LABESCAPE AND BREAKOUT. GAMIFICATION FOR PHOTONICS STUDENTS

Rosa Ana Pérez-Herrera, Santiago Tainta, Cesar Elosúa

Department of Electrical Electronic and Communication Engineering and Institute of Smart Cities (ISC), Public University of Navarra (SPAIN)

Abstract

Nowadays, the idea of using game mechanisms in non-gaming environments has become of great interest in different fields such as education or training. Not only for primary school but also in higher formal education, game-based learning appears to be an emerging trend in wide-ranging knowledge areas such as health, social policy, or engineering, among others. By employing this methodology, the process of learning becomes more motivating while reaching, in some cases, a competitive level.

Game-based learning has been widely adopted in many engineering learning areas, such as for example electronics thanks to the ready availability of low-cost electronic equipment. The authors' extensive teaching experience in subjects related to electronics and photonics has led us to consider its implementation in more ambitious teaching fields. For instance, and despite the broad acceptance, its use in the field of photonics is still very scarce. The high cost of required equipment has hindered the expansion of these strategies, taking its implementation longer than desired and being too expensive at times.

In the present work, the authors propose a planning and design scheme for a new gamification strategy based on an escape-room in which, all the tests to be passed will be related to the field of optics and photonics using low-cost equipment. The main field of application of this novel teaching strategy will be in the practical section of the subjects that is usually carried out in a laboratory and will be aimed at both undergraduate and master's degree students. The resolution of tests in different game sequences of the escape room is proposed, that is, linear, open, or multi-linear paths, adapting the degree of difficulty of the tests to the level of the group of students. Additionally, a co-evaluation method is suggested where the rest of the students will provide a valuable feedback to each one of their colleagues.

Keywords: gamification, game-based learning, technology enhanced learning, motivation, serious game.

1 INTRODUCTION

The use of game mechanisms in non-gaming environments has recently generated an increasing interest for its applicability in different areas, being of special relevance its application in the field of education [1]. The gamification of learning is an educational approach that motivates students to study by using game elements in learning environments [2]. This technique allows the educator to maximize enjoyment and engagement through capturing the interest of students and inspiring them to continue learning. Nevertheless, the planning of lecturing activities following game design principles is a challenge because currently there are no practical guidelines to accomplish it with coherence and efficiency [3].

Among the different available proposals for the integration of gamification in learning environments, serious games [4], [5] has gained an increasing attention in recent years: they are activities that possess all game elements but whose objective is to achieve something predetermined, that is, they are designed not just for fun but also for a specific purpose related to training. The serious games genre implies that the outcome of playing them is always advantageous for the player by facilitating learning experiences. Currently, an increasing number of serious games exist [6] but escape rooms (ERs) [7] have gained an increasing attention as an alternative to more traditional in-class activities [8]. ERs are games in which a group of players have to achieve a certain goal, typically escape from the site of the game, in a limited amount of time by finding clues and solving puzzles found on the premises. The immense popularity that ERs have gained in the entertainment industry has generated an increasing interest for their application in education [9], as they enable an active-learning environment that promotes the collaboration between the students.
Educational experiences based on the use of ERs can be found in both primary and secondary education, although most of the experiences published in scientific journals are developed in higher education [10] and cover a wide range of topics such as STEM [11] [12], foreign languages [13], engineering [14] [15] [16] [17] or medicine [18]. All these topics have in common that the implementation of an ER can be done using readily available equipment with low or moderate cost, which simplifies the design of the puzzles and reduces the time required for the implementation. However, the high cost of the required equipment has hindered the use of ERs in other experimental areas. One of such areas is photonics, where despite the progressive cost reduction of optoelectronic equipment, the budget of an ER with the commonly used laboratory equipment would be excessive. In this paper, we try to overcome this limitation by proposing the planning and design of an ER where all the puzzles to be solved are related to the field of optics and photonics but using readily available or low-cost equipment.

2 CONTEXTUALIZATION

The proposed gamification activity is aimed primarily towards undergraduate students of the Telecommunication Engineering degree at the Public University of Navarra. Nevertheless, the proposal could be easily adapted to other areas, such as physics, or even master’s degree students. The main objective of the activity is the substitution of the laboratory sessions done during the Optical Communications course. In these sessions, different stations are already prepared in the laboratory and the students have to perform different experiments in pairs, such as:

- Measure the intensity-power relationship on a LED and on a laser.
- Make fiber optic splices using professional equipment (see Figure 1).
- View the different modes propagating through an optical fiber (see Figure 2).
- Evaluate the losses introduced using different types of fiber optic cable.
- Visualize the optical spectra for different types of lasers.

Figure 1. Fiber optic fusion splicer.  
Figure 2. Four first LP modes.

The guidance of the students during these activities is based on a laboratory notebook provided by the teacher: it describes and explains the activities to be performed in the different workstations. Moreover, the evaluation of the activity is done using the results delivered by the students in the laboratory notebook, where they must explain and justify the outcome of each experiment. However, despite the close relationship existing between the theory covered in the classes and these experiments, a decline in the interest of the students has been recently observed. As a result of this, the students don’t prepare adequately these sessions, not even reading the laboratory notebook in advance, which makes impossible to fully carry out the proposed exercises and ends in unsatisfactory learning results.

To overcome the existing demotivation, we analyzed different alternatives for the laboratory sessions which ranged from typical solutions (rearrangement of the laboratory activities, substitution of some of the stations, conducting a review test before the laboratory session) to a complete modification of the sessions, replacing them by something different. The conclusion was that a complete rearrangement...
was preferable in order to obtain the desired goals, proposing two interesting strategies: the introduction of Project Based Learning (PBL) in the course by doing a photonics project or the introduction of Gamification by implementing an ER. This decision was reached by doing a comparison between both methodologies (Table 1), concluding that Gamification through an ER would induce a higher motivation in the students, especially due to the competitiveness induced between the different teams.

### Table 1. Comparison of PBL with Gamification

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<thead>
<tr>
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<th>PBL</th>
<th>Gamification</th>
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<tbody>
<tr>
<td>Topics covered</td>
<td>In-deep but focused on the topic of the project</td>
<td>Broad but shallower</td>
</tr>
<tr>
<td>Student interest</td>
<td>Depends on the topic</td>
<td>Depends on the course</td>
</tr>
<tr>
<td>Cost</td>
<td>High cost depending on the project</td>
<td>Depends on the puzzles designed</td>
</tr>
<tr>
<td>Possibility of copying</td>
<td>High, as they can replicate previous projects</td>
<td>Medium, as the puzzles might be similar but the solutions different</td>
</tr>
<tr>
<td>Competition</td>
<td>Not competitive</td>
<td>Highly competitive</td>
</tr>
<tr>
<td>Teambuilding</td>
<td>Potential unbalanced workload</td>
<td>Required to accomplish the challenge</td>
</tr>
<tr>
<td>Decision making</td>
<td>Harder to evaluate</td>
<td>Quick and on real time</td>
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3 DESIGN

The goal of the proposed ER is to provide a teaching environment that motivates and engages students in optics and photonics, also enhancing their communication and teambuilding skills. In order to fulfil these goals, the team size was decided to be four students because it provides an environment where each member can be proactive and involved in the group process [19]. Also, the total time for the resolution of the activity has been established in 60 minutes, introducing a pressure element that forces the students to take quick decisions. However, in order not to frustrate the students, the puzzles are designed so that most of the groups can solve the game in 45 minutes, giving the participants a feeling of accomplishment in order to increase their motivation.

The activity will take place in a separate room in one of the university laboratories and, to guide the students, a computer will act as narrator, providing a backstory and registering the progress of each group. A teacher will also be present and her or his role will be limited to monitoring the progress, verifying for example that no cheating is involved, and providing a debriefing at the end of the session. During the debriefing, two crucial aspects will be discussed: the resolution of the puzzles and the student’s performance. The first aspect will give feedback to the students on how the concepts studied in theory had to be applied, allowing a connection between the knowledge and skills developed in both areas; on the other hand, the teacher will have a valuable feedback of the opinion of the students about the activity. The second aspect allows the students to know if they have reached the required learning goals and, from the teacher point of view, which topics would require a review in the theory classes or a reinforcement in the following years.

To design the puzzles, a sequential puzzle path was chosen as it is easier for the students to understand and it simplifies the monitoring of a group’s progress. In addition, using a linear path allows the individual study of different topics in each of the puzzles and helps to control the difficulty associated to the resolution of each one. The main drawback of a sequential path is the impossibility of finishing the activity if a group gets stuck in one of the puzzles. To overcome this limitation, a hints system is proposed where the students can get information from the narrator but introducing a time penalization. In the proposed design, two hints will be available for each puzzle, being the first one just a lead to the solution and the second the complete solution of the puzzle.

As it has been previously mentioned, the most limiting factor in the application of gamification in the optics and photonics area is the high cost of the equipment involved. To overcome this limitation, we propose to design puzzles based on three fundamental ideas:

1. Reutilization of the material which was being already used in the different stations designed for the laboratory sessions. Additionally, the experiments performed in these sessions will be used for the design of some of the puzzles.
2 Use of some readily available low-cost optoelectronic components such as RGB LED strips, CD’s, TFT screens, polarizers, laser pointers, optical power meters, among others.

3 Use of readily available experimental kits, such as Photonics Explorer [20], that provide all the required materials for the realization of simple experiments. The proposed experiments of the kit will also be used as base for the design of some of the puzzles.

Based on these three principles, a sequence of eight puzzles has been planned for the ER, which covers the following four topics: fundamentals of light, operation of an optical transmitter, optical fiber as transmission medium and operation of an optical receiver. As it can be observed in Figure 3, the four topics cover progressively the different elements of an optical communications system. In the initial design, two puzzles have been prepared for each of the topics, but their number might change depending on the feedback received from the students.

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In the first part of the escape room, some fundamental concepts associated with light will be used for the puzzle design, most specifically, the multiplexing of different wavelengths and the polarization of light. Although the students have already studied the fundamentals of electromagnetic waves in the radiofrequency domain and are familiar with these ideas, we consider that a more visual approach can help them interiorize them. In the first puzzle, the students will have to use a CD as diffraction grating and demultiplex the different spectral components of a multicolored LEDs strip. The strip will be turned on producing an apparently white light but composed of different spectral components in the visible range, which they should compare with an electromagnetic chart to solve the puzzle. Moreover, for the second puzzle the objective is that the students understand the decomposition of light in two polarization components. For this purpose, a code will be presented on an LCD screen whose polarizer has been removed, making thus impossible to read it. To recover the code, the students must use some type of polarizer, which will be available in the room, such as a photographic filter or polarized sunglasses.

In the second stage of the escape room, and after completing the previous puzzles, students will use their knowledge about optical transmitters to move forward. In this case, the participants will have to distinguish between different optical spectra (SLED, Fabry-Perot, or DFB laser) to pass the first of the puzzles, requiring the use of an Optical Spectrum Analyzer which is being already used in the laboratory sessions. Once this part is completed, for the second puzzle they will have to find out the required intensity value that has to be injected into a laser to obtain a previously given optical output power level. The equipment required for this task (laser, optical power meter and power source) is already available, as one of the laboratory stations was to characterize de P-I curve of a laser.

Following, students must then use their knowledge of fiber optics to pass the next phase. At this point, they will have to be able to discern between the electromagnetic field distributions that can be obtained in a transmission medium, in our case an optical fiber, when projected onto a screen (field pattern). These field distributions are called longitudinal modes or linearly polarized (LP) modes, and figure 2 shows an example of the four first LP modes. To obtain the codeword, different cards with field patterns will be available as a catalogue and the students will have to choose the right ones, which are the ones visible in the screen when adequately manipulating the fiber. Additionally, the fiber
used for the projection on the screen will initially be broken, so that the students must splice it before being able to solve the puzzle.

Finally, and in order cover all the elements that make up an optical communications system, two puzzles related to the operation of optical receivers will be presented. In this last section, a curvature sensor based on the use of an optical Fiber Bragg Grating (FBG) will provide the information needed to move on to the next puzzle. In this last step, an optical bidirectional link will be used, and the students will have to decipher a secret message being transmitted through the link that includes the final clue to finish the puzzle. Both puzzles require some specialized hardware that will be reused from previous laboratory activities.

4 EVALUATION

Although the main goals of the proposed activity are to increase students’ motivation and develop teamwork and communication skills, a formal evaluation method is required to individually grade the fulfillment of the formative goals. Evaluation of the students’ performance is an integral part of the activity and substitutes the grading received with the laboratory sessions and which was based on the delivery of laboratory notebooks. Furthermore, it will provide feedback to the teachers, allowing the progressive adaptation of the activity by progressively refining the design and progressively adjusting the difficulty of the puzzles.

The evaluation method will take into consideration three different items, as it can be seen in Table 2. The first evaluation item will assess the performance of each group and it is based either on the number of puzzles solved and the total time taken for the complete resolution of the escape room. These two parameters will score a grading system, taking into account the penalties associated with the use of the hints, so that better grades are associated with a better performance of the group. The objective of this item is to provide information about the group performance, allowing the assessment of the group as a whole and evaluating their competence in problem solving and teamwork. Logically, this part of the grade will be similar for all the students of the same group.

The second evaluation item is based on the debriefing session at the end of the activity with the teacher. During this activity, the teacher can interact with the students, verifying that the teaching goals have been achieved and they have acquired the required competences. Moreover, although the interaction is with the whole group, individual questions addressed to each group member will allow the teacher to differentiate the performance of the different students, allowing the individual grading of each group member. This is a key point to verify that the workload has been balanced as well as to check out the teambuilding success. In the case a member of the group doesn’t justify a decision made by him or her, a person from other group will have the chance to steal points from the previous item if he or she answers the question in detail. The idea of this strategy is, on one hand, to increase the competitiveness between groups and, on the other hand, to improve the teambuilding and confidence between colleagues. An evaluation rubric will be used by the teacher for this second item: it will clearly identify the minimum level of knowledge to pass the whole activity. This rubric will not be available to the students, so that the game is extended to this session and encourage them to be as prepared as possible.

Finally, the third evaluation item is based on a survey done individually after the previous item where the students must weigh the performance of their group partners during the whole activity using an assessment rubric provided by the teacher. The deviation of the score for each member will be considered to evaluate the cohesion of the group, so the whole team will be penalized if this parameter is beyond a certain value. This item can provide a very significant feedback regarding the opinion of the students on their colleagues, allowing the individual assessment of their teamwork, group cohesion and oral skills performance during the activity.

<table>
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<th>Table 2. Evaluation items for the ER.</th>
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<tr>
<td><strong>Activity</strong></td>
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<tr>
<td><strong>Type</strong></td>
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<tr>
<td><strong>Objective</strong></td>
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<tr>
<td><strong>Based on</strong></td>
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<td><strong>Evaluates</strong></td>
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5 CONCLUSIONS

In this paper, the use of gamification for the teaching of photonics in higher education courses has been presented. The proposed strategy is based on the use of an escape room that substitutes the laboratory sessions of an Optical communications course, being the principal objective to overcome the boredom associated to such sessions and to motivate the students towards the study of optics and photonics. Furthermore, this gamification activity is designed to help the students practice valuable skills that are demanded in job market such as teamwork and quick decision making. High costs associated to optoelectronic components are avoided by three different strategies for the design of the puzzles based on the use of low-cost equipment, the reuse of already existing material and the use of readily available experimentation kits. The difficulty level of the game can be adjusted by distinct path activities, considering the sequential approach an optimal starting point. Teamwork and competitiveness are key points of this gamification proposal, so that they are endorsed along all the activity (even when the game is over), offering an added value when compared to other learning proposals. Additionally, an evaluation method which encompasses all the aspects of the activity has been propositioned, incorporating the co-evaluation among the group members as a methodology to evaluate their teamwork as well as a relevant feedback to the teacher in order to improve the performance of the game every academic year.

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REFERENCES


