https://doi.org/10.36315/2025v2end111
Education and New Developments 2025

GAMIFICATION AS A STRATEGY FOR TEACHING MATERIALS IN ENGINEERING

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Abstract

Gamification is presented as an effective pedagogical strategy to increase student participation and improve learning in the higher education context. This paper describes a gamified activity implemented in the subject "Taller de Diseño III", belonging to the Bachelor's Degree in Industrial Design and Product Development Engineering at the Universitat Politècnica de València. The experience took place during the didactic unit dedicated to polymeric materials, combining theoretical contents with a practical dynamic based on the identification of polymers from physical samples of different materials. The activity was structured in multiple phases, allowing students to apply the theoretical knowledge acquired with feedback at each stage. The results obtained show an increase in class attendance, a greater student involvement during the classes and an improvement in the understanding of the theoretical contents with respect to previous courses. This experience is proposed as a replicable model in other didactic units of the subject itself, as well as in other similar technical subjects, reinforcing the value of gamification as an educational tool in the field of engineering.

Keywords: *Gamification, polymers, materials, active learning, engineering.*

1. Introduction

The search for more effective methodologies to improve the teaching-learning process in higher education has led in recent years to an increasing incorporation of active and innovative approaches, especially in technical degrees such as engineering (Crisol-Moya, Romero-López, & Caurcel-Cara, 2020). In this context, gamification has been consolidated as an effective educational strategy that allows transforming the traditional classroom dynamics, increasing student motivation, encouraging their participation and favoring a deeper and long-lasting learning process (Aguiar-Castillo, Clavijo-Rodriguez, Hernández-López, De Saa-Pérez, & Pérez-Jiménez, 2021; Subhash & Cudney, 2018).

Gamification consists of the application of game elements (challenges, rewards, level dynamics, immediate feedback, among others) in non-game contexts, with the aim of generating more attractive and effective educational experiences (Carrascosa, Ylardia, Paredes-Velasco, & García-Suelto, 2024). Its implementation at the higher education level has shown benefits both in terms of student commitment and motivation and in the development of key skills, such as critical thinking, teamwork and decision making (Langendahl, Cook, & Mark-Herbert, 2016; Nyahuye & Steyn, 2022).

In the field of engineering, where content tends to be very technical and abstract, these methodologies are especially valuable. They allow complex concepts to be approached in a simpler way, favoring practical learning and the connection between theory and real application. In addition, they promote a student-centered approach, where the student takes an active role in the learning process (Gamarra, Dominguez, Velazquez, & Páez, 2022).

The present experience is developed in the subject "Taller de Diseño III", belonging to the fourth year of the Bachelor's Degree in Industrial Design Engineering and Product Development of the Universitat Politècnica de València. In it, a gamified dynamic has been implemented within the didactic unit dedicated to polymeric materials, with the aim of reinforcing the theoretical contents through a practical activity focused on the identification of materials from physical samples. Through a phased game, students work in teams, apply their prior knowledge, use digital tools and receive progressive feedback that allows them to improve their understanding.

The purpose of this paper is to present the design, development and impact of this activity, assessing its effect on student participation, motivation and performance, as well as its potential for replicability in other technical subjects.

2. Objectives

The main objective of the proposed methodology is to improve students' learning about the most commonly used industrial polymers through a gamification strategy. This strategy seeks to transform a traditional theoretical session into an active and participative experience that combines theoretical contents with a practical application based on the identification of materials. More specifically, the proposal pursues the following objectives:

- Encourage active student participation.
- Develop practical skills, such as tactile and visual identification of materials.
- Promote teamwork and collaboration.
- Promote critical thinking and informed decision making.
- Increase motivation and interest in technical content.
- Promote the use of digital resources and artificial intelligence tools to support autonomous learning.

In summary, the aim of this methodology is not only for students to memorize the properties of the most industrially used polymers, but also to understand, relate, apply and retain this knowledge in a deeper and more lasting way through an active, collaborative and fun learning experience.

3. Methods

3.1. Subject context

In this case, the activity has been implemented in the subject “Taller de Diseño III” a compulsory subject of the Bachelor's Degree in Industrial Design Engineering and Product Development taught at the Escuela Politécnica Superior de Alcoy of the Universitat Politècnica de València. This course is taken in the first semester of the fourth year of the degree and has a total of 6 ECTS credits divided into 3 credits of Classroom Theory and 3 credits of Laboratory Practices.

The teaching structure of the course is divided into three blocks, each of them taught by a different area of knowledge within the Department of Mechanical and Materials Engineering, corresponding to each area 1 ECTS credit of Classroom Theory and 1 ECTS credit of Laboratory Practices. In this case, the experience described has been developed within the block taught by the area of knowledge of Materials and Metallurgical Engineering, specifically in one of the Classroom Theory sessions.

With regard to the number of students enrolled in the course, it should be noted that during the 2024/2025 academic year, the year of implementation of the methodology described, the course had a total of 64 students.

3.2. Implementation of the activity

Within the block taught by the Area of Materials and Metallurgical Engineering, it has been proposed to introduce a gamified dynamic in one of the didactic units taught in Classroom Theory. In this case, the Classroom Theory of the materials block of the subject is divided into four didactic units, which are the following:

- Didactic unit 1: Selection of materials.
- Didactic unit 2: Polymeric materials.
- Didactic unit 3: Metallic materials.
- Didactic unit 4: Wood.

The proposed activity has been implemented in Didactic Unit 2, focused on Polymeric Materials, which is taught in a 2-hour session. Specifically, during this session, a time was initially dedicated where the teacher gave an explanation of what polymers are and how they are classified, according to their structure, into thermoplastic, thermosetting and elastomeric polymers. In the slides used for the explanation of the Didactic Unit, within each family of polymers, those most commonly used at industrial level are shown, including their properties, their main characteristics and their most common applications (Figure 1).

Figure 1. Slides showing the description of one of the polymers seen in the Classroom Theory session of the Didactic Unit of polymeric materials.

After the theoretical explanation, which takes approximately one hour, the game is played. First, students are organized in groups of four people and have 20 minutes to review the slides of the unit, as well as to consult external resources such as the internet or artificial intelligence tools that allow them to go deeper into the characteristics of polymers. During this time, they also have a help sheet to take notes to facilitate the subsequent identification of materials. After this time, the game is explained to the students, which consists of identifying different types of polymers from physical samples of each one of them. Specifically, the game is divided into 3 parts:

Phase 1 - Initial identification:

Each group is given seven samples of different polymers, numbered 1 to 7, along with a sheet listing the names of the available polymers. Students must match each number to the corresponding polymer by observation and touch alone. They have 15 minutes to complete this part. If they get all the materials correct, they receive 3 points on the final exam for the block and are exempt from answering the questions of the polymer unit.

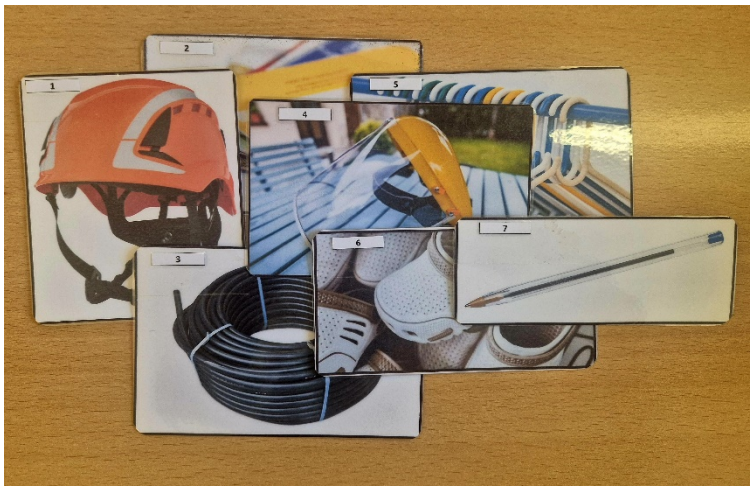
Figure 2. Different polymeric materials samples given to the students.

Phase 2 - Visual clues:

If the group fails to correctly identify all the polymers in the first phase, they are provided with a series of images showing industrial applications of each of the samples. This additional information is intended to facilitate identification. In this phase they have 10 minutes to review the images and correct their sheet. If they achieve complete identification, they receive 2 points on the final exam and can decide whether or not to answer the polymer block questions.

p-ISSN: 2184-044X e-ISSN: 2184-1489 ISBN: 978-989-35728-8-7 © 2025

Figure 3. Visual clues handed out to students in Phase 2 of the game.



Phase 3 - Last chance with feedback:

In case of failing again, the teacher points out on the sheet which answers were correct and wrong. Students have a final 5 minutes to make the necessary adjustments. If in this last opportunity they get all the answers right, they are awarded 1 point on the final exam, having the option of keeping it or answering the block questions on the exam. If there are still errors, no additional points are awarded.

Figure 4. Students during the game proposed in the subject.

4. Discussion

The implementation of a gamified methodology in the Didactic Unit of polymeric materials of the subject has shown significant improvements in different aspects of the teaching-learning process. First of all, a significant increase in attendance was observed in the theoretical session where the game was implemented compared to the rest of the theoretical sessions in which the other didactic units of the block were taught, which are taught using a traditional methodology. This difference is also significant when compared to previous courses, in which participation in the theoretical session of the didactic unit on polymeric materials was notably lower.

In addition to the improvement in attendance, a higher degree of involvement and motivation was detected on the part of the students. The dynamics of the game, together with the possibility of obtaining a bonus in the final exam grade, generated a participatory and collaborative environment. Students were more active in the classroom, working in teams, making use of digital resources and applying their knowledge in a practical way.

Regarding the results of the game, all the groups were able to correctly identify the polymers in some of the phases of the game, which resulted in a better performance in the exam part corresponding to this unit. Even those students who chose to answer the theoretical questions of the unit in the final exam showed, in general, a higher level of understanding than in previous years.

Overall, the results reinforce the value of gamification as an effective pedagogical strategy in the teaching of technical content, not only for its effect on learning, but also for its ability to improve attendance, student engagement and overall classroom dynamics.

5. Conclusions

The introduction of a gamified methodology in the teaching of materials has proven to be an effective tool to promote active learning and improve student engagement in the higher education context. The activity has allowed transforming a traditional theoretical session into a dynamic experience, in which students have been able to practically apply the knowledge acquired, using both tactile and visual analysis of materials and the support of digital tools.

Among the most outstanding benefits are an increase in class attendance, greater student motivation and involvement, and an improvement in the understanding of polymer-related content. The strategy has also favored the development of transversal competencies such as teamwork, effective communication and decision making.

Given the good reception by the students and the results observed, it is proposed to extend this methodology to other didactic units of the subject in future courses. This experience highlights the potential of gamification as a replicable pedagogical strategy in other educational contexts, especially in technical disciplines, where it can contribute significantly to improving both the quality of learning and the students' learning experience.

Acknowledgments

This work has been supported by “Universitat Politècnica de València. Convocatoria A+D. Proyectos de Innovación y Mejora Educativa” through project with reference PIME/24-25/409. The authors would like to thank the Universitat Politècnica de València (UPV) and the Instituto de Ciencias de la Educación (ICE) of the UPV for their help in the formation of the Equipo de Innovación y Calidad Educativa (EICE) called "Grupo de Innovación de Prácticas Académicas (GIPA)".

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