A Gamification Experience and Virtual Reality in Teaching Astronomy in Basic Education

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***Abstract*—Regardless of the country, there is a trend: the world of school and the modern world are two different poles. Young people see school as boring compared to the entertainment of today's technology. Most students prefer to play or surf the internet, but not study. Gamification is projected as a methodological practice that aims to turn classrooms into playful immersion scenarios, using participatory strategies with the incorporation of electronic devices. This article shows the results obtained by applying gamification techniques in the research project aimed at supporting astronomy learning for basic education students. When using the app, the student must overcome challenges to earn different achievements and rewards. Among the results highlights the student's motivation during the learning process and the perception of satisfaction of the personal achievements achieved.**

***Keywords*—Gamification; game-based learning; reward system; student motivation**

I. Introduction

The 21st century is known as the century of creativity, innovation and innovation, as these years face the need to find new ideas and solutions to the many problems that arise in a society of accelerated change (De la Torre, 2006, p.12 cited by [1]). Contrary to this claim, the school creates an artificial environment that does not consider the interests of students and limits their perception and development of the world around them. What's more, teacher and students speak different languages.

Traditionally, the teacher outperforms the student in terms of development and competence, however, in the use of technology the teacher is at a disadvantage because students know and use the new technologies intuitively incorporating them into the way of behavior and socialization. Therefore, an additional problem arises, the students dislike the teachers because they are not in the same tune. Teachers are separated from the modern world, do not use modern educational technologies, have no ICT skills, etc. As a result, students' distrust of the school and loss of learning interest is observed.

Today's children are inundated with entertainment and toys from birth, they perceive that the world is a fabulous place, they consider their parents as magical beings who can be asked or demanded any desire. The Internet and virtual toys create a sense of constant accessibility to anything. Then a question arises how to use technology to motivate learning?

For Marc Prensky, today's young people cannot learn how yesterday's young people cannot learn, so if they learn differently, they must be taught differently, using novel and varied methodologies, forms, methods and means. In this context, gamification arises as a methodology that supports training processes, as it makes learning processes more attractive by enhancing fun, productivity, the ability to retain concepts and the acquisition of skills. Gamification claims the role of games and especially video games, as a vehicle for help for the educational task, allows to involve the student in the practical work inside and outside the classroom, so that it is the students themselves who are the protagonists of their learning processes [2].

According to [3], "*the dynamics of games themselves can increase the attention of students during the learning teaching process by also improving their satisfaction with this process*" . In [4], it states that the game in the context of education aims to teach and reinforce different aspects such as knowledge and skills, such as problem solving, collaboration and communication. One of the most important aspects when gamifying in the educational context, according to [4], is the organization, since it directly conditions the expected results.

Students are growing up in a technified society, so educators need to reconfigure their pedagogical strategies so that students can develop different capacities that enable them to understand and address the changing world around them [5]. That is why, in gamification processes ICTs with mobile devices and cutting-edge technologies are being incorporated [6].

II. Gamification

Even in the last century, L.N. Tolstoy in his work "General Observations to the Teacher wrote: "For a student to study well, he must learn eagerly; for you to study at ease, it is necessary that what is taught to the student is understandable and entertaining; that his spiritual strength would be in the most advantageous conditions".

Since ancient times there has been a close relationship between education and play, from its early stages of life, the human being learns by playing. There are several efforts dedicated to analyzing and redesigning the game model, the pioneers in redefining the game concept and its relationship with new technological developments are [7] and [8]; they propose that one of the fundamental elements of the game is

the relationship between the established rules and the player experience with ample room for maneuverability within those rules; that is, the balance between rules and freedom.

Gamification arises as a form of active learning in which the rules of the game are used to achieve real goals. In a game, boring tasks become interesting, complex tasks become simple, and rejected ones become desirable. This happens, for example, when teaching mathematics is done through non-traditional sessions that include dynamics and technology that make mathematics fascinating and more accessible, so that students are encouraged to participate in activities active and creative in which the necessary knowledge, and required skills are acquired and systematized.

It is important to emphasize that gamification is not synonymous with "playing in the classroom" or "learning by playing", nor is it the same to refer to the term for learning through video games, mobile applications (apps) or any other Information Technology Communication (ICT); but it is the use of game design elements in traditionally non-playful contexts [9], these elements are being the mechanics, dynamics and aesthetics.

Gamify is not a question of "designing a game", but of taking advantage of the reward systems that usually have these (points, medals, levels, missions, challenges, achievements, advantages...), as well as the dynamics and aesthetics to create an experience that maintains the interest in the development of educational content [10].

The concept of gamification, according to [11] was presented by Nick Pelling (2002). In [12] contend that until 2010 the use of the term was not widely used. In their gamification by Design work, [13] defines this concept as "a process related to player thinking and gaming techniques to attract users and solve problems". In [14] it presents the work "The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education" and states that gamification is "the use of mechanisms, aesthetics and the use of thought, to attract people, stimulate the action, promote learning and solve problems". The authors mentioned share the same vision on gamification, focused on the influence it has on the psychological and social behavior of the player. They argue that the elements present in the games generate greater disposition and motivation and increase the time the student spends on them, so they can be used more productively to achieve greater learning.

On the other hand, the study [15] "Social Motivations to Use Gamification: An Empirical Study of Gamifying Exercise" postulates that gamification is the production and creation of experiences that bring feelings of control and autonomy to people, in order to influence their behavior, leaving in the background the enjoyment they may experience during the activity.

For [16] gamification “is the application of game metaphors to real-life tasks to influence behavior, improve motivation and encourage involvement in that task”. This work assumes that gamification is the use of elements of games in playful environments, that is, the application to an activity of the aspects that make a game attractive to favor effort, motivation and performance.

In [17] the authors defend the importance of making a good design of the gamified activity, since it is the main action to be carried out and the one that can condition the good or bad result of the activity. Then, you must choose the elements of the game based on pedagogical criteria that allow to analyze the function and the concrete use of all the resources to be created or used.

Specialists also express the need to include an emotional component in gamification.

III. Game-Based Learning

Game-Based Learning (GBL) uses the game as a vehicle and tools to support learning, assimilation or knowledge assessment. According to Prensky (2001) this type of learning focuses on those games with educational objectives, which enhance learning outcomes and promote a more fun, interesting and therefore more effective experience.

In [18] and [19], they proposed specifically, the notion of game-based learning has involved supporting teaching, encouraging decision-making, valuing the change in game outcomes based on their actions, and boosting social skills alongside work in team.

In this specific typology a series of commonly applied patterns is set up, highlighting the incorporation of rules and restrictions, dynamic and instant responses to the actions taken by the students, challenges suited to the subject of study that catalyze self-efficacy and progressive learning of difficulty [20].

By using digital educational games (supported by ICT), the GBL represents a substantial improvement that it also brings to digital competition.

Among the advantages of GBL are: (a) Motivates the student, (b) Contributes to reasoning and autonomy, (c) Promotes active learning, (d) Gives the student control of their learning, (e) Provides useful information to the teacher, (f) Empowers the teacher creativity and imagination, (g) Promotes social skills and (h) Contributes to digital literacy.

IV. Context

In Peru, astronomy is taught in basic education, and as in other countries, it has a particular problem; teaching is done theoretically, in a few hours of class and at the end of semesters. Students do not pay much attention to the subject, are unmotivated and do not understand the basics of this science. That is why this work describes the experience of designing, implementing and using an application created in order to enhance the learning results of students in Astronomy topics, for which they were proposed as specific objectives:

- Analyzing information about the characteristics of the solar system and planets.
- Differentiate the elements that make up the universe.
- Explain the origin of the universe from the Big Bang theory.

The experience was carried out in 2019 in the field of basic education in Arequipa-Peru, with students of the first degree of secondary education from two national educational institutions. In the I.E. Our Lady of the Assumption has worked with 40 students and in the I.E. Antonio José de Sucre worked with 59 students, in both cases, he was supported by a professor from the I.E. who acted as a pedagogical advisor.

A. Moments of Experience

1) Coordination of visits by San Agustín National University of Arequipa managers to educational institutions.

2) Training session on the use of the application, with assistance of students, teachers in the area of Science Technology and Environment, head and laboratory assistant.

3) Meeting for validation of the first prototype on the platform, in which teachers suggested placing content in an introspective way, that is, starting from the general and approaching particular objects, always with the support of information that serve the student to understand the natural structure or phenomena of the astronomical field.

4) Meeting for validation of the second prototype with modifications made from the suggestions of the previous meeting.

5) Design of the learning session, carried out by teachers of educational institutions considering the skills and capacities to be developed and the respective indicators.

6) Programming the learning session with first grade students.

7) Evaluation of the results obtained.

GBL was used as a teaching-learning model in order to improve students' motivation and involve them in the different topics to be developed in class, all so that the student can identify, recognize and associate the planets and other celestial bodies. To implement this model, the simulation method was used, which is based on an interplanetary journey using virtual reality. To encourage learning, some training mini-games have been implemented, which allow to reinforce the concepts learned.

B. Technical Characteristics

The Unity game engine has been used for system development. The computer application considers two versions.

The first to be used on a computer (2D modules). The second to be used on mobile devices with resolution of 2560 x 1440 pixels, with gyroscopic sensor, Android version 4.1 or higher, which when interacting with Google Cardboard make it possible to display the modules in the virtual reality environment (immersive modules). Using Google Cardboard allows you to achieve greater accessibility through the application, as it is not limited to a physical room.

To use the app, the user must place the mobile device in their VR Box and launch the application.

The decision to use two versions was made because students became dizzy using the VR headset for more than 15 minutes.

All developments have been carried out in constant communication with teachers of educational institutions and under the guidance of astronomy specialists.

V. Description of Modules

To start the trip the student must register: create their username and password. At the end of registration, you enter the application, where with the help of Astronito (user guide), you are given explanations of how to navigate the modules, the game rules, the prizes to win, etc. The record also gives you the possibility to see your progress, the achievements achieved and the ranking achieved (Fig. 1 and 2).

The home screen displays a set of buttons that allow you to access the relevant information (Fig. 3).

The interstellar journey takes place aboard a spacecraft. The journey begins as a crew member. As the study modules progress and the proposed objectives are met, you can become a Stellar Captain (Fig. 4).

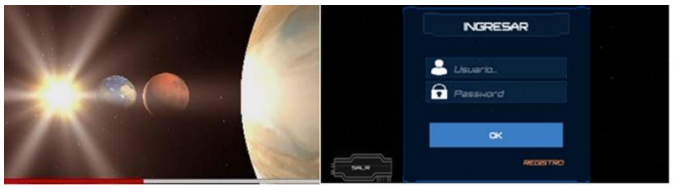

Fig. 1. Admission to the Application.

Fig. 2. Interstellar Travel Home Starting Screen.

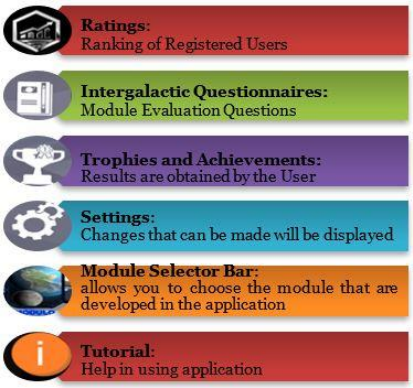

Fig. 3. The Main Screen Buttons of the App.

Fig. 4. Maximum Achievement after Successful Completion of All Modules.

To meet the educational objectives raised and cover the proposed topics, 7 modules were developed. These modules contain the information needed to understand the study topic.

Initially, the development of all modules was planned with the use of virtual reality; however, in the process of developing the application, it was necessary to reduce the time of use of the virtual helmet due to the dizziness experienced by students. As a result, the learning modules were developed in 2D and 3D. As not all students were able to purchase the virtual helmets, they were given the step-by-step instructions to build their own Cardboard with materials that were at their disposal.

When entering any module different options are presented (Fig. 5).

- Videos: educational videos related to the subject in question.
- Virtual game: mini game that supports module learning.
- Questionnaire: set of questions to verify what you have learned.
- Did you know that: interesting facts about the subject covered?

A brief description of each of the modules available in the application is provided below.

"Planet Earth" module: This module makes known the relevant data on planet Earth, in an interactive way it is portrayed the different phenomena through which our beloved planet passes and some of the most important characteristics these ones have (Fig. 6).

This module covers the topics:

- Rotation and Translation of the Planet
- Seasons of the year
- Solstice and equinox.

The information is displayed to the user in the form of audiovisual information through a video.

This module is presented as a single sequence of interactive questions, combining visual and auditory information (Fig. 6). Inside the module you have an interactive mini game that allows you to measure the knowledge acquired on Planet Earth. Each success of the student on the proposed question adds 5 points to the ranking and for each error is subtracted 3 points.

Fig. 5. Module Options Menu.

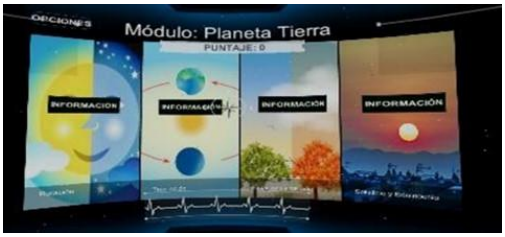

Fig. 6. The Panel View of the "Planet Earth" Module.

With the help of Astronito, if necessary, it is indicated that information is required to improve its performance. The student can view information on the topics to be discussed at the beginning, before questionnaire or minigame, for this action no points are subtracted, but if at the beginning of the sequence of questions the student wants to display the information is subtracted 2 points.

At the end of the module, the accumulated score and the trophy or medal achieved are assigned.

"Moon" module: This module explains the lunar phases and the lunar and solar eclipses. (Fig. 7). Three sequences of interactive questions on a given topic are proposed, which do not follow a specific order.

Question sequences are related to the topics:

- Eclipse Solar, where the student is asked to identify the characteristics that lead to this phenomenon and a simulation of the eclipse is made.
- Lunar Eclipse, similar to the solar eclipse, the student must identify the characteristics that lead to this phenomenon and a simulation of the eclipse is made.
- Phases of the Moon, where the student is sought to identify the position in which the moon should be relative to the student's simulated position on earth, so that each of the 4 main phases of the moon can be observed.

"Solar System" module: Module comprising the entire solar system where Planet Earth is located (Fig. 8). The features it provides are:

- Display the order of the planets.
- Visualize the translation of each planet.
- Display relevant information about each planet.
- Allow to differentiate between planets through your information.

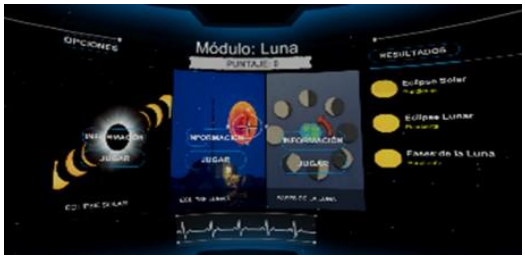

Fig. 7. The Panel View of the "Moon" Module.

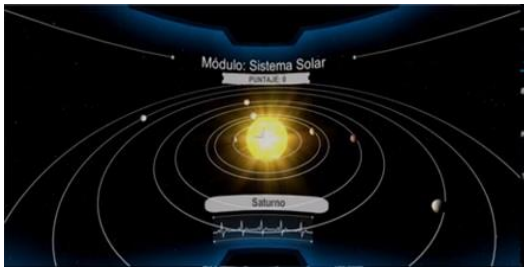

Fig. 8. View of the Minigame of the Module "Solar System".

This module is represented as a mini game where the student must identify the planets and positions that correspond with the help of the information provided by Astronito. At the start of the game, the respective rules and instructions are disclosed. Below is the name of the planet that the user must recognize in the Solar System. In case you hit it is increased by 5 points, otherwise you will be subtracted 3 points. In this module there is no penalty for displaying the information in the middle of the game.

"Minor Bodies" module: This module discloses the relevant data to the smaller bodies (Fig. 9).

An evolutionary conceptualization is proposed that goes in the following order:

- Comets: concepts, parts, types, characteristics and curiosities.
- Asteroids: concepts, characteristics and curiosities.
- Meteoroids, Meteors and Meteorites: Explaining them conceptually with a 3D representation.

Relevant aspects of each of them are determined, and a question is revealed at the end of each of the parties, setting the score and type of award. Each correct answer adds 3 points to the module result.

"Stars" module: This module explains the life of a star, from its creation to its death. In exploratory form, the different types of stars are disclosed (Fig. 10). Through the tour, by self-discovery, all types of stars must be completed and the proposed questionnaires answered. Upon completion of the game, they are assigned the corresponding score and their respective award.

"Galaxies" module: This module explains the different components and different types of Galaxies. In addition, information is given about our galaxy – the Milky Way (Fig. 11).

Fig. 9. Module View “Minor Bodies”.

Fig. 10. Module View "Stars".

Fig. 11. Module View "Galaxias”.

To discover all this information, the student has to complete three missions (Fig. 12):

- Components of a Galaxy - develops in space, where the student visualizes various bodies of space, the goal is to trap the bodies that are part of a Galaxy. The student gets 3 points when capturing the correct components, otherwise 1 point is subtracted.
- Galaxy Types - the student will need to identify the card, which corresponds to the galaxy that appears randomly on the screen, to click on the card, Astronito gives you additional information and so you can be sure of your choice. If the choice is correct, it wins 10 points, otherwise you lose 2 points for each failed attempt, a maximum of three attempts are allowed.
- Milky Way - relevant data about our galaxy are disclosed. Interactively, their different characteristics are displayed and the student is asked to identify them. Each success of the student on the proposed question adds 5 points to the ranking and for each error is subtracted 2 points.

Big Bang module: is the module where one of the theories of Origin of the Universe (Big Bang theory) is released, without touching theories related to the teaching of higher education (quantum and relativity theories) (Fig. 13). After watching an educational video, the learning assessment will be done with the help of a card game, in which the correct position of an event is chosen through a deck, based on the order of its appearance in the Big Bang Theory and according to the question asked.

Fig. 12. Interstellar Missions.

Fig. 13. "Big Bang" Module View.

VI. Reward System

In order to improve the user's interest in the realization of educational activities, a reward system was established, thus creating periodic moments of satisfaction.

- Point Accrual: A system was developed to evaluate the performance of each activity; points are awarded based on the time used to complete an exercise and the number of correct responses.
- Level scaling: Several activities were created, which are placed at difficulty levels. The student starts with basic activities until they reach more complex activities.
- Prizes: Rewards and virtual prizes have been implemented that the student accesses when completing the levels.
- Rankings: The ratings system discloses the progress of each student and promotes competition between them.
- Missions and Challenges: There are challenges, within the application, that are cumulative; Completing one creates a new challenge with a higher level of complexity.

At the end of each module, depending on the score acquired, each user is awarded a Trophy or Medal, which are indispensable to obtain a new badge, and consequently, become An Interstellar Captain, as a result a ranking of users is generated (Fig. 14).

The scores required to earn the Trophy according to the module are presented in Table I.

Fig. 14. Users' Ranking List.

TABLE I. Trophies

Type	Score
Moon Trophy	The Luna module is required with a score greater than 20 points.
	Having a score greater than 10 points, but less than 20 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 20 to get the official trophy.
	Having a score less than or equal to 10 will prompt you to re-develop the module
Earth Trophy	The Earth module is required with a score greater than 30 points.
	Having a score greater than 20 points, but less than 30 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 30 to get the official trophy.
	Having a score less than or equal to 20 will prompt you to re-develop the module.
Solar System Trophy	It is required to complete the Solar System module with a score greater than 30 points.
	Having a score greater than 20 points, but less than 30 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 30 to get the official trophy.
	Having a score less than or equal to 20 will prompt you to re-develop the module.
Minor Bodies Trophy	Minor Bodies module is required with a score greater than 70 points.
	Having a score greater than 60 points, but less than 70 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 70 to get the official trophy.
	Having a score less than or equal to 60 will prompt you to re-develop the module.
Star Trophy	The Star module is required with a score greater than 60 points.
	Having a score greater than 50 points, but less than 60 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 60 to get the official trophy.
	Having a score less than or equal to 50 will prompt you to re-develop the module.
Galaxy Trophy	Galaxy module is required with a score greater than 70 points.
	Having a score greater than 60 points, but less than 70 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 70 to get the official trophy.
	Having a score less than or equal to 60 will prompt you to re-develop the module.
Big Bang Trophy	The Big Bang module is required with a score greater than 70 points.
	Having a score greater than 60 points, but less than 70 points you will be given a silver trophy as recognition, but will not count as an official trophy. You will be asked to win the trophy you earn by taking a score greater than 70 to get the official trophy.
	Having a score less than or equal to 60 will prompt you to re-develop the module.

The information regarding the Medals is set out in Table II.

TABLE II. MEDALS

Type	Score
"Luna" Medal - Total: 30 points	A maximum score of 30 points is required.
"Earth" Medal - Total: 40 points	A maximum score of 40 points is required.
Solar System Medal - Total: 40 points	A maximum score of 40 points is required.
Minor Bodies Medal - Total: 100 points	A score greater than 75 points is required.
"Stellar" Medal - Total: 100 points	A score greater than 70 points is required.
"Galactic" Medal - Total: 100 points	A score greater than 80 points is required.

TABLE III. PARTICIPANTS' BADGE

Type	Score
Crewer	You get it when you start the adventure.
Captain Solar	Required when obtaining trophies from the Moon, Planet Earth, and Solar System modules.
Star Captain	Required when obtaining trophies from Star, Lesser Corps, and Solar Captain badge.
Galactic Captain	Required when obtaining the Galaxy Module Trophy and having Captain Star badge.
Interstellar Captain	Required when obtaining the Big Bang module trophy and having Captain Galactic badge

As a result of their effort, the student can achieve the badges shown in Table III.

VII. RESULTS AND DISCUSSION

The application, described in this work, has the appropriate didactic quality to enhance students' astronomy learning, as each stage of software development was accompanied by the pedagogical evaluation and field tests necessary.

Formed by test groups, it was initially necessary to train both students and teachers in the use of digital tools. Students showed interest in learning the correct handling of the application.

During the tests, the opinions and recommendations of both the students and the teachers were collected as pedagogical advisors.

To validate the application, the methodology developed by Abreu was used, and applied in works in which it was intended to evaluate the didactic aspect of educational material [21].

The criteria used for the evaluation of the application were:

- Environment quality and user interface.
- Content and relevance of information.
- Student control.
- Collaborative learning.
- Targeting.
- Applicability.
- Motivation.
- Flexibility.
- Feedback.

Some results of this evaluation are described in article CINAIC – 2019 [22].

The application was first tested and validated by science teachers from two national schools in the city of Arequipa, what were the test venues, and then with the students of these schools. In addition, the validations were made with the early-year students of the San Augustin National University of Arequipa. Opinions on the application were raised on the basis of a survey on the perception of users as to the usefulness of the application and the satisfaction of its use (Fig. 15, 16 and 17).

The application, described in this work, has the appropriate didactic quality to enhance students' astronomy learning, as each stage of software development was accompanied by the pedagogical evaluation and field tests necessary.

The results obtained show the desirability of applying different teaching methodologies that enhance the learning process of students. Results like these can be improved by combining methodologies such as Problem-Based Learning (PBL), Project-Based Learning (PrBL), among others. Results of such experiences can be seen in [23] and [24].

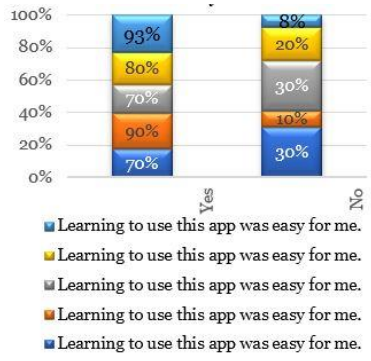

Fig. 15. Some Survey Results.

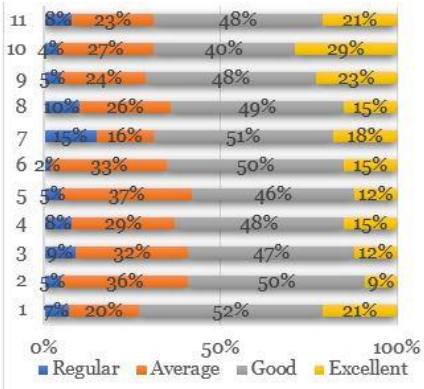

Fig. 16. Utility Assessment Results.

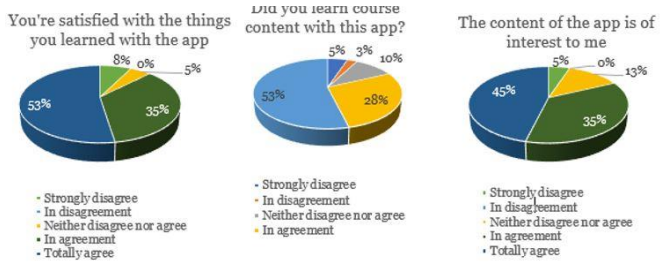

Fig. 17. Some Results Performed.

It is also convenient to measure student satisfaction regarding the use of technology under some model known as the Technology Acceptance Model (TAM), in [25] the TAM model has been applied to measure the satisfaction of virtual platforms in two subjects.

VIII. Conclusions

By applying gamification in the educational context, in addition to improving the level of motivation of students, learnings are promoted from interaction activities with the game.

By applying gamification in the educational field integrating learning and play, it is possible to improve the training process, in addition to improving the learning results, generic skills are developed that will serve the student throughout life.

The didactics of the basic sciences must be strengthened and nurtured by novel and varied methods, techniques, means and forms that promote student participation as the center of the training process, among them the study of Astronomy is underlined.

Gamification of the training process should be considered systematically and inescapable in teaching practice. This is the case that this work is intended to be a boost to continue research processes and application of gamification in different educational contexts.

Acknowledgment

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