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ANALYSIS OF LONG-TERM LEARNING THROUGH GAMIFICATION IN ENGINEERING COURSES

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Abstract

Gamification is an educational strategy to improve the teaching and learning process, based mainly on increasing student motivation. This study describes a teaching innovation project carried out during the academic years 2022/23 and 2023/24 with engineering students from the University of Jaén (Spain). During the first year, a series of gamified activities (quizzes and presentations) were conducted on a selection of topics from different subjects. This allowed analyzing an improvement in students' motivation and self-perception regarding the use of games in class. Subsequently, during the second year, monitoring of the assimilation of units worked on in a gamified way in the previous year was investigated among different groups of students. Specifically, the analysis of results accomplished in the Materials Science and Materials Technology subjects is described, which show a small trend of improvement compared to the control groups that worked on the same units with a classic methodology. However, the extraction of definitive conclusions is conditioned by numerous factors such as the small size of the statistical sample or the different teachers participating in the activity.

Keywords: *Gamification, engineering, students, materials, learning.*

1. Introduction

Gamification has received much attention as a powerful tool for promoting student active learning. The idea of fun is described in a general way as a trigger for increasing motivation and the natural competitiveness among students Thus, the educational community increasingly uses this strategy to train students to learn by playing. It is a tool capable of arousing the student's interest, transforming a routine activity into a dynamic and stimulating one (Kapp, 2014). Specifically, among the benefits described, it stands out that the study is more proactive and that the effectiveness of learning is optimized, mainly in the field of Educational Sciences, Human and Social Sciences, Information Technologies or with the learning of a second language. However, gamification works described in the field of engineering not directly related to information technologies are in the minority (Parra-Santos et al., 2018).

In the case of engineering studies, the use of gamification has also been described as a source of benefits, although there are aspects to be known in more depth such as the influence of the teacher's own role or the evaluation of the improvement in long-term retention of concepts (Leung & Pluskwik, 2018; Júnior et al., 2019).

Concerning this last aspect, the influence of gamification on long-term learning is a complex and nuanced issue. Some studies have found that gamification can lead to improved practical assignment scores and overall performance (Domínguez et al., 2013). Gamification has a positive impact on long-term learning, particularly in terms of motivation, engagement, and learning outcomes (Zainuddin et al., 2020; Nurtanto et al., 2021; Montenegro-Rueda et al., 2023). It can lead to improved student behavior and performance, and can be particularly effective in higher education (Barata et al., 2017). On the contrary, other studies have reported a decrease in motivation, satisfaction, and academic performance over time (Hanus & Fox, 2015). Despite the potential for gamification to engage and motivate students, there is insufficient evidence to support its long-term benefits in educational contexts (Dicheva et al., 2015).

Therefore, while gamification may have short-term benefits, its long-term impact on learning is still uncertain. In fact, the effectiveness of gamification can vary among different student groups, with some students benefiting more than others (Barata et al., 2017) so it is important to consider individual differences in its implementation to enhance long-term learning. Ongoing research continues to explore how gamification can be optimized to maximize its benefits for long-term learning.

2. Objectives

This study describes the first observations and analysis made about long-term learning within the framework of a teaching innovation Project on the Introduction of Gamification in engineering courses at the University of Jaén (Andalusia, Spain). The main objective of this research has been the determination of differences between the long-term retention of content related to the study of metallic alloys by Mechanical Engineering students. Part of these students received instruction with gamification activities while the rest followed traditional learning.

3. Methodology

3.1. Participants

Specifically, the study involves students in Materials Science and Materials Technology courses taught during the academic years 2022/23 and 2023/24, respectively, in the 2nd and 3rd year of the Bachelor Degree in Mechanical Engineering. A sample of 50 students have participated in the proposed activities during the first academic year. However, only 25 of these students have continued to participate in the proposed activity in the second year for the evaluation of long-term learning. The participants were approximately 80% male and 20% female, with an average age between 21 and 22 years.

3.2. Activities

Among all activities proposed in the teaching innovation Project, a game-based pedagogical activity was provided via mobile phones to the 2nd-year students in the academic year 2022/23 to analyze their knowledge in the subject *Strengthening mechanisms of metallic alloys*. In essence, the students must solve a problem posed by solving multiple-choice questions related to the subject, becoming the student protagonist of the narrative. When the student fails a question, there is a time penalty before the trial. All students must respond correctly to all questions to unlock a code and solve the original problem posed. The first three students completing the game were rewarded with a bonus in their marks (final grades) to create a competitive environment and affect their motivation. This game was designed using the Genially platform and consisted of ten questions and closed-response options (Table 1).

Table 1. Questions included in the game related to the study of metallic alloys strengthening.

	Question
Q1	*How does the dislocations movement affect the mechanical strength of an alloy?*
Q2	*How does the grain size of an alloy influence its mechanical strength?*
Q3	*How does the size of the added alloy atom and its concentration affect the degree of hardening in a metalic alloy?*
Q4	*How are the properties of an alloy generally compared to those of the pure, unalloyed metal?*
Q5	*What alloys can be subjected to precipitation hardening?*
Q6	*What is achieved with a maturation time after quenching?*
Q7	*How does the yield strength of a plastically deformed alloy evolve?*
Q8	*Why does the strength increase when plastically deforming a metal?*
Q9	*What processes allow the mechanical properties of a plastically deformed metal to be restored?*
Q10	*What does the critical strain indicate for plastically deformed metals?*

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Before taking the game, the students independently prepared a series of educational videos on this topic in groups of 5-6 members, supervised by the teacher. A control group of students learned the topic in a conventional, non-gamified way.

Students who moved on to the 3rd academic year (2023/24) were re-evaluated on the gamified topics by using the same game / questionnaire. The comparison of the results obtained with those of the group of students with conventional education allows conclusions to be drawn about the capacity for content retention and long-term learning developed by an educational strategy based on gamification.

4. Results and discussion

There is general agreement that gamification increases student motivation and, therefore, can constitute an educational strategy with potential for promoting long-term learning outcomes by increasing engagement. In particular, this study proposed monitoring different groups of Mechanical Engineering students with the objective of evaluating the retention of contents related to the study of metallic alloys in two different academic courses. In the first year, gamified learning environments promoted the active participation and interaction of 50 students. Through repeated practice, feedback loops, and reinforcement mechanisms, it is hypothesized that these learners solidified their understanding of concepts and retained information for longer periods. The evaluation scheduled during the second year showed, however, that only 25 students participated voluntarily in monitoring the activity. This suggests that in the long run motivation can decline. Furthermore, the influence of a novelty effect and extrinsic rewards on motivation is identified, which can lead to greater motivation in the short term, followed by a decrease with further exposure to gamification. Therefore, long-term exposure to gamification as well as the novelty effect should be better explored (Ratinho & Martins, 2023).

Taking into account the small sample of participating students, Table 2 shows the results obtained in the proposed contest. 8 of the participants belong to the group that played the same game the previous year, after making the presentations on the topic. On the contrary, the group with the remaining 17 participants received conventional teaching on the topic. A preliminary observation of the results allows us to detect more difficult questions such as, for example, questions Q5, Q7 and Q8, highlighting the influence of the design of game elements, their alignment with learning objectives and their integration into the curriculum or training program.

The mean scores and standard deviation in each group were: 7.4 ± 1.8 and 6.6 ± 1.8 for students with gamified and conventional learning, respectively. From these results, it could be concluded that the gamification strategy led to a small improvement in the retention of the content taught. However, given the small size of the sample of students evaluated, it is difficult to draw conclusions or significant differences between both groups. In fact, according to Smiderle et al., 2020, gamification affectes users in distinct ways based on their personality traits and specific characteristics.

Besides, there is still very limited literature in the field of effect of gamification on long-term learning. Results seem to be predominantly positive in terms of motivation and engagement but only a few studies confirm clear interconnections with learning outcomes. They can suggest a lack of solid correlations between gamification, motivation and cognitive processes (Azzouz & Gutierrez-Colón Plana, 2020). In this sense, according to the experiment by Dominguez et al., 2013, students who completed the gamified experience got better scores in practical assignments and in overall score, but their findings also suggest that these students performed poorly on written assignments and participated less on class activities, although their initial motivation was higher.

Hanus & Fox, 2015, have described a more negative conclusion. Their results found that students in a gamified course showed less motivation, satisfaction and empowerment over time than those in a non-gamified class. The effect of course type on students' final exam scores was mediated by students' levels of intrinsic motivation, with students in the gamified course showing less motivation and lower final exam scores than the non-gamified class.

In view of these results and previous experiences in the specialized bibliography, future studies should focus on the influence of students' individual traits (e.g., gaming experience, openness to competition and cooperation) on gamification strategies.

Table 2. Quiz answer summary. Right and wrong answers in green and yellow colour, respectively.

STUDENTS WITH GAMIFIED LEARNING ACTIVITIES										
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	GRADE
										8
										9
										5
										8
										10
										5
										7
										7
									Mean	7,4

STUDENTS IN CONTROL GROUP WITH CONVENTIONAL LEARNING										
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	GRADE
										8
										8
										8
										7
										7
										4
										4
										9
										7
										6
										8
										6
										5
										9
										8
										4
										4
									Mean	6,6

5. Conclusions

In conclusion, the study sheds light on the complex dynamics surrounding the implementation of gamification in educational contexts, particularly within the realm of Mechanical Engineering education. While initial findings suggest a potential for gamification to enhance student engagement and retention of content, nuanced challenges emerge upon further investigation. The observed decline in voluntary participation over time and the variable impact on motivation underscore the need for a deeper understanding of the long-term effects of gamification. Despite some indications of improved retention with gamified approaches, the small sample size limits the conclusiveness of our findings. Moreover, contrasting studies highlight the diverse effects of gamification on different facets of student performance and motivation. Moving forward, future research endeavors should prioritize exploring individual student

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traits and preferences to tailor gamification strategies effectively. By addressing these complexities, educators can harness the full potential of gamification to create engaging and effective learning environments in Mechanical Engineering and beyond.

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References

Azzouz, N., & Gutierrez-Colón Plana, M. (2020). Effect of Gamification on students' motivation and learning achievement in Second Language Acquisition within higher education: a literature review 2011-2019. *The EUROCALL Review, 28*(1), 57-69. https://files.eric.ed.gov/fulltext/EJ1257523.pdf

Barata, G., Gama, S., Jorge, J., & Gonçalves, D. (2017). Studying student differentiation in gamified education: A long-term study. *Computers in Human Behavior, 71*, 550-585. https://doi.org/10.1016/j.chb.2016.08.049

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. *Journal of Educational Technology & Society, 18*(3), 75-88. http://www.jstor.org/stable/jeductechsoci.18.3.75

Domínguez, A., Saenz-De-Navarrete, J., De-Marcos, L., Fernández-Sanz, L., Pagés, C., &
Martínez-Herráiz, J. J. (2013). Gamifying learning experiences: Practical implications and outcomes. *Computers & Education, 63*, 380-392. https://doi.org/10.1016/j.compedu.2012.12.020

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80*, 152-161. https://doi.org/10.1016/j.compedu.2014.08.019

Júnior, E. S., Reis, A. C. B., Mariano, A. M., Barros, L. B., De Almeida Moysés, D., & Da Silva, C. M. A. (2019, June). Systematic literature review of Gamification and Game-based Learning in the context of Problem and Project Based Learning approaches. *11th International Symposium on Project Approaches in Engineering Education (PAEE), 16th Active Learning in Engineering Education Workshop (ALE)*, 169-177.

Kapp, K. (2014). Gamification: Separating Fact from Fiction. *Chief Learning Officer, 13*(3), 45-52.

Leung, E., & Pluskwik, E. (2018, June). Effectiveness of Gamification Activities in a Project-based Learning Classroom. *2018 ASEE Annual Conference & Exposition*, Paper ID #22413. https://doi.org/10.18260/1-2--30361

Montenegro-Rueda, M., Fernández-Cerero, J., Mena-Guacas, A. F., & Reyes-Rebollo, M. M. (2023). Impact of Gamified Teaching on University Student Learning. *Education Sciences, 13*(5), 470. https://doi.org/10.3390/educsci13050470

Nurtanto, M., Kholifah, N., Ahdhianto, E., Samsudin, A., & Isnantyo, F. D. (2021). A Review of Gamification Impact on Student Behavioral and Learning Outcomes. *International Journal of Interactive Mobile Technologies (IJIM), 15*(21), 22-36. https://doi.org/10.3991/ijim.v15i21.24381

Parra-Santos, T., Molina-Jordá, J. M., Maiorano-Lauria, L. P., & Casanova-Pastor, G. (2018, October). Gamification for formative assessment in the framework of engineering learning. *TEEM'18: Proceedings of the Sixth International Conference on Technological Ecosystems for Enhancing Multiculturality*, 61- 55. https://doi.org/10.1145/3284179.3284193

Ratinho, E., & Martins, C. (2023). The role of gamified learning strategies in student's motivation in high school and higher education: A systematic review. *Heliyon, 9*(8), e19033. https://doi.org/10.1016/j.heliyon.2023.e19033

Smiderle, R., Rigo, S. J., Marques, L. B., Peçanha de Miranda Coelho, J. A., & Jaques, P. A. (2020). The impact of gamification on students' learning, engagement and behavior based on their personality traits. *Smart Learning Environments, 7*, 3. https://doi.org/10.1186/s40561-019-0098-x

Zainuddin, Z., Chu, S. K. W., Shujahat, M., & Perera, C. J. (2020). The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educational Research Review, 30*, 100326. https://doi.org/10.1016/j.edurev.2020.100326