TAECon, a web-based platform to promote STEM

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Abstract
In this paper, we present TAECon, a web-based platform designed to support STEM promotion sessions carried out by the Polytechnic School of Girona's University at higher schools. The platform combines gamification, serious games, content editors, and automatic correction strategies in a single framework. TAECon is used to prepare game sessions that turn around a central story with eight main characters from different ethnicities and genders that have to recover their identification cards. Players working in groups or individually and in face-to-face or virtual sessions have specific editors to design and enter solutions of challenges (or problems) and enigmas (or subproblems) created by STEM experts using the content editors of the platform. According to the type of enigma, correction techniques automatically evaluate responses and assign the corresponding reward. The platform has been used by more than a thousand students from fifty secondary schools. To collect the platform impressions, more than 250 students answered a questionnaire and 17 secondary school teachers were interviewed. As reported by the information collected, the platform was appreciated by both students and teachers. Users enjoyed the challenges and the game sessions. To conclude, TAECon can be considered a good strategy to promote STEM.

Keywords: STEM, Serious games, Gamification, Automatic correction, Content creation

1 Introduction

The advances in digitalization and robotics and their extensive application in many different areas have led to a great demand of STEM (science, technology, engineering, and mathematics)-skilled professionals [1]. However, contrary to the market needs, the interest of primary and secondary school students for scientific-technological subjects and the number of students that enroll STEM degrees are lower than the desired ones [2–5]. Several reasons such as the applied STEM teaching methodologies which present concepts that seem unrelated to reality or the students perceived difficulty with STEM contents have been considered as possible causes of this low interest [6, 7]. To overcome this situation, different programs and strategies have been proposed [8–17].

In this paper, we present a web-based platform designed to create STEM interest in students that may have not otherwise considered a STEM career. The platform is used in STEM promotion sessions carried out by the Polytechnic School of Girona's University at different higher schools of our country. The platform integrates gamification and serious games approaches, automatic content creation strategies, and automatic correction techniques in a single framework designed to create STEM material for promotion purposes.

Gamification incorporates game design elements in a non-game environment system to make learning more motivating and engaging [18]. It is applied in many different fields including commerce, tourism, health, or industry [19], and also in the context of STEM education [20–23]. One step further from gamification are serious games. These have been defined as games that not only entertain, but also teach or transmit some knowledge. Over the last few years, there has been a rapid growth of serious games in educational contexts motivated by two main factors [24]. On the one hand, the teaching and learning paradigm where the learner becomes the center of the process and practice takes an important role. On the other hand, the ability of serious games to capture students' attention and engage them in the exposed content by providing virtual environments to practice [25]. Serious games have also been applied in STEM education and their benefits have been studied by many authors that highlighted their effectiveness in the improvement of teamwork, problem solving, or communication skills, among others [26–34].

Although serious games (as well as gamification) are an emerging focus of research and development, the design and creation of these games are costly in terms of time and effort. Such a complexity is still higher when different concepts have to be transmitted in the context of a single game. In our case, we want to promote STEM at secondary schools by considering the different degrees of the Polytechnic School of our university (including electronics, agriculture, chemistry, etc.) and by using problem-based learning (PBL), a strategy for teaching in which learning activities are developed around a problem and students are challenged to explore and develop potential solutions [35]. Since games are an effective context for PBL [36], our idea is to design a serious game with challenges (or problems) related to these degrees. In addition, we want an open game where experts on STEM can create challenges and add them to the platform in the context of a general story (game mission) in order to maintain coherence. To reach these objectives, the following tasks need to be carried out:

- First, it is necessary to make the creation of challenges as simple as possible. Teachers are the experts on the topics that have to be transmitted and hence the best creators of challenges. However, they may not be familiar with serious games environments and if the creation process is complex, this may be a handicap.
- Second, the challenge has to be seen as a game mission with the corresponding reward once achieved. The reward system has to be related to the challenge achievement and techniques to automatically compute it are required.
- Third, it is necessary to create an open story that can fit different audiences and is capable of integrating new challenges without losing the story plot. This implies defining the narrative, the aesthetics, the scenarios, etc.

With all these issues in mind, we have designed a platform with different functionalities capable of solving them all. Particularly, the proposed platform integrates:

(i) Content creation editors that, according to the type of challenge, provide specific forms with a set of fields that need to be filled to select, for instance, the scenario where the challenge has to take place, the characters that have to appear, the text describing the challenge, the type of action that has to be carried out to solve the challenge, etc.;

(ii) Correction strategies that can be linked to the challenges to automatically detect if the user actions are correct or not, and then assign a reward to the user; and

(iii) A set of graphical components such as scenarios, characters, interfaces, etc. which can be added to a general story that can be extended according to the content creators' needs and presented in a game mode. These graphical components complement the content creation editors allowing challenges to be presented in a game mode.

The combination of these elements allows the creation of game sessions specifically designed for the target secondary schools. These sessions are composed of different challenges, previously designed by experts on the topic using the content creation editors, and stored in the platform database. Sessions are carried out under advise of a STEM promoter and all the actions carried out by the students will impact on the reward system updated according to automatic corrections.

The aim of the paper is to present the platform and the impressions that have been collected in different testing sessions. This process has involved more than a thousand students from fifty secondary schools. To collect the platform impressions, more than 250 students answered a questionnaire and 17 secondary school teachers were interviewed. According to the information collected, the platform was appreciated by both students and teachers.

Besides this introduction, the paper has been structured as follows. In Section 2, related work is presented. The design requirements of the platform are given in Section 3. In Section 4, the main components of the serious game are described. In Section 5, the details of content creators and automatic correction strategies and their link with the serious game are given. In Section 6, the platform implementation is presented. Results and discussion are given in Section 7 and Conclusions in Section 8.

2 Related Work

STEM education has given rise to different lines of research with the common aim of increasing the number of STEM-skilled professionals. The lines of research closest to our proposal are presented below.

An important focus of research has been centered on the role of teachers in STEM education [12]. Basically, four strategies to teach STEM can be considered. The classical approach, symbolized as S-T-E-M, considers the four subjects independently with no integration between them and with no relation to real-world situations. Research indicates that this approach makes the interest of the students difficult to maintain [37]. The second approach integrates two of the four STEM disciplines trying to apply knowledge and skills learned from these to real-world problems. Generally, the combined subjects are science and mathematics (SteM) [38]. Although a connection between subjects exists, their independence is still preserved. The third approach aims to overcome the limitations of the second one and integrates one of the STEM disciplines into the other three. Normally, engineering is integrated into science, technology and mathematics, or technology into science, engineering and mathematics [39, 40]. The last approach, considered the most appropriate and also the most complex to apply, combines all STEM contents into a single one trying to reproduce real-world situations. Research reveals that using such an interdisciplinary approach stimulates higher-level thinking skills and problem solving, among others [41, 42]. However, its application requires teachers not only to know the content of all the disciplines, but also to feel capable of creating cases that allow students to solve them while deepening their content knowledge [43]. Teachers have to face many challenges and obstacles, including the creation of new materials from scratch, the use of new teaching technologies, or the definition of new assessment strategies. In addition, their teaching skills and understanding of STEM learning need to be improved to ensure a proper implementation [44–47]. In this context, although our proposal will be used for promotional purposes, it can also be seen as a complement to teaching tasks, providing advanced functionalities such as authoring tools that make the creation of material easier as well as the creation of real cases where knowledge can be applied.

The role of students' learning attitude in STEM education has also become an important focus of research [48, 49]. STEM initiatives aim to increase the number of students pursuing STEM subjects, and also ensure that students are well-prepared and suitably qualified to engage in STEM careers. Different studies have been carried out to explore how students' engagement varies in the different STEM environments [50–54]. In addition, evaluations of the acquired STEM skills [48, 55] and also of the students' preferences according to teaching methodologies [56–59] have been carried out. In this context, our proposal aims to exploit the research results obtained and virtually present real-world situations where STEM contents can be applied. Virtualization of use cases requires state-of-the-art technologies, which lead to the last focus of research, the design and application of new technological tools and frameworks to support STEM teaching and learning. Different technology-supported pedagogic models have been proposed based on gaming, virtual laboratories, or augmented reality, just to name a few [60, 61]. It has been proved that these models have the potential to improve students' learning outcomes, including development of higher-order thinking skills, and to expand the range of learning opportunities made available to students. Moreover, it has been seen that the proposed tools can be used to support a specific subject or STEM as a whole. In this context, our proposal will provide tools to easily create virtual scenarios to connect students to STEM learning and also increase their interest and motivation [62]. Virtual scenarios will be presented in the context of a game, and gamification will be used to exploit their benefits [63, 64].

Our proposal is not intended to replace other proposals that promote STEM, but to complement them with functionalities that facilitate the tasks of content creators while trying to arouse students' interest. Furthermore, although it will be presented as a tool to promote STEM, it is also suitable for an academic context and also as part of summer camps or extracurricular activities.

3 Platform Design Requirements

The platform is conceived as a framework that, following a serious game approach, aims to promote STEM contents and motivate students to enroll in STEM degrees.

3.1 Challenges, Enigmas and Sessions

The key point of the platform is the *challenges*, which can be seen as problems to be solved. The challenges will always be associated with a visual resource, including 3D scenarios, videos or images, and a description that presents the situation. Challenges will be composed of *enigmas*, which can be seen as sub-problems. Enigmas will always follow the same structure with a description to present the situation, a set of help instructions, and a solution type, which can be a number, a text, an image, etc. that defines the information that has to be entered to solve the enigma. Enigmas will also have a contribution on the final mark which can be seen as a reward.

The challenges should be organized in *sessions*. Each session will be related to a group of students. Sessions can be configured to determine the order of the challenges, the location of these challenges on a previous selected image that acts as a map, restrictions on the number of attempts or time to solve it, whether the challenge has to be solved individually or in groups, and also the reward strategy.

3.2 Platform Functionalities

The platform functionalities have been defined considering the two user profiles that have to be supported, the content creators and the content consumers. The platform will have a registration system to control user access.

The *content creators* are responsible for challenges, enigmas and sessions creation, and with this purpose the platform will provide them with:

- editors to create challenges, enigmas and sessions,

- graphical content to create the challenge scenarios,
- a repository to maintain all challenges, enigmas and sessions, and
- a questionnaire system to prepare questions and collect answers to evaluate different aspects of the platform.

The *content consumers* (or players/students) will solve the challenges and enigmas in the context of a session. The platform will provide them with:

- access to challenges and enigmas in the context of a session,
- specific interfaces for entering the solutions of the enigmas,
- working areas defined according to the type of enigma to prepare solutions, and
- feedback to know the correctness of their actions.

Note that to enter a solution two strategies are supported. In the first one, content consumers work on the solution on their own and, once they know it, they enter it into the system. In the second one, content consumers use the provided working area to prepare the solutions.

The platform will be responsive and multi-language. In addition, it will have a modular design to be easily extendable. Since technological devices differ between centers, it will be accessible via web to ensure no restrictions related to the device used other than an internet connection.

4 The Serious Game

Once requirements have been defined, our interest has been centered on the four main elements involved in a game design: the story, the aesthetics, the mechanics, and the technology. All them are described below.

4.1 Story

The story defines the sequence of events that take place in the context of the game [65]. In our game, the story is led by seven characters of different sexes and ethnic groups (see Figure 1). They met in an annual Technology, Architecture and Engineering Conference, known as TAECon, to share the information they have collected during the year from their areas of residence in order to plan the actions to be carried out in the next year to maintain the planet. At the time of transferring the collected information to the servers of the center they will see that their access cards have been stolen. This will start a countdown in which a series of challenges composed of various enigmas must be solved to recover the access cards. These challenges will be related to STEM issues, requiring teamwork (or individually, if necessary) and the application of STEM knowledge for their resolution.

The story and the characters are introduced in a video presented when entering into the platform. This video ends with characters in a room with a big screen on one of the walls. The screen shows a map with icons in the places where the challenges that have to be solved to recover the cards take place (see Figure 2). In the current version of the platform, the last challenge is always the same and requires players to enter the codes that are obtained in the previous challenges. This last challenge recovers the cards.

Figure 1: *The characters of the serious game representing different sexes and ethnic groups.*

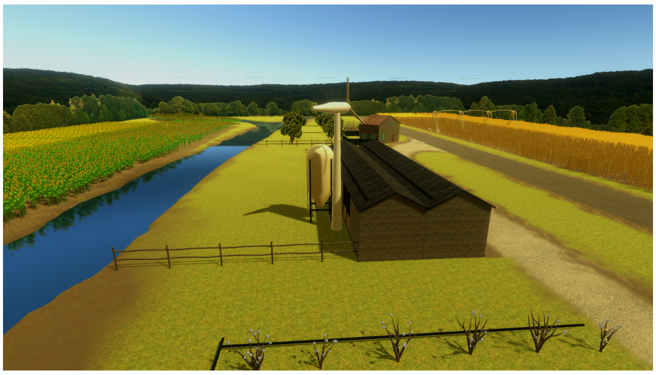
Figure 2: *The end of the introductory video with the map presenting the challenges that need to be solved to recover the stolen cards.*

4.2 Aesthetics

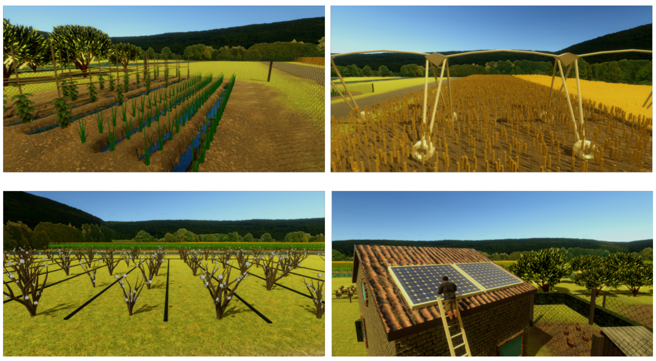
Aesthetics refer to how the game looks and sounds and has the most direct relationship to a player's experience [65]. In our game we selected aesthetics contemporary with the player. See for instance Figures 1 and 2, or Figure 3, where an example of a challenge that takes place in a city party is illustrated. In this last figure, the first image presents the city square where a power cut will interrupt the party and the user will have to solve an electrical problem to recover power, and the second image presents a concert scheduling panel. After being informed about scenarios, musical groups, and scheduling restrictions, the player will have to propose a concert scheduling. From this example it can be observed that, generally, the challenge has assigned a global 3D scenario (in this case, the city party) and the different enigmas related to the challenge take place in different parts of this main scenario (in this case, the concert scheduling is performed in the concert panel, but there are others enigmas that take place on the music stage or at the bar). Another example is presented in Figure 4.

To maintain coherence between challenges, a pre-defined set of interfaces with the same distribution of buttons and colors is given. Some of these interfaces can be seen in Figure 5(a), (b) and (c), where the interface used to present a global scenario with a brief description, the warning message that summarizes the enigma to be solved, and the help image provided by one of the characters are shown.

Figure 3: *Scenes of a city party challenge that will require different user actions to ensure that it can be celebrated. The first image presents one of the scenarios that will suffer a power cut, and the second one the concert scheduling.*



(a)



(b)

Figure 4: *(a) A challenge scenario and (b) scenarios of different enigmas related to the challenge.*

4.3 Mechanics

Mechanics are the procedures and rules of the game and describe its goal, how players can and cannot try to achieve it, and what happens when they try [65]. In our platform, STEM concepts introduced via challenges and enigmas are the key of the mechanics. We have classified enigmas according to the type of action that has to be entered to solve them. These actions can be done externally to the platform or using editors specifically designed to perform them. We denote these editors *Solution Spaces* (see Figure 5(d-f)).

The current version of the platform supports basic and advanced types of solutions. The basic ones are:

- Test, when the player has to select one answer from a set of possible solutions.
- Text, when the player has to enter a text.
- Value, when the player has to enter a number.
- Image, when the player has to take a photo using the device camera.

The advanced ones are:

- LED, when the player has to obtain the contribution of red, green, and blue components to obtain a determined colour. In this case, it is necessary to manipulate different led components to obtain the correct solution. The interface used to enter this solution type is shown in Figure 5(d).
- Construction, when the player has to construct something. For instance, in a challenge with a port scenario where part of a bridge is broken and it has to be reconstructed, the player has to create the more resistant structure. To design this solution, the platform provides a solution space where magnetic sticks and balls can be manipulated and work as a construction editor (see Figure 5(e)).
- Restriction, when the player has to propose a solution that has to satisfy a set of restrictions. For instance, in the concert scenario the musical groups scheduling has to be proposed taking into account scenario restrictions. To enter the solution, a pre-defined grid provided by a specific editor has to be filled.
- Containers-Measurements, when the player has to measure some properties of the contents of different recipients and select one of them as the solution of the enigma. For instance, oils with different properties are given to the player and the best one for cooking has to be selected. The related editor is shown in Figure 5(f).

Once content creators know the concepts to be transmitted, they create the challenge selecting a scenario, a description of the problem, and the different enigmas that will compose it. For each enigma, the required solution is defined according to the type of enigma. Note that, different to classical games, the interaction can be seen as a problem-solving strategy.

The classification of enigmas allows to define templates for its creation (content editors) and also for its automatic correction (see Section 5). Moreover, the modular design of the platform allows the integration of new types of enigmas, new editors to enter the solutions and also solution spaces for the player to prepare them.

4.4 Technology

The technology can be presented as the medium in which the aesthetics take place, the mechanics will occur, and through which the story will be told [65]. With the aim to reach as much public as possible, the platform has been designed with the only technological requirement of internet access. Its responsive web design ensures the web-page layout adaption to different devices such as cellulars, tablets or computers. More details about technology are given in Section 6.

5 Content Creation Editors

To prepare a STEM promotion session it is necessary to create challenges, enigmas, select characters, etc., and also to define the parameters of the session such as the number of challenges, the rewarding system, etc. To enter this information, the platform provides two different editors, one for challenges and enigmas, and another for sessions. Editors have been designed in a form mode where the user has to enter the information related to each one of the fields. The details of these editors are presented below.

5.1 Challenge and Enigmas Editor

For each challenge at least one enigma is required. For this reason, the editor has been divided into two parts: the first one to enter the challenge information, and the second one to enter the information about the enigma. The latter is used as many times as there are enigmas to be created. The part of the editor corresponding to challenge creation is presented in Figure 6. Following the order number, the fields that have to be filled to create a challenge are: (1) the challenge's name; (2) the scenario, which can be selected from a repository with different 3D scenarios (see first image of Figure 3 and Figure 4(a)); (3) the location of the loaded scenario where the challenge will take place (see second image of Figure 3 and Figure 4(b)); (4) a description of the challenge that will be stored in the system repository for other content creators to have more details about the challenge; (5) a warning message that summarizes the problem (see Figure 5(b)); (6) an introduction to the challenge for the content consumer (see Figure 5(a)); (7) the character that will show help messages to the player; (8) a selection option to set the order in which the enigmas related to the challenge have to be solved; (9) *public/non-public* option to determine if the created challenge can be used by other content creators or not; and (10) tags to classify the created challenge in the platform database. Once this information has been entered, the content creator accesses the part of this editor related to enigmas. To enter the information of an enigma, a form similar to the previous one is used. In this case the fields to be filled are: (1) the enigma's name; (2) the enigma's description; (3) the solution type and the parameters that indicate when the solution is correct (e.g. in a test solution, the correct option; in a value solution, the range of values considered correct; in a construction solution, a manual action will be required to grade the construction, etc.); (4) an optional *Select solution space* field that, when selected, causes the platform to provide users with an interface to enter the solution of the enigma (see Figure 5(d-f)); (5) the time to solve the enigma; (6) the number of attempts allowed; (7) instructions to follow; and (8) hints that will be presented in a help mode. Instructions and hints can have text, images or both (see Figure 5(c)).

5.2 Session Editor

The last editor has been designed to create sessions. This can be used when at least one challenge exists in the system database. In this case, the editor provides a form with the

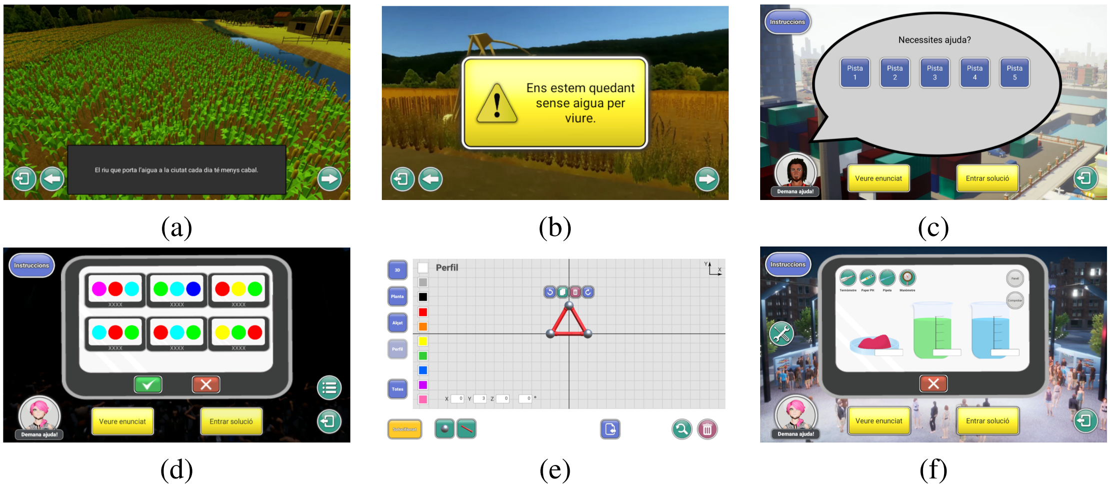


Figure 5: *(a) Challenge description; (b) Warning message; (c) Help dialog; and the editors created to prepare a solution for (d) a LED enigma, (e) a construction enigma and (f) a measurement enigma.*

following fields: (1) the contact information and the information of the school where the session will take place; (2) the session objective selected from a set of possible options; (3) the target users; (4) the person responsible for the session; and (5) the image that will be used to set the challenges, i.e. the one that will appear in the meeting room at the end of the game's introductory video (see Figure 2). Once this information is entered, a new interface with the list of challenges stored in the platform database appears and the session creator has to select the challenges and place them on the image. The process ends when all challenges are placed.

5.3 Correction Strategies

The correction strategies have been defined for each type of enigma. In some cases, the correction can be completely automatic, since it only requires comparing values or checking if a value is in a given range, while in other cases it is more complex. For instance, in the case of scheduling problems, a method to control if the proposed solution satisfies the set of imposed restrictions has been programmed. An example of this situation is the challenge presented in Figure 3. Not all the enigmas can be corrected automatically. In the case of construction enigmas, for example, the person responsible for the session has to check the proposed construction and then assign a grade. In these cases, a specific interface session is provided that is responsible for checking the solution and entering the grade.

The current version of the platform considers all the enigmas with the same weight in the final reward. However, the platform has been programmed to be adjusted according to the user needs.

6 The Platform Implementation

The platform follows a client-server architecture. Figure 7 shows a general view of this architecture, with its main elements and its communication strategies. It has an Apache web server, and a MySQL database management system to store the data. To implement the interfaces and the logic of the application, we used HTML5 and JavaScript, respectively. There is also a Unity client to manage Unity scenes and game mechanics.

In Figure 8 the main modules of the platform and its functionalities are presented. These

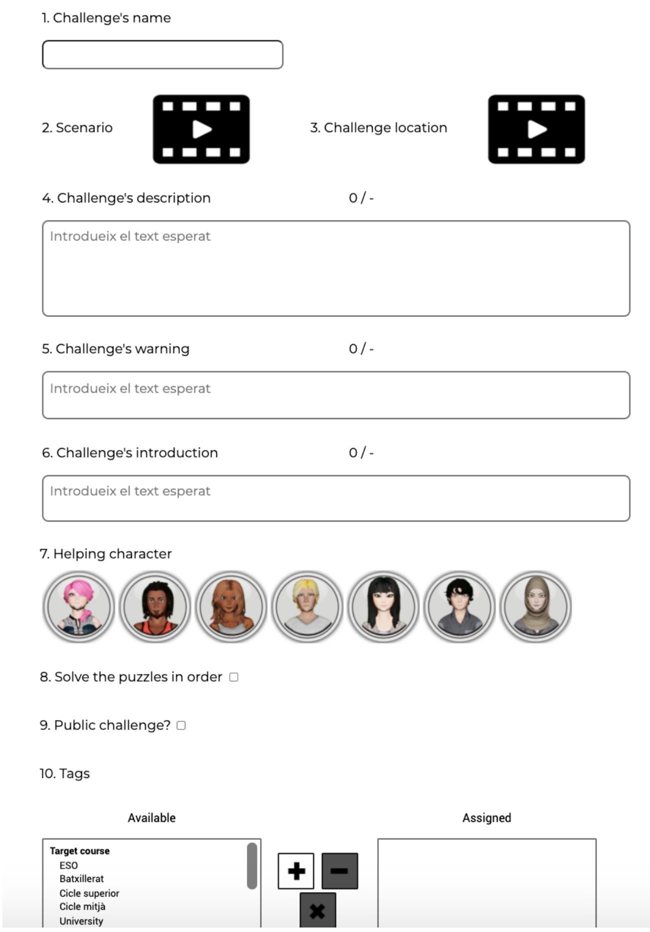


Figure 6: *Part of the form provided by the challenge-enigma editor that has to be filled to create a challenge.*

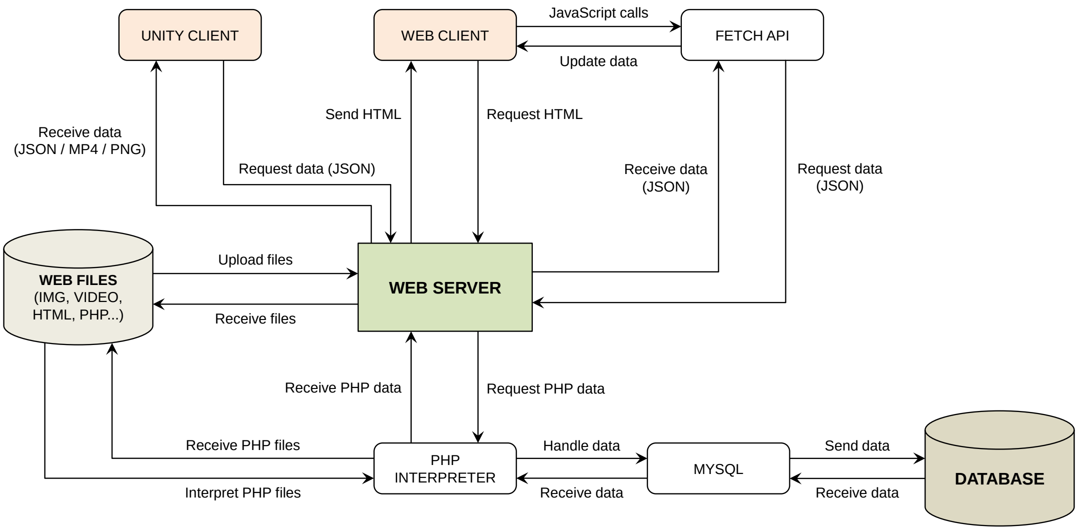


Figure 7: *Client-server architecture of the TAECon platform.*

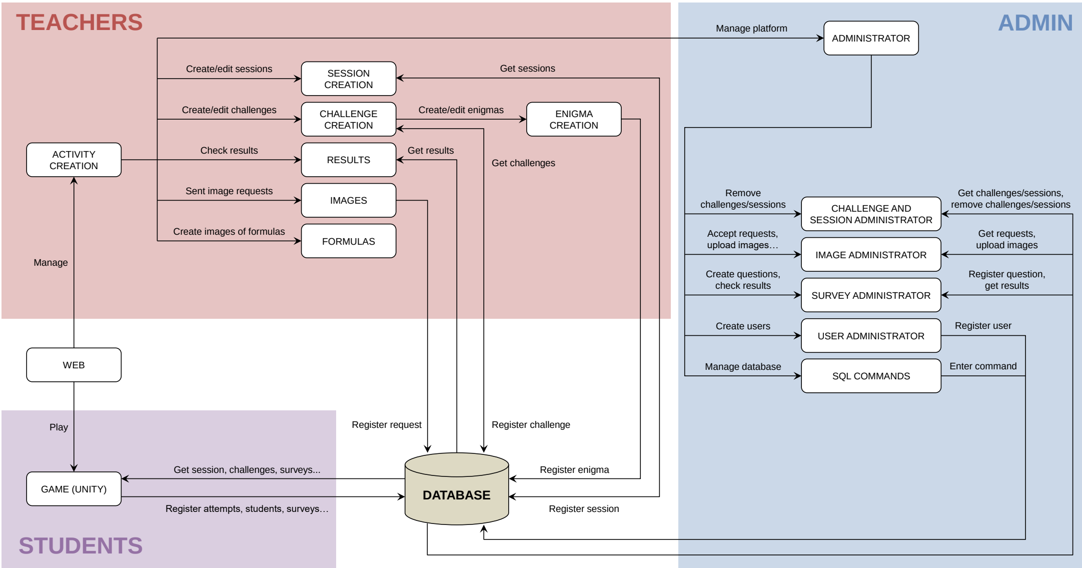


Figure 8: *The main modules and functionalities of the TAECon platform.*

are grouped considering the three user types: content consumers, content creators, and administrator. To enter into the system, a username and a password are required. The administrator controls sessions, challenges and enigmas, multimedia components, questionnaires, users, and all the SQL commands of the database. The content creators can create sessions, challenges and enigmas, check the solutions, and ask for multimedia elements. The content consumers play the game by solving enigmas of the challenges defined in the context of a session. There is a central database to maintain all the information.

7 Results and Discussion

Testing has been done in a three-phase process. The first phase, focused on challenge creation, started presenting the platform to coordinators of Polytechnic School degrees. After introducing the idea of the platform and the content creation editors, we asked them for challenge proposals. The STEM promoter, an engineer, was responsible for collecting the different proposals and adapting them to the platform. Such an adaption required the modelling of different scenarios, new characters, and, in some cases, the creation of space solution editors and new solution types. These processes were done by programmers of our laboratory. The phase ended with three main scenarios and different challenges and enigmas covering subjects from different fields.

The second phase started with the creation of sessions and their testing in a controlled scenario to check the correct performance of all the platform functionalities. This phase was carried out by the STEM promoter and personnel from our laboratory. After some adjustments on the platform, the third phase started with the testing in real scenarios. In this phase, the STEM promoter contacted secondary schools of our country offering the possibility of a STEM workshop using TAECon. Since this first contact, more than fifty sessions have been done involving more than $1,000$ students. Prior to the sessions, the promoter interviewed the contact at the secondary center to determine the challenges that best suited the students. Then, a face-to-face or a virtual session was carried out. Generally, sessions are of one hour and a half and are composed of six challenges with several enigmas. At the end of each enigma, the system provides a code to the students. These codes are entered as the solution of the last challenge. If all the codes obtained are correct, the identification cards are recovered and the

Figure 9: *Images of one of the promotion sessions with the promoter introducing the game and some students solving a challenge.*

server room can be opened. In Figure 9 images from one of this sessions are presented.

Although in first sessions it was not used, the platform provides functionalities to integrate questionnaires to analyze different aspects of the platform. This functionality has been used in the last 14 sessions which involved 272 students aged 14-15 years old. Our interest was centered on the platform acceptance with three questions: (1) Did you enjoy the TAECon activity? (Yes/No); (2) Grade the TAECon session (Likert scale ranging from 1 (don't like at all) to 5 (liked very much)); and (3) Give a comment about your impressions (open text). The answers for the first question were: 236 enjoyed the session, 13 did not enjoy, and 23 did not answer. Therefore, more than 86% of participants enjoyed the session carried out with the platform. The TAECon session was graded as follows (grade, number of students): (NA, 14), (1, 3), (2, 35), (3, 130), (4, 78), and (5, 12). From these results, it can be seen that students greatly valued the TAECon session. Regarding open questions, students generally appreciated the session and also identified the challenge they enjoyed the most. They also complained that some challenges required more time than the given one or that concepts to be applied were a little bit difficult. They also emphasized that they enjoyed working in groups and compete with other groups.

In addition, we interviewed the teachers to collect their first impressions. We asked them: (1) if they considered the session interesting (Likert scale ranging from 1 (don't like at all) to 5 (liked very much)); (2) if they consider that the platform will be a good strategy to increase the interest on STEM degrees (grade from 1 to 5). From 17 interviewed teachers, the answers presented as (grade, number of teachers) for question 1 were: (5, 7), (4, 8), and (3,2), and (5,3), (4, 11), and (3, 3) for question 2. As a general comment, they considered the platform a very good strategy to promote STEM, but they asked the challenges to be more related with the contents of the subjects they are teaching.

Although a further evaluation is necessary with more questions and more participants, from the initial data we consider that TAECon can be a suitable tool to promote STEM contents. It is well-accepted for both students and interviewed teachers and also for content creators. However, we consider that there are still different issues that need to be faced.

On the one hand, it is necessary to collect more challenges and group them in topics in order to evaluate if it is better to create sessions covering different areas or a single one. It is also necessary to identify the degree of complexity of the challenges and set the help according to it. The reward system also needs to be improved; now it only considers whether the challenge has been achieved or not, the number of attempts and the time to solve it. Other items to measure aspects of students' performance would be interesting. However, it is not clear how to assess them automatically.

On the other hand, it is necessary to involve secondary teachers in the content creation process. In addition, we consider that TAECon platform can be used not only for the promotion sessions, but also as a complement to the secondary school classes. The platform's ability to integrate new challenges could be used to prepare material that complements the teacher's explanations.

Finally, focusing on students, the study has been carried out with students in the 3rd and 4th grade of our Compulsory Secondary Education corresponding to 9th and 10th grades of the international educational system. At these grades, the curriculum is the same for all the students and it is in the 11th grade when they have to choose one of the following directions: Sciences, Technology, Humanities or Economics. Generally, this choice will determine the degree they will study. We selected 3rd and 4th grade students with the aim to clarify their future directions and motivate them to choose a STEM-related degree. However, we think that this work has to be done not only at this stage, but in lower ones. It has been seen that the younger students are exposed to STEM actions, the more likely it is for them to make a STEM career choice [66–68]. This requires the preparation of challenges suitable for different audiences with enigmas of different levels of difficulty.

8 Conclusions and Future Work

To promote students' interest in STEM and encourage them to pursue careers in the STEM fields, developed and developing countries are implementing STEM programs and policies. In this context, and with the aim to promote STEM at secondary schools of our country, we have created TAECon, a web-based platform that combines serious games, gamification, content editors, and automatic correction strategies in a single framework. TAECon supports two user profiles, content creators and content consumers, and provides functionalities to create, solve and assign rewards to challenges and enigmas that require STEM concepts to be solved. The platform has been used in game sessions at fifty secondary schools involving more than a thousand students. From these, more than 250 have answered a questionnaire from which it has been seen the well acceptance of the platform. Moreover, it has been seen that it can be used not only to promote STEM, but also as a complement to secondary school classes.

As a future work, we will focus on the creation of more challenges covering more types of enigmas which will require the implementation of new editors and new correction strategies as well as new solution spaces. In addition, we will carry out a retrospective study to evaluate the influence of TAECon sessions in the students' vision of STEM and their career selection.

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