

Mobile Devices Supporting People with Special Needs

Tihomir Stefanov, Silviya Varbanova, Milena Stefanova

Department of Mathematics and Informatics
University of Veliko Tarnovo
Veliko Tarnovo, Bulgaria

Abstract—Over the years, various devices designed for people with special needs have been used for a while and then replaced with modern devices to make everyday life easier. The development of mobile devices is especially improved today and through them different everyday activities are facilitated, not only by people with special needs. The purpose of this paper is to present some of the modern mobile devices with an analysis of their operating systems, functionalities, applications and design. Based on the research, their usability for both sighted and visually and hearing-impaired users is described. Attention is paid to the preferences formed among users when using specialized applications developed for mobile devices. Based on a survey of specific target user groups, the paper provides summary results to support the thesis on the importance of the facilities, offered by modern mobile devices.

Keywords—Mobile devices; mobile operating systems; Android; iOS; special needs; visually impaired; hearing impaired; e-learning

I. INTRODUCTION

The last few years have seen increased use of mobile devices by users of all ages to accomplish a variety of tasks [2]. In the recent past, their main purpose has been solely for communication. Today, however, using smartphones and tablets, people around the world not only communicate with each other, but work and play by sending and receiving information of all kinds, quickly and easily. It is not yet possible to draw an accurate conclusion as to what percentage of users have completely replaced PCs and laptops with smartphones, and in some professional fields, this is already a fact.

Nowadays, there is an increased interest of people of different nationalities and with diverse health status in professions related to programming and IT. This has contributed to the updating of curricula at universities to include new courses in computer science. The use of computer techniques is particularly important for the laboratory lessons in these subjects. In a number of educational establishments, there are also some students with special needs, which determines the implementation of modern ways and devices in order to provide better and more effective learning. However, not all teachers receive specialized training in teaching the blind or hearing impaired, and the implementation of new ways and the integration of a variety of devices would support the educational process.

The study aims to observe the learning process in leading computer courses for students with visual or hearing impairments. Learning, when supported by the use of smartphones and tablets provides alternative solutions for the

hearing impaired or visually impaired – such as special educational tools within a real learning environment or a learning resource center [12].

In our country over the past decade, there has been an increased use of mobile devices and apps among people with special needs, including those who are blind or hard of hearing. The size and weight of the devices are of particular importance for these user groups, especially in daily carrying and use anytime and anywhere possible.

Comparing today's devices with those of ten years ago, there has been a significant change in the external design and the replacement push-button keypads with touch screen displays, which is both a convenience and a drawback for some user groups [13]. Older users have used button keyboards in the past, and touch screens today. Younger users have grown up with mainly modern devices with touch functions

II. RELATED WORK

It took less than a century to advance technology in the areas of hardware and software, and to replace John Atanasoff's large-scale computer with Steve Jobs' smartphone. Over the years, the Internet has established itself as the primary medium for searching, storing and sending data. Users visit leading websites and social networks on a daily basis. The World Wide Web has become popular and has encompassed users' lives completely, not only in their work but also in their leisure time.

This has led to the development, testing and optimization of various applications for computer and mobile devices by specialists in computer companies. The demand for laptops and computers designed for different activities – for office or home, professional, gaming, multimedia has increased. However, there is a preference for the use of smartphones or tablets among 'different' users, namely those with special needs.

According to the World Health Organization, nearly 2.2 million people are visually impaired worldwide. It is particularly important for them to navigate and move around safely, both in open and in unfamiliar indoor spaces [8]. Navigating corridors, sidewalks, stairways, and narrow walkways makes it difficult for the blind. After years of research, navigation aids and systems for mobile devices such as GPS systems have been developed to replace 3D printed maps with protruding dots or magnetic boards [10].

With the development and deployment of voice assistants such as Siri for Apple, Alexa for Amazon, Cortana for Microsoft, Assistant for Google and others, visually impaired

users are greatly facilitated. They now have the ability to do a variety of activities not only through computers, but also through smartphones. Especially when searching for literary resources. In this regard, libraries in educational institutions and localities could provide library services and materials through specialized applications for mobile devices, in order to facilitate their use by the blind [6].

Regarding reading and writing texts, blind people can use Braille in several different ways: with a Braille typewriter or tablet, via a computer or a mobile device [9]. Applying Braille to read and understand text has been the only traditional way for the blind to receive information in the recent past [18]. According to Radulov, however, learning it was an easier process than applying it [16]. Today, braille keyboards and braille tablets greatly facilitate the use of devices as priority tools of accessing needed information [14].

The application of innovative technologies is important for the quality of the learning process among general groups, which include both able-bodied and students with special needs. Usually students with problems are given fewer assignments as they fail to cope and slow down the learning process. Specialized applications have been developed to help them and the teachers to facilitate the learning process of the tasks [3]. The Scrum methodology is one of the most suitable ways to implement software development management, as the purpose of this methodology is to work together and adapt to changes that occur within the project. The application developed within the research of Boza-Chua, Gabriel-Gonzales and Andrade-Arenas, targets students with visual impairment in order to improve the quality of teaching for student teachers [3].

In recent years, due to various reasons, the number of people with hearing problems in the World has been increasing. Currently, there are about 120,000 people with hearing impairment in Bulgaria. In the future, it is expected that one in ten will have some degree of hearing impairment. Everyone with a hearing impairment also has the right to be perceived as healthy. They should be given the opportunity to be educated and to work regardless of the difficulties they face. To communicate with each other, these users use a special language called sign language based on the dactylic alphabet. There are around 25,000 sign language speakers in Bulgaria.

Surveys conducted with users on a predefined or random topic in conversation, and with a trained associate have found that users who made the call without a mobile device were more reliable. However, for people with special needs, the results were different – it was found that through the mobile device they perceived the information better due to mimic gestures [7].

One of the main requirements for admission of students to the University is to pass an entrance examination. However, many higher education institutions do not have the facilities to conduct entrance examinations for visually or hearing impaired people. The need for tools to enable them to perform optimally in the entrance examination are important. To this end, the implementation of web applications that could provide online application capabilities is needed. These applications could

also be beneficial for any of the ongoing examinations during the training [4].

The provision of resource support and out-of-class and learning activities through mobile devices is also supportive of the hearing impaired and is widely applicable in Asia. With the help of resource teachers, pupils and students with hearing impairment are motivated to participate in the learning process and activity. Last but not least, the assistance provided by a parent or relative in the home environment is also of particular importance for improving learning efficiency [17].

In the learning process, the hearing impaired people need proper communication regardless of their age, social status and nationality. Specialized applications are being developed to recognize terms from different languages. The added learning features in these applications are designed to intensively train users in the use of sign language. This can be achieved by voice recognition of words or by typing the words in the selected spoken language. Next, the application displays the appropriate written language images. The research of Setiawardhana, Hakkun and Baharuddin is aimed at developing an Android-based application that directly interprets the sign language, provided by the sign language, into written speech. The translation process starts from hand detection using Opencv and translation of hand signals with K-NN classification [17].

In life, these users often use social networks and video conferencing to communicate with each other. They use the language of the deaf to transmit and perceive information. For convenience, through mobile phones and the Internet, they can exchange information anywhere, anytime.

III. ANALYSIS OF POPULAR MOBILE OPERATING SYSTEMS

New phone models developed in recent years feature not only convenient designs, but also improved versions of both operating systems and software applications. This has led to an increase in users replacing desktops and laptops with modern phones. Improvements in new smartphones are directly aimed at helping people with special needs, and many apps have been developed to help these users in due course.

Just ten years ago, the fact that blind people could use computers, tablets and smartphones was not accepted. Today, visual impairments are no barrier to this, given that blind people perform important work, learning and mobility tasks using their mobile phones. The built-in accessibility features available in smartphones make the process much easier [15]. For example, for getting around, reading emails, online shopping, banking or booking, listening to music. Screen readers such as VoiceOver, TalkBack are also used for the services listed. Blind people can also perceive images accompanied by descriptions through them. Can also successfully use speech-to-text functions when sending messages [5].

Years ago, the popular mobile operating systems were Symbian, Palm, Windows Phone and BlackBerry. The leading operating systems current in modern mobile devices are Android, iOS, and Harmony OS. In this report, only the capabilities of the first two will be discussed, due to the minimal spread of the Harmony OS in Bulgaria at the moment.

In modern smartphones, the 'Accessibility' mode includes options related to screen readers and display settings such as screen magnification, pronunciation of on-screen elements, voice reading, volume up. These features are particularly useful for people with special needs.

A. Features of iOS 16

In iOS, facial recognition of people is implemented through the built-in camera application, which is also helpful for visually impaired users. iOS was originally introduced in 2007, with built-in features to help people with special needs available with the very first versions. Although it supports as many popular languages such as English, Spanish, German, for many years, it has not offered a Bulgarian version.

Localization for Bulgaria was first introduced on September 7, 2022, and the new iOS-16 download became available to users on September 12, 2022 [1]. This version is backwards compatible with all Apple phones – since the iPhone 8, which was introduced in September 2017. This allows people with special needs to take advantage of the opportunity provided without needing devices in the high price range.

In Fig. 1, functionalities of OS are shown in separate groups – for the hearing impaired, visually impaired and physically limited, respectively. The 'VoiceOver' feature speaks out items on the screen and provides helpful hints, where it can also be controlled using simple gestures. On initial activation of this feature, a wealth of detailed information is presented which is useful to the disabled user and their social assistant. Customization includes the ability to set the voice, pronunciation, tone and speed of utterance from the device. For convenience, the additional option of recognizing the phone owner's voice is also provided. The mobile OS also offers Bluetooth connectivity to Braille devices.

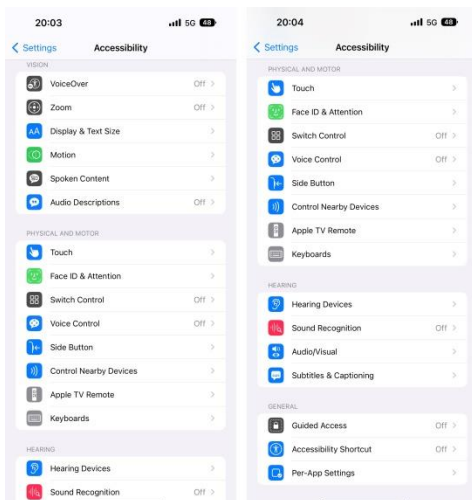


Fig. 1. Functionalities of iOS 6 for People with Special Needs.

Partially sight impaired users are provided by: the ability to zoom the screen, increase text size, adjust color schemes, negative and black and white mode. Hearing impaired people offer the possibility to connect with hearing aids via Bluetooth and a sound recognition option. In the 'Audio/Visual' menu, settings for Mono Audio, Notifications, 'LED Flash for Alerts'

and 'warnings' are collated. In addition, the smartphone supports and adds subtitles and captions for user ease.

The Physical and Motor section includes 'Touch', 'Face ID & Attention', 'Switch Control', 'Voice Control', 'Control Nearby Device' and 'Apple TV Remote'. This section adds options for specific keyboard and side button settings on the device. With all the above-mentioned conveniences of iOS 16 for users, the use of Siri voice assistant can be added, which, however, does not yet support the Bulgarian language.

B. Features of Android 12

The first version of Android was introduced at the end of 2007, with the first T-Mobile G1 (HTC Dream) device running it being introduced in October 2008. In just a few years, Android became the most mainstream OS for mobile devices [23]. Unlike devices at the high end of the price spectrum running iOS, Android is affordable for users with minimal financial means. Another advantage of the Android mobile OS, besides being free, is that every smartphone manufacturer is licensed to use it. The first version of the operating system localized in Bulgarian was Android 2.3 Gingerbread, introduced in 2010.

The menu for people with special needs is located in the 'Accessibility' section (Fig. 2.). It includes 'Recommended for You', 'Visibility Enhancement' and 'Hearing Enhancement', 'Interaction and dexterity', 'TalkBack'.

The TalkBack feature provides speech feedback so the device can be used without looking at the screen. Apart from this feature, visibility enhancement settings are available in Android, which include high contrast theme, fonts, button coloring, animation removal, color inversion.

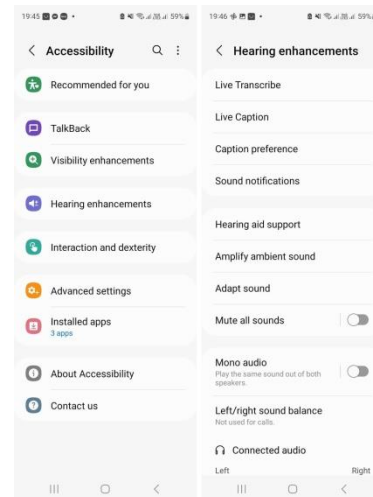


Fig. 2. The Menu in Android 12 for People with Special Needs.

For the hearing impaired, there are personalization options that cover quickly "finding the relevant written symbols of speech sounds", sound notifications, hearing aid support, amplification of external noise, muting of all sounds, left/right sound balance. Unlike iOS, no option has been added in Android to adapt the device to recognize the user's voice. The Physical Restrictions and Movements section houses options for voice control, answering and ending calls, touch duration,

and more. English Android users are facilitated with Google's voice assistant, but only when setting commands in their native language. Full localization of Google Assistant in Bulgarian is not yet available. In addition to the capabilities of the mobile OS, smartphones extend their functions for people with disabilities through dozens of specialized applications. A more extensive exploration of their capabilities would be a topic for future work.

IV. MOBILE APPLICATIONS TO SUPPORT STUDENTS IN CODE DEVELOPMENT

The use of mobile devices to carry out various daily tasks is almost inevitable in today's information society. Integrating modern technologies and devices into the learning process of students and pupils is important. The inclusion of mobile devices as an aid to learning also greatly facilitates people with special needs, especially those who are hearing or visually impaired. Thanks to this, access to educational resources is becoming a reality for an increasing number of such learners [12]. Recent years have seen increased use of the Android operating system in combination with specialized applications for creating programming code and the ability for beginners to write source code in popular programming and markup languages, scripting languages, and layout.

Leading subjects such as Computer Science, Information Technology, Web Technology, Internet Programming in Higher Education and Schools are categorized as complex. The formation of algorithmic thinking and code design and implementation habits by learners, especially those with special needs, requires time, guidance and persistence. To provide the ability to input the code in markup languages, scripting languages, layout styles such as HTML, JavaScript, CSS, PHP and other technologies, specialized text editors are needed for both desktop and mobile devices. In terms of functionality, they have options for quick debugging, automatically adding code or working with more than one file at a time, and existing customization options in terms of themes. The main task of students is to adapt to using these editors as a medium for writing and reading code. Only then, they could independently implement codes according to predefined criteria.

As a practical experience, it can start with easier tasks involving tagging, basic elements such as headings, paragraphs, images, links, buttons, forms, and more. Moving on to the layout of the elements using styles and defining their dynamics. The idea is to gradually build practical skills in using popular text editors for mobile and desktop devices.

During classes, a common practice in recent years is for students to use their personal mobile devices to write programming code as well. Screens of the two of the mobile applications used for this purpose are presented on Fig. 3.



Fig. 3. Screens of Web Master's HTML Editor Lite and Droid Edit.

Some of the popular mobile applications for writing programming code are:

- *Web Master's HTML editor Lite* – popular and easy to use editor for Android. Provides the ability to write codes in HTML, CSS, PHP, and JavaScript [22].
- *Droid Edit* – intended for Android analogue of the Notepad++ editor for Windows supporting not only HTML, PHP, CSS, JavaScript, but also C++, C#, Java, Python [20].
- *AnWriter* – widely applicable editor, shown on Fig. 4, with the ability to enter codes in jQuery, Angular, Bootstrap, SQL, LaTeX [19].

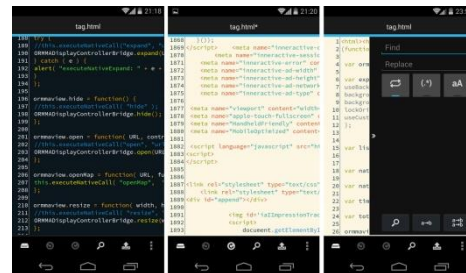


Fig. 4. AnWriter Mobile App Screens.

- *Quoda CODE Editor* – specialized editor (Fig. 5.) for programming languages such as Haskell, Lisp, HTML, C#, C++, Ruby, Python, SQL, XML [21, 22].

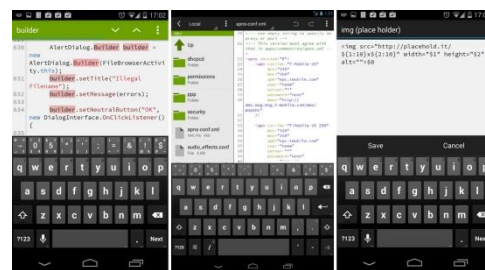


Fig. 5. Quoda CODE Editor, Supporting Functional Programming Too.

V. MOBILE DEVICES AND THEIR ROLE IN EDUCATION

Every blind person has the right to adequate education. However, not all blind people in Bulgaria and around the world have the opportunity to complete their studies. One important factor is the need for appropriate technological tools. Based on studies carried out involving both blind students from Latin America and their parent-assistants, applications for mobile devices have been developed to improve their social life and promote their education. The study points to the design of applications for developing computer games, even by the blind themselves, as a good practice [3].

Until recently, it was impossible to use the phones in educational institutions. In recent years, however, there have been cardinal changes that have gradually necessitated the use of mobile devices by both teachers and learners [2]. The need for quick access to electronic resources has led to their increased use.

During the pandemic of Covid-19, e-learning established itself as an alternative form of attendance in many countries around the world. Everyone involved in online learning – teachers, students, pupils, even parents – had to work in virtual classrooms, which took considerable time to adapt to. Through mobile devices, all learners are greatly facilitated – including those with special needs – when they need to access electronic resources for reading, editing, sending and archiving theoretical information or practical assignments [11].

Schools and universities have made a rapid transition to electronic platforms and this has resulted in the need for students to have the appropriate computer equipment and devices for greater ease of communication. Gradually, their use has become established in almost every discipline. A variety of disciplines focusing on different areas are being taught in leading universities in the country and often programming, web design, multimedia, giving basic knowledge in the IT field are more preferred by the learners.

In recent years, more and more people with special needs are completing their higher education. The fact that mobile devices are finding application in the learning process, which facilitates the perception of information by these groups of users, contributes to this. In the Faculty of Mathematics and Informatics at the St Cyril and St Methodius University of Veliko Tarnovo, the leading specialties in the Bachelor's degree are Computer Science, Informatics, and Software Engineering. Students of these specialties receive the necessary knowledge from qualified university lecturers and experts from computer companies. The faculty also trains students with special needs who successfully complete their education, regardless of whether they are hearing impaired or visually impaired.

The problems encountered during the E-learning of students with hearing impairments were mainly related to the perception of voice information. On the other hand, the provision of electronic resources by lecturers in the form of text files and multimedia presentations contributed to overcoming such difficulties.

VI. MOBILE DEVICES AND THEIR USE IN ACCOMPLISHING SPECIFIC TASKS

For the implementation of specific tasks, the considered editors for smartphones can be used by the visually and hearing impaired without significant difficulties.

For the purpose of the study, in some of the laboratory classes of the leading courses in the Faculty of Mathematics and Informatics, students were given three sample problems with the aim of deriving results related to the topic of this paper, which are summarized in Table I. Both able-bodied students and students with visual and hearing impairments were included as user groups.

The following tasks, described below, were set to be completed within two to four class periods.

First Task: to implement a web page (portfolio) including personal information about a student using the web technologies, scripting languages, markup languages and layout using a personal mobile device and an online text editor. Web page to include elements such as images, headings, paragraphs, buttons, navigation, forms.

The time to complete the assignment is two class periods. As a result, the number of students who completed the task according to the criteria set for its implementation is summarized. The assignment is provided for a group of 10 to 15 students. In completing this assignment, students use a text editor for HTML and CSS of their choice. Some of the more famous editors for Android are presented next section of the report.

In the 'UX/UI Design' classes, students develop prototypes using modern web technologies such as HTML 5.0, CSS 3, Java Script, TypeScript, Bootstrap 4, JQuery, React, AngularJS, and others. The applications being developed are for educational purposes and are not yet available online. One of the conceptual projects is a website for selling mobile devices for all users, including blind and hearing impaired people. The project is designed for both desktop screens and mobile devices (Fig. 6).

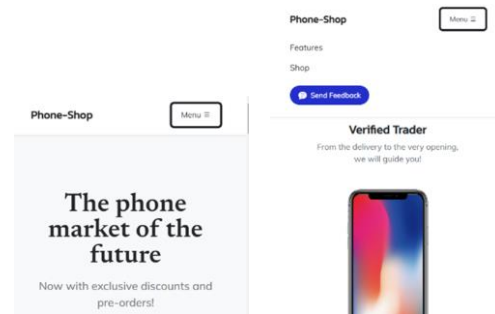


Fig. 6. Design of the Developed Website for Mobile Devices.

The student integrated an embedded audio file reader into the project homepage, the code for which is presented in Fig. 7. A user-friendly and easily reachable navigation of the website has been achieved, which also offers a contact form.

```
<audio id="features" src="/audio/features.mp3"></audio>
<audio id="intuitive-audio" src="/audio/intuitive-solution.mp3"></audio>
<audio id="jump-shop-audio" src="/audio/jump-to-shop.mp3"></audio>
<audio id="phone-market-audio" src="/audio/phone-market-of-the-future.wav"></audio>
<audio id="phone-shop-audio" src="/audio/phone-shop.wav"></audio>
<audio id="send-feedback-audio" src="/audio/send-feedback.wav"></audio>
<audio id="shop-button-audio" src="/audio/shop.mp3"></audio>
<audio id="stop-waiting-audio" src="/audio/stop-waiting.mp3"></audio>
<audio id="wide-variety-audio" src="/audio/wide-variety.mp3"></audio>
<audio id="exclusive-audio" src="/audio/exclusive.mp3"></audio>
<audio id="mobile-app-audio" src="/audio/mobile-app.mp3"></audio>
<audio id="new-age-audio" src="/audio/new-age.mp3"></audio>
<audio id="devices" src="/audio/devices.mp3"></audio>
<audio id="flexible-use" src="/audio/flexible-use.mp3"></audio>
<audio id="referral" src="/audio/referral.mp3"></audio>
<audio id="verified-trader" src="/audio/verified-trader.mp3"></audio>
```

Fig. 7. Part of the Source Code of the Created Audio File Reader.

Another of the student projects is a web-based quiz application designed for blind users and implemented for both desktop systems and mobile devices (Fig. 8).

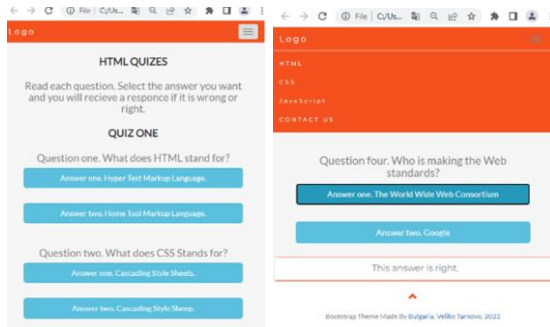


Fig. 8. Screenshots from the Mobile Version of the Developed Application.

In the tests made, blind users easily and quickly adapted to the information presented in the application. When viewed with the Google Chrome browser and the Screen Reader turned on, the reader tells out the text part and thus made it easier for blind users to get the content of each page. When viewed with browsers such as Opera, Avast Secure Browser, Firefox, a pre-configured NVDA or JAWS voice reader is required. The template project is a Web Technology related quiz and includes two key questions and the option for two answers. When one of the answers is selected, its correctness is displayed at the bottom of the page. Two functions implemented in JavaScript verify the received answers (Fig. 9).

```
<script>
function rightAnswer() {
document.getElementById("foo").innerHTML = "This answer is right.";
document.getElementById("foo").focus();
}
function wrongAnswer() {
document.getElementById("foo").innerHTML = "This answer is wrong.";
document.getElementById("foo").focus();
}
</script>
```

Fig. 9. The Function Code is Implemented using JavaScript.

Task Two: Each student should familiarize themselves with the curriculum of a given discipline through the E-student system. For this purpose, a personal mobile device should be used.

The guiding criterion for the task is to apply the UX/UI design principle for the number of clicks (up to three times).

As a result of the task performance, the number of students who successfully comply with the set principle is counted – on the first and second visit to the system, respectively. The task is assigned in groups of 10 to 15 students. The number of students who completed the assignment according to the guidelines is reported as the result.

Task Three: Implement an online market research and simulation of a product or service purchase, optionally via a mobile device or computer, using existing websites.

The task is set in a group of 10 to 15 students. Students who completed the task using the pre-set criteria of using a mobile device, laptop or desktop system are scored. Students' opinion on which device they would prefer in a repeat market research for online purchase is recorded, with 72.73% choosing their personal mobile device over a laptop or desktop system.

A summary of the results is presented in the following Table I.

TABLE I. TASKS ASSIGNED COMPLETED BY STUDENTS

Student's results	Task 1	Task 2		Task 3	
	One solution	Ist option	2nd option	Ist option	2nd option
Users with special needs	3	1	2	3	2
Regular users	47	96+36	125	117	98

VII. CONCLUSION

The idea of this report is not only to promote modern devices, their functionalities, purposes and applications, but also to present the opportunities for some specific groups of users to use them as an aid. In everyday life, education, science and work, people with special needs experience communication difficulties in perceiving and transmitting information that should not be a barrier to their current and future development.

The design of assistive applications for mobile phones is the subject of research, analysis and testing, and implementation in the future, in order to support visually impaired users. People with hearing impairments find it difficult to perceive 'talking' information such as music, news, and multimedia information. However, the perception of textual information in the form of emails, subtitles and messages facilitate communication and data perception.

Screen readers have been developed for the visually impaired to make it easier for them to use mobile devices. Blind people cannot perceive visual information; rather they 'listen fast'. For the hearing impaired, the perception of 'talking' information is partial or impossible. They adapt to perceiving visual information. Regardless of whether the disorder is congenital or acquired, it results in impaired motor, visual and auditory functions.

According to Stephen Hawking, the ability of people to integrate to changes is important. This applies in full force to all people with and without special needs. As the main task of devices is to serve them.

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