

Discovering *EnjoyCircuits*: the Mobile App for Fundamentals of Electric Engineering

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Abstract- Mobile applications have experimented a huge evolution in the last years. These applications are already an important tool in our daily life. From the point of view of the penetration of this mobile technology in the different scales of the society, university students are one of the main users of this mobile technology. For this reason, this work proposes a learning mobile application entitled *EnjoyCircuits* for Fundamentals of Electric Engineering of the Industrial Technology Engineering Bachelor. This mobile application is a learning tool based on the resolution of quick problems of circuit theory. With *EnjoyCircuits* students can do a dynamic review of the Fundamentals of Electric Engineering anywhere and anytime. Moreover, they can compete with other users in the *EnjoyCircuits* ranking.

Index Terms- Mobile application; Bachelor of Industrial Technology Engineering; Fundamentals of Electric Engineering.

I. INTRODUCTION

The world experiences a continuous evolution due to the advances in technology. From the point of view of the academic community, it is worth exploring the new opportunities provided by new technologies. These advances have allowed the use of novel communication channels to expand the knowledge around the world. In summary, this new academic era matches perfectly with the concept of anywhere and anytime.

This current technology situation has particularly promoted the development of learning tools based on the distance learning concept (d-learning). The d-learning concept can be defined as a way of remote learning without a regular face-to-face contact with a teacher in the classroom. In this regard, different platforms of d-learning have been proposed during the last decade [1-4]. Although there are different d-learning variants, all of them must satisfy the universal instructional design principles for d-learning tools [5-6]. These universal principles can be summarized in the following points:

- P1) equitable use
- P2) flexible use
- P3) simple and intuitive use
- P4) perceptible information
- P5) tolerance for error
- P6) low physical and technical effort
- P7) community of learners and support
- P8) instructional climate

Even though different d-learning platforms based on the previous universal principles have been developed, the real turning point in the d-learning history appears with the

arrival of the handheld computers and smartphones, due to their relative low cost and their great integration in the worldwide population. The d-learning methods based on the mobile technology are defined as mobile learning (m-learning) [5]. This version of d-learning is relatively novel, however different alternative of m-learning tools have been explored [5-]. In this regard, mobile applications are an interesting alternative due to their high integration in our daily life. In fact, nowadays there is a large number of mobile applications based on language learning language [7] or basic scholar concepts (mathematics, geography ...) [8]. However, there is still an emptiness in the development of mobile applications for university subjects. This fact surprising when the college students are precisely one of the main consumers of mobile applications [9]. For this reason, this work proposes an m-learning application entitled *EnjoyCircuits* for Fundamentals of Electric Engineering in the Bachelor of Industrial Technology Engineering at the University of Malaga (Spain). This m-learning application has been developed by researchers of the ACETI research group. Although this research group already has some experience in educational publication based on electric engineering [10-15], this work is presented as a new teaching research line for ACETI.

Obviously, the objective of this m-learning application is not to replace the master classes of Fundamentals of Electric Engineering. *EnjoyCircuits* must be employed only like a support of these master classes. The proposed learning mobile application is based on the resolution of quick problems related with the main modules of Fundamentals of Electric Engineering. These modules are available in *EnjoyCircuits* with the following titles:

- M1) basic concepts
- M2) knots and meshes methods
- M3) basic theorems
- M4) ac-current problems
- M5) three-phase problems.

This initial version of *EnjoyCircuits* includes a set of 116 problems. The users of this m-learning application can find in this set of problems: multi-option problems, numeric problems and matrix problems. Although the nature of these problems is different, all of them are close problem that can be quick solved. In order to increase the motivation of the students in the use of *EnjoyCircuits*, a ranking based on the final score of users is implemented. For this purpose, a score system has been developed. In the proposed system, the final score is function of the resolution time, since

EnjoyCircuits is an m-learning tool based in the resolution of quick problems.

The paper is organized as follows. Section II describes the academic context of *EnjoyCircuits*. The development of this m-learning application and the software employed in the building process are detailed in the section III. Section IV discovers the main modules of the proposed learning mobile application and conclusions are finally summarized in the last section.

II. ACADEMIC CONTEXT

As noted above, *EnjoyCircuits* is an m-learning tool for the students of Fundamentals of Electric Engineering. This subject is lectured in the second course of the Bachelor of Industrial Technology Engineering from the University of Malaga (Spain). Fundamentals of Electric Engineering has been historically known as Theory of Circuit and it is a basic subject in the majority of engineering bachelor. The academic information of Fundamentals of Electric Engineering is included in the *Verifica* Memory of the Bachelor of Industrial Technology Engineering [16]. Following the above mentioned memory, the Fundamentals of Electric Engineering syllabus can be shifted in five modules where the modules 1, 2 and 3 have an important teaching load (see Table I for more details).

Although the table 1 shows that the modules of *EnjoyCircuits* exactly match with the syllabus of Fundamentals of Electric Engineering of the Bachelor of Industrial Technology Engineering, the use of *EnjoyCircuits* is not only restricted to students of this bachelor degree since Fundamentals of Electric Engineering is a common subject in different engineering bachelors. For example in the University of Malaga the syllabus of this subject is common in the following bachelor degrees: Industrial Technology Engineering, Electric Engineering, Electronic Engineering, Mechanic Engineering, Energy Engineering, Industrial Design Engineering and Mechatronic Engineering. Therefore, due to the basic nature of the proposed subject, *EnjoyCircuits* can be a useful learning tool for a large number of students at the University of Malaga.

III. MOBILE APPLICATION DEVELOPMENT

The developed application is based on the Android technology. This mobile operative system (MOS) was selected due to its popularity in the development of mobile applications. However, other mobile operative systems could be used without technical restrictions.

On the other hand, although Android Studio is the main employed software in the building process, several software tools have been used in the development of *EnjoyCircuits*. This section introduces these software tools and describes their main features. Fig. 1 shows a scheme of the main building process of *EnjoyCircuits* and the different software tools employed in the development of these building process.

TABLE I

FUNDAMENTALS OF ELECTRIC ENGINEERING SYLLABUS

B1. Fundamental elements and circuit analysis (22.5h)
- Basic concepts
- Basic theorems
- Knots and meshes methods
B2. Analysis of ac-current circuits (18h)
B3. Three-phase circuits (13.5h)
B4. Transient process (4.5h)
B5. Electric machines (1.5h)

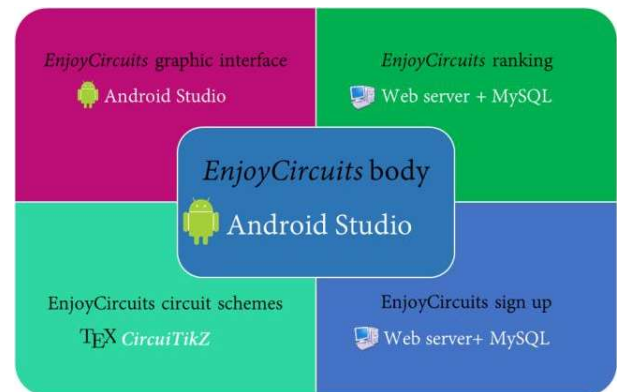


Fig. 1. *EnjoyCircuits* scheme and employed software.

A. Android Studio

EnjoyCircuits was designed using the software Android Studio. This software is the official integrated development environment (IDE) of Android. It was announced in 2013 and replaced Eclipse as official IDE of Android. This IDE is written in Java and it is available for Windows, Linux and Mac OS. Android Studio supports all the languages of IntelliJ IDEA (one of the first available Java IDEs). Two building options are available in Android Studio. The first of these building modes is based on the employed of Java language (see Fig. 2). The application body was bought using this Android Studio mode while the *EnjoyCircuits* graphic design was realized with the second building mode. This other mode is a graphic interface which allows the development of the graphic design of the mobile applications (see a screenshot of this mode of Android Studio in Fig. 3).

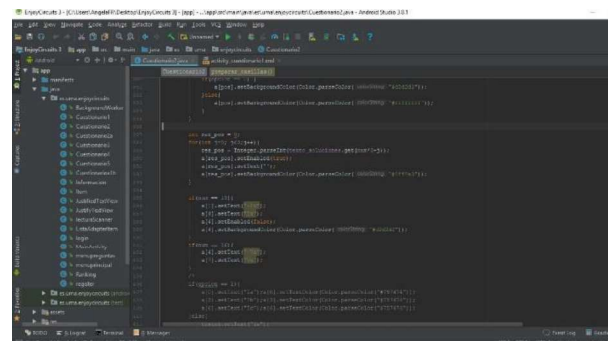


Fig. 2. Screenshot of the Java mode of Android Studio

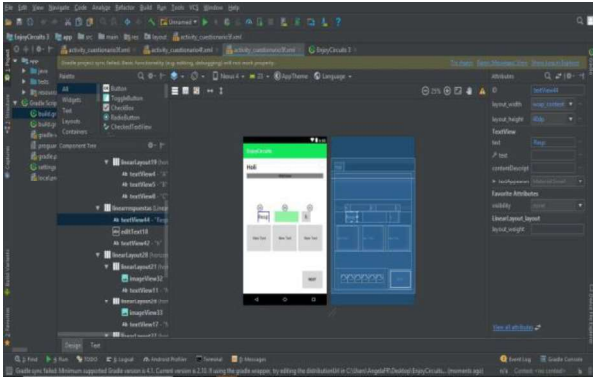


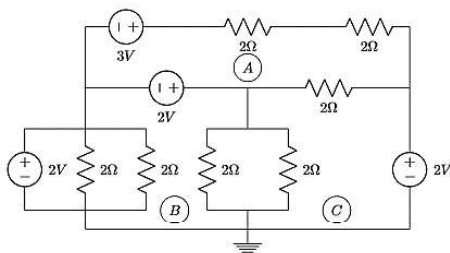
Fig. 3. Screenshot of the graphic design of Android Studio

B. CircuiTikZ

EnjoyCircuits presents a huge number of problems with electric circuit schemes. For this reason, it is necessary to select a suitable tool for the electric circuit design. There are two requirements in this design process: *i)* a suitable quality of the figures and *ii)* a low computational weight of the figures. Attending to these two requirements the *CircuiTikZ* tool was selected to design the electric circuit schemes of *EnjoyCircuits*. *CircuiTikZ* was initiated by Massimo Redaelli in 2007 and was created as a tool for creating exercises and exams. This design platform is based on the LaTeX language. The use of *CircuiTikZ* is, of course, not limited to academic teaching. The package gets widely used by engineers for typesetting electronic circuits for articles and publications all over the world. *CircuiTikZ* provides the necessary electric components to build the different implemented electric schemes of *EnjoyCircuits*. An electric circuit designed using *CircuiTikZ* is represented in Fig. 4.

C. Web server and database

The *EnjoyCircuits* ranking needs a web server to establish the communication between the smartphones and the database where the global ranking of *EnjoyCircuits* is calculated. For this purpose, a virtual machine was employed to define the communication between the *EnjoyCircuits* application and the database of the web server. This database must receive the registration information of the users and the user score in the different exercises. On the other hand, the web server must deliver to the *EnjoyCircuits* application the position and the final score of the users in the *EnjoyCircuits* ranking. The management of the database is realized with MySQL. This software is employed in the management of database and is the open source database most popular in the world.

Fig. 4. Electric circuit scheme created using *CircuiTikZ*.

IV. DISCOVERING ENJOYCIRCUITS

This section allows discovering the proposed mobile application. A tour by the different sections of *EnjoyCircuits* is realized. In this tour a brief description of the different screens of *EnjoyCircuits* is also provided.

A. *EnjoyCircuits* initial screen

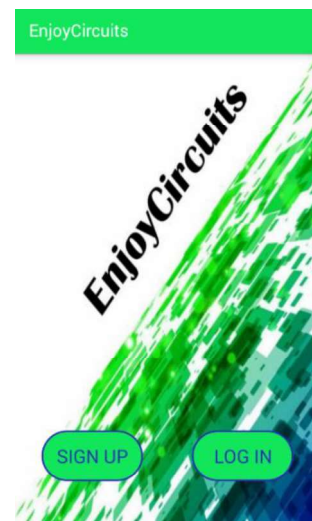
The initial screen of *EnjoyCircuits* presents two access options for the users. The new users can access the registration process if the *Sign Up* option is selected. On the other hand, the previously registered users can access to their personal accounts with the *Log In* option. Fig. 5 shows the *EnjoyCircuits* initial screen with the two previously mentioned access options.

B. *EnjoyCircuits* sign up screen

In Fig. 6 the registration screen of *EnjoyCircuits* is depicted. As it is usual, the users must provide some personal data on this type of screen. The personal information is necessary to realize the sign up process in *EnjoyCircuits* in the following: name, surname, nick, university, email, national document of identification (DNI) and password. This sign up process is necessary to realize the suitable tracking of the student evolution in the mobile application. For this reason, *EnjoyCircuits* is programmed to avoid the duplication of users. Hence, two users cannot share *nick* or *email*, this fact also allows preventing problems in the access or in the calculation of the *EnjoyCircuits* ranking. Moreover, in order to realize a suitable tracking of the Fundamentals of Electric Engineering students, the national documents of identification are also verified.

C. *EnjoyCircuits* Log In screen

On this screen, the users can access their personal account with their previously registered nick and password. In order to reduce the time in the login process, the proposed mobile application allows remembering the required personal information of the *Log In* screen. To do it, the users must select the available *Remember me* tick. A screenshot of the *Log In* screen is represented in the Fig. 7, where the abovementioned option is included.

Fig. 5. *EnjoyCircuits* initial screen.

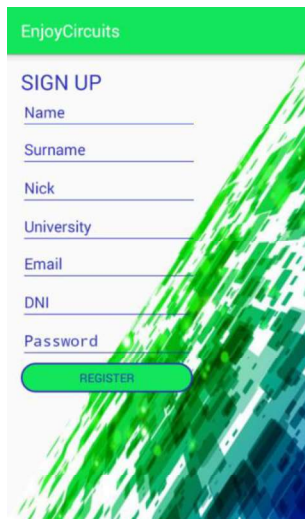


Fig. 6. *EnjoyCircuits* Sign up screen.

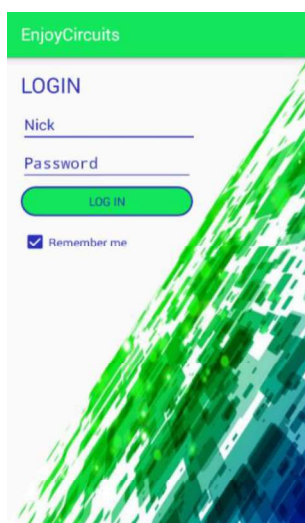


Fig. 7. *EnjoyCircuits* Log In screen.

D. *EnjoyCircuits* main screen

The *EnjoyCircuits* main screen presents the five problems modules of this learning mobile application. Fig. 8 shows these five blocks of *EnjoyCircuits* where the abovementioned set of 116 quick problems are distributed. Moreover on this main screen, the user can refer the *EnjoyCircuits* ranking or the *EnjoyCircuits* information screen. During the first seconds in this screen, a toast message appears with the total user score.

E. *EnjoyCircuits* evolution screen

Fig. 9 shows the evolution screen of one module of *EnjoyCircuits*. In the first access to the block, the problems appear marked in a gray tone, indicating that the problem has not yet been solved. *EnjoyCircuits* employs a green tone for problems resolved satisfactorily. On the other hand, if the answer is erroneous, a yellow tone is employed to identify the problem. The proposed scale of colors can be observed in Fig. 10. This fact allows the user to identify in a simple way which problems he/she has failed and need

to be reviewed. Moreover, a toast message informs the user about the obtained score in the corresponding block.

F. *EnjoyCircuits* problems

Android Studio allows defining different type problems. *EnjoyCircuits* exploits this important advantage of Android Studio providing different type problems in this initial version. These problems can be structured in the following three groups:

- i) multi-option problems (see Fig. 11)
- ii) matrix problems (see Fig. 12)
- iii) numeric problems (see Fig. 13)

These problem types are obviously different, but all of them are quick resolution problems. This feature has been considered in the score system of *EnjoyCircuits*, including the resolution time in the final problem score. In other words, the final score is inversely proportional to the time employed in the resolution of the problem. Of course, if the response is erroneous the final score of that problem is zero. Furthermore, that problem will never count for the ranking score, even if the user provides the correct answer in a new attempt (keeping always the previously mentioned yellow color).

On the other hand, the *EnjoyCircuits* problem screen also offers information about the evolution of the user in the corresponding block. The user evolution is indicated through the *EnjoyCircuits* progress bar. This progress bar employs the number of *EnjoyCircuits* logos on the screen to provide a certain information about the evolution in the block (see Fig. 11 for more details).

G. *EnjoyCircuits* ranking screen

Since the competitive nature of humans is a powerful learning tool, the implementation of competitive activities is a usual practice nowadays in the academic community. For this reason, this learning mobile application presents the *EnjoyCircuits* ranking. With the implementation of this ranking the authors hope to increase the motivation of the students in the use of *EnjoyCircuits*.

As previously mentioned, this ranking is calculated using the database implemented in the web server. In order to safeguard the identity of the users, the *EnjoyCircuits* ranking provides only the user nick and the final score (see Fig. 13).

H. *EnjoyCircuits* information screen

As usual in these mobile applications, *EnjoyCircuits* presents an information screen. This information screen provides the main objectives of this learning mobile application.

On the other hand, this information screen also gives more details about the *EnjoyCircuits* score systems. In this regards, the influence of the resolution time in the final score is described in details. The proposed score system can be observed in the Fig. 14.



Fig. 8. EnjoyCircuits main screen.

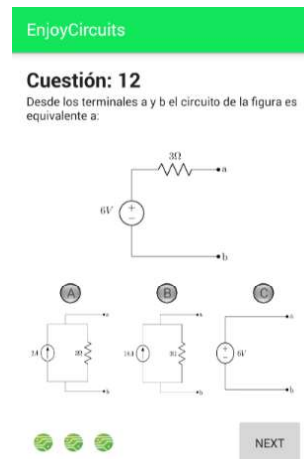


Fig. 10. Example of multi-option problem with tactile response.

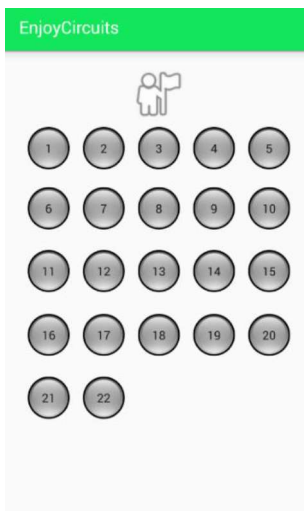


Fig. 9. EnjoyCircuits initial evolution screen.

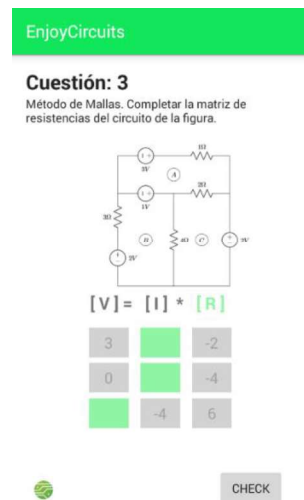


Fig. 11. Example of matrix problem.

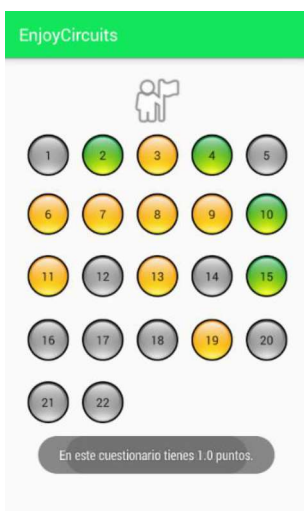


Fig. 10. EnjoyCircuits evolution screen.

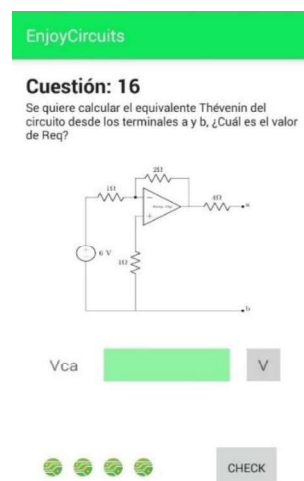
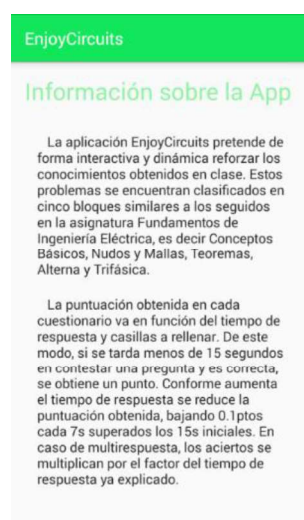


Fig. 12. Example of numeric problem.



EnjoyCircuits			
RANKING			
	Nick	Universidad	Puntos
1	laraLarsson	Madrid	68
2	Clau89	Málaga	54
3	EstherMar	Málaga	43
4	Stephe92	Sevilla	30
5	martalopez	Jaén	5
6	holi	Sevilla	1
7	h	Jaén	0
8	marta	Málaga	0
9	susana	Sevilla	0
10	julia67	Malaga	0
11	lau89	Sevilla	0

Fig. 13. *EnjoyCircuits* ranking screen.


Información sobre la App

La aplicación *EnjoyCircuits* pretende de forma interactiva y dinámica reforzar los conocimientos obtenidos en clase. Estos problemas se encuentran clasificados en cinco bloques similares a los seguidos en la asignatura Fundamentos de Ingeniería Eléctrica, es decir Conceptos Básicos, Nudos y Mallas, Teoremas, Alternancia y Trifásica.

La puntuación obtenida en cada cuestionario va en función del tiempo de respuesta y casillas a rellenar. De este modo, si se tarda menos de 15 segundos en contestar una pregunta y es correcta, se obtiene un punto. Conforme aumenta el tiempo de respuesta se reduce la puntuación obtenida, bajando 0.1ptos cada 7s superados los 15s iniciales. En caso de multirespuesta, los aciertos se multiplican por el factor del tiempo de respuesta ya explicado.

Fig. 14. *EnjoyCircuits* information screen.

V. CONCLUSIONS

Attending to the new technology situation in the academic world, this work proposes a learning mobile application entitled *EnjoyCircuits* based on the resolution of quick problems of Fundamentals of Electric Engineering. The users of this mobile application can perform a dynamic review of the basic concepts of Fundamentals of Electric Engineering while they compete with other *EnjoyCircuits* users. Although, this work only introduces the first version of *EnjoyCircuits*, this initial version is already available in the Google Play Store. To validate the goodness of *EnjoyCircuits*, the authors suggest the following validation methodology. Firstly, a satisfaction survey must be realized to the students of Fundamental of Electric Engineering. Moreover, the authors also propose the analysis of the variation in the number of students that pass the Fundamental of Electric Engineering subject. However, several courses of experience are necessary to obtain conclusive results with this validation methodology. Therefore, in this regards this

work cannot yet provide information about the goodness of *EnjoyCircuits* if this validation methodology is used.

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