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RESEARCH ARTICLE

Hausar Kurma: Development and Evaluation of Interactive Mobile App for the English-Hausa Sign Language Alphabet

AHMED LAWAL[1], NADIRE CAVUS[1,2], ABDULMALIK AHMAD LAWAN[3], AND IBRAHIM SANI[4]

[1]Department of Computer Information Systems, Near East University, 99138 Nicosia, Cyprus
[2]Computer Information Systems Research and Technology Center, Near East University, 99138 Nicosia, Cyprus
[3]Department of Computer Science, Kano University of Science and Technology, Wudil 713281, Nigeria
[4]School for Special Education, Federal University, Gusau, Gusau, Zamfara 860231, Nigeria

Corresponding author: Ahmed Lawal (ahmedkaura@gmail.com)

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ABSTRACT This study aimed to assess the effectiveness of a mobile app named "Hausar Kurma" in teaching English to Hausa-speaking hearing impairment students in Nigerian special schools. A single-subject design was used to evaluate the impact of the application. Evidence-based practices were employed to assess the performance of the educational tool and to ensure compliance with the gold standard. Various single-subject design methods, including the celeration line, binomial test, and Wilcoxon signed-rank test, were used. A sample of ten primary school students selected from a special education school was used in this study. A pretest examination was conducted, followed by eight weeks of training using the developed mobile app, and a posttest examination was carried out. Our findings demonstrate the effectiveness of evidence-based research for evaluating educational tools and their efficacy in special education. A higher number of data points above the celeration line indicated a significant improvement in participants' academic performance. Additionally, the binomial test conducted after a 95% confidence interval yielded a probability of 0.0098, indicating a noteworthy enhancement in student performance. At the same time, a Wilcoxon signed rank test conducted using IBM SPSS Statistics 27 on the pretest and posttest data yielded an effect size of 0.633, indicating a strong Cohen's large effect classification. Similarly, the usability test conducted indicated a higher acceptance rate of the application by the users. The results of this study confirm the utility of the app and recommend its implementation in special schools to enhance English language instruction for hearing impairment and hard-of-hearing Hausa-speaking students in special education institutions.

INDEX TERMS Special education, hearing impairment students, English language teaching, Hausa sign language, primary school.

I. INTRODUCTION

There are approximately 360 million hearing impairment or hard-of-hearing people around the world, of which 8.5 million are Hausa-speaking and reside in northern Nigeria [18]. These groups of people find it difficult to communicate with and integrate themselves into their communities. It is also difficult for them to acquire formal education together with their peers because of numerous factors, including social and academic challenges [20]. Over the years, Nigerian governments have implemented various policies and strategies for special education of people with special needs. One of these policies is the establishment of a committee in collaboration with the ministries of health, labor, social welfare, and other stakeholders that would coordinate the activities of special needs and inclusive education [21], [47]. Similarly, different interventions for the establishment of special schools, curriculum reviews, and institutional development frameworks

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have been implemented, while providing education for people with special needs free of equal opportunities for all learners [21].

However, a large portion of the Hausa hearing impairment community is either out of school or has enrolled but finds it difficult to study English or other subjects. Educational interventions have failed to address the methods of delivery that cause a gap between disabled learners and their peers [5]. Particularly in Nigeria, learners with special needs are included in mainstream classes without adequate provision of learning aids, especially educational technologies for sign language translation and interpretation [21].

This study aimed to evaluate the effectiveness of a developed Android mobile app called Hausar Kurma for teaching English to Hausa hearing impairment students in Nigerian Special Primary Schools. The study established the existence of a significant difference between the pretest and posttest performances of the students.

This paper is organized into five sections, including an introductory section. Section two highlights the conceptual framework of this study. Section three presents the related literature. The fourth section discusses the methodology, prominent computer-aided tools used in information system development, and future research directions. Finally, the fifth section concludes the paper and presents the findings.

II. RELATED RESEARCH

Usability is defined as the learning ability, efficiency, memorability, errors, and user satisfaction, for which evaluation methods are performed using certain procedures [24]. A single-subject study involves a prospective and intensive study of individuals by manipulating interventions controlled across discrete steps [38]. It is an alternative to group design and is used in special education because of the provisions it provides for people with disabilities, allows evaluation of the effectiveness of an intervention on students [3], and establishes evidence-based practice [44]. Traditionally, single-subject studies have been graphically analyzed using visual analysis, in which the trend, level, variability, and slope of graphed data are considered for interpretation [43], [45]. However, visual analysis is subject to subjectivity and inconsistency in the evaluation of interventions [45]. It should be supplemented with other evaluation methods unless there is a clear pattern with sufficient and stable baseline data [46]. Similarly, a single-subject study was conducted in a pretest/posttest to evaluate the efficacy of software in enhancing the writing skills of children with poor handwriting skills [29]. A quantitative study using a single-subject reversal design was implemented in [9] to study the impact of a computer-based system called an iStation on the reading achievement of third-grade students with learning disabilities. The author used a sample of 100 third-grade students with learning disabilities, ANOVA to analyze the quarterly assessment of the data, and an F-ratio to analyze whether the computed means differed from one another.

The same methodology was used in kindergarten classes to investigate the reduction in students' disruptive behavior [10]. Attention Deficit Hyperacidity Disorder (ADHD) has been treated for three 8-9 years in children [11]. Predict or assess interventions for students to improve oral reading in word lists, prose passages, and letter lists [12]. Factors that enhance the use of augmentative and alternative communication (AAC) in successful implementation, acquisition, and usage have been identified in people with autism spectrum disorder (ASD) [14]. The effectiveness of point-of-view video modeling was determined by adopting a single-subject research methodology to improve the mathematical skills of elementary school students with ASD [15]. Chee et al. [17] developed an Android app to aid the limited vision, hearing impairment, and non verbal individuals' learning processes through social constructivism. The app contains a translator, chat, Bluetooth chat, and standalone communication helper used to enhance the accessibility of the app.

Other applications have also been developed for the translation of sign language, which is used for teaching on Android, as well as for cross-platform devices. In this respect, [64], [65], [66], [67], [68], [69] developed sign language translators for the Android platform that translated the Indian, Indonesian, Hindi, and Filipino languages. References [70], [71], [72], and [73] developed cross-platform applications also aimed at translating sign language to English for educational purposes.

On the other hand, to evaluate the usability of the developed mobile device application, the Wilcoxon signed-rank test was used by [53] to conduct a study using a pretest/posttest to observe the effectiveness of a fading technique method in behavior modification treatment for three hearing impairment students. The authors introduced 15 new vocabulary words to hearing impairment students within four 60-minute sessions.

Reference [60] found a strong correlation between age, Intelligent Quotient (IQ), and period of sign language use on a five-point Likert scale in an application called Miranda Warning, and Waiver translated English into its corresponding American Sign Language. Similarly, [61] conducted a usability test using a sample of 10 hearing impairment participants and 15 normal volunteers to evaluate an Android application that translated Arabic signs into the corresponding English language for Arabic-speaking hearing impairment students. The authors used a 5-point Likert scale to obtain a 95% success rate. Another study [62] performed visual and qualitative analyses of an Android app developed for students with hearing impairments to accelerate reading fluency. Based on the literature review, it was determined that mobile applications have been developed by other researchers. However, it has also been determined that these applications are either not performed following ISO standards for usability tests or are only developed and not used in experimental studies, that is, in experimental studies with Hausa hearing impairment students. However, since Hausa hearing impairment students have special needs, the mobile applications developed should respond to their needs one-on-one. For this reason, there is a need for mobile applications that can be used for educational purposes to teach Hausa hearing impairment students in English.

III. CONCEPTUAL FRAMEWORK

A. SIGN LANGUAGE AND MOBILE DEVICES

Sign language is a coordinated gesture through which hearing impairment or hard-of-hearing people communicate with their surrounding communities [18]. The advent of information and communication technology has facilitated the translation of sign language to students with special needs in educational settings. Additionally, mobile devices provide new possibilities and support for teaching and learning by integrating learning tools that can be adopted for educational purposes by hearing impairment students [2], [5], [16], and [17]. Mobile devices also facilitate learning by creating innovations, extending learning environments, and motivating and enhancing collaboration among students, both inside and outside the classroom [26]. More than three billion mobile devices are currently in use worldwide [5]. However, these devices are used and developed stereotypically regardless of the hearing impairment community [23], [52]. Moreover, to design a system tzs3321 hat that is accessible to the hearing impairment community, certain features must be considered, including interaction ability with the sign language, the number of hearing impairment people in a community, and multiple dialects of the sign language [23]. Similarly, to evaluate the performance of designed systems in the hearing impairment community, a usability test must be conducted [22].

B. SYSTEM EVALUATION

Usability testing is a method used in the evaluation of a developed system, service, or product to identify problems and collect quantitative and qualitative data [4]. It is used to determine the effectiveness and satisfaction of products or services using a given set of standards [8]. The main goal of usability testing is to identify the components of software that work and those that do not in assessing user efficiency, effectiveness, and satisfaction. It is also used to validate the functionality of the system and detect errors [24]. The evaluation is performed on a developed system by considering users' opinions so that the system can be improved based on the evaluation of the results [1].

People with hearing disabilities are usually less literate and find it difficult to use English [5], which implies the need to be supported with pictures, images, videos, etc. to make it easier for them to remember and recognize the meaning of a particular sign [2]. Accordingly, usability testing can be performed using demography, existing approaches, observing user behavior, user motivation, end-to-end user experience, and overall user impressions [6]. To effectively achieve well-designed usability testing and system evaluation that meets mobile-based app/software quality and ISO standards that suggest functional, reliable, efficient, maintainable, attractive, understandable, accurate, and portable software products, [2], [5]

C. EVIDENCE-BASED PRACTICE

Evidence-based practice is a scientifically verified intervention procedure considered to be effective enough to change behavior and performance, and to evaluate the efficacy of interventions on a particular group of participants under given conditions [10], [16], [36]. Techniques that conform to ISO standards are used to evaluate the efficacy of mobile app interventions developed for special education [2], [5]. Many methods have been used to conduct quantitative research on special education, including quasi-experimental, causal-comparative, and single-subject studies [9]. A quasi-experimental design is evidence-based practice that is conducted with barriers to conducting randomized control trials [48]. It is used in comparative interrupted time-series design, matching and propensity score design, instrumental variable design, and regression discontinuity design [13]. On the other hand, the causal-comparative study is used to determine the cause-and-effect relationship between variables. However, the presence of many variables limits their application. It is used in the determination of t-tests, non-parametric statistics, analysis of variance, and so on [9]. Another method used to establish evidence-based practice is a single-subject study [16], [36], which is commonly used to test the efficacy of an intervention [10]. It is also used to compare the performances and behaviors that occur in an experiment before and after an intervention [3].

D. SINGLE-SUBJECT STUDY

A single-subject study is evidence-based research that is frequently used in experimental design [38]. It relies heavily on visual analysis procedures as the primary means of evaluation, and statistical tests as secondary [36]. It is used because of its practical application in special education, with a low-incidence student population and ethical considerations. It supports the individual participant, operational definition, baseline or intervention conditions, experimental control, target behavior that can be measured repeatedly, interventions that can be repeated systematically, and visual and statistical analyses of the interventions [35], [36], [40]. The lack of formal decision rules, reliability of judgments, and propensity for type I errors hamper the application of visual analysis [19], [37]. However, some striking features of statistical analysis are that it is used when there is unstable baseline data; it can detect small treatment effects that may be ignored in visual analysis; and when used in serially dependent data, consistent results are obtained [37].

According to [3], the basic characteristics that make a single-subject study desirable in special education include reliable measurement, repeated assessment, baseline and treatment conditions, description of conditions, and a single-variable rule. Similarly, [35], [36], and [40] asserted that a single-subject study is ideal for special education for the following reasons: when conducting a group experiment, when a small number of participants is to be considered; it measures the performance of individual participants, making intervention and evaluation critical; the need for a control group does not exist as each participant serves as his or her own control group; the ethical problem of withholding treatment from the control group is eliminated; it is suitable for teacher-initiated research in schools, and direct interpretation of results. A single-subject study identified causal relationships between an intervention and an observed effect in a specific setting and context and with a specific individual [36]. It allows the intervention to be removed at a given juncture to ascertain whether there is a functional relationship between the intervention and desired behavior in special education [35]. It can be used to replicate studies on a larger scale [9]. An important feature of a single-subject study is its application to a single participant and a range of three to eight or more participants at a time [3], which is more applicable than quasi-experimental or causal comparative studies. The split-middle method of trend estimation or celeration line, two-standard deviation band, randomization tests (t-test and f-test), and autoregressive integrated moving average (ARIMA) are the common methods used to compute single-subject studies [37], [40]. It can be performed through judgments, quantitative (means, trend, variability, etc.), and statistical analyses (celeration line, running medians, two standard deviation bands, etc.) [41]. However, there are no rules for determining the number of participants in a single-subject study [2]. This study was conducted using visual analysis and other statistical methods, as emphasized by [3] and [33], indicating that statistically reliable and significant results can be obtained through comparison.

IV. METHODOLOGY

In this study, a single-subject study was implemented, which is the most feasible and cost-effective type of research used in research involving people with disabilities in special education [3]. This is because of the common attributes of a few observations [37], [49], and the strategy used to obtain reliable results is to compare results from more than one methodology [3], [33]. A quasi-experimental research method on a single-subject study with a one-group pretest-posttest method that measured the behavior of subjects before and after treatment [53] was used to collect quantitative data.

A. PARTICIPANTS

In special education, a single-subject study that allows individual students to be treated as a unit of concern and employs a small sample size is typically used [3]. One of the essential features of a single-subject study is the individual participant data analysis [35], [44]. It can also focus on multiple participants in the range of three to eight [39, p. 166]. It typically includes three to five subjects with the same performance problem to evaluate the intervention and locate an individual subject [27, p. 184]. In this study, a sample of ten Hausa-speaking hearing impairment primary school students of Zamfara State Special School, Gusau, was selected using judgmental or purposeful sampling for the experiment, as shown in Table 1. The table shows six and four students, representing 60 percent male and 40 percent female students, respectively, with an average age range of 5-7 years, respectively. The head teacher/principal of Zamfara State Special School Gusau consented to the research as custodians and guardians of the students entrusted by the government. It is extremely difficult to select an adequate number of participants from the population because of limited accessibility [35]. The same set of participants was used to conduct the usability test. This is used to describe the quality and suitability of the application from the students' perspective [2]. Data collection was facilitated because the students were familiar with ASL and HSL and participated in the training. A five-point Likert scale was used to collect the students' opinions and evaluate their applications.

TABLE 1. Student demography.

Student ID	Gender	Age
Stud-1	Male	7
Stud-2	Male	6
Stud-3	Female	7
Stud-4	Male	7
Stud-5	Male	7
Stud-6	Male	6
Stud-7	Female	5
Stud-8	Female	6
Stud-9	Female	7
Stud-10	Male	7

B. THE DEVELOPED MOBILE APP: THE HAUSAR KURMA ANDROID APP

The proposed mobile app was developed as an artificial intelligence (AI)-based system and android-based educational system to help Hausa-speaking hearing impairment students learn English in Nigerian special schools. The Android app was chosen because of its versatility and because it does not require the Internet to operate [17]. A fast and easy web-based artificial intelligence (AI) platform, referred to as Google Teachable Machine (GTM), was used to develop and train the model. GTM allowed us to create machine learning models accurately and precisely using a convolutional neural network [32]. This is achieved through the provided project methods such as images, poses, and audio. The most important feature of GTM is that machine learning, training, and image classification can be achieved without any code or technical expertise [35], [39]. TensorFlow.js files, which can be used to train and run user models on Java-enabled tools including node.js, P5.js, Glitch, TensorFlow, and Java [28], [34], were created from the GTM model. In this study, the GTM Image project was used to train the model with a standard image size of 224×224 pixels.

Image classification projects involve input in the form of a picture or video stream, giving an output class and a probability that the input is of a particular class [34]. Each

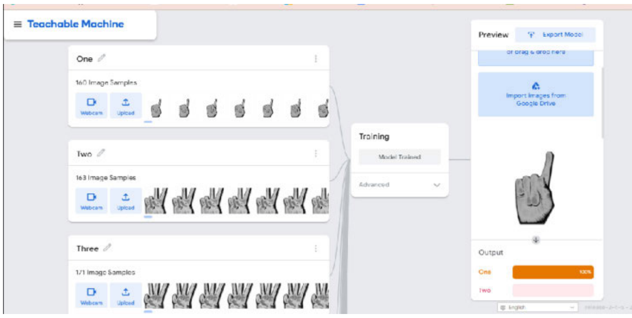

FIGURE 1. Accuracy of image classification from the Google teachable machine corresponding to one in the Hausa Sign language.

class contains a minimum of 160 to 176 sample images that are used to train the model. To have higher classification accuracy, the model default settings of 50 epochs, 16 batch sizes, and 0.001 learning rates were adopted. The model training was observed to have been completed in fifteen minutes and forty-three seconds. The accuracy of the trained model was tested in the teachable machine preview pane, as shown in Figure 1. It can be observed that an accuracy of 100 percent for image classification has been achieved. The model was finally converted as a zipped and downloaded as a quantized TensorFlow or TensorFlow lite (.tflite) file for integration into Android Studio using the Java programming language for local use [34]. TensorFlow Lite is a lightweight deep-learning framework that allows users to deploy models on mobile devices, microcontrollers, and other devices [30]. These are achieved by training or using existing models, converting the model into a flat buffer, compressing the quantized tflite file onto a mobile or embedded device, and converting the 32-bit floats into an 8-bit integer that runs more efficiently on Graphic Processing Units (GPU) [31]. The final copy of the project was saved in Google Drive for retrieval and future updates.

The exported TensorFlow Tflite ML model was implemented using the Android Software Development Kit (SDK) with Android Studio chipmunk/2021.21, API level 28, minimum SDK 21, compiled SDK 29, target SDK 30, and Gradle Version. Runtime version 11.0.12+7-b1504.28-7817840, an AMD64 Processor, and OpenJDK 64-Bit on Windows 10 were used in the development of the app. Integration was achieved by importing the extracted tflite ML model into the ml folder of the studio, and the labels.txt files were integrated into the asset folder. Extensible Markup Language (XML) is used in the design of user interfaces. Similarly, the Java programming language was used for programming and the SQLite relational database was used to store the images of the Hausa sign language, admin, student, and student performance records in the system. The application design and the manner in which the application interacts with each component are shown in the workflow diagram in Figure 2.

The effectiveness of the app was checked by conducting visual and statistical analyses of the data collected using pretest exams (baseline), after which the students were trained on the use of the Hausar Kurma Android app within eight weeks of class tutorials and posttest exams (intervention) that were conducted after the training. A sample image of the application user interface is shown in Figure 3a and 3b.

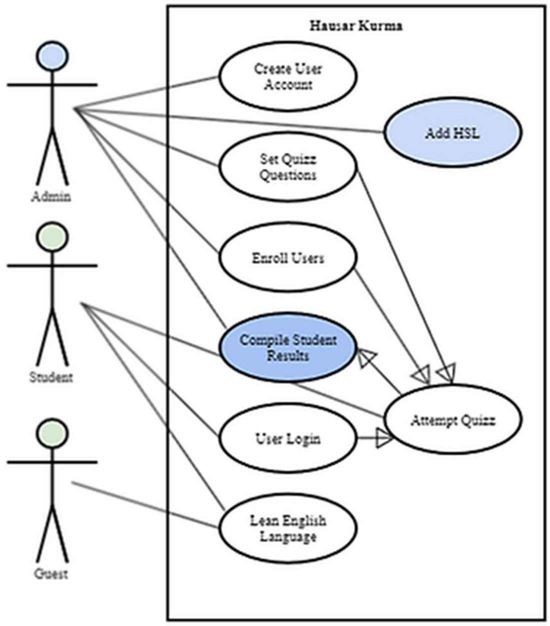

FIGURE 2. Use-case diagram.

C. DATA COLLECTION TOOLS

1) PRETEST

A pretest is a measure used to establish prior knowledge, and is conducted at the beginning of an experiment on the target group [7], [9]. In this study, the pre-test consisted of ten objective test questions, each with ten marks. It contained alternative answers from 1 to 5, as shown in Figure 4. The questions comprised of two additions, two subtractions, three multiplications, and three divisions. The students were given 60 minutes to answer the questions. These questions were reflected in the student syllabus for the first term. It should be noted that all questions were contained in the app used for training. As shown in Tables 3 and 4, each question answered correctly was scored 10 points for each participant.

2) POSTTEST

A posttest was conducted to measure learning outcomes [7]. This was performed after eight weeks of student training using the developed Android mobile app to evaluate the students' academic performance. It contained the same questions as the pre-test and was conducted in the same manner as the pre-test.

3) USABILITY TESTING

In mobile device applications, usability testing was performed using the ISO 2001 standard [5]. Usability is defined as the learning ability, efficiency, memorability, errors, and

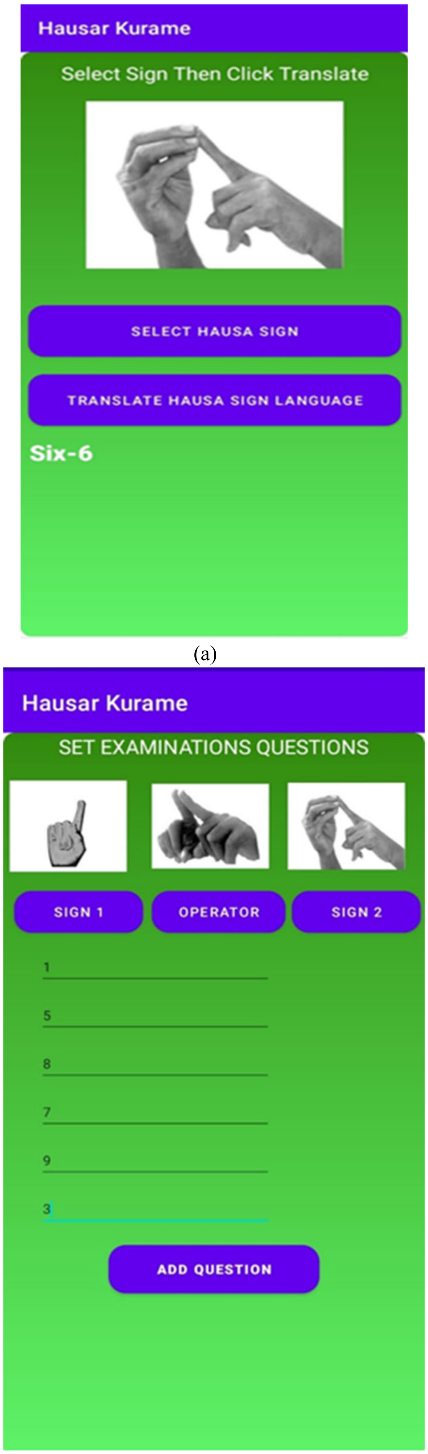

FIGURE 3. HSL translation into English from the application user interface of the developed mobile app.Set examination question application user interface of the developed mobile app.

user satisfaction. The evaluation was performed as previously described [24]. A five-point Likert scale consisting of eight questions was used to obtain students' opinions about the developed mobile app, as shown in Table 2.

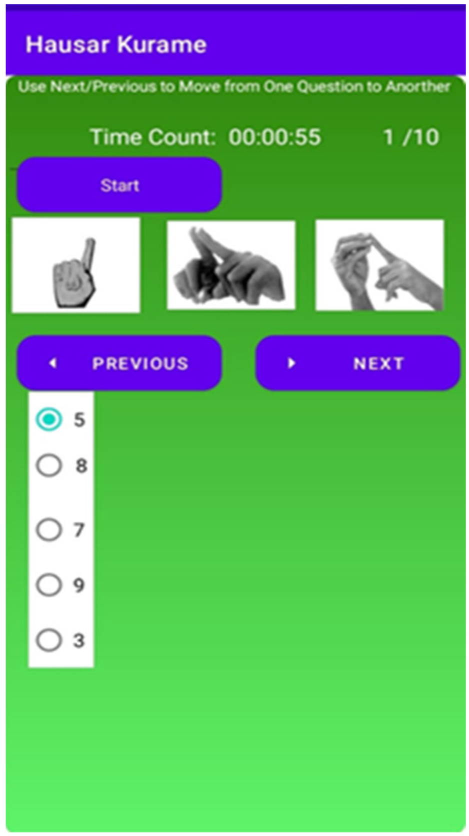

FIGURE 4. Pretest - posttest question design.

D. DATA ANALYSIS METHODS

Visual analysis allows researchers to graphically display results and communicate the interpretation of experimental data. This was used to represent the slopes and linear trends of data points. It includes indicators such as the levels, trends, and variability of data from each phase. A celeration line is a visual analysis tool used to conduct a statistical analysis of data by graphically presenting the data on a chart [3], [41], [19]. It is a method for determining the proportion of data that falls above or below a line. An increased number of observations above the celeration line suggests a change in target performance [33]. The advantages of using a celeration line in the evaluation of the performance of a system include economy compared to other methods and changes in the pattern displayed to measure performance, which is valuable compared to statistics for readers to understand experimental results [3], [41]. Similarly, some limitations of the celeration line were outlined in [3]. Graham, Karmarkar, and Ottenbacher [41] included nonstandard criteria of measurement; disagreement between raters, which makes it difficult to determine whether the intervention has produced a difference due to the wide range of scores; the changes that may occur during the intervention may not manifest instantly; the baseline improvement that exists may not necessarily be due to the intervention; graphs may lead to inaccurate interpretation of results, and small changes may not be visually evident.

TABLE 2. Students' opinion/response about the developed mobile application.

S/No	Scale Item	Mean	Standard Deviation (δ)
1.	How can you rate the usefulness of the developed mobile app?	4.20	1.146
2.	How can you rate the way students manipulate the developed mobile app?	4.07	0.799
3.	What is your rating of the developed mobile app	4.20	0.884
4.	What is your rating of the accuracy of translation of the HSL into English Language mobile app?	3.73	1.033
5.	What is your rating of the interface design of the mobile app?	4.27	0.704
6.	How do you rate the available information that can be access by the mobile app?	3.93	1.163
7.	What is your rating of the performance of the mobile app?	4.13	0.743
8.	What is your rating of the accessibility of the required information from the mobile app?	3.87	0.834

Scoring: 5=Very Good, 1=Very Poor

The binomial test was used to test whether there was a difference between pretest and posttest scores and to test whether the division of the midline was correct [42].

The Wilcoxon signed-rank test is a non-parametric test used to test whether a difference exists between two paired samples [53]. This is equivalent to a paired sample t-test in which the data do not meet the assumptions of the paired sample t-test [54]. In this study, the two samples to be compared were the results of the pretest and posttest examinations.

TABLE 3. Pretest exam scores.

St_ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	TOTAL SCORE
Stu-1	10									10	20
Stu-2	10				10						20
Stu-3	10					10			10		30
Stu-4	10					10	10				30
Stu-5	10	10		10							30
Stu-6	10		10								20
Stu-7	10		10			10			10		40
Stu-8	10	10	10	10			10	10	10	10	80
Stu-9	10		10			10			10		40
Stu-10	10	10		10		10					40
Average Score								35			

To obtain consistent results, the IBM SPSS Statistics 27 software was used to test the data.

A usability test was conducted using a questionnaire containing eight questions, prepared using a five-point Likert scale [5]. Each question was prepared to determine the existence of any positive responses and the students' ratings of the usability of the developed mobile app. The responses were Very Poor = 1, poor = 2, acceptable = 3, good = 4, and Very Good = 5, where *Very Good represents the* positive response and *Very Poor*represents the students' negative responses about the usefulness of the application. Means and standard deviations were computed using IBM SPSS Statistics 27.

E. THE APPLICATION

The evaluation process of the application was initiated by introducing it to the students. First, pre-test exams, which are tests conducted before the application of an intervention to the target group, were conducted. This was conducted using the sample questions shown in Figure 4 in the application quiz to ascertain the level of understanding of the syllabus for that term. The test was marked and individual student scores were recorded on a score sheet. Average scores for the pre-test examinations were also computed. After the pretest exams, three hours of lecture sessions per week for eight weeks were provided, during which the students conducted various training activities using the Hausar Kurma app. After the lectures, a posttest exam to evaluate the students' performance was conducted, marked, and recorded on the posttest exam score sheet. The Pretest/posttest single-subject study celeration line, binomial test, and Wilcoxon signed-rank test were used to measure the impact of the application on student performance. The results of the three methods were compared to determine the efficacy of their application.

F. RELIABILITY AND EXTERNAL VALIDATION

Although a single-subject study provides methods that support evidence-based practice, there are many concerns regarding its internal and external validity and generalizability [3]. The external validity problem can be overcome by repeatedly testing the effects of the experiment across different participants [3], so that it can be generalized to other behaviors, treatments, individuals, and settings [44]. To overcome these problems, direct replication of the study to students in other special schools has been implemented [35]. This experimental control allowed us to analyze the effect of the app repeatedly and reliably using a single participant or a small number of participants across different schools to enhance the external validity and reliability of the study [59].

V. RESULTS

A. PRETEST SCORES

The pre-test exam was used to check students' prior knowledge of the subject matter at the beginning of the program. The total number of participants was $N = 10$, the average score was 35, and the mean and standard deviation were 30 and 17.8, respectively. Similarly, three participants obtained a total score of 20%, three obtained 30%, 3 participants got 40%, and one obtained 80%.

B. POSTTEST SCORES

The posttest exam was used to measure the learning outcomes at the end of the program intervention [7]. The results of the posttest exam are presented in Table 4. One participant achieved 60% accuracy, five achieved 90% accuracy, and four achieved 100% accuracy. Consequently, at the end of the experimental study, using the developed mobile app, as shown in Table 4, the posttest scores of all students increased compared with their pretest scores. As shown in Figure 6, careful observation of Participant 8 (Student ID=Stu-8), who scored 80% during the pre-test, is noteworthy. However, it should be noted that the same participant obtained 100% on the posttest, indicating an impact of the intervention. Moreover, Stu-1 and Stu-2 received the lowest score of 20 in the pretest and, as seen in Figure 6, they increased their scores to 90 in the posttest. An average score of 91 percent on the posttest exams indicated a significant improvement in the students' performance using the developed mobile app compared to the average score of 35 on the pretest exams.

C. THE IMPACT OF THE INTERVENTION

It can be seen from Figure 6 that the students' posttest scores increased compared to their pretest scores. However, to determine whether the increase in pretest and posttest scores was statistically significant was determined using, three methods were used: the celeration line, binomial test, and Wilcoxon signed-rank test. A higher number of points above the line indicate the impact of the application. In the binomial test, the probability of the null hypothesis, given as 0.0098, also indicated the impact of the study. The Wilcoxon signed-rank test ($Z= 2.82$, $p< 0.05$) and Cohen's d ($r= 0.633$) indicate how statistically the application impacted students' performance. In general, the results obtained from the students' pretest and posttest exams clearly showed the impact of the application, as shown in Figure 6.

Regarding the usability of the application, according to the data analysis, the majority of respondents thought that the developed mobile app was very useful for learning English. They also rated the developed mobile app highly in terms of its performance, usage, system manipulation, and interface design. However, in terms of the accuracy of the translation, available information, and accessibility of the required information, students' perceptions were equally acceptable, as shown in Table 2.

The binomial test was used to test whether there was a difference between pretest and posttest scores and to test

TABLE 4. Posttest exam scores.

St_ ID	Q1	Q 2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	TOTAL SCORE
Stu-1	10	10	10	10	10	10	10	10		10	90
Stu-2	10	10	10	10	10	10	10	10	10		90
Stu-3	10	10	10	10	10	10	10	10		10	90
Stu-4	10	10	10	10	10	10	10	10		10	90
Stu-5	10	10	10	10	10	10	10	10	10	10	100
Stu-6	10		10				10	10	10	10	60
Stu-7	10	10	10	10	10	10	10	10	10	10	100
Stu-8	10	10	10	10	10	10	10	10	10	10	100
Stu-9	10	10	10	10	10	10	10	10	10	10	100
Stu-10	10	10	10	10	10		10	10	10	10	90
Average Score											91

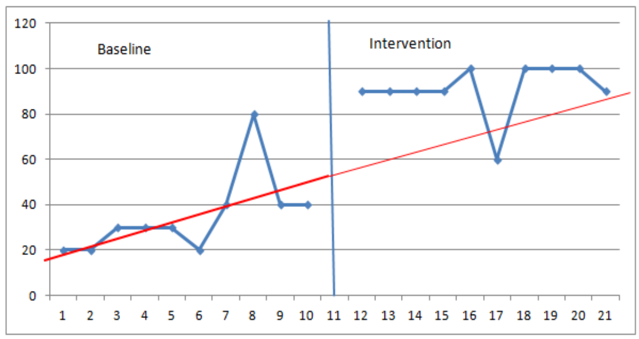

FIGURE 5. Celeration line and binomial test methods.

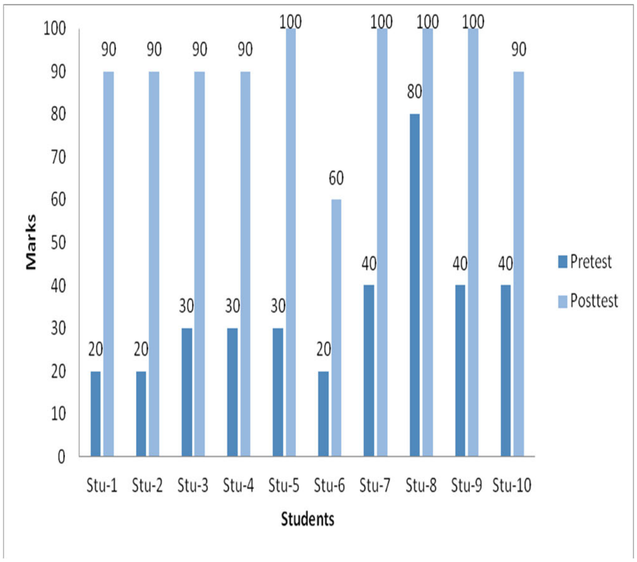

FIGURE 6. **Pretest and posttest scores.**

whether the division of the midline was correct. As shown in Figure 5, nine observations were above the celeration line, indicating the impact of the intervention. It was calculated using the Microsoft Excel BINOMDIST function by taking the following parameters: Numbers_s = 9, which is the number of points above the celeration line in the intervention section; trials_s = 10, which is the number of participants; probability_s = 0.05, which is the probability of occurrence; and cumulative = false. The probability of the outcome of the null hypothesis H_0which was 0.0098, indicated that there was a significant difference between the pretest and posttest scores. This indicated that the application had a significant effect on student performance.

Moreover, an analysis of the results before and after the intervention was compared. The average results showed that students performed better (median = 90) after the intervention than before (median = 30). A 2-related sample Wilcoxon Signed Rank test indicated that the improvement was statistically significant (Z= 2.82, $p<$ 0.05). To determine the magnitude of the difference between paired samples, an effect size $r = 0.633$ was obtained, indicating the practical significance of a study with an effect size r greater than 0.5 [54].

D. DISCUSSION

This study applied the Celeration Line, Binomial test, and Wilcoxon signed-rank test. The results are shown in Figure 5 (celeration line and binomial test methods). The celeration line indicates the total number of outcomes above and below the celeration line, which implies a significant improvement when the number of points above the celeration line is above 50 percent [42]. This outcome corresponds with the findings of [51], who applied visual analysis and compared it with other statistical methods to analyze their relationship in a single-subject study. However, the computed binomial test value yields 0.0098, which is below 0.05, and we accept the hypothesis that there is a significant improvement in student performance, which is in tandem with the results obtained by [42]. Figure 6 shows the significant improvement recorded using the two methods as a baseline and the intervention observation tests for student performance. Simultaneously, the Wilcoxon signed-rank test results indicated a significant improvement in students' performance using the developed mobile app (Z= 2.829, $p<$ 0.05) and an effect size of $r =$ 0.633, also indicating a strong Cohen's classification, which is consistent with the study conducted by [53].

The mean and standard deviation of the usability test were statistically analyzed to determine the opinions of the students regarding the developed mobile app [57], [58]. The results showed that The most significant result was for scale item 5: *What is your rating of the interface design of the mobile app? (M = 4.27*, SD = 0.704). Scale item 1: *How can you rate the usefulness of the developed mobile app? (M = 4.20*, SD = 1.146); and scale item 3: *What is your rating of the developed mobile app?* (M= 4.20, SD = 1.146) were equally significant. Another item considered favorable for the application was scale item 7. *What is your rating of the performance of the mobile app?* (M = 4.13, SD=0.743). System performance metrics, such as app startup, flexibility, and user experience, were considered as good indices in the evaluation. Scale item 2: *How can you rate the way students manipulate the developed mobile app? (M = 4.07*, SD = 0.799) *w*as rated equally positively by the students, which indicates that they had learned how to use the application and could manipulate it. However, students' opinions on scale item 4: *What is your rating of the accuracy of the translation of the HSL into the English language mobile app? (M = 3.73*, SD = 1.033) was also acceptable, although it was not highly rated by the students. This may have occurred because the students were not familiar with the way HSL is used in English teaching and the language has not been integrated into the school curriculum. Item Scale 6: How do you rate the available information that can be accessed by a mobile application? (M = 3.93, SD=1.163) HSL has not been the formal language of instruction in Nigerian special schools and, as such, is not fully integrated into the school curriculum. Item scale 8: *What is your rating of the accessibility of the required information from the mobile app?(M* = 3.87, SD=0.834). The efficiency of the developed mobile application, which includes the students' performance and their capabilities [57] in the use of the application, can be used to assess their performance in the use of the application.

E. LIMITATIONS OF THE STUDY

Some of the limitations found in the course of conducting this study include a lack of adequate literature on HSL, a lack of adequate training facilities, especially an Android mobile app, a lack of training devices in the school, a lack of adequate training of college staff in formal ASL and HSL, and the existence of different dialects of HSL. HSL has not been formally adopted as a communication medium in Nigerian special schools. Therefore, it is thought that the developed mobile application will slightly remedy this deficiency a little bit and provide benefits by helping both teachers and students. Another limitation of this study is the lack of external validation of the data, which is inherent in a single-subject study, and it is recommended that visual analysis be compared with other statistical analyses to obtain better results, as recommended by [3] and [37]. Equally, the lack of adequate training time is another limitation of the study, as the training used a two-hour lecture period every week for eight weeks, which we believe has influenced the outcome of the study.

VI. CONCLUSION

We recommend the adoption of the application in Nigeria's special schools to enhance the teaching and learning capabilities of Hausa hearing impairment or hard-of-hearing students. It is also used for the management of special schools in the management and administration of examinations, courses, and syllabus administration as well as for staff and student administration. Similarly, for the research community, it is recommended that other areas include the development of HSL translators on the iOS platform, web-based HSL translators, development of different dialects of HSL, development of an assistive tool for Hausa-speaking out-of-school children, and development of desktop applications for HSL use. Other statistical methods used to ascertain the efficacy of the application for implementation include two standard deviation bands: randomization tests, t-tests, F-tests, and autoregressive integrated moving average (ARIMA).

According to literature, students can use many mobile applications to learn English. However, it is also known that the use of mobile applications for educational purposes is not sufficient for students with special needs, especially for Hausa-speaking hearing impairment students. However, due to the principle of equality in education, it is necessary to develop mobile applications that can be used by hearing impairment students to teach English. Therefore, in this study, a mobile application was developed to teach English using the Hausa sign language, considering the special conditions of hearing impairment students using ISO standards. The results obtained from the experimental study to determine the educational effectiveness of the mobile app were statistically significant. As a result, the developed mobile application has proven to be useful in teaching English to hearing impairment children of the primary school age in special education schools. For this reason, it can be concluded that this app will be useful as an educational tool for Hausa-speaking hearing impairment children who use Hausa sign language.

AUTHOR CONTRIBUTIONS

Conceptualization: Ahmed Lawal and Nadire Cavus; data curation: Ahmed Lawal and Ibrahim Sani; formal analysis: Ahmed Lawal, Nadire Cavus, and Abdulmalik Ahmed Lawan; investigation: Ahmed Lawal, Nadire Cavus, and Abdulmalik Ahmed Lawan; methodology: Ahmed Lawal, Abdulmalik Ahmed Lawan, and Ibrahim Sani; project administration: Nadire Cavus and Abdulmalik Ahmed Lawan; resources: Ahmed Lawal and Ibrahim Sani; software: Ahmed Lawal and Abdulmalik Ahmed Lawan; supervision: Nadire Cavus; validation: Nadire Cavus and Ibrahim Sani; visualization: Nadire Cavus and Abdulmalik Ahmed Lawan; writing—original draft Ahmed Lawal and Ibrahim Sani; writing—review and editing: Ahmed Lawal, Nadire Cavus, Abdulmalik Ahmed Lawan, and Ibrahim Sani. The published version of the manuscript has been read and approved by all the authors.

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INSTITUTIONAL REVIEW BOARD STATEMENT

This study was conducted in accordance with the ethical standards of Near East University, Cyprus.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all the subjects involved in the study.

DATA AVAILABILITY STATEMENT

Owing to privacy concerns of the children, the data for this study are not publicly available in the public domain. This information can be obtained from the corresponding author upon request.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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AHMED LAWAL received the B.Sc. degree in computer science from Usmanu Danfodio University, Sokoto, Nigeria, and the M.C.A. degree from Hamdard University, New Delhi, India, in 2011. He is currently pursuing the Ph.D. degree in computer information systems with Near East University. His research interests include system development, artificial intelligence, and computer vision.

NADIRE CAVUS received the B.Sc. degree in computer information systems and the M.S. degree in business administrative sciences from Near East University, Nicosia, Cyprus, Turkey, in 1995 and 1997, respectively, and the Ph.D. degree from the Department of Computer Information Systems, Near East University. She was an Assistant Professor, in 2008, an Associate Professor, in 2011, and a Professor, in 2016. Since 1995, has been with Near East University, where she is currently a Lecturer with the Department of Computer Information Systems. Her research interests include e-learning, m-learning, learning management systems (LMS), virtual learning environments, artificial intelligence, and information systems.

ABDULMALIK AHMAD LAWAN received the bachelor's degree in computer science from Kano University of Science and Technology (KUST), Nigeria, and the M.Sc. and Ph.D. degrees in computer information systems from Near East University (NEU), Cyprus. He is currently a Lecturer with the Department of Computer Science, KUST. His research interests include human–computer interactions, educational technologies, emerging technologies, autism research, and eHealth among others.

IBRAHIM SANI received the degree in NCE special education (hearing impairment) from the Federal College of Education (Special) Oyo, Nigeria, in 2008, and the degree in special education (hearing handicap) from the University of Jos, Jos, Plateau, in 2014. He is currently pursuing the master's degree with the University of Ibadan, Nigeria. He teaches with the School for Special Education, Gusau, Zamfara, Nigeria. His research interests include inclusive education, sign language for the hearing impairment, and hearing impairment-related issues.