MeriCOIN: Enhancing Motivation and Continuous Learning in Computer Engineering Students Through 3D Printed Rewards

Joaquin Gayoso-Cabada
Universidad Politécnica de Madrid
Escuela Técnica Superior de Ingeniería de Sistemas Informáticos
Madrid, Spain
j.gayoso@upm.es

Daniel López-Fernández
Universidad Politécnica de Madrid
Escuela Técnica Superior de Ingeniería de Sistemas Informáticos
Madrid, Spain
daniel.lopez@upm.es

Edmundo Tovar
Universidad Politécnica de Madrid
Escuela Técnica Superior de Ingenieros Informáticos
Madrid, Spain
edmundo.tovar@upm.es

Aldo Gordillo
Universidad Politécnica de Madrid
Escuela Técnica Superior de Ingeniería de Sistemas Informáticos
Madrid, Spain
a.gordillo@upm.es

Gustavo Adolfo Hernandez Peñaloza
Universidad Politécnica de Madrid
Escuela Técnica Superior de Ingeniería de Sistemas Informáticos
Madrid, Spain
gustavo.hernandez.penaloza@upm.es

***Abstract*— This research-to-practice full paper describes a case study conducted at the *Escuela Técnica Superior de Ingeniería de Sistemas Informáticos* at the *Universidad Politécnica de Madrid*, within the subject of Software Engineering Fundamentals. In this study, physical rewards, called MeriCOINs, were introduced as a way to gamify the subject. These rewards were progressively awarded to incentivize students throughout the course. These MeriCOINs were given as prizes within educational games and multiple-choice exam simulations presented as contests through the Wooclap tool. Students could use these MeriCOINs as part of the course process for queue advancement and late submissions. A notable improvement in student motivation and performance was achieved according to the perceptions of both students and teachers. A process for manufacturing and editing MeriCOINs using sustainable and low-cost processes was designed, which not only allow for easy and inexpensive implementation of the rewards but also establish them as a valid educational approach that can be replicated in different courses and contexts.**

Keywords*— *Educational Innovation, Gamification, Physical Rewards, Student Motivation, Continuous Assessment.

I. INTRODUCTION

Classroom gamification is an educational strategy that employs game elements to enhance student motivation and engagement in the learning process [1]. It has emerged as an innovative approach in both basic and higher education with excellent results [2][3]. This educational approach has proven effective in a variety of disciplines and contexts, even extending beyond the realm of education into the labor market [4][5]. Similarly, the use of physical rewards as incentives has always been part of the mechanisms to encourage participation and performance [6]. These rewards, ranging from certificates to medals, serve as reinforcement and motivation mechanisms. These experiences, commonly used in the field of sports, have been applied in education with good results [7][8].

The combination of gamified classroom sessions with physical reward processes is not new but must be adapted year after year to maintain appeal across years and courses, and to ensure sustainable creation and editing within the ecological and sustainability framework, particularly in higher education [9][10].

A. Classroom Gamification

Classroom gamification is an educational strategy that uses game elements to motivate and engage students in the learning process [1]. This technique has gained popularity in university settings due to its ability to increase students' intrinsic motivation and improve their participation in academic activities. This is particularly relevant the case of university students who, due to personal planning issues, often do not realize the volume of material to study until the exam period is close.

Numerous studies have demonstrated the benefits of classroom gamification in university contexts. There are studies that evaluate the academic performance of university students by gamifying subjects, showing improvements in student participation and academic performance by providing a more interactive and enjoyable learning environment [2][3]. Similarly, other articles highlight that gamification can improve knowledge retention and student satisfaction by transforming educational tasks into motivating and rewarding challenges [11][12][13][14].

B. Physical Rewards as a Motivational Mechanisms

The use of physical rewards as motivational mechanisms is well known within the realm of sports [7]. Due to their success, they have been applied to other fields. One area where their influence has been direct is in business, where incentive methods, productivity awards, and performance-based rewards have long been implemented [6]. Additionally, multiple studies have applied these techniques to the field of education as a means of motivating students in their studies with tangible rewards, both in basic education courses [8] and at the university level [9][10][15].

When applying physical rewards in the educational context, several unique challenges must be addressed. First, the volume of rewards must be sufficient to meet student demand and must have a minimal cost to be reproducible on an annual basis. Another crucial aspect is the systematic edition of these rewards between years and courses, which is key to the sustainability of the idea. Lastly, the ecological impact of the manufacturing, distribution, and recycling processes of the production materials and manufacturing waste must be considered.

II. Motivation and Problem Design

The creation process of physical rewards for gamified courses addresses multiple needs identified by the faculty at the *Escuela Técnica Superior de Ingeniería de Sistemas Informáticos*, *Universidad Politécnica de Madrid*. The first need arises from the nature of their courses, which require continuous study due to the complexity and volume of the material taught. Additionally, many subjects are taught progressively, starting with basic concepts that serve as the foundation for the next stage, and that stage for the following one, with the complexity increasing as the course develops. This type of learning is effective, but it implies that if the concepts from the previous stage are not well understood, the increasing complexity can lead to a loss of knowledge absorption and student demotivation. This can create a spiral effect that continues until the thread of the course is regained, or in the worst case, the total loss of the subject itself. This directly implies the need for continuous study that allows for evolutionary learning of concepts with increasing difficulty and the necessity to understand the concepts step-by-step. All these factors require students to maintain a steady study rhythm to avoid delays and ensure a deep understanding of the content at the time of instruction, which is essential for their academic success.

Another key need identified is to motivate students, especially since they can experience a loss of interest due to frustration from partial exam results or a decrease in performance due to interruptions like local holidays, partial project submissions, or studying for exams and assignments from other subjects. These factors can negatively affect their motivation and ability to maintain a consistent focus on the course. Therefore, it is necessary to implement strategies that help students overcome these challenges and maintain their interest and commitment to the course.

In this context, a significant improvement in class participation based on the attainment of tangible rewards has been observed in prior work [9][10]. These rewards not only serve as a tangible incentive for students but also positively reinforce their effort and participation. Experience has shown that physical rewards can increase student motivation, fostering greater involvement in academic activities and more active participation in the classroom. Inspired by similar projects with successful outcomes, such as those presented in some articles like [13], [14] and [15], the effectiveness of gamification strategies and tangible rewards in the academic context is recognized.

Additionally, the possibility of redeeming these rewards for options to customize their learning introduces an additional dimension of motivation. Students can use their rewards to access course-related benefits such as skipping queues during tutorials, getting priority access to learning games, late submissions of projects, or participating in exclusive educational games. This flexibility allows the physical rewards not only to recognize students' efforts but also to provide them with additional tools and opportunities to enhance their learning and performance.

Improved study habits are also expected to be driven by competitiveness among students to obtain these exclusive rewards. This is encouraged by the unique acquisition of rewards through study, variability between years, and between different courses. The rewards should foster a sense of healthy competition among students, motivating them to strive harder to earn these recognitions and rewarding the acquisition of expected competencies and learning outcomes. This exclusivity and annual variability are expected to make the rewards highly valued, increasing their motivational impact and the students' desire to stay committed to their studies to obtain them.

Finally, it is crucial that the rewards are easy to produce, editable year after year, and ecologically viable in their production process as well as in the waste management. This is critical due to the volume of subjects where these rewards are expected to be applied (for example, in the subject involved in the case study presented in this paper were enrolled about 350 students). The selection of material and the design of the rewards should be done considering these factors, ensuring that the rewards are sustainable and practical to produce in large quantities. This consideration not only facilitates the implementation of the reward strategy but also reflects a commitment to environmental sustainability and educational responsibility by both the faculty and the students.

III. Case Study

A. Presentation

The first decision point was the incorporation of this proposal into a typical subject that met the expected standards of volume and difficulty to be addressed. The chosen subject was Software Engineering Fundamentals, a course where part of the authors teaches. The teaching team is in favor of incorporating this type of initiative and is willing to actively participate in the experiment's processes and help in selecting the prize by analyzing prototypes and their final results. It is also a good experimentation ground since the strengths and weaknesses of the subject are already known, along with periods of reduced performance in terms of motivation, attendance, and knowledge acquisition. This subject dramatically deals with the problem of continuous study for linear understanding of concepts since it always builds its lessons on previous lessons in an ascending manner. The target subject is taught in multiple degrees at the *Escuela Técnica Superior de Ingeniería de Sistemas Informáticos* as a mandatory course, with a total of 383 enrolled students in the course where the experiment was conducted, within the fourth semester of the corresponding degrees.

Within this subject, gamified elements already existed, with several classes replaced by game-based learning activities, such as Lego serious games activities [16][17], the VR-based video game ScrumVR [18][19][20], other web-based educational video games [21][22], and educational escape rooms [23][24]. Additionally, to simulate multiple-choice exams, the online tool Wooclap (https://www.wooclap.com/) is used to create live contests where students participate individually in solving multiple-choice questions similar to the test they will face in the subject's exams, inspired by questions from previous academic years' tests.

The subject teachers also observe that at the beginning of the course and after long holiday periods, students' motivation declines, which is when part of these gamified lessons are used. The rest are used in the days leading up to partial exams as a motivation mechanism for studying. This planning aims to maintain students' interest and motivation during critical periods, offering additional incentives to help them overcome difficulties and maintain a positive focus on their learning.

To address the need for continuous study due to the volume, difficulty, and need for stepped understanding of the subject's concepts, it was decided to reward the individuals or teams with the best results in each of these gamified lessons. This strategy ensures that students remain engaged with the material regularly, encouraging active participation and constant preparation through activities that make learning more dynamic and engaging.

To improve class participation based on obtaining physical rewards, it was established that the possibility of winning these rewards would only be given through participation in classroom activities, and it would be impossible to obtain them in activities outside the established schedule. This decision promotes attendance and active participation of students within the subject since to resolve doubts and achieve better results in the tests, they must be present and committed during class sessions and scheduled activities, asking questions more directly about the concepts, not only for direct learning but also for deep understanding of them for these activities and the possible victory that will provide them with the desired prize.

The possibility of exchanging these rewards for learning customization options was designed not to negatively affect other students' grades. Exchangeable prizes were chosen to offer advances in waiting queues for review and late project submissions in this first year of experience. This measure ensures that incentives are beneficial to the winners without negatively impacting the performance of students who did not earn MeriCOINs in practice. All students had the same opportunities to earn MeriCOINs, and the teachers ensured that students' waiting times were not increased by the queue advancements applied by the MeriCOIN winners.

This approach aims to improve students' academic performance by fostering competition among them through the use of exclusive physical prizes, which are one-time only manufactured. By introducing different physical rewards each year and ensuring that the winner is not known until the end of the activity, students are motivated to compete with each other in the hope of obtaining the exclusive reward, always maintaining the perception that the prize is attainable at all times.

B. Production of MeriCOINs

To meet the need for easily producible, editable and environmentally friendly prizes for a high volume of students and multiple prize deliveries, a simple coin design created with OpenSCAD (https://openscad.org/) was chosen (Fig. 1).

Fig. 1. Design in OpenSCAD of the coin used as reward.

The OpenSCAD software allows to design and modify the design using source code that generates the reward in a 3D model. The reward design was simplified to a coin with a 22mm radius and 4mm width, selected from among several prototypes (Fig. 2). This choice of coin was agreed upon with the subject's teachers and included the logo of the *Escuela Técnica Superior de Ingeniería de Sistemas Informáticos*, the subject, and the year of manufacture. The edge of the coin was engraved with the name of the university and the school once again. The printing was done in 3D, using sustainable PLA material, ensuring efficient and eco-friendly production in a biodegradable material where waste can be recycled into filament to minimize ecological impact.

Fig. 2. Prototypes of the physical reward, featuring different sizes, colors, and shapes.

This printing was carried out using a school-owned Ender-3 3D printer, utilizing golden PLA material to simulate a real gold coin. Throughout the experiment, more than 100 coins were created, including both prototypes and coins delivered to the students. The name chosen for this award was MeriCOIN (Fig. 3), alluding to the concepts of merit due to the student's merit associated with earning it and the shape of the coin. This experiment was applied in all groups where the subject was taught during the academic year 2023-2024.

Fig. 3. Image of a MeriCOIN.

C. Research instruments

First, in order to evaluate the impact of this initiative, the observations made by the teachers of the subject in the classroom have been considered. Moreover, in order to evaluate the initiative in a more rigorous way, a questionnaire was also used as a research instrument to collect the students' perceptions toward the MeriCOIN initiative.

Of the 383 students enrolled in the course, 116 (30.3%) agreed to participate in this study through the provision of the pertinent informed consent and completed the questionnaire voluntarily. This questionnaire had a dichotomous question (yes/no) to assess whether the initiative had seemed positive to them, two questions to indicate how they had or would have used MeriCOINs, and seven quantitative questions (see Table I) that could be rated on a Likert scale of 1 to 5, where 1 means "not at all" and 5 means "very much" to assess the academic impact of the initiative. In addition, the questionnaire also had

open-ended questions to collect textual comments on the students' impressions and improvement proposals.

IV. RESULTS

Since the inception of the MeriCOIN awards, a positive attitude towards the proposal has been evident among the students. They have shown active interest, frequently inquiring about upcoming events for obtaining the MeriCOINs, included topics, and deadlines for obtaining them. This initial curiosity and enthusiasm already reflect a change in the class dynamic, with students being more motivated and engaged in gamified activities. In recent assessments, a notable improvement in students' attitudes towards these activities has been observed, leading to increased participation and attendance both in class and in the actual gaming activity, as perceived by the subject teachers.

To validate these findings, it is necessary to review the results obtained from the questionnaire. Out of 116 responses received, 99% of respondents felt that the MeriCOIN initiative positively impacts the university according to their judgment. Regarding how they plan to use the coin, 80% of students who obtained a MeriCOIN stated they would not spend the coin but rather prefer to keep it as a memento of the subject. Additionally, 66% of respondents who did not obtained a MERICoin indicated they would choose the same option. These results suggest that, besides serving as a motivational incentive, MeriCOINs also hold significant sentimental value for students, or the rewards available for redemption are not attractive enough to offset this sentimental factor.

Concerning the impact on the subject, the results shown in Table I demonstrate positive values in all evaluated aspects, indicating that students not only appreciate the applied initiative but also perceive a tangible benefit in their learning, motivation, continuous study, and participation in the subject. Moreover, when asked about the reissuance of this initiative in the next academic year, or the implementation of initiatives similar to MeriCOIN in other subjects, students also answered in the affirmative.

In conclusion, these quantitative results reinforce the positive qualitative perception already gathered by teachers during the initiative's implementation, confirming that the introduction of MeriCOINs has had a beneficial impact on students' motivation and performance.

Additionally, an open-ended question was included to assess the design and other possible awards, where students generally expressed positive views on the use of 3D physical trophies, the design used, provided new ideas for coin editing in future years, and suggested new award ideas that they believe would be more appealing for redemption in future years.

From the overall set of responses to the question "*If I could redesign the MeriCOINs (or another 3D prize item), I would like it to be...*", it is worth noting that many of them reaffirmed the complete success in the choice of the type of MeriCOINs with comments *"The Mericoins are perfect, I wouldn't change anything."*, *"They are fine"*, *"They are well designed."*, *"It is good that it is a coin" or "It is perfect"*. Others, however, propose changes in the prize sizes with comments *"The design is very good, I would like them to be a little smaller."*, *"That it is a little less thick to be able to comfortably store it in your closed fist."* or *"Same design but perhaps a little smaller."*. Other students, on the other hand, propose a partial or total change in the design, which could be interesting as a future idea *"That the back has the front part and is not flat."*, *"A katana, a small computer, something related to the degree."*, *"A characteristic object of the career."*, *"Ball"* or *"a Cup"*.

Table I: Questions and results obtained from the perceptions questionnaire

Perceptions Questionnaire			
Question	***Likert (1-5)***	***Value***	***Mean (SD)***
I believe that the use of MeriCOINs has had a positive impact on the subject.	1	3 (2.6%)	4.25 (0.946)
	2	2 (1.7%)	
	3	17 (14.7%)	
	4	35 (30.2%)	
	5	**59** (50.9%)	
I consider that the use of MeriCOINs has energized the execution of activities like Wooclap.	1	2 (1.7%)	4.46 (0.845)
	2	2 (1.7%)	
	3	9 (7.8%)	
	4	31 (26.7%)	
	5	**72 (62.1%)**	
I consider that the use of MeriCOINs has positively contributed to my motivation when studying.	1	7 (6%)	3.85 (1.169)
	2	7 (6%)	
	3	26 (22.4%)	
	4	32 (27.6%)	
	5	**44 (37.9%)**	
I consider that the use of MeriCOINs positively contributes to continuous study throughout the course.	1	3 (2.6%)	4.09 (0.965)
	2	4 (3.4%)	
	3	19 (16.4%)	
	4	43 (37.1%)	
	5	**47 (40.5%)**	
I consider that the use of MeriCOINs should be continued in the coming years in the Software Engineering Fundamentals subject .	1	2 (1.7%)	4.62 (0.739)
	2	0 (0.0%)	
	3	6 (5.2%)	
	4	24 (20.7%)	
	5	**84 (72.4%)**	
I consider it would be beneficial to implement initiatives like MeriCOIN in other subjects.	1	2 (1.7%)	4.53 (0.835)
	2	2 (1.7%)	
	3	8 (6.9%)	
	4	24 (20.7%)	
	5	**80 (69.0%)**	
I consider that the physical design of the MeriCOINs is appropriate.	1	2 (1.7%)	4.41 (0.882)
	2	3 (2.6%)	
	3	10 (8.6%)	
	4	31 (26.7%)	
	5	**70 (60.3%)**	

Regarding the future prizes for which the MeriCOINs could be exchanged with the question *"If I could choose another prize associated with the MeriCOINs (or another 3D prize item), I would like it to be..."*, some of them view repeating the prizes favorably *"I think they're fine as they are now."*, *"Nothing"*, or *"None"*. The vast majority of responses advocate for giving a grade increase or even passing the course: *"Round up some grade"*, *"A 10 in the subject"*, *"Increase a few tenths in the grade"*, *"Grade increase"* or *"A little bit of grade."*. On the other hand, another large group would like a physical product outside the scope of the school or related to the school's own operations: *"Beer."*, *"A figurine of something."*, *"A real coin."*, or *"a menu ticket from the cafeteria"*.

V. CONCLUSIONS

Initiatives like classroom gamification have previously shown to enhance the learning process in terms of student motivation and participation. The current proposal reaffirms that the use of physical rewards is a valid method for achieving these improvements, while also incorporating a sustainable production process over time in terms of editing, adaptability across different years and courses, and with significant value. Furthermore, these rewards are eco-friendly and low-cost,

making them ideal for continuously gamifying the classroom without producing long-term environmental impacts due to the biodegradability of the chosen product and recycling of production waste.

Based on the teachers' impressions and the results gathered from the perceptions questionnaire completed by the students, we can claim that the implementation of MeriCOINs in the Software Engineering Fundamentals subject has not only increased student motivation and engagement but also created a more dynamic and positive learning environment. This confirms that tangible rewards can be an effective and economical tool for fostering continuous study and active participation in the academic setting. It is expected that learning outcomes will also improve in this course.

Moreover, beyond students have a favorable attitude towards the type of reward, they are even assisting in the MeriCOINs future works since they have provided ideas that will help create an attractive and sustainable reward in value due to updates reflecting new trends and student needs.

A. Limitations and Future Work

Despite the positive results of this contribution, it is not without limitations. First, the results are based only on teacher impressions and student questionnaires. As future work, it would be interesting to include academic data and analyze the correlation of grades and absenteeism rates with the acquisition and use of MeriCOINs. Second, the study design precludes making a strong claim that the use of MeriCOINS objectively improves student performance. In this sense, as future work, it would be interesting to carry out an experimental study that would allow more solid conclusions to be drawn.

Beyond that, the initiative of MeriCOINs is proposed to be extended in several different directions.

Firstly, the creation of prizes of other materials and the study of performance differentiation among them, exploring the use of techniques such as laser cutting or advanced printing methods like Stereolithography (SLA) and Selective Laser Sintering (SLS). This diversification would allow for evaluating the impact of different materials and techniques on the perception and value of rewards, providing valuable data on the effectiveness and student preference towards various forms of physical rewards. It will also provide us with more flexibility in the type of reward, including the possibility of combining various production techniques to meet students' demands.

Secondly, the cross-sectional application of the initiative across subjects in the same course is proposed. This approach would include studying the balancing of students' study load by incorporating these rewards alternately between subjects. By strategically distributing incentives, the students' effort could be better balanced, fostering consistent participation at the grade level and continuous study, not only for a single subject but planned at the grade level. This could also help balance the workload for students during specific periods and exams across different subjects.

Lastly, the application of the initiative in the business sphere could be explored. The feasibility of using such physical rewards as a method of motivation in companies could be investigated, as well as how these initiatives can contribute to keeping employees motivated, thus improving their work performance. This study could include the evaluation of the effectiveness of physical rewards in the professional environment and their impact on productivity and employee satisfaction. Within this point, the challenge arises of not only finding attractive elements for someone progressing through a subject but also motivating a continuous worker who may remain in the same position or work environment for years.

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