A Student-Centered Approach to Learning Mathematics and Physics in Engineering Freshmen Courses

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***Abstract*— It is very well known that one of the most important reasons for abandonment in Engineering freshmen courses is the difficulty expressed by students for understanding very basic and essential Mathematics and Physics' concepts. But this is not the only reason for such a problem, the other very important cause for students' maladaptation during their first courses at the University, is the teacher-centered model which predominates in a clear majority of Higher Education courses. This paper will describe an ongoing experience which involves first, the development of small apps (learning objects) to be used in mobile devices by freshmen in Mathematics and Physics' courses and, second, the research about its impact in terms of learning outcomes. This methodology implies a Student-Centered and Active Learning approach, as students learn at their own pace by interacting with the apps, not only during lecture hours but, especially, before arriving to School, thus implementing a "Flipped-Learning" methodology. We will also describe in this paper the very first promising results obtained during this year as well as lessons learned during the first phase of the project developed during last year.**

***Keywords*— Student Centered Learning; Active Learning; Flipped Learning; Mobile Learning**

I. INTRODUCTION

This paper describes an ongoing research project that has begun in January 2017 at the Universidad Tecnologica Nacional, Facultad Regional Buenos Aires in Argentina, particularly in the framework of the activities developed in the Educative Research and Innovation Center [1]. As it was described in our previous paper [2], our project is aimed to make it easier for freshmen to understand basic Mathematics and Physics concepts, and some others like Algebra and Computing Algorithms, by using small applications – from now on described as Apps – that run on the students' own personal smartphone devices. For that purpose, we have been using the platform Qdex [3] developed by the Canadian company Quanser [4].

During the first year we were focused on the development of the content for the Apps and the development of the Apps themselves. Professors involved in the project prepared and adapted the content for the particular characteristics of the devices in which it would be displayed, which means, basically, the limitation in screen size and the possibility of adding interactivity. At the same time, scholarship students learned how to develop the Apps using the Qdex platform and interacted with professors in order to obtain a product which would satisfy both didactic and technical requirements. This second year of the project was not only devoted to the development of more Apps, but to test the previously developed ones in real environments and to receive feedback from students and professors who are using the Apps in actual learning scenarios.

II. PEDAGOGICAL FOUNDATIONS

The concept of mobile learning (m-learning) is primarily associated with the use of small digital devices, such as laptops, mobile phones, PDAs, tablet PCs, and any handheld device that has some form of wireless connectivity in an educational environment. But this is a very utilitarian and technocratic point of view that does not reflect the real implications of using mobile devices for learning. In a paper by Laouris and Eteokleous [5] the authors pose that a new framework for the definition of mobile learning needs to be proposed, one that considers a repertoire of domains, and which embraces not only technical, methodological and educational aspects, but also considers social and philosophical dimensions. Without going into deeper considerations in this matter, which is certainly not the goal of this paper, we need to clarify here, according with Barbosa and Geyer [6], also cited in the previously mentioned paper, that mobile learning is fundamentally about increasing learners' capability to physically move their own learning environment with them and that the mobile context permits not only constructivist approaches to be employed, but also contextual learning environment as they move.

Having said so, we may also affirm that mobile devices are the most suitable resource available for communication and exchange between people, particularly for its great portability and ubiquity. In this context, many applications for mobile devices are becoming key tools for facilitating and motivating students' learning, and we may ask ourselves: what attracts them more? probably, connectivity; anywhere and at any time. This leads us to think about learning that takes place both inside and outside the classroom.

Currently, the development of mobile technology goes hand in hand with certain habits and practices of use that have managed to become true personal and professional "prostheses" [7]. In this way, the mobile feature has more to do with the "mobility" of the user than with the mobile property of the device. If we refer to the use made by students, mobile is the only technology they have permanently inside and outside the classroom, becoming true mediators between school and extracurricular contexts.

Contextualized learning through mobile devices is an emerging trend, whether we consider technological factors as those that make learning personalized. The NMC Horizon Report [8], developed each and every year in collaborations with experts from all over the world, includes a prospective about the technologies with greater impact in the educational field and, since 2010, it includes mobile devices as one of the main trends. Nevertheless, the last report published in August 2018 warns about significant challenges impeding technology adoption in higher education, particularly in terms of digital equity, because the Bring Your Own Device (BYOD) movement has widened the access gap as not all students have the technology – smartphones, tablets, and laptops – needed to participate and this is one aspect that should be carefully considered in the near future.

The use of mobile applications in Higher Education has shown that it improves levels of interpersonal relationships and learning skills. Thus, mobile learning requires methodological and didactic redesigns, with precise objectives linked to sequential micro tasks that guarantee effectiveness [9]. Mobile learning requires instructional models and educational approaches that account for their particularities. Escala [10] highlights the importance of a simple and friendly interface that integrates a multimedia component and offers the user the possibility to work with short, attractive and available modular activities at the right time. The mobile instructional model is based on informal learning; however, we have been able to account for its use within a formal class space.

The mobile learning environment of this work has an instructional design with a simple interface, which integrates interactive components and short modular activities of an attractive nature to contribute to situated learning. It is important to note that this technology/solution is particularly suitable for a flipped-learning approach, also because, once downloaded to the phone, there is no need for an Internet connection.

III. APPLICATIONS

As it has been previously described, the Apps have been developed using the Qdex platform [3]. During this process we have received permanent support from Quanser by means of documentation, source code templates, examples and also through the support forum [11]. In the following paragraphs we will briefly describe the various Apps developed since the beginning of this project

A. Physics Apps (Geometric Optics)

A very important design requirement was that the Apps should be no longer than 10 screens long and no more than 40 lines per page. This requirement was established by us for didactic reasons, in order not to make the process of browsing the App tedious. Hence, the concepts developed by the professor were divided into four Apps: Fundamentals, Light Reflection, Laws and Questions and Problems (Fig. 1).

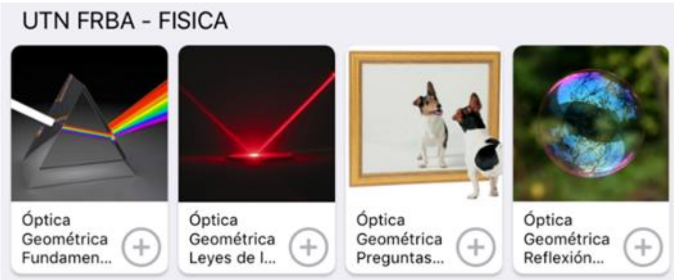

Fig. 1 Physics Apps in qdex Play

Using tools offered by the platform for plotting and scripting [12], we created several interactive simulations, like the one

Fig. 2 Light beam reflection simulation

showed in Fig. 2 in which the student can verify the reflection angle for different incidence angles. Each App has been organized into three sections: information, interaction or experimentation and interactive questionnaires.

B. Mathematics Apps (Riemann Sum)

Our first goal was to embed GeoGebra simulations into our Apps, but it was impossible to do so because there is no way to integrate them into the Qdex App. Hence, we decided to develop the simulations using the tools included in the platform. The result was presented in the form of different equations with which the user can operate in order to select and modify the number of intervals under or over the curve and verify how the approximation value differs from the real one, as it can be seen in Fig. 3

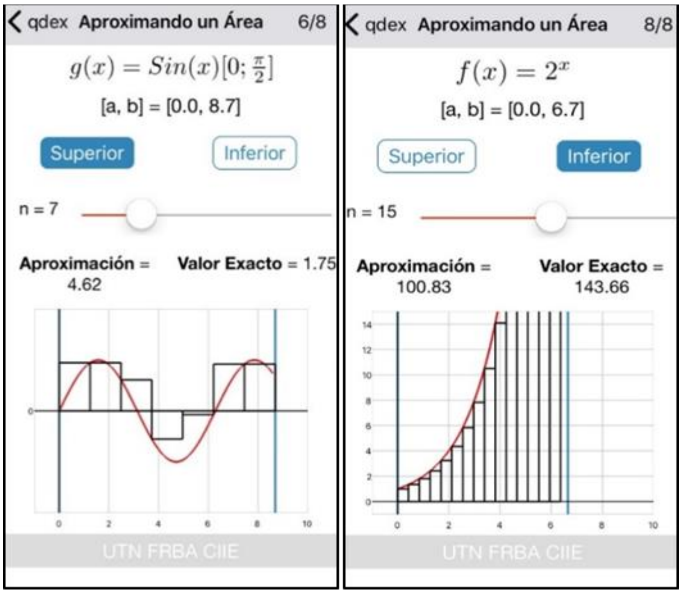

Fig. 3 Riemann Sum Apps

C. Algebra Apps

Based on the experience acquired by developing the previously described Apps, and due to a requisition posed by an Algebra professor, we decided to develop two new ones. The requirements for these new Apps were related with the need to graph a point in a three-dimensional system. As the platform didn't have a native specific component for doing so, we created an "ad hoc" solution which allows students to enter the

Fig. 4 Plotting a point in a three-dimensional system

coordinates and plot the point in perspective in a three-axis graph (Fig. 4).

2D vectors were able to be represented using resources available in the SDK (Software Development Kit) provided by the platform, by combining interactions and quizzes. (Fig. 5)

Another custom component was developed for questionnaires, in this case with mutually excluding and interactive checkboxes (Fig. 6)

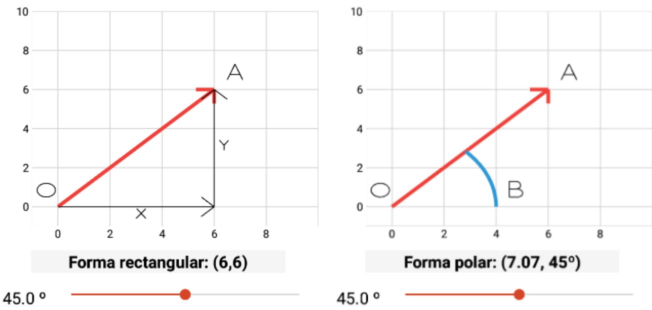

Fig. 5 2D vector in polar and rectangular representation

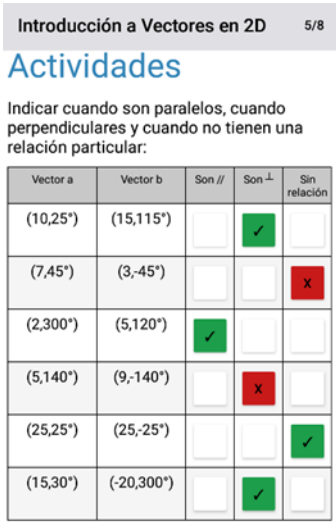

Fig. 6 Questionnaires

Algorithms Apps

Considering the potentiality of the platform's simulations, we develop three more Apps to explain the "bubble", "selection" and "insertion" algorithms. The operation of each algorithm is described in a visual way using interactions that represent the step-by-step execution of the code lines and its corresponding data update. We also developed another App for explaining the concept of the stack structure.

All contents are managed with the Qdex Manage Console that allows assigning, grouping and authorizing modules (Apps) to users, and also to obtain usage statistics for each App. Based on a series of metrics, it is possible to download a CSV file with data such as: total downloads, downloads per day, membership of groups, interaction with the components or the time on each page. Table I shows the "Time on pages" metric for one of the Algebra Apps.

TABLE I. TIME SPENT ON EACH PAGE OF THE MODULE "INTRODUCCION A VECTORES EN 2D" (IN SECONDS).

Page	Sources	Total	Min	Max	Average	Median
1	139	403854	63	29551	2905	907
2	131	163971	58	12561	1252	481
3	117	301986	19	279859	25811	5931
4	92	533179	41	233227	5795	876
5	80	1226893	11	182985	15336	3355
6	50	1071605	143	20855	21432	837
7	32	473056	39	113019	14783	5992
8	19	53274	17	7722	2804	1472

IV. RESULTS

By the time this paper is being written, we are still working on this project, so these are preliminary results. Moreover, even though the total number of courses and students using these Apps is very significant, only a small portion of them has completed the evaluation surveys. Anyway, the results obtained so far allow us to be very optimistic about how the goals of this project has been achieved. The following graphics (Fig. 7 to 10) show the students' answers to the most important questions. We received a total of 103 answers (10 for Algebra, 57 for Physics, 6 for Mathematics and 30 for Algorithms).

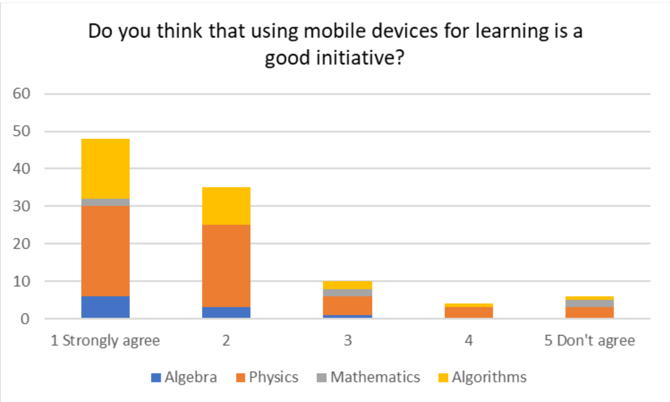

Fig. 7 Results according to the survey answered by students

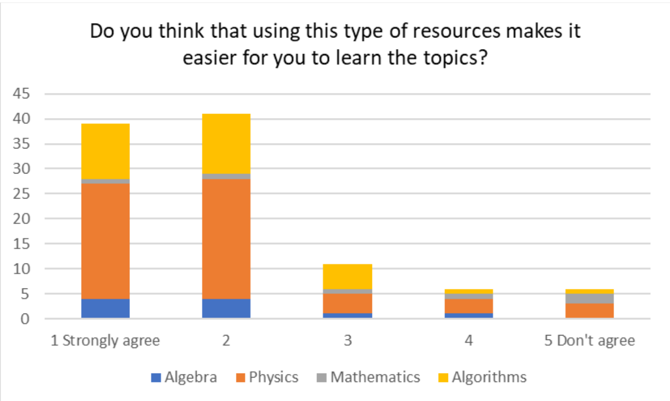

Fig. 8 Results according to the survey answered by students

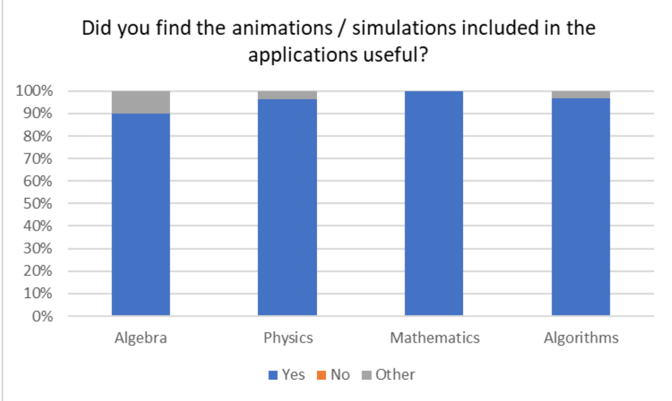

Fig. 9 Results according to the survey answered by students

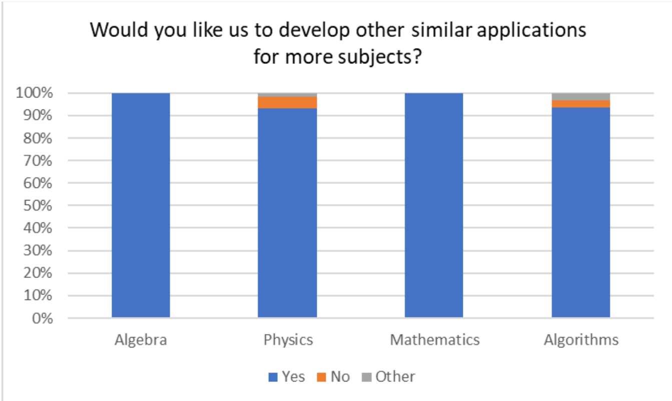

Fig. 10 – Results according to the survey answered by students

These graphics exempt us from further explanation as the results are clearly very positive. We will anyway include some comments in the following conclusions' section.

Besides these quantitative results, we can also highlight a qualitative and very important outcome evidenced *in situ* while doing this experience, and it was the immediate and positive acceptance of the students when asked to use their smartphone as a tool for learning (Fig. 11 and 12)

Fig. 11 Students using their smartphones in classroom

Fig. 12 Students using their smartphones in classroom

V. CONCLUSIONS AND FURTHER WORK

Even though this research project will continue till the end of this year, we can now enumerate several positive outcomes:

1) From a technical point of view: We have been able to learn how to effectively use the Qdex platform to produce applications that meet the learning outcomes raised by teachers.

2) From a pedagogical point of view: We have verified that the use of mobile devices for learning produces a positive impact in student's learning. The results of the survey, included in section IV, confirm our previous assumption about the willingness and good predisposition of the students to use this technology for learning.

3) From an institutional point of view: Several colleagues have shown interest in developing new Apps to be used in their own courses which allows us to envision a dissemination of this kind of experiences throughout the School and, probably, in other schools.

Also, some drawbacks were identified:

1) Even though the markup and the programming language (Lua) used for developing the Apps is very intuitive and ease to use, we can not think about professors developing Apps by themselves, unless they have previous programming abilities, namely IT professors.

2) The cost of licensing the tool for a great number of students might be a limitation, specially in developing countries and particularly in our University which is free for students and solely funded by federal budget which is always scarce.

3) It would be good to have multi language support for the developoing platform as well as for the Qdex Play.

We think that the positive results obtained so far allow us to propose to the authorities of our School the creation of a permanent group of scholarship students who will offer developing services to all the professors interested in creating their own Apps.

Other idea we are working on is to develop short tutorial videos explaining how to create an App, which will be available for any professor interested in creating Apps by their own.

It is important to state here that we have verified our initial supposition about the effectiveness of this methodology to promote a Student-Centered approach to learning. Conversely, we haven't been able to verify that this methodology may effectively reduce the abandonment in Engineering freshmen courses because we would need a more extensive and longitudinal study to certify this assumption.

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REFERENCES

[1] CIIE - UTN, [On line]. Available: www.ciie.utn.edu.ar.

[2] U. R. Cukierman, M. Agüero, S. Silvestri, R. Delmonte, J. Drangosch, L. Gonzáles Corrao, D. Pérez Ferrando y L. Saclier, «Bridging the gap between first-year students and Engineering: A novel application of mobile technologies for improving Mathematics and Physics learning,» de WEEF 2017, Malaysia, 2017.

[3] Quanser, «Qdex,» Quanser, [On line]. Available: https://qdexapps.com/.

[4] Quanser, «Quanser,» [On line]. Available: https://www.quanser.com/.

[5] Y. Laouris y N. Eteokleous, «We need an educationally relevant definition of mobile learning,» de 4th World Conference on Mobile Learning. 28-43., Cape Town, 2005.

[6] D. Barbosa y C. Geyer, «Pervasive personal pedagogical agent: A mobile agent shall always be with a learner,» de Proceedings IADIS International Conference Mobile Learning 2005, Malta, 2005.

[7] T. Lara Padilla, «Mlearning. Cuando el Caballo de Troya entró en el aula,» de Tendencias emergentes en Educación con TIC, Barcelona, Asociación Espiral, Educación y Tecnología, 2012, pp. 263-274.

[8] S. Adams Becker, M. Brown, E. Dahlstrom, A. Davis, K. DePaul, V. Diaz y J. Pomerantz, «NMC Horizon Report,» EDUCAUSE, Louisville, 2018.

[9] M. Vergel Ortega, J. J. Martínez Lozano y S. L. Zafra Tristancho, «APPS en el rendimiento académico y autoconcepto de estudiantes de ingeniería,» Revista Logos Ciencia & Tecnología, vol. 6, nº 2, pp. 198-208, 2015.

[10] N. Escala, «Researchgate,» January 2015. [On line]. Available: https://www.researchgate.net/profile/Nella_Escala/publication/304463014_Hacia_unos_principios_del_diseno_instruccional_para_el_aprendizaje_movil_m-learning/links/577074e608ae10de639c0b54/Hacia-unos-principios-del-diseno-instruccional-para-el-aprendizaje-m. [Accessed on: September 2018].

[11] Quanser, «qdex Support Desk Forum,» [On line]. Available: https://qdexapps.zendesk.com/hc/en-us/community/topics.

[12] Quanser, «Knowledge Base,» [On line]. Available: https://qdexapps.com/knowledge.