Received 3 January 2019
Revised 11 June 2019
Accepted 12 June 2019

A prototype mobile application for the Athens Numismatic Museum

Pantelis Chasapis
Department of Informatics, University of Piraeus, Piraeus, Greece
Sarandis Mitropoulos
Ionian University, Corfu, Greece, and
Christos Douligeris
Department of Informatics, University of Piraeus, Piraeus, Greece

Abstract

The continuous development of mobile platforms provides the opportunity to integrate and improve existing applications or to introduce new features to make life better. The purpose of this paper is to investigate the use of mobile platforms in civilization (museums) and present the design and the implementation of a mobile application that satisfies various design criteria. Through this application the visitor can navigate and tour virtually in the museum through a smartphone. In addition, features have been included in the application that make it easier for a user to visit the museum. First, we present the operating parameters and the aesthetic presentation of the application, which delimits usability and ease of access through the interfaces of a smartphone. Then we highlight the cloud features that were exploited in the application. Then, an extended evaluation of the mobile application is presented, that proves its high applicability and user acceptability.

Keywords Mobile applications, Google Firebase, Numismatic Museum, Audio tour guide, Material design
Paper type Original Article

1. Introduction

The rapid growth of mobile devices [1] and the need for instantly available information have led to the emergence of modern electronic applications and services, designed to facilitate remote communication and to enable users to navigate and receive the necessary information directly through the internet and, lately, though cloud services.

As far as museums are concerned, most museums have created their web sites where visitors can find the appropriate information they are interested in regarding the museum's content and to access the museum's contact details. Nevertheless, most museums have not

Publishers note: The publisher wishes to inform readers that the article "A prototype mobile application for the Athens Numismatic Museum" was originally published by the previous publisher of *Applied Computing and Informatics* and the pagination of this article has been subsequently changed. There has been no change to the content of the article. This change was necessary for the journal to transition from the previous publisher to the new one. The publisher sincerely apologises for any inconvenience caused. To access and cite this article, please use Chasapis, P., Mitropoulos, S., Douligeris, C. (2019), "A prototype mobile application for the Athens Numismatic Museum "A prototype mobile application for the Athens Numismatic Museum", *Applied Computing and Informatics*. Vol. ahead-of-print No. ahead-of-print. https://10.1016/j.aci.2019.06.001. The original publication date for this paper was 14/06/2019.

Applied Computing and Informatics
Vol. 19 No. 1/2, 2023
pp. 144-172
Emerald Publishing Limited
e-ISSN: 2210-8327
p-ISSN: 2634-1964
DOI 10.1016/j.aci.2019.06.001

created the most "user-friendly" sites and the content they contain does not meet today's museum goers' expectations, who demand immediacy and a wide range of information.

This paper presents the development of an Android application for the Athens Numismatic Museum and will show how the modern technologies [2] can improve the user experience [3] by providing more thorough information and touring capabilities in the museum [4]. In this paper, we will initially talk about the problem space associated with the research and development of our application. Then, the related work is analyzed, as well as the technologies that were used to build the application.

In addition, we will present the requirements analysis, the system and the main implementation issues through appropriate UML charts. The functionality of the application is also depicted through screenshots and appropriate descriptions. We created a questionnaire through which we were able to evaluate the application to see, if the application meets various user needs in terms of usability and functionality [5]. The results of this evaluation are also presented. Finally, future improvements are discussed and concluding remarks are presented.

2. The problem space

In the past, when the technology had not entered in our everyday life, the museums did not have the proper means of informing the visitor. The visitors could be informed by phone or through brochures about the museum. Guided tours or dedicated tour guides were the main ways one could get information regarding a museum. Just before the spread of the Internet, museums slowly started to add digital media in their operations, for example, computers, projectors, and Walkman audio tours. With the arrival of the internet, the museums gradually began to develop web sites, and, then, with the ubiquity of mobile devices Android/iOS/Windows Phone applications were offered to the public [6].

Through these applications, visitors can now take a tour of the museum through three-dimensional imagery, to focus more on some exhibits that has impressed them [7], to get informed about an event to be held, to receive information about the museum and even to experience an audio guided tour in their language of choice.

Through mobile applications, the visitors can organize their time at the museum more productively, focus on the exhibits they are interested in, and browse museum services remotely [8]. They no longer need a laptop, just a portable device that has internet access provides faster service and shorter waiting times.

3. Related work

In this section, the basic features of some museum Android applications are presented. The selection of these museums was based on the features they possess, their visual design and because they are some of the world's largest museums. Finally, we discuss research work related to this paper.

3.1 Related systems

The Louvre Museum in synergy with Satraps has developed its own application. Through this app the visitor can navigate through a three-dimensional representation of the floor plan of the museum for a better understanding of the area. Using the 3-D floor map,[1] visitors can locate the exhibits of interest, purchase audio guides for a sound tour for each exhibit. One of the main features of the application is the non-permanent connection to the internet. It is also easy to use, and the user interface is very friendly. Another characteristic feature is the provision of audible guided exhibits of six hundred exhibits as well as the three dimensional and interactive representation of 60,000m^2 of the museum. Visitors are also provided directions to the site via

the global positioning system (GPS). Finally, the app is compatible with devices running newer versions than Android 4.3 and iOS 8.0 and it is available in seven different languages.

The Dali Museum, which is located at St, Petersburg, Florida, presents the career of the well-known painter Salvador Dali. The Dali Museum Virtual Tour is a digital tour that allows visitors to experience Dali's obsession, humor and talent. The Virtual Tour presents basic key works from every moment of its artistic activity. On the positive aspects of the application is the offline operation. On the negative, the floor plan of the museum is a photograph, which is not interactive, and it has only a small number of few functions. The application is available in the Google Play Store,[2] where visitors can download it and use it to tour the museum premises. Beyond its offline operation, this application has a variety of features. First, the user interface is easy to use and modern. It does not require a permanent Internet connection and provides a free sound description of the exhibits. It also allows visitors to choose between four different languages and to share their exhibits on social networks.

The corresponding app for the British Museum[3] covers all the exhibits in the museum such as Ancient Greece and Egypt and it also features a three-dimensional representation of the floor plan and a sound tour. However, the design of the application has not followed Google's Material Design [9] guidelines. The interfaces and the overall state of the application point to an outdated design compared to the two previously presented user-friendly applications. In addition, in our test we faced delays in the application.

Finally, the Metropolitan Museum of Art in New York, one of the largest and most important art museums, in 2015[4] made available to the public applications for mobile devices running Android and iOS. Their main features are the user-friendly experience, the three-dimensional floor plan and the ability to add a position on the map for an easy viewing of the exhibits and a suggestion system based on user habits. Nevertheless, a constant Internet connection is required for its operation.

3.2 Research work

In this subsection, we will discuss systems under development by considering their features and the technologies they use. Their main characteristic is the effort to improve the visitors' tour experience in museums with the most up-to-date technologies.

The Museum Mobile App Guide [10] is an implementation for the Classic Motor Museum in Cyprus. Through the application, visitors can browse the museum's exhibits and find the required information. The application features two languages to facilitate visitors. At the same time, the exhibits contain audio information in both languages, allowing the visitor to use their own smartphone without the need for extra equipment from the museum, reducing the cost of visiting. Finally, the application enables users to upload their own photos from the museum with their comments as well as any complaints/suggestions.

As technology has substantially evolved in the recent years, QR codes[5] have begun to spread widely and they have been introduced into our everyday lives. The museums place QR codes next to the exhibits so that through an appropriate application, visitors can get information about the exhibit.

In the recent years, AR (Augmented Reality) is beginning to appear in our daily routines and is helping us in many areas.[6] In Augmented Reality, artificially digital 3D objects are integrated in real-time into the existing environment, giving you the ability to interact with the user. Augmented Reality applications use the device's GPS to locate the user's location, the compass to locate the device orientation, and the camera to capture the surrounding area. Besides the smartphones, transparent masks or head mounted displays are also used to view Augmented Reality.

An implementation of AR technology is the application "Step by Step" a Mobile Guide [11] of the Palazzo Madama museum at Torino Italy. The visitor can navigate the museum's premises through augmented 360 images. The application has augmented reality features at

2013 when the Android OS did not have any built-in library to develop these functionalities. The latest updates of Android OS bring augmented reality features to the developers and give them the opportunity to build impressive applications.[7] With the 2D/3D navigation the visitors receive the appropriate directions to find the rooms or the exhibits of interest. Developers have set hotspot at the photos of the rooms so that the user can interact through them, having access to information and photos/videos of the exhibits. To improve the user experience of their application further, through a questionnaire they collected from two hundred visitors' feedback were used to achieve their goal. Through the results, they created the second version of the application, redesigning the application and focusing on simplicity the interfaces and the ease of use.

Thanks to further improvements in AR technology and hardware, the developers have been able to add new features to their applications. The mobile devices now have more computational power to perform tasks where only a strong computer could cope with in previous years. Such an implementation is the AR-Museum [12] which enables the visitor to interact with museum paintings by changing colors at any level of the painting and providing a different way of entertainment at the museums. The application provides two methods for color change, the first through an appropriate algorithm produces an automated result. And the second through manual selection, when the user is clicking an area in the painting, the image begins changing the colors randomly in that selected area.

3.3 Related work analysis

In this subsection, we will provide an analysis of the previously presented applications and research work in relation to their features. The Louvre Museum and the Salvador Dali Museum are the applications that stand out for most of their features, their modern design and their easy-to-use user interface [13] and they do not require a permanent Internet connection. They feature a multitude of exhibits with a sound tour and support various languages. On the other side, the absence of 3-D imaging in the Dali Museum's app and the fact that the floor plan is just a photo and do not give the capability to the user to select and navigate directly to a desired exhibit or room.

In addition, the implementation for the British Museum is one of the first attempts to create an application that improves the touring experience of the visitors. This application includes a wide variety of exhibits. It also has a sound tour and audio reading of text for people with visual impairments. In relation to the other museums we mentioned, it has the oldest design and some response delays are observed.

The Metropolitan Museum of Art in New York follows Google's Design Material design rules and has several of the features of the above-mentioned museums. Compared to the other applications it contains the largest integration of social networking tools into the application and the ability to create an account to suggest visitors based on parameters which rooms exhibits to visit based on their favorite categories and according to their available time.

As far as research work is concerned, the three implementations mentioned above have been following the current trends of designing. In terms of functionality, we the Museum Mobile App Guide has the ability to upload visitors' images to the application and audio information about the exhibits. Finally, "Step by Step" a Mobile Guide and AR-Museum incorporate AR capabilities, even more applications in the future will adopt AR capabilities and we will see new ideas on how to improve the touring experience of the visitors.

4. Our prototype system

In this paper, we will try to develop a mobile travel application for museums that follows Google's designing rules of Material Design and that provides the visitors with the necessary functions and elements that do exist in the applications presented above. The most important feature of the application is its ease of use and user-friendliness [14], exploiting the

appropriate resources to avoid overloading the device memory/cpu [15], to be responsive to any type of device depending on the screen size (tablet/smartphone), providing appropriate information depending on the user's screen and exploit new cloud computing technologies.

The museum that has been chosen for the design and development of the application is the Athens Numismatic Museum[8] because it is an extremely interesting museum, with an increasing number of visitors discovering it, rare exhibits and an excellent building in terms of architecture.

4.1 Requirement analysis

This subsection provides a description of the requirement analysis. In summary, through the application, the visitor will be able to browse the museum premises, get information about the rooms and the exhibits it contains, receive the appropriate information to access it, and receive push notifications from the museum about new events and news. There is also the capability of an audio tour through which the visitors will download the appropriate guided tour at their preferred language.

4.1.1 The more general requirements of the system. One of the main features of our application is the ability to work seamlessly on all devices regardless of their size, specifications, and operating system version. The users should be able to use smaller sizes as well as larger ones such as tablets. The application should be properly optimized so as not to cause functional problems for users [16] even if they do not have a powerful device. In addition, we have to follow the Google designing rules of Material Design, to provide to our users the best user- friendly experience.

One of the main designing goals is to run the application offline because the users may not have mobile device with internet connection at the time of their visit. To resolve this problem, we use a local database in the application, which contains all the information and photos about the Museum. In order for our application to facilitate visitors who do not know the Greek language, we decided that it was necessary to add the English language as well. In addition, we want our users to communicate to each other, this presupposes that the users must create a user account to sign in and they have the ability to change their passwords. To improve the user experience of our application, the users must have the ability to add their favorites exhibits and rooms, so when they are in the museum, they can navigate through the exhibits of interest to them and see information about them. Furthermore, we will use Google Map for easy access to museum.

The users will be able to find the best ways in which they can reach the museum. Through the application, the user should be able to tour the museum with an audio guide tour which is integrated at the application. The users will have the ability to purchase these tours through PayPal. Finally, we will add push notifications to inform the visitors of the museum, about special events and ticket discounts [17].

4.1.2 The requirements about development. About the administrator, we need to have the ability to update the local database of our application, without updating the application in Play Store. In addition, we will create the appropriate analytics about the visitors and their habits, through Fabric-Crashlytics we will maintain better our application. The application has been deployed to run on devices running larger than the Android 4.1 operating system. A local database has been used to store all the necessary information and the user can run the application without the internet. Google Firebase services are also used to send and receive information, update the database, receive and push notifications, and other features [18].

Using the Google map, the visitor can easily and quickly get the right instructions to reach the museum. JSON technology is also being used to communicate with Google Maps and get the right information from the Cloud. Finally, the Fabric SDK is used to check for debugging, to detect any application bugs. The programmer, through a special interface, can see at any time why the application stopped working [19].

4.2 System design

Based on the above requirements analysis, we present the design of the application through UML charts. We also present use cases and the features that are added to the application.

4.2.1 User roles. As mentioned in the requirement analysis, there are two types of users, the visitors and the administrator in the application, so there is a distinction between their capabilities. Each type of user has different access rights to the application. The visitors have a direct contact with the application through their devices, while the administrator has access to the application functions through a dedicated interface from a website. These two roles will be presented in detail and through appropriate case scenarios.

a) Features available to visitors

They can choose the appropriate language, Greek or English, when the application starts. After choosing the language, the application proceeds to the main interface where the users can access the features of the application. At these interfaces, the user can have easy access to the list of rooms contained in the museum. There is also a timeline[9] which contains all the exhibits in chronological order. The visitors can add any rooms or exhibit as their favorite and using the audio tour guide, they can explore the museum with any Android device. In addition, the users can see the plan floor of the museum and browse the existing rooms.

There are interfaces where the user can get informed about all he will need to visit the museum, like the ticket cost, contact details, the upcoming events and how to access the museum. Furthermore, we have added a Portal where the visitors can write their experience from their visit to the museum, read other visitors' posts and comment on these posts. Adding posts and comments requires user registration.

Finally, the visitors can receive push notifications if they choose to be notified by the museum. The notifications concern events, news and whatever the museum chooses to promote. All the characteristics of the above features are presented in the use diagram of Figure 1.

b) Features available to the administrators

The administrators (admins) must have the ability to manage the user profiles and add or edit various details. They can also create and update the interface of events and the Portal where the users can get informed about the latest events and updates regarding the museum. In addition, the administrator can update the cloud audio files and database of the application with the latest available versions. Finally, the administrator has access to Google Analytics and Fabric Crashlytics (Figure. 2).

The admins do not have access to the application through the visitor interface, but through a browser. Firebase has a cloud database that contains user data, events, visitor reviews, posts, and PayPal transactions. In addition, there is Firebase Storage where the audio guides archives are uploaded.

4.2.2 Designing the user login and registration process. In the requirements analysis, we saw the necessity of registering and connecting the visitor to the application. It is advisable to pay attention to the planning of the process that will be followed when a visitor is connected to avoid any errors. The user registration can be done either through the application or by the administrator via Firebase [20]. The information a user will need to register is an email, a username and a password.

All the data are stored in the cloud database, and the password is encrypted so that only the user knows it. During the registration, the above items are requested. In the case where the user has not entered a field, the user receives an appropriate message to fill in the empty field and proceed. In addition, we check if the email is in the correct format and is not being used by another user. Otherwise, they receive an error message and ask them to change the fields to

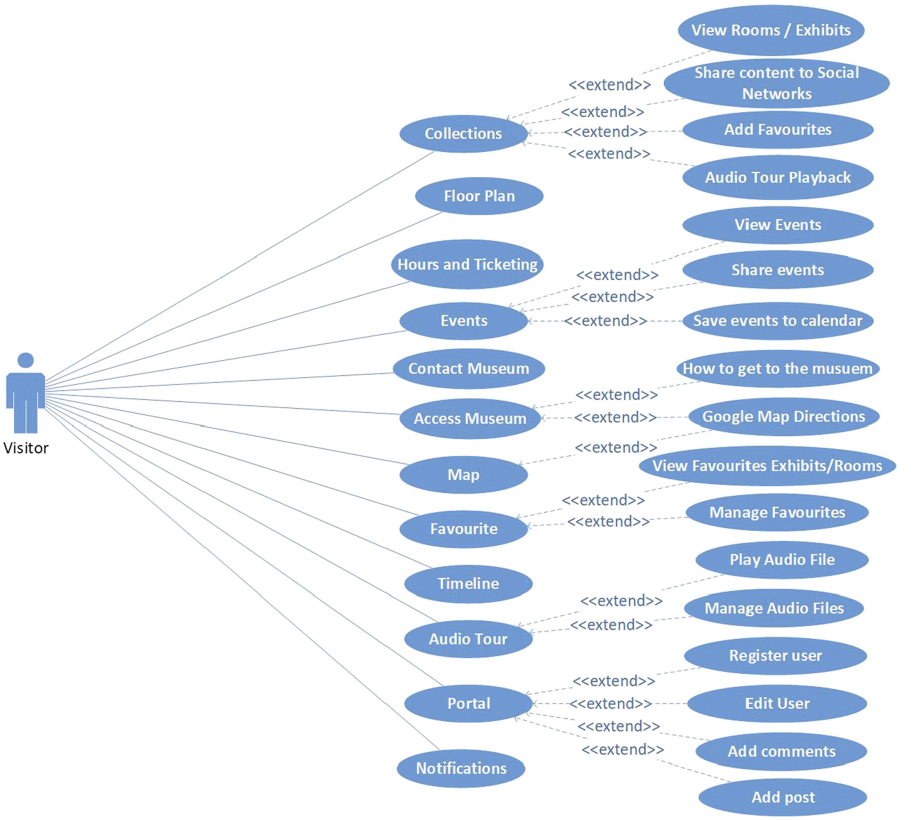

Figure 1.
Visitor use case diagram.

complete the registration. The sequence diagram of Figure 3 describes the registration process.

4.3 Implementation approach

In this subsection, we present the technologies we used to develop the application and the problems we encountered during the implementation.

4.3.1 Development technologies. At first, we will make a small analysis of the technologies and their features that were used.

a) SQLite Database

The implementation of the application created the need for the availability of a local data storage and the capability to use the application without a permanent Internet connection. The user should have direct access to the data regarding the exhibits and the rooms of the museum. The SQLite database [21] was used to manage these data. SQLite is an open source database, exploits the relational database template and incorporates features such as SQL syntax, transactions, and ready situations.

b) Google Firebase

Firebase is a cloud (BaaS) service used to develop mobile and web applications. It enables developers to add features to applications according to their needs. The application that has

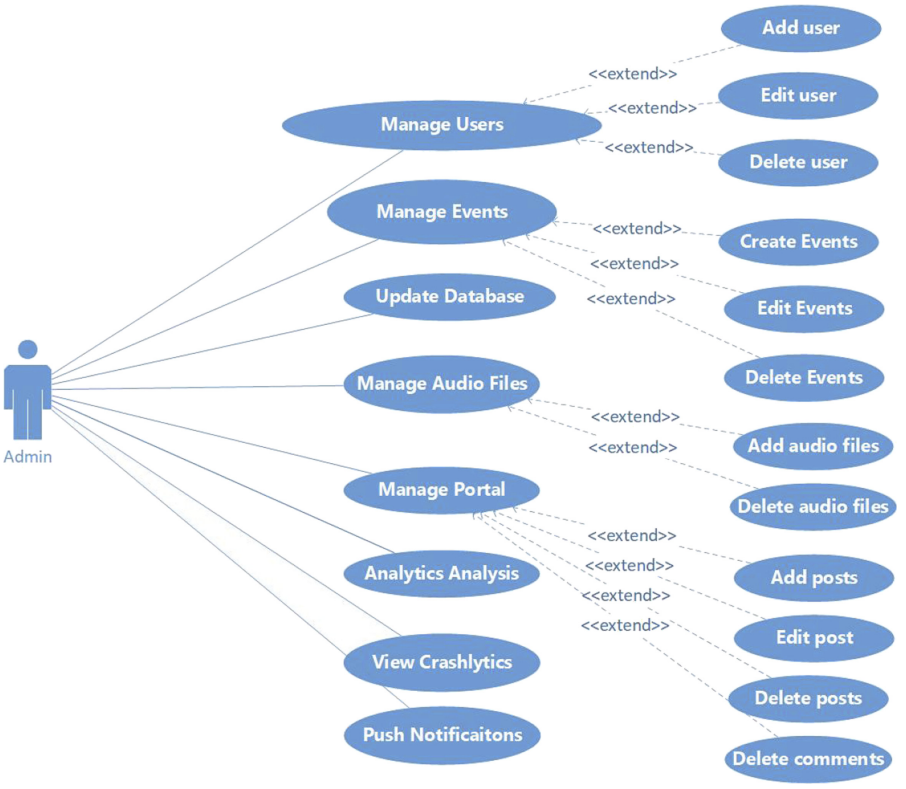

Figure 2.
Administrator use case diagram.

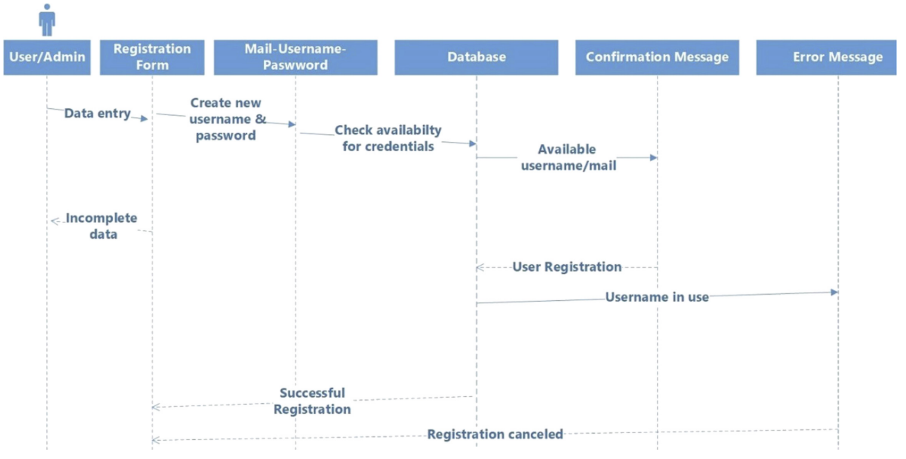

Figure 3.
User registration sequence chart.

been created has made extensive use of Firebase features. One of the main reasons we chose Firebase was its ability to add cloud functions without a physical server, and it is provided free of charge, until a certain usage limit. One additional main feature is ability to be incorporated seamlessly into the Android operating system.

The Firebase features that were added to the application included Firebase Analytics, Realtime Database, Cloud Storage, Cloud Messaging and Remote Configuration.

c) Fabrics Crashlytic

Fabrics Crashlytic is an SDK that records instabilities in applications. It is available on the iOS/Android/Unity platforms, allowing developers to find the code line that caused application instabilities and errors. When the instability occurs, and before the application stops responding, it sends the necessary data to the Fabric database, which is available to the developer in the next two minutes or if the device does not have access to the Internet when it connects to internet sends the data. At first it was used exclusively on portable devices, but today it is also used on websites.

4.3.2 Implementation issues. During the implementation, we encountered problems with the images of the application. The problems related to how we manage to decode and display fast and efficiently the images, without having problems with low-end devices. In addition, we wanted to handle problems with memory and disk caching, since we must cache the images for faster loading. Another problem we faced was threading. We wanted to download the images without provoking delays in the UI thread and to download them in a background thread. In addition, we faced problems with concurrency and delays at lists, when a user was scrolling fast, or the number of the items was too large. We resolved these by using Glide.

Glide is an open source media management library, where we can find it at GitHub [22]. First, we need to add the library to our application, in order to download the necessary files. After that, we can now use Glide to solve the above problems. All that remains is to use the appropriate command. Finally, Glide undertakes to manage all the problems mentioned, all we must do is to give it the image source and in which ImageView we will display the image. And with this process, we display an image without the problems we discussed.

4.4 Operation demonstration

In this subsection, we will see in screenshots how our application works. We will show the most important interfaces and features that we have added to our application. Firstly, when the user enters the application, the Splash interface (Figure 4) displays the choice of the desired language between the Greek and the English language. Prior to selecting the language, the application logs on to the Firebase Storage where the newer version of database is located, if the local base device is newer or older than the Firebase database.

If the application finds that there is a newer version of the database in Firebase, then it informs the user through suitable message and proceeds to download the database. The user can cancel the download and proceed to the main interface. At the beginning of the download, it temporarily stores the exhibits and the rooms of user that has chosen as favorite. Finally, when the download is completed, the favorites are added to the new database and the users can choose the language that they want to proceed with the application.

After the Splash interface, the users go to the main interface, where they can navigate through the six buttons of the main screen (Figure 5). At the top left of the title, there is a menu button of a list with the additional application interfaces, and at the end of the toolbar there is the home button through which the user returns to the main interface when he is in another interface. Through this list the user can navigate directly and quickly to the desired interfaces.

By selecting the Collection button, a list is displayed showing the eight topics (Figure 6) of the Numismatic Museum, from which the user can choose to see the category of interest.

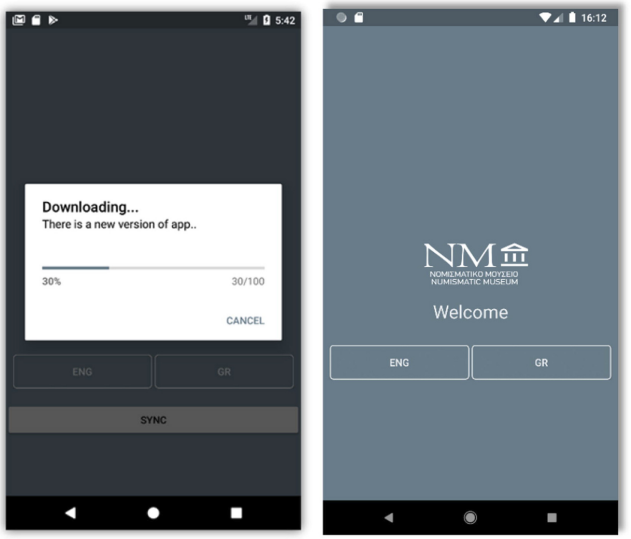

Figure 4.
Splash screen.

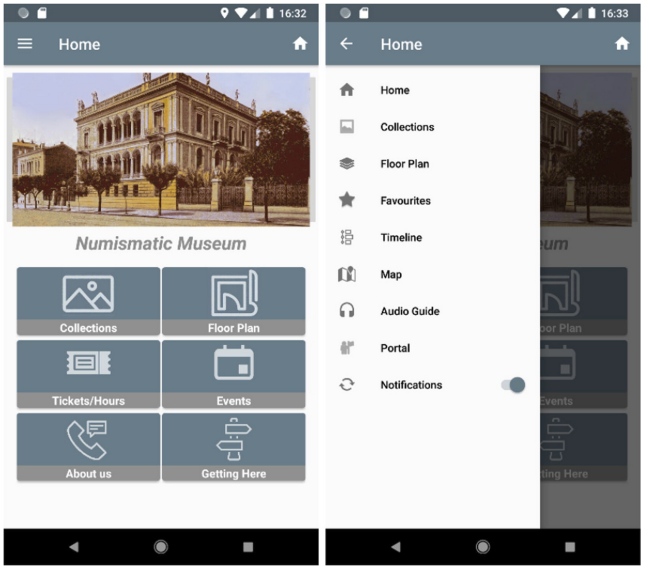

Figure 5.
Dashboard interface (Schliemann Mansion: Licensed by: CC BY-SA 3.0 (Accessed: 10/6/2019)).

As we can see in the interface that appears when the user chooses, except from reading the text, he can magnify the text in a larger font, to choose the category /exhibit as a favorite, so that they can navigate through their favorite interface directly. In addition, they can purchase the audio tour by selecting the play button. (Figure 7) An appropriate window will appear to inform them about the purchase cost and the terms. If there is no internet connection the application will inform the users with a suitable dialog. If the user opts for the purchase, the PayPal interface is displayed where the user can register the username

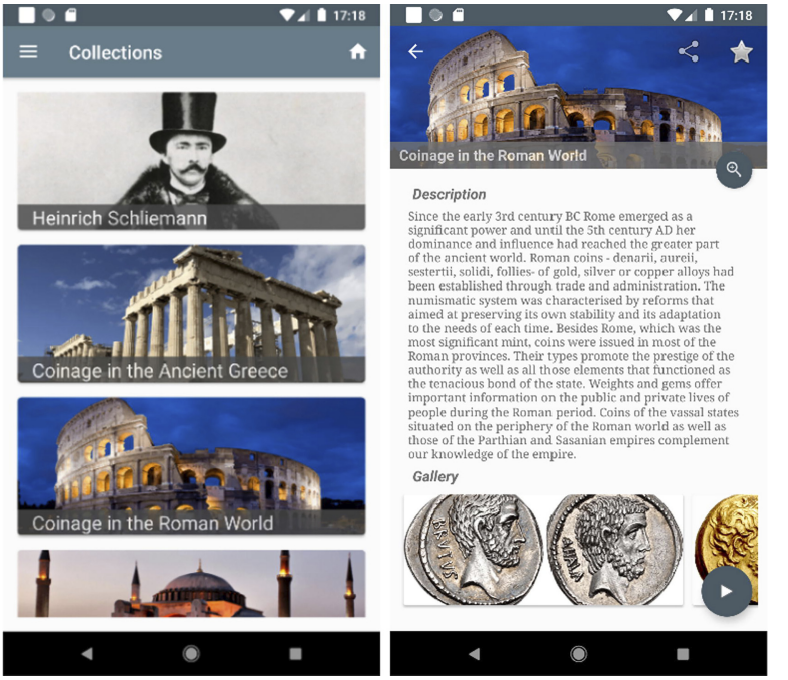

Figure 6.
Collection and Detail interface (Colosseum: Photo by David Cliff (Accessed: 10/6/2019), Acropolis: Licensed by: CC BY-NC-ND 2.0 (Accessed: 10/6/2019), Heinrich Schliemann: Licensed by: CC BY-SA 3.0 (Accessed: 10/6/2019), M. Brutus Coin: Licensed by: CC BY-SA 2.5 (Accessed: 10/6/2019), Titus Quinctius Coin: Licensed by: CC BY-SA 4.0 (Accessed: 10/6/2019)).

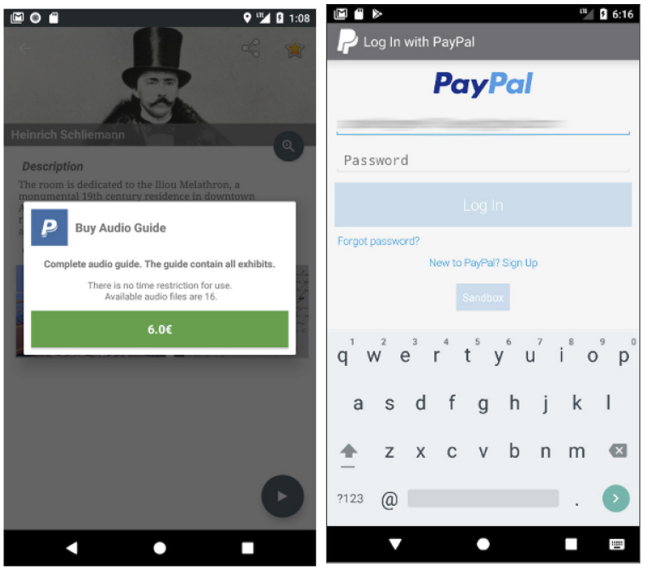

Figure 7.
PayPal screen.

and password of his PayPal and proceed to the purchase. If the data are not filled in correctly or if there are missing items, the user will be informed by an appropriate message.

Once the purchase process is completed, the user can download the audio files according to the language they have chosen. PayPal issues the transaction code, which is stored in the local database so that it does not need a continuous Internet connection to verify if the user has purchased the audio tour. The transaction code is also stored in the Firebase database, so if the user wants to re-install the application, do not need to buy the tour again.

By pressing the play button, the user receives a message if they want to authorize the application to read the audio files from the device storage [23]. If the user accepts these permissions, application proceeds to check the availability of the audio file on the device, if the file is existing, it will start playing, otherwise the audio guides interface will be displayed where the user can download the files.

The download process is managed through the Firebase SDK, in case the download is interrupted either because the user has changed the application with other or received an incoming call, the download pauses and we register a download point to a variable so that when the user returns to the application, we will continue downloading from where it stopped. If the download stops unexpectedly, via message we inform the user that the download is not completed, and it tries to download the file again. Finally, the user can play the audio files if they have downloaded it or deleted the audio files separately.

At the end of the Collection's interface there is a horizontal gallery in which there are photos and descriptions of the exhibits in each room and category. The user can browse between the photos to save them as favorites. Finally, there is a notification button on the interface toolbar, where the content is shared with social networks.

If the user chooses to see the floor plan (Figure 8) from the dashboard, has the choice to see the floor plans of the two floors of the museum. Switching from the two buttons to the end of the interface, the two images are interactive and the user by selecting one of the rooms opens a new interface and accesses the room information he has chosen. At the top of the interface, as shown in the pictures below, there is a memorandum of the rooms.

One of the most important interfaces of this application is the Portal (Figure 9). Through the Portal, the users can comment on any of the existing posts or create a post by themselves. In order to read the comments, it is not necessary to create an account. In case the user wants to comment or upload a post, it is required to create an account. The contents of the event interface are stored in the Firebase Database.

When entering the interface, the user views the posts available for reading by selecting one of the posts. Opening a new interface where the user observes the user's nickname on the toolbar that uploaded the post, the date of posting, and the menu button where different options are given depending on the user's status. If the user has been logged in, it is possible to disconnect and change the password through an email, otherwise they are prompted to register.

By selecting the Sign Up/Login option (Figure 10), the user can now create a new account or sign in with the information they had already created. When registering, it is necessary to fill in a username, an e-mail and the security code. In case they do not complete any of the fields and click either to enter or register it is informed that it has not filled in all the details.

Having completed the registration, it is now possible to make a new post, as shown in Figure 11. The post title and the description are mandatory fields. If the user skips one of the two fields, the user will be updated to fill in the empty field. In adding comments, the user can upload up to eighty characters, this limit has been set so that the Firebase database does not fill up with many elements as its free version and has limit usage.

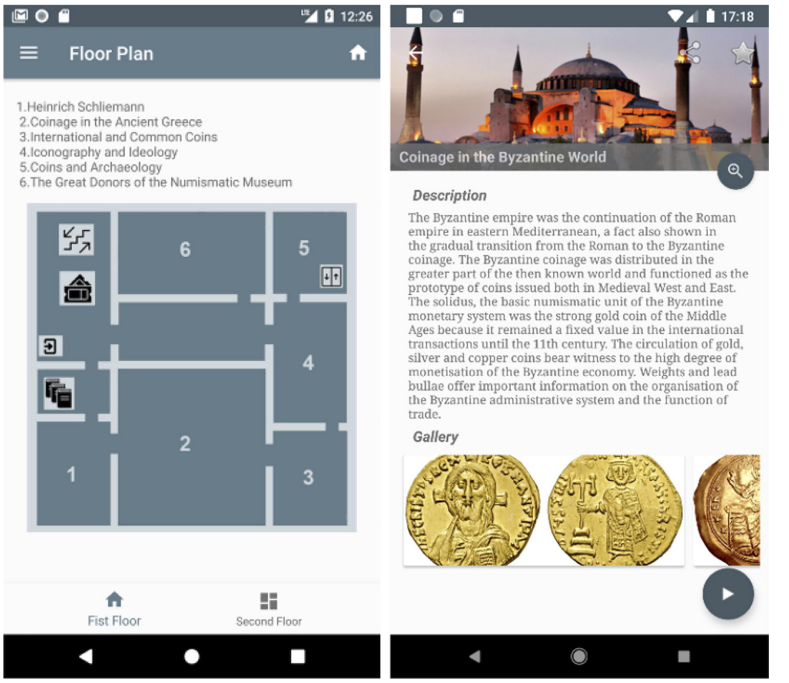

Figure 8.
Floor plan interface (Hagia Sofia: Photo by David Spender (Accessed: 10/6/2019), Justinian II: Licensed by: CC BY-SA 3.0 (Accessed: 10/6/2019), Hyperpyron of Alexius I: Licensed by: CC BY-SA 2.5 (Accessed: 10/6/2019)).

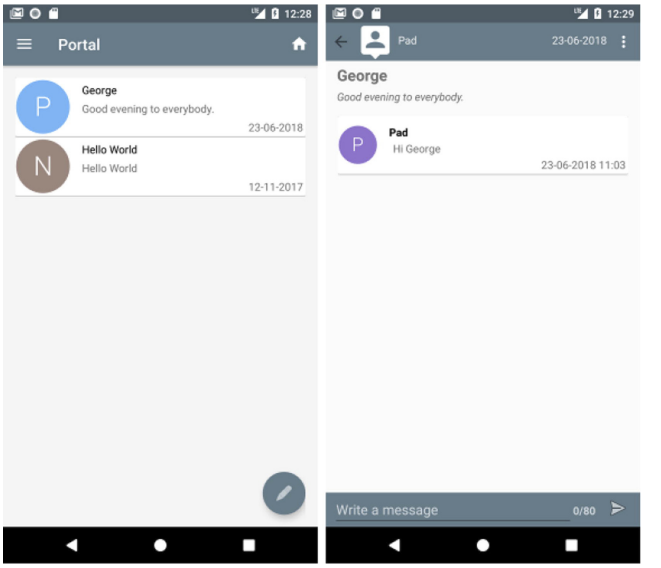

Figure 9.
The Portal interface.

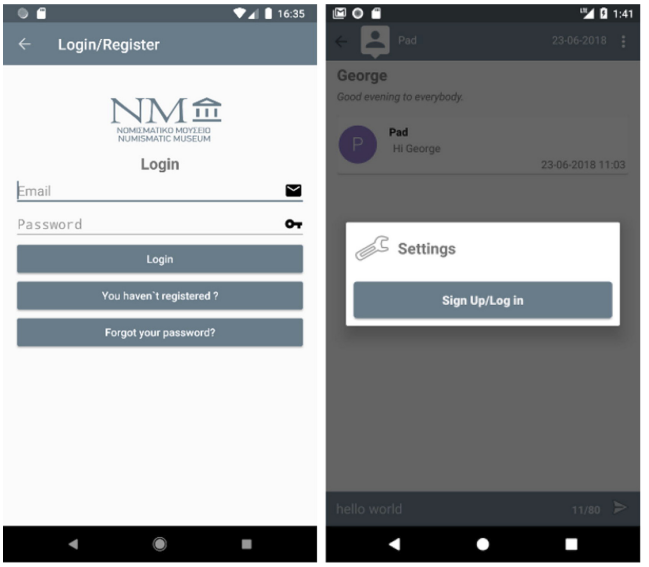

Figure 10.
Register and Portal interface.

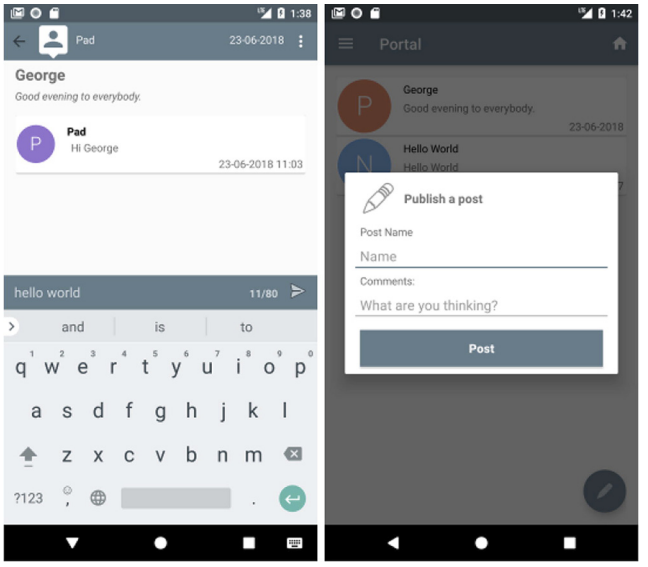

Figure 11.
Add comment and post in Portal.

5. Evaluation

A questionnaire was created through which the application assessment was carried out to determine whether it meets the user needs in terms of usability and functionality. To evaluate the application, the usability questionnaire was sent to twenty-five users via email through the Google Forms platform.

In the evaluation process, the selection of the respondents was based on their familiarity with the technology and on the fact that they have visited at least one museum in the recent years and, optionally, that they have visited the Athens Numismatic Museum. Through these criteria, we wanted to ensure that the users would give us the best possible feedback to understand if our application's features would satisfy their requirements to visit the Athens Numismatic Museum or if they needed further improvements. The respondents were from eighteen to thirty-five years of age with higher education as younger educated people are usually more familiar with the technology and from different business workspaces.

Before the questionnaire was sent, we delivered to the users a final version of our application to their devices, to try our app and to detect any bugs. In addition, we sent them instructions about how to download and install the application at their smartphones as we see at the Appendix A. About the bugs we are using Fabric Crashlytics, through which we would draw the appropriate conclusions about how crash free our application is. The questionnaire includes twenty-six open and closed questions, divided into four sections and it was distributed between 21 December 2017 and 27 January 2018.

The sections of questionnaire:

- Demographic information about the users who took part in the evaluation.
- In the second section, queries concern about user's habits and the degree of familiarity with smartphones.
- In the third section, we evaluate the usability of the application.
- Finally, in the last section the questions are related to the functionality of the application.

These modules measuring users' satisfaction with the application's functionality, contain questions that seek to identify any additional user needs that might be useful to add to future versions of the application.

At the end of this survey, we drew our conclusions and updated the application based on the results. It is in our plan to send a second questionnaire in the future to a larger variety of people, based on wider age and with less familiarity with technology.

5.1 Presentation of evaluation results

In this section, we will present the questions from which we extracted the most important conclusions and we analyze the results of the twenty-five users who replied. We will mention why the questions were asked and how they are linked [24]. The whole questionnaire is available in Appendix B [25]. In the first two sections, we wanted to collect information from respondents from their daily routine, about their intimacy with new technologies and demographic information to make our conclusions based on the audience that responded to our questionnaire. Most of the users were men, most of them held a university degree (Figure 12) and worked as private employees. The responders seem to be fully familiar with smartphones, and with modern technologies and devote several hours of day using their devices, which means that they will be more precise and objective with their answers. Thus, we will be able to extract more significant and reliable results about our application.

The users were asked about the amounts they spend each month on the apps they have installed on their devices. This question is important for us because then users will be asked about purchases within our application, in order to understand the user's habits about shopping online through applications. The majority of respondents (68%) replied that they do not spend any amount monthly on their applications and only the 24% said they spend less than one euro (Figure 12). The results show us that the users prefer free applications available

on the Google Play Store and that they do not spend significant amounts on the services they offer.

In the next section, the respondents were asked about the usability of the application and about the user friendliness and the user experience of the application, in order to draw the appropriate conclusions how the users see our application and whether we have achieved our goals during designing As we see most of the respondents reported to us that the navigation was simple and easy to use (Figure 13). The flows between the user interfaces were understandable and did not face any problems during the navigation. The content of the application was useful and clear (Figure 13). With the above questions we want to understand how friendly our application is and how easy to use, the following questions are relevant about the design of the application in terms of the overall appearance and content. We ask the users about the aesthetics of the application and the clarity of the text and the images. All the respondents answered positively about the visual result of the screens of our implementation. The quality of the images left them satisfied and the text was clear and did not render any visual problems as see from the Figure 14.

In the last part of the questionnaire the respondents were asked about the functionality of the application. Through these questions we will try to export conclusions if the features we have provided to the application cover the needs of the visitors and we will ask for their views on features that have not been included in this first release of our application and are considered important for future upgrading of our implementation.

The application contains many photos from the museum's content and the audio guided tour that will consume a lot of data from the user's plan or we will need a stable and well covered Wi-Fi of the museum area. In addition, the visitors may do not have a device with 3G/4G connection to use the data of their plans and we will face extra charges using their plans outside the country where they come from. To solve the problems mentioned, during the designing of the application, it was considered necessary to run the application without the need for a permanent connection to the internet. So, a local base was created on the user's device so that the application works in the museum or anywhere else without being continuously connected to the internet. The respondents were asked if they consider it necessary to have a continuous internet connection, from the results we will extract significant information's about users habits and if during the design we achieved the result we set as functionality and if it is considered important for users.

Figure 15 shows that the majorly of respondents (56%) kept a neutral position about a permanent internet connection, the 20% believed that an application is needed to maintain a continuous connection to the Internet and only 24% considered that the applications did not need to be connected permanent to the Internet. Through the replies, we see that users are not totally negative to have their devices connected to the Internet, but they are not absolute in the opposite view. The majority of users responded neutral, meaning that users either have a large data plan to spend on a guided tour, or assume the existence of a Wi-Fi connection capable of meeting the needs of the visitors.

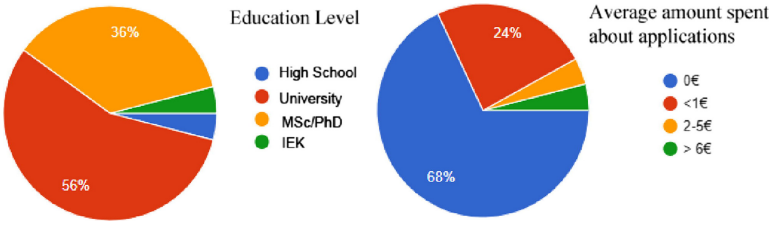

Figure 12.
Average amount spent about applications and education level.

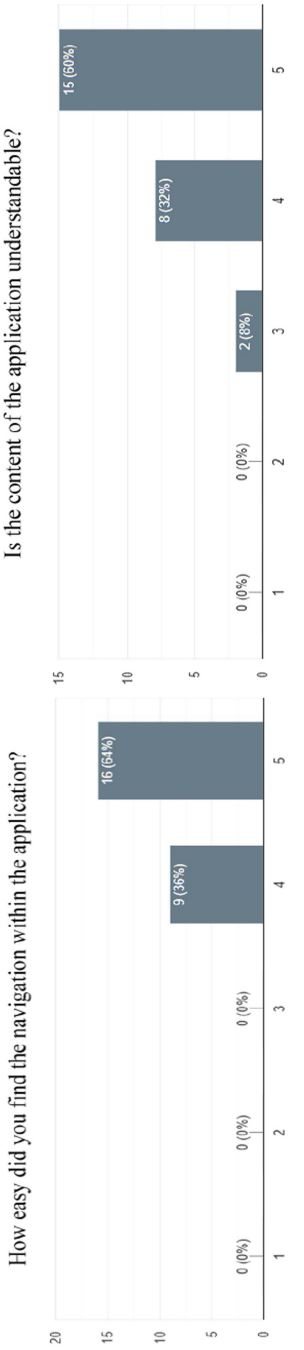

Figure 13.
Ease of use and the content of application.

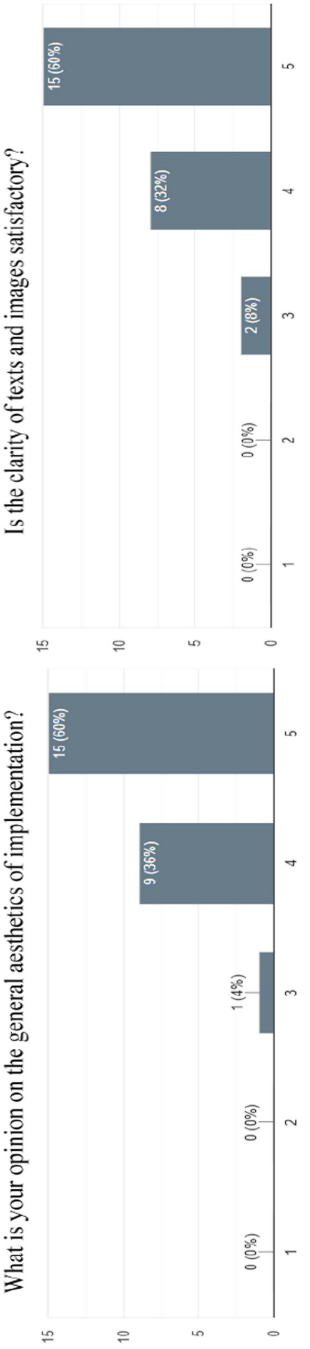

Figure 14.
Aesthetics of application and clarity of content.

Furthermore, the next two questions are related to whether users will use our application to navigate the museum and whether they will use the integrated audio tour guide by the application, or they will continue to prefer a tour guide by people.

It is important for us to know if the user will generally use our application and one of the most important features we developed. So, let's see what trend is prevailing today on which tour method users prefer and if the users want to change their habits. The most common tour method in a museum is by a guide, of course there is a tour through sound devices for several years, but we would like to know how they see to use a mobile application for their tour exclusively. As we see at Figure 16, users mostly see the use of our application positively during their tour of the museum, and 64% of them prefer to use our application's audio tour compared to the classic guide. It appears that users over time are increasingly using new technologies, adapting to new trends and being positive about using them.

5.2 Evaluation results summary

By summing up the questionnaire we extracted important information about our implementation and user habits. We have seen that users prefer free applications through the Google Play Store and that they do not spend significant amounts on their apps. However, in our case, when asked about the purchase of the audio tour through the application, they responded positively. It shows us that if a feature is deemed necessary, users will move on buying this.

Then in terms of design, through the replies we see that designing of the application following Google's Material Design Guidelines has brought the desired results, we have not received any negative feedback on the above questions that show us the positive feeling that users have experienced during the use of the application. And one of the most important goals during the development was achieved, where it was to be friendly and easy to use.

In addition, through the respondents we received significant results on the features we performed. Users have helped us to understand some of their habits and have prompted us to improve our application by adding new features. Also, it was important for us, through the results to understand how we achieved the goals we set before start the implementation.

Finally, as reported in the other papers at subsection 3.2, their results fall with the results of our research on related systems, the effort for simple, comprehensible and easy-to-use design has been achieved. In terms of features, we gave users enough capabilities to meet

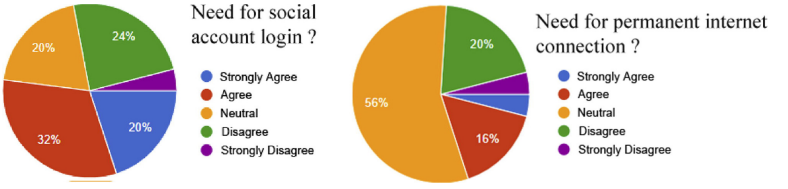

Figure 15.
Permanent connection and social login.

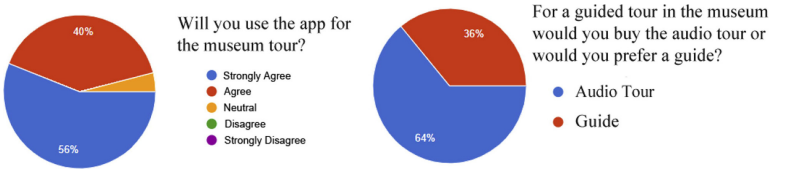

Figure 16.
App usage and tour method.

most needs, and through the questionnaire we mentioned, we achieve to collect additional information from the respondents for further improvement in the future.

6. Discussions on systems

In this section we will talk about our application in relation to the aforementioned applications and how we managed to solve the issues of the Problem Space. Designing our application, we have managed to reach and overcome some of the above-mentioned applications.

Following Google Designing Guidelines of Material Design help us to create a user-friendly application, easy to use, through simplicity the user is not tired of intricate graphics and the flows between the interfaces are clear. The interfaces have a beautiful design and the application runs equally well on devices with lower processing power and capabilities, creating an immediate user interface in comparison of aforementioned applications where we faced usability and delays problems.

We added the Portal in our application, a feature that is not available in the above-mentioned apps, we want to give to our visitors the ability to have direct access communication with another visitors, to share their thoughts and concerns about Numismatic Museum of Athens and everything else they want to discuss.

Finally, through the features of the audio guide tour, the timeline of the exhibits, the Portal and the information interfaces, we bring visitors closely to new technologies and improve their quality of the tour.

7. Future work

In our times the development of smart devices and services is rapid and continuous, every application needs to be upgraded and improved. So, the capabilities of the implementation that we have implemented can be extended in the future in several directions.

At the interface of Collection, we can add swipe gestures to the gallery so that the users can change the images of the exhibits through the appropriate movements on the screen and adding audio snippets per exhibit so that the user is more fully informed.

In the audio tour guide, we can add the ability to change the language internally to the interface and add keys to allow the user to move forward or back to the tour, such as modern video and audio playback applications. Through the questionnaire we learned that users prefer to sign up for the application via a social networking account, so it would be important to include them in the second version of the application.

In addition, taking advantage of AR technology, the visitors will be able to interact with museum exhibits through their smartphone, receiving additional information and audiovisual material about the exhibits. We could still create a game base on AR technology for younger age visitors.

Finally, we could add beacons [26] besides every room or exhibit. Firstly, the visitor must have opened the application and the Bluetooth connection of their device. When the visitor

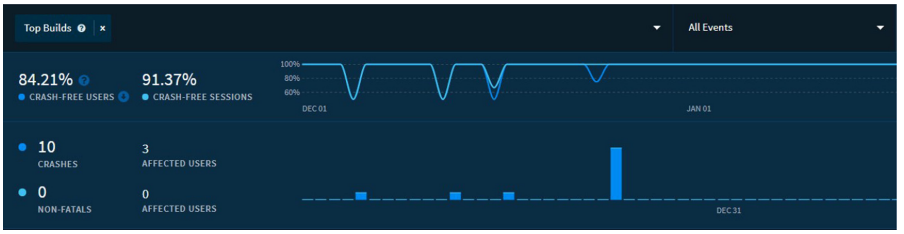

Figure 17.
Crashes that were recorded using fabric.

comes closely to an exhibit, the application recognizes the beacon and can display the exhibit description to the user and can play the audio tour guide.

8. Conclusions

Technology is evolving rapidly, and this enables more and more embedded systems to be implemented to meet the increased needs in everyday life. At the same time smartphones that have experienced rapid growth in recent years and have become essential products in everyday life. Smartphones offer too many services to meet our needs, facilitate our daily lives and provide us with useful and difficult to find in the past.

In this paper, we presented the design and the implementation of a prototype Android smartphone application as a case study for the Athens Numismatic Museum. Through our application, we have tried to improve the museum tour experience, the visitors can learn more about the exhibits through their smartphones using modern technologies. We also wanted to prove that museums can be made even more accessible to the younger people, by creating a user-friendly application to convince them that visiting a museum can be more entertaining.

Finally, by the questionnaire we exported significant results about users' habits and ways to improve our application. The respondents gave us positive feedback on the application in terms of features and visual design. Through the responses, we have been able to better understand which features seemed useful to users and which needs further improvement and redevelopment, so that in the future, functionalities such as augmented reality can be integrated. Finally, as the application stability is concerned, the application did not show any instability to the users which is confirmed by the questionnaire and the Fabric Crashlytics (Figure 17).

Notes

[1] Louvre Museum (Accessed: 1/4/2019).

[2] Dali Museum (Accessed: 1/4/2019).

[3] British Museum (Accessed: 1/4/2019).

[4] https://play.google.com/store/apps/details?id=org.metmuseum.android.met (Accessed: 5/9/2018).

[5] https://en.wikipedia.org/wiki/QR_code (Accessed: 1/4/2019).

[6] https://medium.com/predict/the-future-of-augmented-reality-90143b98f7a3 (Accessed: 1/4/2019).

[7] https://developers.google.com/ar/discover/ (Accessed: 1/4/2019).

[8] http://www.enma.gr/ (Accessed: 27/03/2018).

[9] https://artsandculture.google.com/partner/numismatic-museum (accessed: 27 March 2018).

References

[1] K. Parmjit, S. Sumit, Google Android a mobile platform: a review, Recent Advances in Engineering and Computational Sciences, 6–8 March 2014, IEEE, (2014), pp. 1–5.

[2] S. Medić, N. Pavlović, Mobile technologies in museum exhibitions, Turizam 18 (4) (2014) 166–174.

[3] G. Stephen, Mobile App UX Principles, (2015), Available Online at: https://storage.googleapis.com/think-emea/docs/article/Mobile_App_UX_Principles.pdf, accessed 20 April 2017.

[4] M.K. Othman, H. Petrie, C. Power, Measuring the usability of a smartphone delivered museum guide, Sci. Direct 97 (2013) 629–637.

[5] C. Jiyoung, Creating an evaluation system for a mobile application design to enhance usability and aesthetics, (2012), Available Online at: https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=3751&context=etd, accessed 22 June 2017.

[6] O. Rotne, V. Kaptelinim, Design choices and museum experience: a design-based study of a mobile museum app, CLIHC in Carrillo, 2–6 December 2013, Springer, 2013 (2013), pp. 9–13.

[7] W. Xu, J. Zhang, Mobile application used in museum learning and its case study, International Conference of Educational Innovation through Technology (EITT), 16–18 October 2015, IEEE, (2015), pp. 90–93.

[8] A. Koskiola, Mobile Solutions and The Museum Experience, (2014) Available Online at: http://www.diva-portal.org/smash/get/diva2:729950/FULLTEXT01.pdf; accessed 10 July 2017.

[9] Material Design Guideline, (2016) Available Online at: https://material.io/design/guidelines-overview/, accessed 05 February 2017.

[10] T. Burcu, K. Hafize, Museum guide mobile app: the face of the near east university classical car museum, Procedia – Soc. Behav. Sci., Sci. Direct 131 (2013) 278–285.

[11] I. Rubino, C. Barberis, Enhancing a museum mobile application through user experience design: a comparative analysis, (2014), Available Online at: https://pdfs.semanticscholar.org/2978/b23891ee6ef4c5661fc92322835bb57210f2.pdf, accessed 15 March 2017.

[12] M.Ryffel, AR Museum: A mobile Augmented Reality Application for Interactive Painting Recoloring, (2017), Available Online at: https://studios.disneyresearch.com/publication/ar-museum, accessed 10 February 2018.

[13] R. Harrison, D. Flood, Usability of mobile applications: literature review and rationale for a new usability model, . Springer J. Interact. Sci. 1 (1) (2013) 1–16.

[14] I. Lake, Building a Responsive UI in Android, (2016), Available Online at: https://medium.com/google-developers/building-a-responsive-ui-in-android-7dc7e4efcbb3, accessed 14 May 2017.

[15] G. Singh, Android App Performance Optimization, (2017) Available Online at: https://medium.com/mindorks/android-app-performance-optimization-cdccb422e38e, accessed 15 July 2017.

[16] R. Boyer, K. Mew, Android Application Development Cookbook Second Edition, Pack pub, (2016).

[17] Phillips et al, Android Programming the Big Nerd Ranch Guide 2nd Edition, Big Nerd Ranch Guides, (2015).

[18] W. Alexander, P.J. Diestel, H. Deitel, Android 6 for Programmers an App-Driven Approach, 3rd Edition, Prentice Hall, 2016.

[19] J. Horton, Android Programming for Beginners Jim Wilson, Creating Dynamic UI Android Fragments, Packtpub, Birmingham, 2013.

[20] R. Tamada, Android Getting Started with Firebase- Login and Registration Authentication, (2017) Available Online at: https://www.androidhive.info/2016/06/android-getting-started-firebase-simple-login-registration-auth/, accessed: 5 April 2017.

[21] M. Murphy, The Busy Coder's Guide to Android Development, Android UI Design, CommonsWare, (2009), accessed 17 September 2017.

[22] E. Chidera, Glide like a Boss – Advanced Android Glide Tips (2017), Available Online at: https://medium.com/@elvischidera/glide-like-a-boss-advanced-android-glide-tips-d0288ea77de9, accessed 20 April 2017.

[23] M. Raj, Handling Runtime Permissions in Android, Available Online at: https://medium.com/@muthuraj57/handling-runtime-permissions-in-android-d9de2e18d18f, accessed 20 February 2017.

[24] A. Stoica, G. Fiotakis, Usability evaluation of handheld devices: A case study for a museum application, ICOM-AVICOM in Proceedings of the Third International Conference of Museology in Mytilene, Greece, 5-8 June 2006, Research Gate, , 2005 (2005), pp. 1–9.

[25] Questionnaire of Numismatic Museum: Available Online at: https://drive.google.com/file/d/1sVN6A8e-O44ZFswkzuffb4sIMqaLBUCv/view?usp=sharing, accessed 6 April 2019.

[26] Google Developers, Get Started with Beacons, Available Online at: https://developers.google.com/beacons/get-started, accessed 17 May 2018.

Appendix A

Installation instructions

We sent an email to the respondents with the appropriate instructions about how to download and install the application. And the link of the questionnaire so they can complete it once they test our application.

Firstly, we instruct the respondents to download the application via a link, informing them that their device should have a version of the Android operating system bigger than 4.1. Then, if they had downloaded the appropriate file, they would have to install the application on their following the Figure 18. Now with the app installed, users can try it out. In order the users to test the audio guide tour, test accounts were provided so that respondents could virtually buy the audio tour to test this function of our app.

Finally, the respondents were informed that they can complete our questionnaire through the application by selecting the questionnaire option in the menu as shown in the Figure 19. Selecting the last option of the menu, the questionnaire opened through the browser that the respondent had installed.

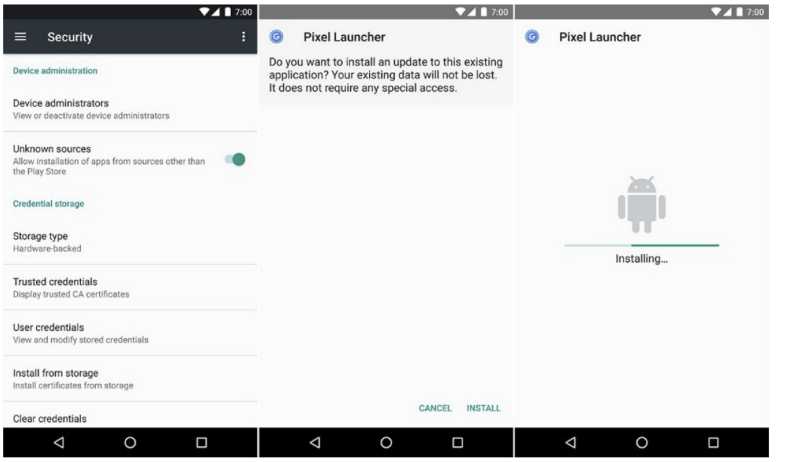

Figure 18.
Application installation.

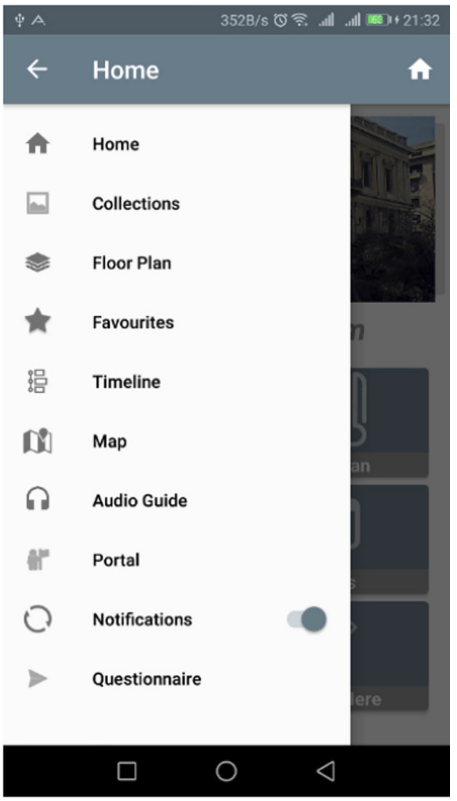

Figure 19.
Questionnaire at the application.

Appendix B

The questionnaire and the corresponding results

See Figures 20–38.

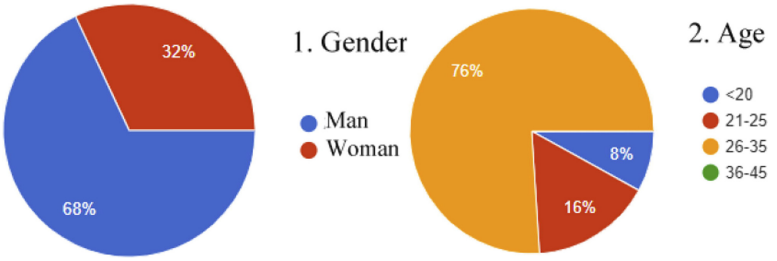

Figure 20.
Questions 1–2.

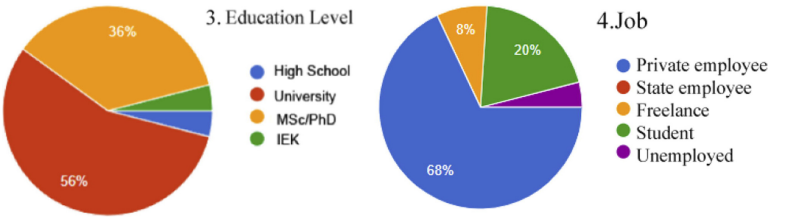

Figure 21.
Questions 3–4.

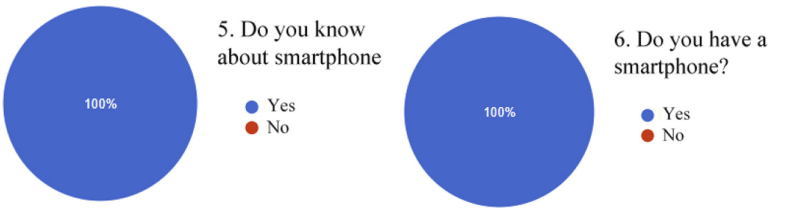

Figure 22.
Questions 5–6.

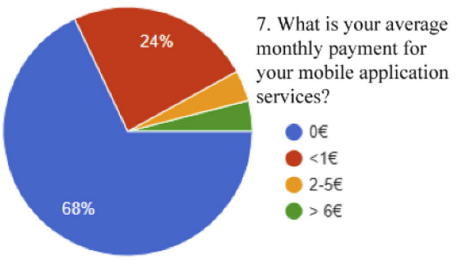

Figure 23.
Question 7.

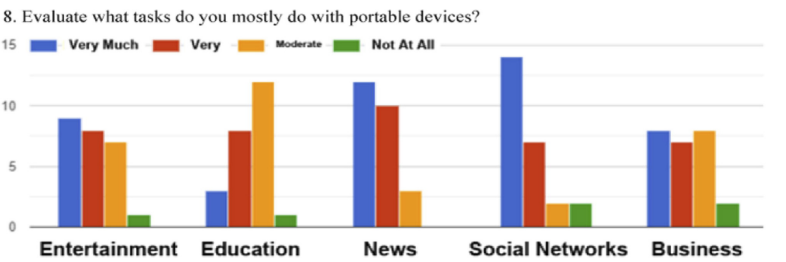

Figure 24.
Question 8.

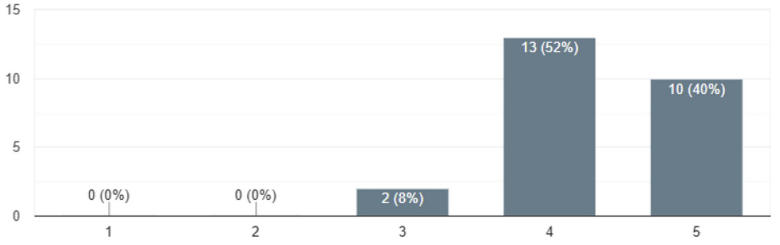

Figure 25.
Question 9.

10.How easy did you find the navigation within the application?

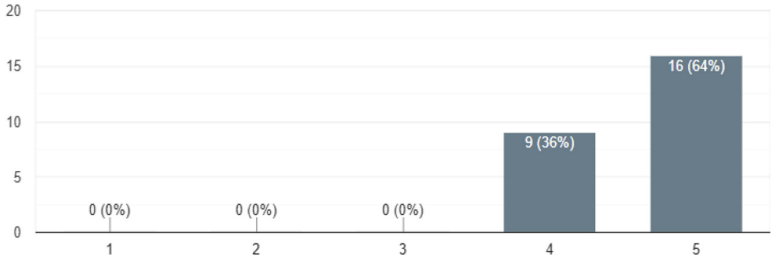

Figure 26.
Question 10.

11. Is the content of the application understandable?

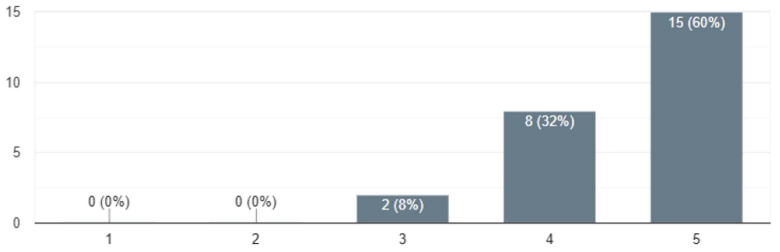

Figure 27.
Question 11.

12. Is there a consistency in the terms and symbols used?

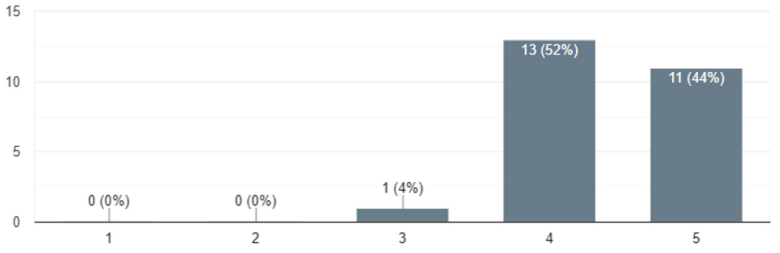

Figure 28.
Question 12.

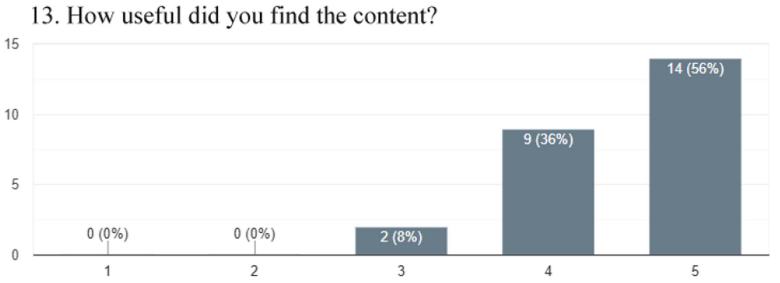

Figure 29.
Question 13.

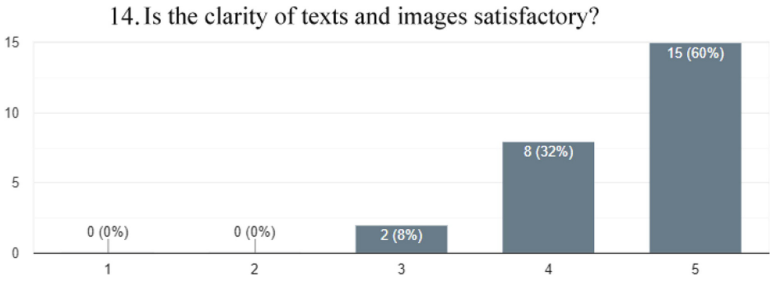

Figure 30.
Question 14.

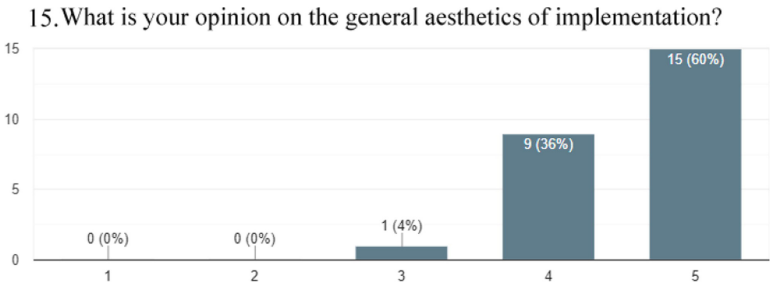

Figure 31.
Question 15.

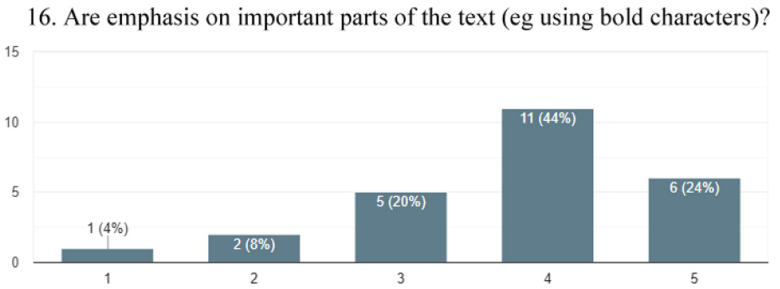

Figure 32.
Question 16.

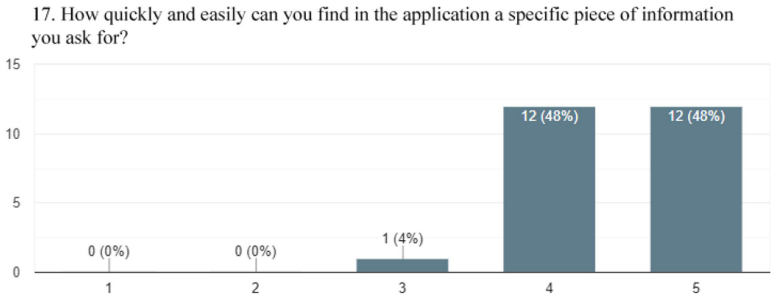

Figure 33.
Question 17.

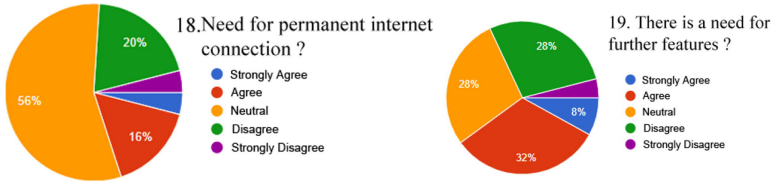

Figure 34.
Questions 18 and 19.

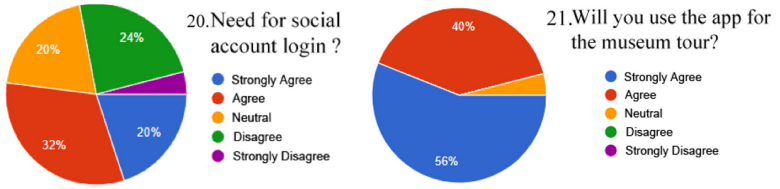

Figure 35.
Questions 20 and 21.

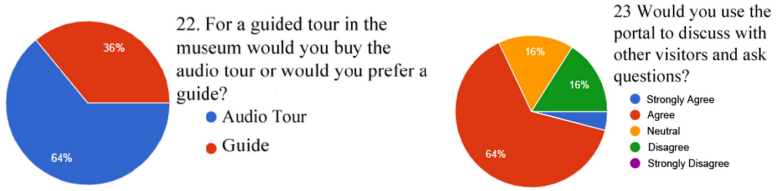

Figure 36.
Questions 22 and 23.

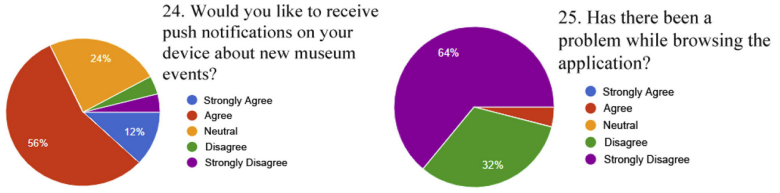

Figure 37.
Questions 24 and 25.

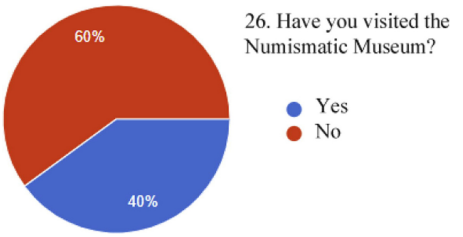

Figure 38.
Question 26.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aci.2019.06.001.

Corresponding author
Pantelis Chasapis can be contacted at: pandelis.cha@gmail.com