabling them to write and read proficiently and become self-reliant. This study has explored the development of a wearable assistive technology that will help the visually impaired students in the academic pursuit.

In conclusion, the development of wearable devices in education offers promising solutions to the challenges faced by students with disabilities. Our research has highlighted the potential of these technologies to improve assessment processes, support personalized learning, and create more inclusive educational environments.

While challenges remain, this study has laid the foundation for further exploration and innovation in the field of special education. As we move forward, it is our hope that the findings and recommendations presented in this thesis will inspire future research and collaboration, ultimately leading to more accessible, equitable, and inclusive education for all students, regardless of their abilities or disabilities.

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