USABILITY EVALUATION OF A MOBILE PHONE BASED BRAILLE LEARNING APPLICATION "MBRAILLE"

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ABSTRACT

The introduction and evaluation of Braille-learning tools are not receiving attention despite the need for talking books and Braille reading materials. As the Braille learning tools are very limited in developing countries, newly introduced tools and technological solutions need to be properly evaluated for implementation with the required improvements. The current study evaluated a smartphone-based interactive application "mBRAILLE" for teaching early Braille-writing skills in English and Bangla. The mBRAILLE is developed to provide a cheap and affordable technology to the visually impaired (VI) students in Bangladesh. The application will help them learn Braille. A two-stage evaluation was performed in Bangladesh to determine the effectiveness of the application. The first stage of evaluation was performed with five school-aged VI children and five teachers from a blind school to determine the satisfaction level of the users while interacting with the application. This evaluation focused on 5 usability criteria, namely, learnability, memorability, efficiency, error, and satisfaction. After using mBRAILLE, participants evaluated the interfaces of the application through a specific questionnaire. Evaluation results showed that mBRAILLE meets the considered usability criteria, indicating that the interaction between application and users was on a desired level of satisfaction. Additionally, teaching ability of the application was evaluated by 5 real users in the second stage of evaluation, with a positive result. Therefore, given that the application is an effective tool to learn and teach English and Bangla Braille, it can be implemented in Bangladesh to assist VI students.

Keywords*: *Assistive Technologies, Usability, Braille, Visually impaired, Mobile application

1.0 INTRODUCTION

Bangladesh is a low-income country in which nearly 19.6% physically challenged individuals reside; these individuals have at least one disability [1]. The number of visually impaired (VI) people in Bangladesh is approximately 750,000 [2]. The country contains a total of 341,819 VI children (about 19.7% of disabled children) in the 6-11 age group [3]. Besides, literacy rate in Bangladesh is as low as 57.7% that demands for ensuring education for all including persons with disabilities [4]. However, providing education for this large number of VI people is challenging. Blind and visually impaired students (VIS) in Bangladesh face numerous challenges in educational institutions [5]. Limited resources are the main challenge of blind schools [6]. The Braille beginners do not have any technological tool that can help them learn Braille, because they cannot study by themselves; thus, they only use "slate and stylus" to write braille [7].

Educational tools and devices that are available in market for sighted students do not meet the requirements of VI people. Thus, VI people have to buy tools produced especially for them. However, most of those tools are very expensive. A suitable software or application on the hardware that they already have like mobile phone could reduce the costs immensely [8]. Therefore, a mBRAILLE was introduced to assist Bangladeshi VI students in learning both Bangla and English Braille [9]. After the development of the application, an evaluation is performed to verify its usage. The applications' main goal is to assist the VI and blind students learn English and Bangla Braille without anyone's assistance. This article discusses the after-development evaluation study of the developed application mBRAILLE. To achieve the main objective, an intensive evaluation is carried out in two stages, in which usability test and teaching performance of the application are evaluated.

2.0 REVIEW ON EVALUATION OF BRAILLE BASED TECHNOLOGIES

Diverse initiatives and interventions based on the mobile phone were introduced to assist VI people [10]. BrailleType is one of the most recently developed single-finger text-entry method based on the Braille alphabet [11]. The performance of this method was assessed against Apple's VoiceOver approach with the participation

of 15 blind subjects. Thus, BrailleType was identified to be significantly easier and was less error prone. Perkinput is a touchscreen-based text entry method for VI people [12]. A total of 8 blind subjects who were proficient in Braille evaluated the efficiency of the Perkinput method compared with iPhone's accessible text entry method VoiceOver. The Perkinput was 50% faster, and the number of errors on Perkinput was only half that made on VoiceOver. VB Ghost, an educational gaming application, is mainly developed for VI people who are identified as advance learners and already know many English words [13]. Haptic and audio feedback help the player to give the input in a braille game, but an implementation or evaluation report is not found. Similarly, without the implementation or evaluation report, it is very difficult to identify and justify the suitable technological solution. An evaluation study helps obtain insight into any technological solution or device. Literature review revealed that if a large-scale evaluation to justify the system's effectiveness is not possible, then it can be done with a few participants. A number of braille input methods and braille-based software have been evaluated previously with small numbers of informants [14] [15] [16]. For example, Toussaint and Tiger considered only four participants to evaluate an instructive procedure for teaching early Braille-reading skills [17]. Whereas, only three respondents were participated to study line-tracking instruction using stimulus fading to teach tracking across larger gaps [18]. Recently, a computer program for teaching braille-to-print letter relations was also evaluated by 4 participants only [19].

3.0 USABILITY

3.1 Definition of Usability

Usability is a key attribute to evaluate the usefulness of a product user interface [20] and a measurable characteristic. Usability answers the question, "how easy is it for novice and casual users to learn the user interface?" [21]. According to Nielsen, "Usability engineering refers to many techniques and concepts for assessing a product or a system's ease of function based on systematic evaluations, system inspection, and research methods" [22].

According to Nielsen, five main usability characteristics are unique, and the priority scale can be differed among these five characteristics [22]. Together with that, several additional parameters of usability must also be considered in designing a system [22][23][24]. However, designers should focus on specific usability goals in accordance with the aims of a system [21][25][26]. The classic usability engineering referred by Nielsen has five components as discussed in the following section.

3.2 Usability Goals

• "**Efficiency** of use indicates high productivity level of users' performance within a specific time after they have learned the system". Efficiency also refers to the speed of the users' performance to tasks.

• "**Learnability** is defined as ease of learning a system by users that enables them to use new system to do productive work easily". Additionally, it answers the question, "how easy is it for users to accomplish basic tasks for the first time during a design encounter?" Learnability refers to the easy understanding of users to perform the work successfully by using the system.

• "**Memorability** refers to the ability of users to remember the steps of a system. The system is easy to remember when it provides identical instructions for similar types of task". In addition, memorability also refers to the fact that when a user starts reusing the application or software after a period of not using it, he/she can easily re-establish the proficiency on it.

• "**Errors** occur when a user fails to achieve the desired goal while using the system". Number of errors, severity of these errors, and easiness to recover from the errors must be considered to the identification of this usability goal.

• "**Satisfaction** is the subjective opinion of the user's satisfaction; during use, the users reveal whether they like the system or not" [21][22][23].

4.0 APPLICATION “mBRAILLE”

Integrated development environment (IDE) Android Studio was used to develop the user interfaces of mBRAILLE. The touchscreen feature of smartphone is utilized for providing gestural input, and auditory output can be received by users to access the menu options, or any button. Moreover, for easier finger placement, the touchscreen area is subdivided into different portions to the edge of mobile phone. To assist in positioning on each page, mBRAILLE offers voice instruction. VI users have to install the application on their mobile devices before using it.

4.1 mBRAILLE Interfaces

Fig. 1 presents the developed interfaces, wherein the dashed-red arrows show how the English feature will continue from one page to another. Additionally, the solid-blue arrows demonstrate how the Bangla feature will continue in the application.

Several instructions are the same for all the feature of the application. These instructions include the following. First, "Next (next page) - Flip right." Then, to get into next page, the users’ have to flip right. Second, “Back (previous page)-Flip left”, if the users want to go to the previous page, they need to flip right at the current page. Third, “OK (done with something) - Flip up (towards the top of the phone)”. If the users are done with their input or task, they need to flip up. Finally, “Exit (if the user wants to end) -Flip down (toward the bottom of the phone)”. If the users think that they are done or just want to exit from the application, they need to flip down to exit. Other descriptions of the application are provided in a previously published article [9].

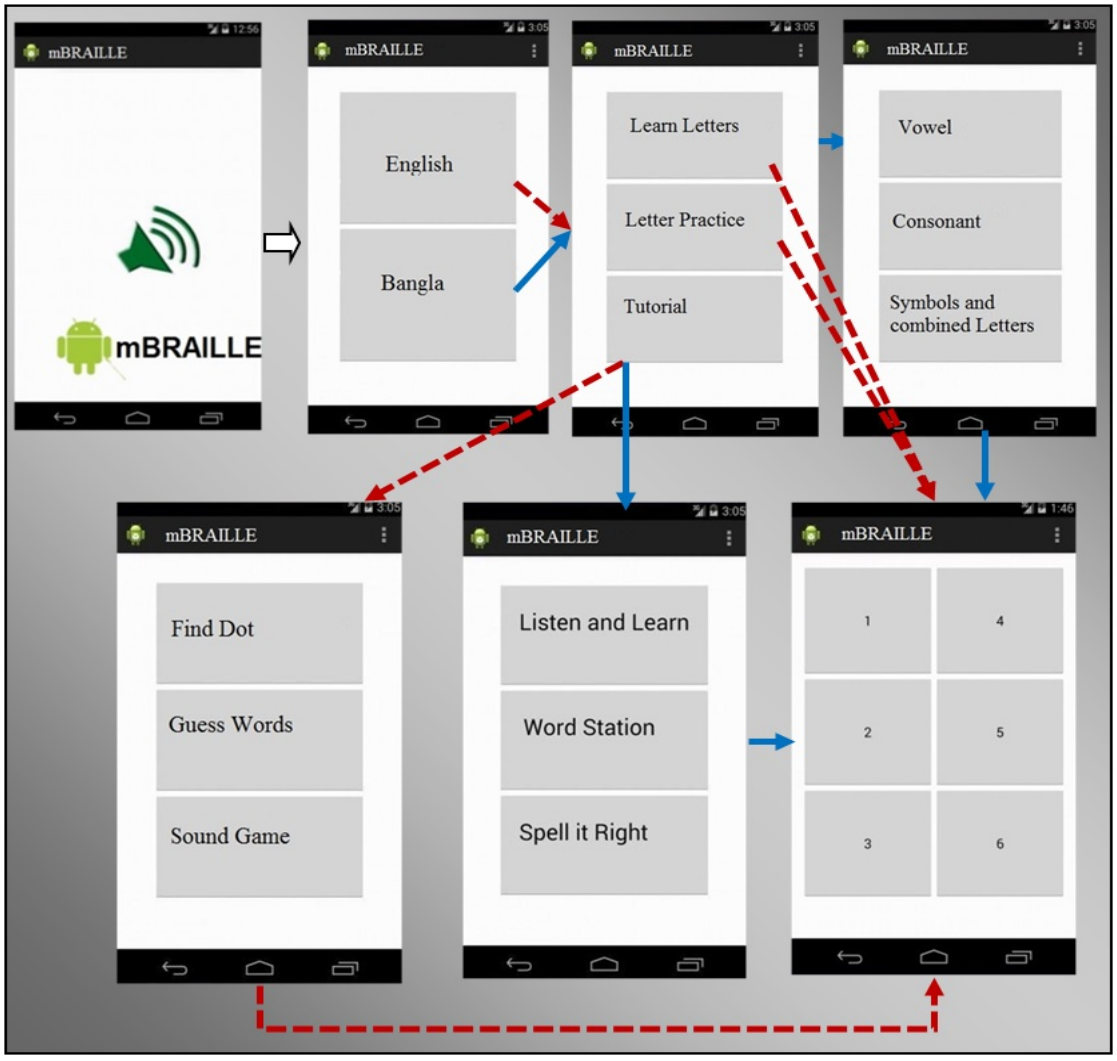

Fig. 1: mBRAILLE interfaces with features navigation

The application, mBRAILLE has main two features, namely, English and Bangla. Both features comprise of three subfeatures, i.e., learn letters, letter practice, and tutorial. In learn letters, users get assistance to learn each letter through an instruction as this subfeature describes the specific dot combinations to be pressed to write any letter. After learning the letters, users can practice the dots combination through the letter practice subfeature. These two subfeatures work similarly for both Bangla and English. However, tutorial contains different subfeatures for English and Bangla, and these subfeatures work like a game, where users can earn points for each correct answer. English tutorial includes three subfeatures: “Find dot”, “Guess word”, and “Sound game”. In "find dot," the user is asked to write a specific letter by imputing the dots. In the "Guess word,” the user is asked to guess and answer any word. For example, guess a word with three letters and starts with a specific letter. In the "Sound game," the user hears a sound (animal/birds/musical instruments) and is asked to write the name of that specific thing. Bangla tutorial includes three subfeatures: “Listen and Learn”, “Word Station”, and “Spell it Right”. Bangla Listen and Learn and Bangla Word Station are similar to the “Sound Game” and “Guess Words” features, respectively. In the "Spell it Right" subfeature, the user is asked to spell a specific word, and then, he or she needs to press the dot combination for that word.

5.0 USABILITY EVALUATION

To study the usability of mBRAILLE, users’ opinions were collected. Basically, testing, inspection, and inquiry are the three types of usability evaluation methods [26]. Testing refers to the process of operating the system prototype by a user and observing the systems responses by an evaluator. Whereas, inspection refers to examine the usability-aspects of prototype by either software developers, usability experts, or real users. Inquiry method refers to gathering information of users through discussing according to whether they like or dislike, their understanding and requirements of the system while operating it. In this article, testing and inspection methods are followed. This evaluation was conducted in two stages. First, the usability evaluation of developed interfaces was carried out. In this stage, the performance of mBRAILLE was evaluated by collecting the opinions of experts and advanced Braille learners. Second, usability evaluation of mBRAILLE in terms of teaching to the VI students was conducted. In this stage, VI students used the application, and their performances were recorded.

5.1 Stage 1: Evaluation Of Interfaces

The aim of this stage 1 evaluation was to assess the usability of developed interfaces of mBRAILLE. Users’ interaction with the application was also identified through this stage of evaluation.

5.1.1 Participants

Four blind teachers and one sighted teacher participated in this study. Additionally, there were five blind students who already knew Braille very well. Table 1 shows the respondents’ particular in stage 1. In this study, the interfaces were used on an Android phone for evaluation. After the detailed explanation of how the program works, the respondents were asked to use it. The participants were from Baptist Mission Integrated School in Dhaka and Dhaka Blind School, Bangladesh. Fig. 2 shows a teacher using the application in the provided device.

Table 1: Demographic Information of the Respondents in 1st Stage

Participants	Sex	Age	Sight	Experiences in smartphone	Have smart/ Android phone	Experiences in Braille-based assistive technologies
Teacher 1	F	36	Blind	Yes	Yes	No
Teacher 2	M	40	Blind	Yes	Yes	No
Teacher 3	F	35	Blind	Yes	Yes	No
Teacher 4	M	52	Blind	Yes	Yes	No
Teacher 5	F	50	Sighted	Yes	Yes	No
Student 1	M	15	Blind	Yes	Yes	No
Student 2	M	16	Blind	Yes	Yes	No
Student 3	F	8	Blind	No	No	No
Student 4	M	13	Blind	No	No	No
Student 5	F	14	Blind	Yes	No	No

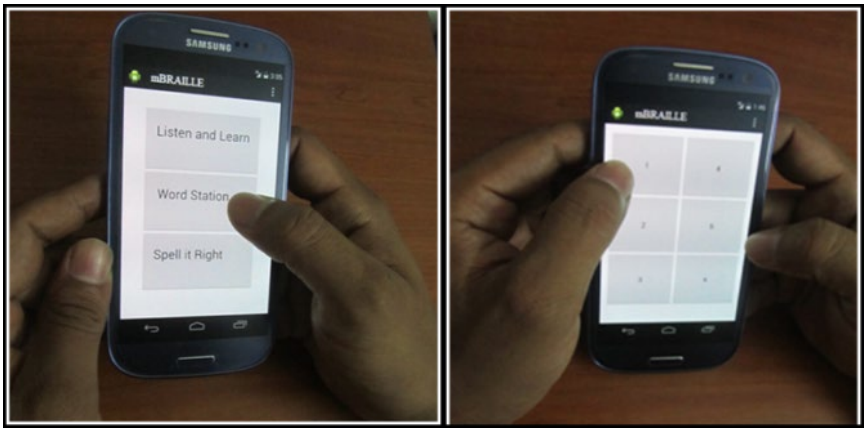

Fig. 2: A teacher testing the application interfaces.

5.1.2 Evaluation procedure

To find out the application usability ratings, the teachers and students were asked usability related questions after using mBRAILLE interface. All the usability goals (learnability, memorability, efficiency, error, & satisfaction) established during design and development phase of mBRAILLE were considered to design the questionnaire.

Fig. 3 presents a summary of the selected usability rating statements from the questionnaire. This questionnaire mostly contains questions that help identify the rate of the usability goals by the respondents [27]. The perception of the users on the design of the interfaces is obtained and analyzed through this evaluation. When the participants were ready to answer the questions, the questionnaires were provided to them. For the blind participants, one person read the statements/questions and asked to rate it. Scoring scale was set to 1–5; where, "1 = completely unsatisfied", "2 = slightly satisfied", "3 = satisfied", "4 = very satisfied", and "5 = completely satisfied". The person who read the questionnaire for a blind respondent was responsible for recording the rating for each question. The respondents' rating for mBRAILLE was determined through this evaluation.

Efficiency	• The auditory and vibrational output will help VIS to know where they are in the App and what to do next. • The user interface layout is easy to distinguish and provide error messages that clearly indicate what you did wrong and what to do next
Learnability	• The application will help in learning to blind users with no prior knowledge of Braille. • Allow the experienced users to get the benefits to correct their mistake regarding Braille dots.
Memorability	• Layout prompts and fields on each screen is clear, easy to understand and remember. • The application will help to memorize the Braille dots and facilitate learning with minimal amount of training
Error	• Provide enough options to correct the user's mistake. • Allow the experienced users to get the benefits to correct their mistake regarding braille dots.
Satisfaction	• Instructions are clear enough to understand the Braille method and Bangla Instruction is helpful. • Allow you to exit if you don't want to execute the task, without any side effects.

Fig. 3: Summary of the selected usability rating statements from questionnaires.

5.1.3 Results

The VI respondents relied on their experience and intuition to interpret the findings on the mBRAILLE interfaces. The average rating from all respondents for each usability goal are presented by Fig. 4. At first, average rating of each question was calculated, and then the mean rating of satisfaction of the respondent on each usability goal was calculated. The users' average or mean rating for all usability goals was above 4. In the evaluation questionnaire, rating 5 was considered highly satisfactory, and 4 was considered very satisfactory. Therefore, this rating implies the happiness and satisfaction of the respondents with the learning application. This test was performed to collect constructive feedback from the experienced users and experts, as it is difficult for the real users (mainly 6 to 10 years old) to give any feedback. As the application was already developed, only the usability of the interfaces was evaluated in this study.

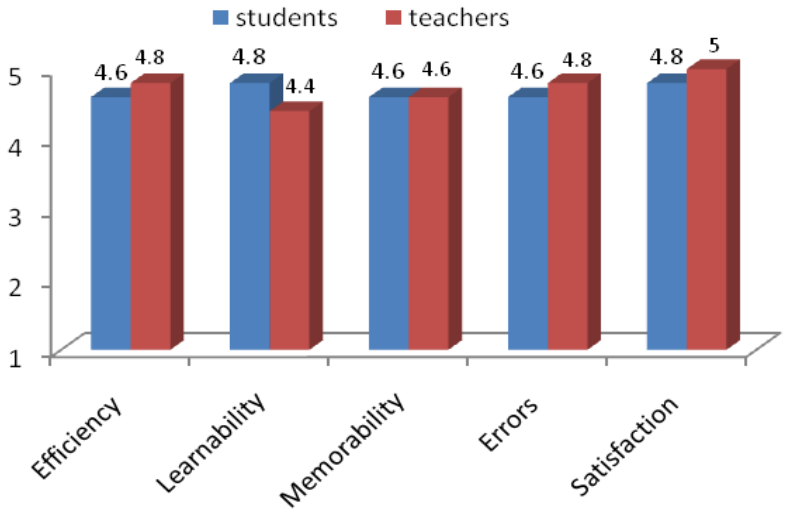

Fig. 4: The average rating for usability goals.

5.2 Stage 2: Teaching Through The Application

To evaluate the performance of mBRAILLE for teaching English and Bangla Braille, another study was conducted with real users. The following subsections describe this stage of evaluation in detail.

5.2.1 Participants

Five blind primary school students participated in this evaluation. These real users are from "Baptist Mission Integrated School" in Dhaka, Bangladesh. In this school, the interfaces of mBRAILLE were demonstrated in class I, and five students were randomly selected based on their previous experience of using Android phone. Table 2 presents the information of respondents in this stage.

Table 2: Respondents' Particulars in 2nd Stage

Participants	Sex	Age	Class	Sight	Experiences in smartphone	Have smart/ Android phone	Experiences in Braille-based assistive technologies
Student 1	M	8	I	Blind	Yes	No	No
Student 2	F	7	I	Blind	Yes	Yes	No
Student 3	M	7	I	Blind	Yes	No	No
Student 4	F	8	I	Blind	Yes	Yes	No
Student 5	M	9	I	Blind	Yes	No	No

5.2.2 Procedure and setting

The whole study was conducted in four phases, namely, before training (BT), after training (AT), follow-up 1 (F1), and follow-up 2 (F2). In all phases, participants tested four different options of the application, which are "Learn Letter" and "Letter Practice" for both English and Bangla options. The percentage of the correct answers was recorded in every phase.

Before training (BT):
In this phase, participants were asked to use the application following the voice instructions provided by the application. However, several basic instructions were provided to introduce the application and to explain how the options work in this application. The participants were asked to use the application and tried the first 10 letters of the "Learn Letter" and "Letter Practice" options for Bangla and English without any prior training. Time was not limited in this phase. Participants took 20 min to 30 min to complete the task.

After training (AT):
In this phase, participants were trained individually for 1 h on how to use the application after the first phase. After the training, they were asked to try 10 letters randomly from the "Learn Letter" and "Letter Practice" options for both English and Bangla Braille.

Follow-up (F):
After the training phase, F was done in two times. F1 was conducted on the next day of training and the F2 was done 1 week after F1. In this phase, they were again asked to complete the same tasks with 10 randomly selected letters. Time was limited to 20 min only for both follow-ups (Fs).

5.2.3 Results

Fig. 5 represents the percentage of correct answers for different options by the individual students in four phases.

Overall, students' performance in BT phase is very poor as expected because of no prior knowledge in using the application. For example, in BT phase Student 1 answered correctly 6, 5, 3, and 4 letters among 10 letters for the options "learn letter (English)," "learn letter (Bangla)," "letter practice (English)" and "letter practice (Bangla)," respectively. After training, Student 1 performed better and answered correctly 8, 8, 7, and 6 letters among 10 letters for the same options, respectively. All the individual graphs show that the lowest percentage is obtained in BT phase; and the highest performance is obtained in F2. Almost all the graphs show the increasing rate of the percentage after each phase of evaluation. In few cases, the result is stable particularly when the participants performed 100% in F1 phase.

Participants performed better in the "learn letter" option than the "letter practice" option for both English and Bangla because the "learn letter" option provides information regarding the dots combination for each letter; however, the "letter practice" option does not provide information regarding the dots combination. For example, in "learn letter" option, the application provides the instruction "to write the letter A, you have to press dot 1." However, in "letter practice", application gives the instruction like "press the dots combination to write the letter you want to practice." For example, the user press 2 and 3; then application provides the instruction like "you

pressed 2 and 3 and the letter is B." If the users press any wrong combination, then the application informs them about the wrong answer. Therefore, to try "letter practice" option, the students need to know the dots' combination to practice. As the "learn letters" option provides the dots' combination, it is easier for the students to perform using this option.

Students 2 and 4 performed better in the F phases compared with the other students, because both of them have smart phones. Unfortunately, poor result was observed for Student 1, who is only 7 years old. He could not manage to achieve 100% correct in any of the phases. Another observation was that the female students performed better compared with the male students because of their maturity and concentration levels.

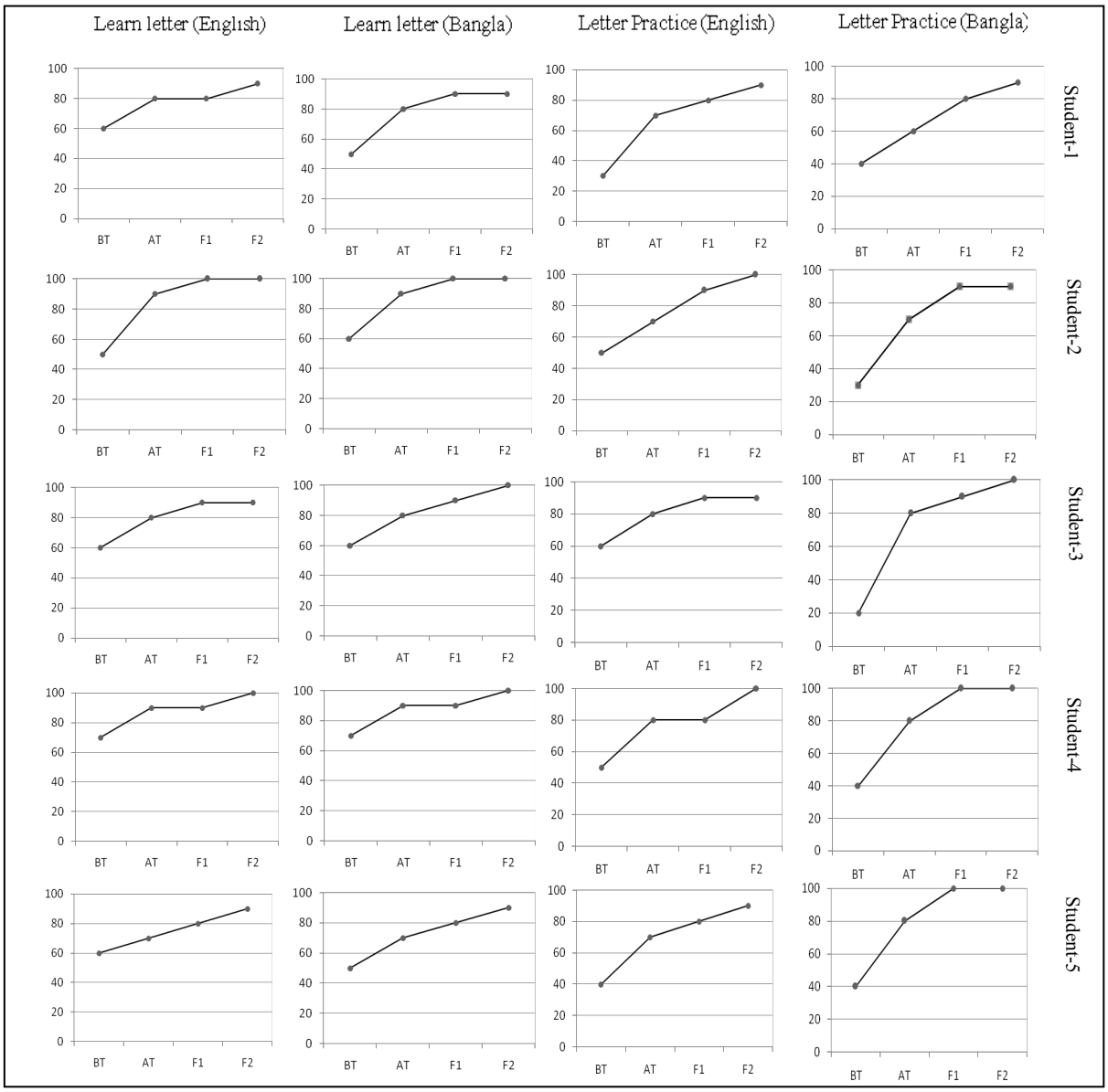

Fig. 5: Percentage of correct responses (BT = Before Training, AT = After Training, F1 = Follow-up 1, F2 = Follow-up 2).

6.0 DISCUSSION

The first stage of evaluation result indicates that the user can easily interact with the application as it meets all the usability goals. This result shows that users are able to learn Braille successfully by this application. The second stage of the evaluation result proves that mBRAILLE can assist the VI students of Bangladesh to learn Braille without any ones' assistance. Although the students made plenty of mistakes initially, they improved after a few trials and managed to use the application effectively with few mistakes. In some cases, they did not

do any mistakes in F2. Therefore, the application interacts satisfactorily with the users and can be used effectively to teach Braille to a beginner. All students who participated in 2nd stage of evaluation have previous experience in using Android phone at home, such as calling, call receiving, and listening songs. This result might differ for the users who do not have such experience.

7.0 CONCLUSIONS

The mBRAILLE is an effective technological solution that can help the VI students of Bangladesh overcome the challenges in learning Braille. This article aims to identify the usability of the interfaces of mBRAILLE and how well it can assist the VI students to learn basic Braille. The goal of the application is learning Braille (both Bangla and English) on touch screen mobile phones. This evaluation particularly measures the major aspects of usability goals that include efficiency, learnability, memorability, satisfaction, and error. The respondents are satisfied with the application. The students and the teachers of blind schools suggested implementing mBRAILLE, so that the beginners can practice by themselves and learn to remember the Braille dots combination quickly.

The VI in Bangladesh find it difficult to get education because of the lack of resources and technological solutions. Moreover, few studies have been performed on this field, thereby leading to inadequate information and data. Therefore, this research can contribute to the further research on this area of study as a guideline for usability evaluation of Android phone-based new technologies.

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