An augmented reality platform targeted to promote learning about Planetary Systems

M. C. Costa [1,3], A. Manso [1,2], J.M. Patrício [1,2], A. Carvalho [1], B. Alegria [1], V. Zinatulins [1],
[1]Instituto Politécnico de Tomar (PORTUGAL)
[2]Ci2 – Smart Cities Research Center, Instituto Politécnico de Tomar (PORTUGAL)
[3]UIED* - Unit of Research Education and Development, Universidade NOVA de Lisboa (PORTUGAL)
manso@ipt.pt, ccosta@ipt.pt, jpatricio@ipt.pt, afecarvalho@ipt.pt

Abstract — **We present a mobile augmented reality platform targeted to promote learning about planetary systems. The architecture of this platform includes a mobile application and a back-office that allows teachers to choose the planetary system they intend to present to their students. Furthermore, they can introduce information about celestial bodies, such as stars or planets and develop a set of multiple-choice questions to assess student's learning about the subject matters they teach. Also, after playing the game, the data collected by the application is sent to the information system that processes it and makes it available to teachers. With these functionalities, this paper intends to propose this platform as a resource to be implemented in any level of school syllabus.**

Keywords – Mobile learning; augmented reality; collaborative learning environments; learning object repositories; astronomy.

I. Introduction

We present a Mobile Augmented Reality (MAR) platform targeted to promote learning about the planetary systems of the Universe. For this reason, the MAR platform was entitled PlanetarySystemGO [1]. Augmented Reality (AR) is an emerging topic that permits to combine the real world with virtual objects [2, 3] and has the potential to engage students in practice-based activities [4] and to learn about STEM [5]. Concerning that there is a gap in the literature about the use of MAR applications in formal learning environments [6, 7], the PlanetarySystemGO is an important contribution in this matter [1] because it may be implemented in schools. The architecture of this platform allows teachers to introduce contents according to the grade level they teach. For example, teachers may introduce the information about each celestial body that they find relevant for their class according to school syllabus (Figure 1). In this regard, we intend that teachers gain knowledge and skills to use this resource with their students.

The architecture of the PlanetarySystemGO platform includes a mobile application and a back-office, amongst other components [1]. The mobile application consists of a location-based game that can be played using a smartphone with components such as camera, Global Position System (GPS), gyroscope and accelerometer. The players start at a given coordinate (the Star) and are guided by the application in order to find the orbits and the planets of the planetary systems. Besides finding information about the planets (Figure 1), when each planet is captured a multiple-choice question needs to be answered. At each stage of the game (finding the orbit, "hunting" the planet and answering the question) the players gain points (Figures 1, 2 and 3).

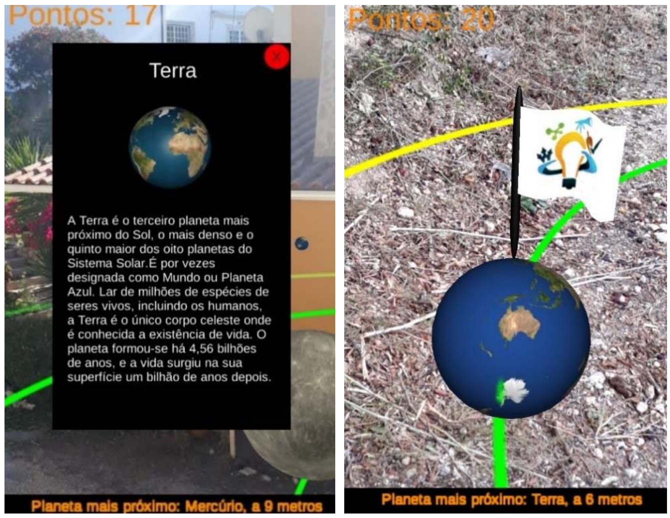

Figure 1: Our Solar System and information about the Earth.

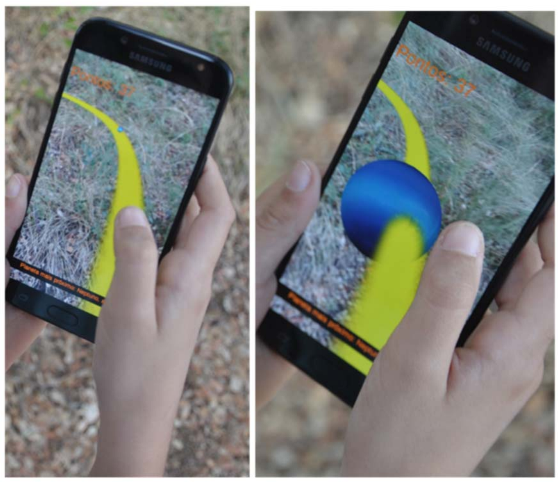

Figure 2: The sequences of the game: finding the orbit and hunting the planet.

978-1-7281-3182-5/19/$31.00 ©2019 European Union

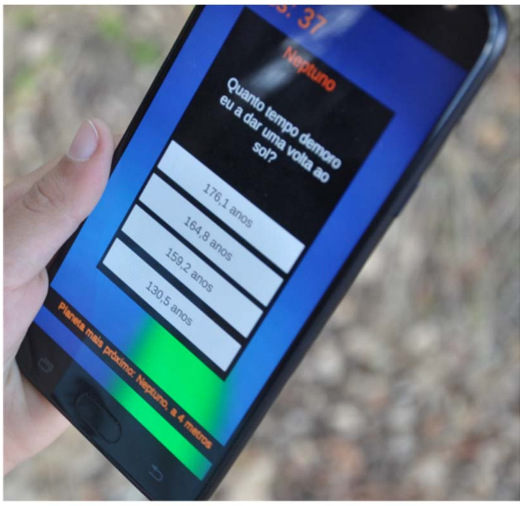

Figure 3: Neptune's question: How long is my travel around the Sun? This player has 37 points.

The underlying back office system permits teachers to choose the planetary system they intend to present to their students and to introduce information about the celestial bodies, such as stars or planets. Also, teachers may develop a set of multiple-choice questions to assess student learning about the subject according to school syllabus. Furthermore, after playing the game provided by the mobile application, the data collected during the game is sent to the information system, that processes it and makes it available to teachers.

Concerning the authors previous work, this study contributes to the literature by highlighting the back-office as a resource that can be used by teachers to promote learning about planetary systems according to any level of school syllabus. In this regard, we present the particular case of the implementation of our Solar System, which we intend to be used by teachers. This work is situated within the context of collaborative learning environments and learning object repositories. For a literature review about this matter the interested reader may see [8].

In this paper, we begin by describing the context and background of this study. Next, we present the back-office structure and how it can be used by the teachers. Because this is a work in progress, we did not have yet the opportunity to provide implementation tests about the use of the back-office by teachers. But, as soon as possible, we intend to perform several tests with primary and secondary teachers in order to disseminate the results.

II. BACKGROUND AND CONTEXT OF THE STUDY

The PlanetarySystemGO platform is being designed and developed by computer engineering students in the context of their final project before graduation and in the framework of a problem-based learning methodology [9]. The students are supervised by higher education teachers from a Polytechnic Institute of Portugal (four first authors of this paper). Every school year a new group of students takes the challenge of keeping upgrading the platform in order to provide new functionalities. The challenge of the school year 2018/2019 proposed to the computer engineering students (two last authors of this paper) was to develop the back-office in order to become more accessible to be used (user friendly) by any teacher of any school level no matter his background about using emergent technologies.

The PlanetarySystemGO platform is an evolution of a previous game intitled SolarSystemGO initially designed to promote learning about our Solar System [5]. First implementation tests occurred with primary school children in informal learning environments. In the school year 2017/2018, an implementation test was performed in a formal learning environment at a primary school with a 4th grade primary school class with 20 students [9]. The students were organized into five groups according to the number of available mobile phones with the application. After the students played the game, a questionnaire was applied to them in order to assess the impact of the game on the class. First two questions were: “Did you have fun playing the game?” and “Would you like to play it again?” (Figure 4).

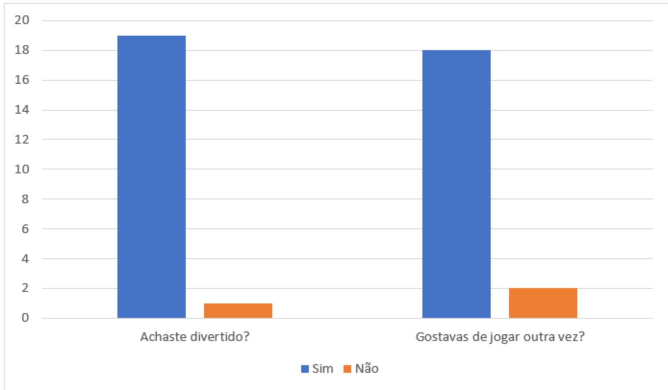

Figure 4: Results of the students' answers to the questions: Did you have fun playing the game? Would you like to play it again? The blue color (on the left) is for “yes” and the rose color (on the right) for no.

As can be observed in figure 4, most students answered that they enjoyed playing the game and would like to play it again.

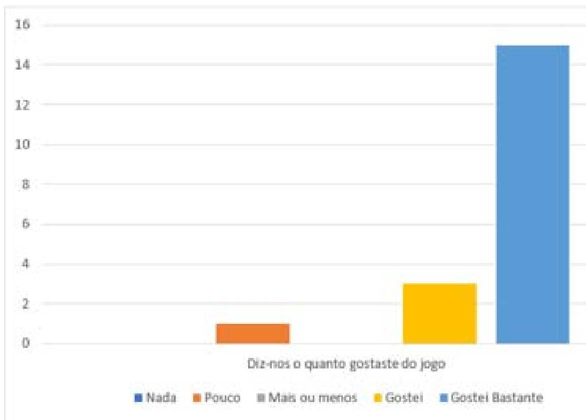

Figure 5: Results of the answers of the students to the question: How much did you like the game?

Another question was: How much did you like the game? Following a Likert scale, the options to answer this question are:

"I did not like it at all", "I liked a little", "I liked it more and less", "I liked it" and "I really liked it" (Figure 5).

According to figure 5, no one answered "I did not like it at all" and "I liked it more and less", only one student answered "little" (orange color), three students "liked it" (yellow color) and fifteen students "I really liked it" (light blue color). The student who answered "I liked a little", was an autistic child. He explained that he did not like to run, and his team was running all the time. Also, the teacher answered a questionnaire, where she referred that the game provided the students with a real experience that improved their learning about the Solar System contents [1].

After each test with the targeted public of the game, a reflection is performed with the engineering students' supervisors in order to plan how to upgrade the game to achieve better results in the next experience. Considering the good results related to the preliminary versions, as described above, the next challenge is to implement the PlanetarySystemGO platform in the framework of a teachers professional development context, in order to provide them with knowledge and skills to be able to use this resource to promote learning about planetary systems according to school syllabus and the grade level they teach.

III. THE PLANETARYSYSTEMGO PLATFORM

In the framework of augmented reality, the real world of our game is the environment, where the player is inserted and the virtual objects (digital objects) that are superposed on this environment are celestial bodies such as stars and planets. The real world is captured by the mobile camera and the user's location is gathered by GPS technology.

The PlanetarySystemGO platform architecture includes a backend that comprises three layers: web services, back-office and storage (Figure 6). To understand how these services interact among each other and with the mobile augmented reality layer the reader is directed to [1]. Since there are few studies that integrate augmented reality applications with a pedagogical approach or instructional strategy and, also, most of the existent studies use marker-based technology [6], our system features an innovative contribution, in the sense that it provides an augmented reality location-based application for educational purposes [1].

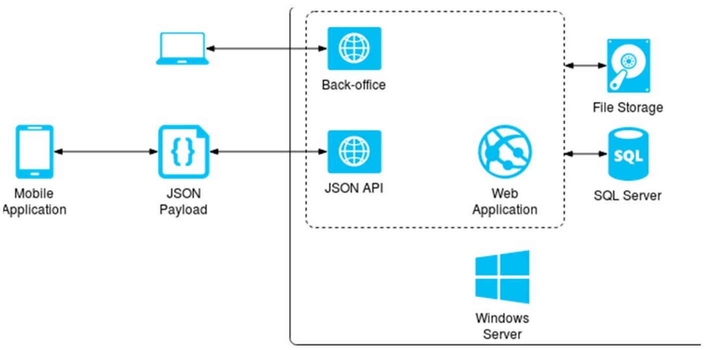

Figure 6: The back-end architecture of PlanetarySystemGO.

In this paper, we intend to extend our preliminary work by exploring the functionalities of the back-office as a resource to be used by the teachers in order to promote learning about the planetary systems of the Universe.

IV. PLANETARYSYSTEMGO BACK-OFFICE

PlanetarySystemGO uses a gamification strategy where the students search for celestial bodies of the Universe that virtually circulate in the real environment of the player (captured by the camera) through the mobile application. When the celestial bodies are found, information about their characteristics is provided by the system and a multiple-choice question needs to be answered. At each stage of the game the player gains points as he succeeds by either finding the planets' orbits, the celestial bodies or answering the questions correctly (Figures 1, 2 and 3). The scores are displayed in the mobile phone screen and at the end of the game the player can compare his score with the other players. During this process, the player learns contents related to the celestial bodies he found. Furthermore, the answers given to the multiple-choice questions provide assessment of his knowledge about the several celestial bodies.

The back-office included in the PlanetarySystemGO platform provides the development of the application in the mobile phone. In this way, it is responsible for its parameterization and for the processing and presentation of data collected during the game. For this reason, all the collected data provided by the player's experience is made available to the teacher through the back-office. Therefore, the teacher can access the scores of each student and the answers that each student gave to each question. For example, figure 7 shows the results of the final score of each of the five teams who played the game, which are received through the back-office.

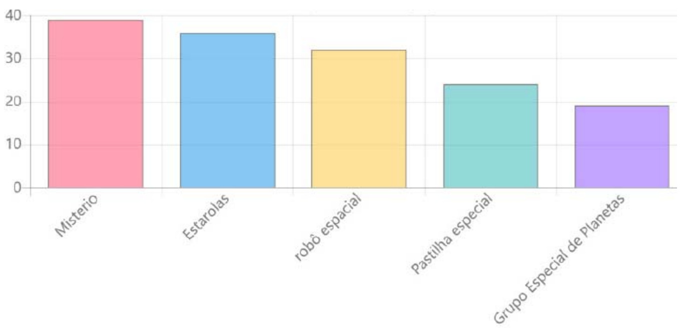

Figure 7: Results of the scores of the five groups who played the game

gg Unfortunately, one of the mobile phones had a lower performance than the other four and this was one the main reasons for this worst result. In fact, variables related to sensors such as gyroscope and accelerometer may compromise the efficacy of finding orbits and planets and the problem increases with lower performing mobile phones.

As referred before, besides our Solar System, in a final stage the celestial bodies may be any planetary system, asteroids, comets or black holes, amongst others. Each object contains information that may be provided by multimedia, text, images or animations, which allows the transmission of knowledge and stimulates learning about the referred objects. Besides these contents, each object also contains data that is transmitted to the mobile application in order to control the presentation and the movements of the objects in augmented reality, which is visualized by the user in the mobile phone screen. For example, when the orbit is found, it changes its color from yellow to green (Figure 1) and when the planet is captured it receives a flag with a logo from the broader project [10, 11].

The astronomical objects and the planetary systems that group them together are stored in repositories that allow the sharing of pedagogical contents among teachers. We define three types of repositories in our information system: The public repository that is accessible to all users; the repository of the school or group of schools that is accessible only by the teachers of that school and the private repository of the teachers (Figure 8).

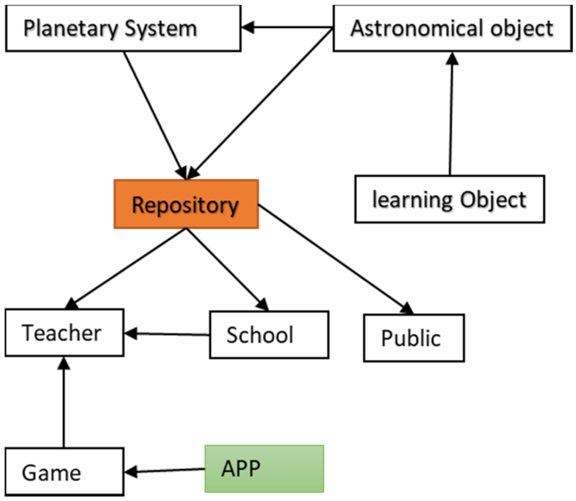

Figure 8: Database Model.

The pedagogical contents, such as planetary systems or astronomical objects, may be created by teachers and included in their private repository. However, the system allows that this content is shared to the remaining repositories. These contents can be created from scratch and the system will register its authorship. Alternatively, they can be built from existing objects in other repositories and in this case the system registers the co-authorship. In this last option, the teacher makes a clone of the original object and changes it to adapt it to the didactic contents he wants to teach. This change can be the translation of the object into a different language, allowing the internationalization of the system, or the adaptation of the learning object to be adequate to the grade level of the teacher's students.

Figure 9 is an example of a repository that was designed by the computer engineering students [11] and includes information about our Solar System, namely information about the Sun and planets. Figure 10 gives an example of the page with the questions about the celestial bodies. In this particular case, the multiple-choice questions that are visible in figure 10 are related to the Sun. Other pages with questions about the planets have a similar image.

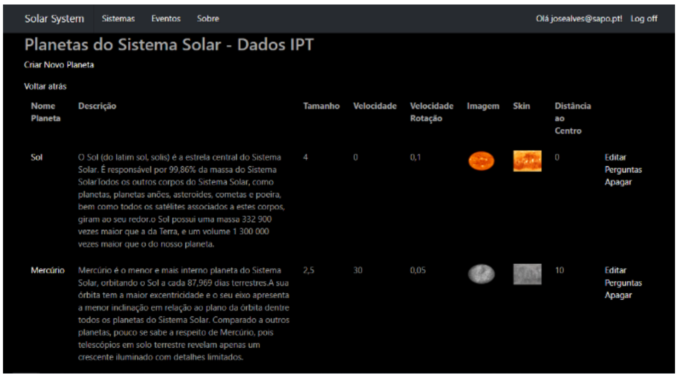

Figure 9: Repository of our Solar System.

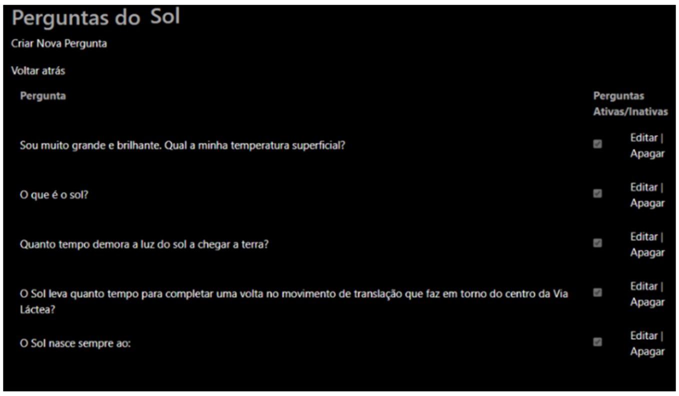

Figure 10: Page with the questions about the Sun.

The use of repositories accelerates the production of pedagogical content by cloning and adapting existing objects. Registration of authorship and co-authorship has several features in the system:

- Attribution of copyright for all those who participated in the development of the content and its recognition by the other teachers.
- Permission to make available, change, or remove object from repositories. Once an object is made available only its authors are allowed to manipulate it. Other users can only make clones of the previous objects and if they change them, they become co-authors of the clone.
- Responsibility for the provided content. With this authorship we are contributing to the self-regulation of the repository, namely concerning ethical issues.

In summary, the game consists of a planetary system that includes a set of celestial objects and is parametrized to be played in a real environment in the context of augmented reality provided by the application. The games may be designed by the teachers with the objects from their private repository. In this way, the original objects of the school or public repositories are preserved and the integrity of the contents defined by their authors is guaranteed.

The great advancement in this version of the system is the repositories of objects, which promotes the sharing of teaching resources among teachers and the introduction of the concept of astronomical object that allows to represent any astronomical body that the teacher intends to explore.

V. Conclusions and Future Work

We present a Mobile Augmented Reality (MAR) platform targeted to promote learning about planetary systems. Concerning that there is a gap in the literature about the use of MAR applications in formal learning environments [6], the PlanetarySystemGO is an important contribution in this matter [1]. Also, our system consists in a location-based application, which is an innovative contribution since most of the existent studies use marker-based technology [6].

The architecture of the PlanetarySystemGO platform includes a mobile application and a back-office, amongst other components [1]. In what concerns with the authors previous work, this study contributes to the literature by highlighting the back-office as a resource that can be used by teachers to teach about planetary systems according to school syllabus and the grade level of their students. In this regard, teachers may introduce the contents about the celestial bodies they intend their students to learn (Figure 9) and the multiple-choice questions (Figure 10) that they find appropriate in order to evaluate the students' knowledge about these contents. Also, all the collected data provided by the students, when playing the game, is made available to the teacher through the back-office, namely the answers that the students gave to the questions and the scores of each player (Figure 7). The new contribution in this version of the system is the repositories of objects that permits the teachers to introduce contents and to share this information with their students and, also, with their peers, including the whole school.

Since this is a work in progress, the application and the back-office need several upgrades. For example, it is necessary to improve the algorithm in charge of the analysis and processing of data from the sensors in order to achieve a better performance when finding the orbits and planets. As far as the back-office is concerned, a more user-friendly interface needs to be created to facilitate the introduction of the information and provide a better visualization (Figures 9 and 10). Also, we did not have yet the opportunity to provide implementation tests about the use of the back-office by teachers. Due to the positive results about the implementation of the game in formal learning environments (Figures 4 and 5), namely the teachers' opinion about the game who refer that the game provides the students with a real experience that improves their learning about the Solar System [1], we believe that we will also have good results in this new experience.

Acknowledgment

*This work is supported by national funds through FCT - Foundation for Science and Technology, I. P., in the context of the project PTDC/CED-EDG/32422/2017

References

[1] A. Manso, M. C. Costa, J. Patrício and A. Carvalho, "PlanetarySystemGO: An augmented reality application to explore the Universe," in *15th China-Europe International Symposium on Software Engineering Education (CEISEE)*, Caparica - Lisboa - Portugal, 2019.

[2] R. T. Azuma, "A survey of Augmented Reality," *Presence. Teleoperators and Virtual Environments,* vol. 6, pp. 355-385, 1997.

[3] G. J. Hwang, P. H. Wu, C. C. Chen and N. T. Tu, "Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations," *Interactive Learning Environments,* vol. 24, no. 8, pp. 1895-1906, 2016.

[4] P. Fotaris, N. Pellas, I. Kazanidis and P. Smith, "A systematic review of Augmented Reality game-based applications in primary education," in *Proceedings of the 11th European conference on games based learning (ECGBL17)*, Graz, Austria, 2017.

[5] M. C. Costa, J. M. Patricio, J. A. Carrança and B. Farropo, "Augmented reality technologies to promote STEM learning," in *2018 13th Iberian Conference on Information Systems and Technologies (CISTI)*, Cáceres, Spain, 2018.

[6] F. Saltan and O. Arslan, "The use of augmented reality in formal education: a scoping review," *Eurasia Journal of Mathematics, Science & Technology in Education,* vol. 13, pp. 503-520, 2017.

[7] G. Koutromanos, A. Sofos and L. Avraamidou, "The use of augmented reality games in education: a review of the literature," *Education Media International,* vol. 52, pp. 253-271, 2015.

[8] K. Clements, J. Pawlowski and Manouselis, N., "Open educational resources repositories literature review–Towards a comprehensive quality approaches framework," *Computers in human behavior,* no. 51, pp. 1098-1106, 2015.

[9] M. C. Costa, A. Manso and J. M. Patrício, "Design of a mobile augmented reality game in the framework of problem-based learning," in *11th Annual International Conference on Education and New Learning Technologies (EDULEARN19)*, Palma de Maiorca, Espanha, 2019.

[10] M. C. Costa and L. Loureiro, "Learning by experimentation: Children's laboratory experiences at the Polytechnic Institute of Tomar," *International Journal of Learning and Teaching,* vol. 8, no. 2, pp. 119-128, 2016.

[11] M. Silva, R. Lopes e T. Faria, Projeto Final - SolarSystemGO, Tomar: Instituto Politécnico de Tomar, 2018.