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PAPER

Physics XP: Integration of ChatGPT and Gamification to Improve Academic Performance and Motivation in Physics 1 Course

Saul Beltozar-Clemente[1](✉), **Enrique Díaz-Vega**[2]

[1]Dirección de cursos básicos, Universidad Científica del Sur, Lima, Peru

[2]Departamento de ciencias, Universidad Privada del Norte, Lima, Peru

sbeltozar@cientifica.edu.pe

ABSTRACT

The understanding of the physics course (PC) at the university level faces many challenges, highlighting the gap in mathematical knowledge and conceptual phenomenological analysis that affect the assimilation of more advanced physical concepts. The synergistic integration of artificial intelligence (AI) and gamification into the teaching and learning process transforms this process into an engaging and collaborative experience, improving interaction and personalization of learning and incorporating game elements to increase student participation and motivation. The objective of this research was to measure the influence of the integration of ChatGPT, AI, and gamification on the academic results and motivation of students in the physics 1 course. A total of 188 students participated in this study: 98 students in the experimental group and 90 students in the control group. The grades obtained in the standardized evaluations were compared in both the partial exam and the final exam of the physics 1 course, and a Likert-type questionnaire was used for motivation. The results show a better academic performance (AP) of the students in the experimental group than the control group, which is statistically evidenced ($p < 0.01$). It also shows that students who developed the course using ChatGPT AI and gamification developed a more positive attitude towards interest, usefulness, self-efficacy, active participation, and personal satisfaction in the physics 1 course.

KEYWORDS

artificial intelligence (AI), ChatGPT, gamification, academic performance (AP), motivation, physics course (PC)

1 INTRODUCTION

The understanding of the physics course (PC) at the university level faces multiple challenges [1], evidencing its complexity for the acquisition of knowledge by many university students [2]. In a broader context, the disconnect between abstract concepts and practical applications generates an obstacle to the understanding of

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the course [3]. The data reveal that there is a gap between the prior mathematical and conceptual knowledge bases [4], which negatively impacts the assimilation and phenomenological interpretation of the more elaborate physical concepts [5]. These deficiencies are more specifically reflected in crucial areas such as kinematics, statics, and dynamics of a particle or rigid body [6], where problems related to spatial visualization and the preference for memorization strategies instead of analysis and comprehension approaches are identified [7] [8]. Specific data reveal disparities in achievement rates, highlighting the need for disruptive methodological strategies to overcome physics [9] [10] and mathematics course challenges [11] [12].

In today's educational environment, ChatGPT technology, developed by OpenAI [13], has emerged as an innovative tool based on artificial intelligence (AI) [14]. ChatGPT uses advanced language models to generate contextual and coherent responses [15], offering a more personalized and dynamic learning experience [16]. This approach revolutionizes the interaction between learners and content [17], providing adaptive responses that go beyond static information [18], thus creating a more interactive and enriching educational environment [19]. A key feature of ChatGPT is its ability to personalize learning by adapting to the particularities of the learner [20]. Motivation in PC requires curiosity, patience, and perseverance [21]. We can define motivation as the interest that drives the student to learn, deepen the scientific concepts, and know how to apply them in their daily activities [22].

In parallel, gamification has been highlighted as an effective pedagogical strategy [23] that incorporates game elements in non-game contexts [20]. By introducing game mechanics such as rewards and challenges [24], gamification seeks to increase student engagement [25] and motivation [26]. This methodology improves the learning process into an engaging and collaborative experience [27], promoting a deeper understanding of concepts [28]. Gamification not only motivates learners [29] but also promotes long-term retention of information [30].

The objective of this research was to determine the influence of integrating ChatGPT, AI, and gamification on the academic performance (AP) and motivation of students enrolled in the physics 1 course.

2 RELATED WORK

The following is a study that delves into the advantages and drawbacks of utilizing ChatGPT and gamification as a teaching method. The authors in [31] assess ChatGPT's capability to respond to quantum physics inquiries by formulating a series of highly complex questions. The findings reveal that it fails to distinguish between various physics concepts, resulting in incorrect responses regarding the quantum physics curriculum. This leads to the conclusion that it can only assist students in grasping quantum physics at a fundamental level. Additionally, the authors in [32] provide straightforward examples of incorporating ChatGPT into the physics curriculum to foster critical thinking. The outcomes indicate a positive influence on students' perceptions of ChatGPT's benefits. Similarly, in [33], the authors investigate diverse viewpoints on ChatGPT's application in math education. They employ a qualitative method in two phases: exploratory and applicative. Their results suggest that ChatGPT's accuracy and efficacy are contingent on the complexity of mathematical problems. They recommend a more thorough exploration of ChatGPT's effectiveness to ensure its proper integration into math education and learning.

Similarly, in [34], they developed a gamification didactic strategy that was applied in mathematics and PC in an engineering degree program. The methodology uses a STEAM approach and educational robotics, resulting in increased motivation

due to the use of gamification in a realistic context. Additionally, they [35] describe the results obtained by integrating gamification in the classroom to examine engagement and learning behavior. The study employs a mixed-methods design, evaluating movement in mind and thematic analysis. The results revealed the potential synthesis of movement in mind and flow theory in learning as a new conceptual scheme. Similarly, in [36], they designed a web-based and gamified AI-enabled online learning course for introductory PCs. The aim was to create a personalized tutor that offers a unique and effective learning experience. The AI-enabled gamification platform served as an efficient feedback tool for both teachers and students.

3 METHODOLOGY

The study was conducted as part of Physics 1, a course that is common to all professional programs at the faculty of engineering of the Private University of the North. The study was carried out during the academic semester of 2023-2. The operational design of integrating ChatGPT and gamification into the Physics 1 course is illustrated in Figure 1.

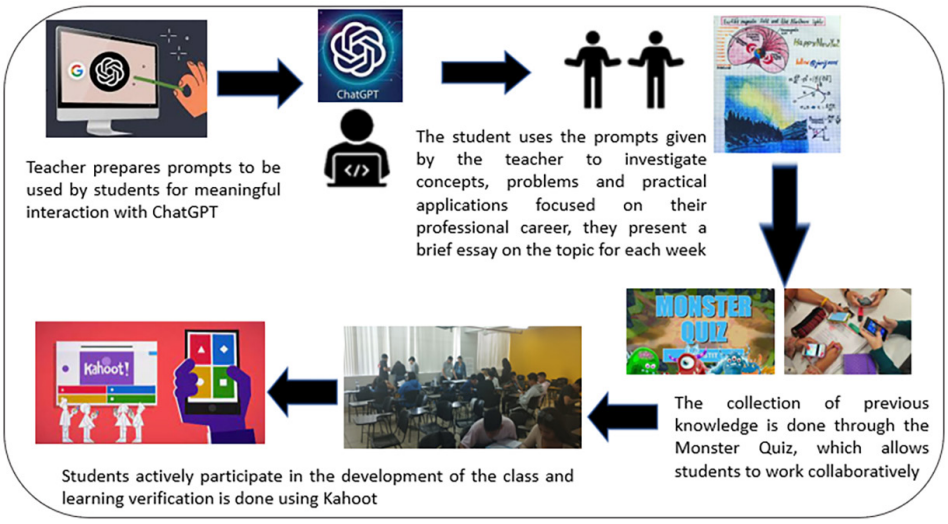

Fig. 1. ChatGPT and gamification integration flowchart

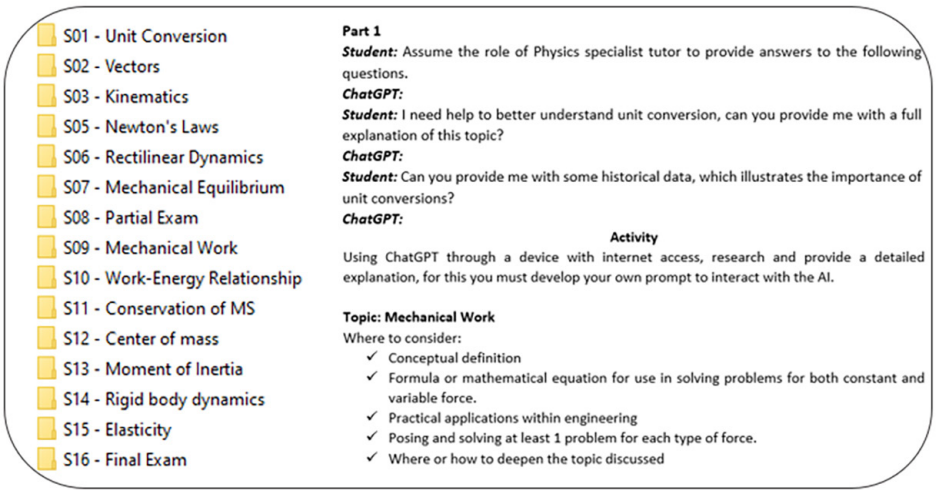

Fig. 2. Topics developed and ways to use ChatGPT and gamification

Figure 2 illustrates the topics developed based on the syllabus for the 2023-2 semester through the integration of ChatGPT and gamification. It also presents a model of the weekly interactions that students engage in with ChatGPT to enhance their learning significantly by utilizing these technological tools.

This study is a quasi-experimental study. The independent variables are ChatGPT integration and gamification, and the dependent variables are motivation and academic performance.

The participants were 188 students from the Faculty of Engineering enrolled in the Physics 1 course, which corresponds to the third cycle of the Private University of the North. 98 students were assigned to the experimental group, and 90 students were assigned to the control group. To analyze the impact of integrating ChatGPT and Gamification on AP, the grades obtained in the standardized evaluations for both the partial exam and final exam of the Physics 1 course in weeks eight and 16 of the academic semester 2023-2 were compared, as indicated in the course syllabus, for both experimental and control groups. The results were analyzed using IBM SPSS Statistics 28 software. A Likert-type questionnaire was used to assess motivation, focusing on dimensions such as interest in the course, usefulness, self-efficacy, active participation, and personal satisfaction. The questionnaire comprised 24 questions, with the first four focusing on the participants demographic profile, and the remaining 20 divided into five blocks of four questions each to evaluate interest in the course, usefulness, self-efficacy, active participation, and personal satisfaction. Each question was rated on a 5-point Likert scale, where 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; and 5 = strongly agree. The internal consistency test using Cronbach's alpha for the questionnaire items yielded a score of 0.92, indicating excellent internal consistency and reliability for its execution according to theory [37].

4 RESULTS

4.1 Impact of ChatGPT and gamification integration on academic performance

At the end of the standardized evaluations and upon obtaining the students' grades in each of their assessments, the Kolmogorov-Smirnov normality test was conducted, yielding a value of $p < 0.01$.

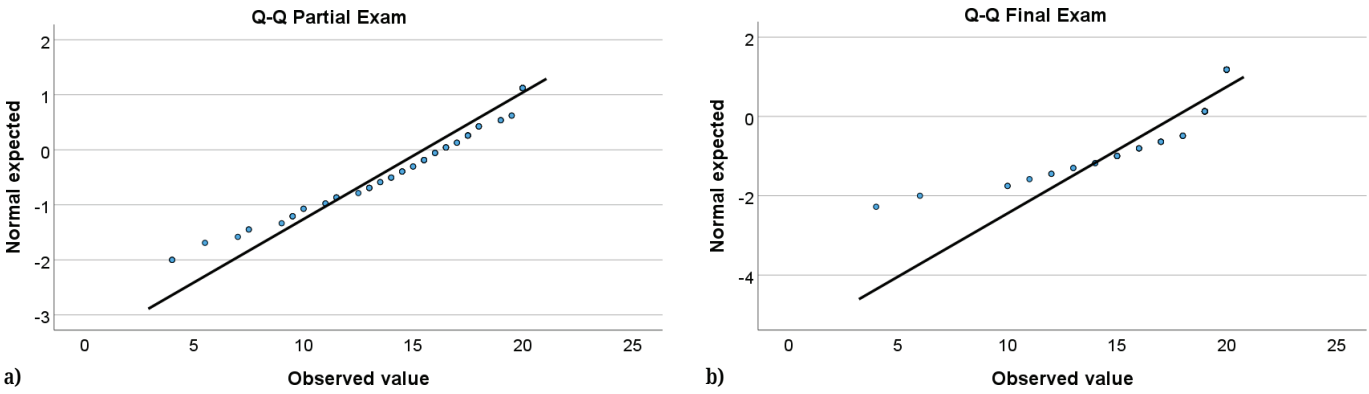

Fig. 3. Q-Q chart normality test

It can be observed in Figure 3 that the scores grouped around the line are dispersed among themselves, which leads us to deduce that the grades obtained by the students in the partial evaluation (a) and final evaluation (b) do not have a normal distribution.

In this study, the Wilcoxon nonparametric test was used to calculate statistical parameters such as mean, median, standard deviation, and variance for the midterm and final exams for each of the groups. Similarly, a significance level with a two-tailed 95% reliability was established to compare the homogeneity of the data obtained. ($\alpha = 0.05_{2\ tails}$)

Table 1. Academic results of the partial evaluation

Group	N		Media	Median	Standard Deviation	Variance
	Valid	Lost				
Control	83	7	13.52	14.50	3.84	14.75
Experimental	87	11	15.48	16.50	4.35	18.91

Table 1 presents the consolidated statistics for the partial exam. In the control group, we observe a mean of 13.52, a median of 14.50, a standard deviation of 3.84, and a variance of 14.75. Additionally, there are seven missing data points, representing students enrolled in the course who did not take the evaluation. For the experimental group, we see a mean of 15.48, a median of 16.50, a standard deviation of 4.35, and a variance of 18.91, along with 11 missing scores. Based on these results, we conducted the non-parametric Wilcoxon test, yielding a value of $p < 0.01$, concluding that there is a statistically significant and substantial difference between the grades of the experimental group and the control group following the implementation of classes involving ChatGPT and gamification elements. ($\alpha = 0.05_{2\ tails}$; $p < \alpha$)

Table 2. Academic results of the final evaluation

Group	N		Media	Median	Standard Deviation	Variance
	Valid	Lost				
Control	83	7	14.03	15.98	3.28	10.76
Experimental	87	11	17.67	19.00	3.14	9.83

Table 2 presents the consolidated statistics for the partial exam. In the control group, we observe a mean of 14.03, a median of 15.98, a standard deviation of 3.28, and a variance of 10.76. Additionally, there are seven missing data points, representing students enrolled in the course who did not take the evaluation. For the experimental group, we see a mean of 17.67, a median of 19.00, a standard deviation of 3.14, and a variance of 9.83, along with 11 missing scores. Based on these results, we conducted the non-parametric Wilcoxon test, resulting in a value of $p < 0.01$, concluding that there is a statistically significant and substantial difference between the grades of the experimental group and the control group following the implementation of classes involving ChatGPT and gamification elements. ($\alpha = 0.05_{2\ tails}$; $p < \alpha$)

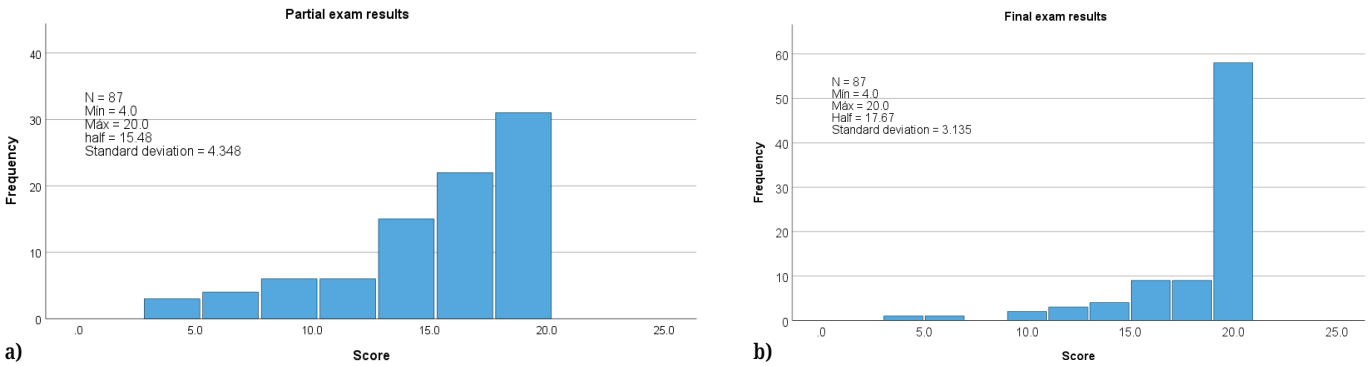

Fig. 4. Experimental group evaluation results

Figure 4 displays the results of the partial (a) and final (b) exams of the experimental group. The range of students' scores is between 4 as the minimum and 20 as the maximum. Additionally, it is evident that in the final assessment, over 50% of the students achieved the optimal score of 20.

4.2 Impact of the integration of ChatGPT and gamification on motivation

Once all the answers to the questionnaire were obtained, they underwent a Kolmogorov-Smirnov normality test, resulting in a $p < 0.01$.

The various ways in which students in the physics 1 course utilize ChatGPT are illustrated in Figure 5. It is evident that there is a greater inclination towards seeking explanations of concepts (38%) and requesting summaries and explanations on how to solve problems (31%).

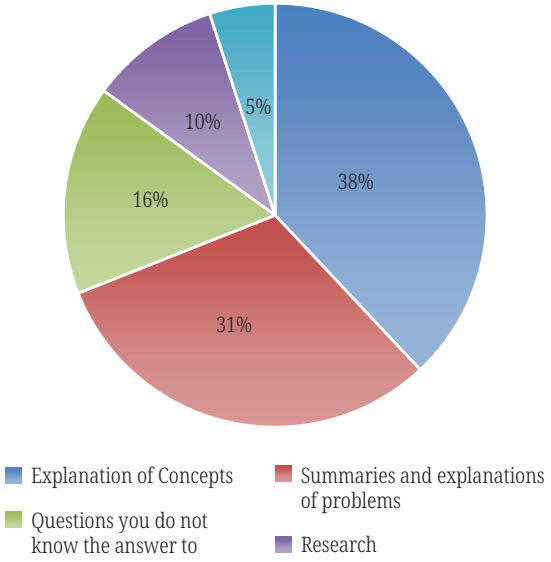

Fig. 5. Ways in which students use ChatGPT

The percentage weighting of motivation in its dimensions—interest, usefulness, self-efficacy, active participation, and personal satisfaction—of the students towards the Physics 1 course under the integration of ChatGPT and gamification in the teaching and learning process can be observed in Table 3.

Table 3. Development of motivation for each dimension

	Dimensions				
	Topic Interest	Utility Perception	Self-Efficacy	Active Participation	Personal Satisfaction
Strongly disagree	16%	4%	5%	1%	1%
Disagree	14%	5%	7%	4%	6%
Neither agree nor disagree	16%	18%	23%	15%	20%
Agreed	31%	39%	49%	59%	56%
Agree	24%	34%	16%	21%	17%

We can observe a more positive attitude among the students after engaging with these technological tools during their learning. This is supported by 56% of students agreeing and 17% strongly agreeing with the progress and achievements they have made in the physics 1 course using ChatGPT and gamification. Simultaneously, 59% agree and 21% strongly agree that active participation in the course activities throughout the semester has contributed to improvements in their AP. Additionally, 49% of students agree and 16% strongly agree that the integration of ChatGPT and gamification has helped them become more self-sufficient in their study methods, leading to increased self-confidence. It is also noted that 39% agree and 34% strongly agree that the integration of ChatGPT and gamification is beneficial for their physics 1 learning and their professional academic development. Furthermore, 31% agree and 24% strongly agree that the integration of ChatGPT and gamification has sparked greater interest in studying the course topics week by week.

Figure 6 shows a word cloud extracted from the students' one-word definitions of the performance and usefulness of ChatGPT during their learning in the physics 1 course.

Fig. 6. Students' definition of ChatGPT

5 DISCUSSIONS

In this study, we analyze the impact of integrating ChatGPT, AI with gamification elements such as Monster Quiz and Kahoot on the AP and motivation of students in the physics 1 course.

Study results reveal a positive and significant impact of integrating ChatGPT and gamification in the physics 1 course on students' motivation and AP. The high number of positive responses indicates that introducing these technologies has positively influenced student's perceptions of learning physics, not only in terms of academic outcomes but also in areas such as interest, perceived usefulness, and self-efficacy. The substantial percentage of active participation underscores the effectiveness of the activities proposed in the physics 1 course, showing that students have become more engaged in the learning process.

In addition, the data reflect an improvement in students' confidence in their study methods and a more positive perception of the usefulness and relevance of course content. These results suggest that the integration of AI, such as ChatGPT, and gamified strategies can not only positively influence academic results but also the attitude and perception of students towards the educational process. This provides a solid basis for the continuation and expansion of this approach in physics education.

In conclusion, the results of this study are related to the objective, which was to evaluate the impact of integrating AI and gamification elements on the AP and motivation of the physics 1 course. The results demonstrate how we can effectively integrate AI and gamification elements in higher education to create more engaging, enjoyable, and stimulating learning environments, thereby enhancing the digital competencies of the participants in this process.

6 CONCLUSION

In conclusion, the findings of this study support the effectiveness of integrating ChatGPT, AI, and gamification as pedagogical tools in the Physics 1 course. Enhanced AP, motivation, active participation, and positive student perceptions of learning demonstrate the transformative potential of these technologies in the educational environment. This study emphasizes the significance of embracing innovative approaches to enhance the learning experience, facilitate a deeper understanding of physical concepts, and cultivate a more dynamic and engaging educational environment.

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8 AUTHORS

Saul Beltozar-Clemente holds a degree in Mathematics and Physics from the National University of Central Peru. He also earned a Master's degree in Education Sciences from the National University of Education in Peru. Additionally, he obtained a degree in Scientific Research from the Universidad de Ciencias y Humanidades in Peru. He is certified in Agile Project Management by Technologic de Monterrey in Mexico. Currently, he serves as a professor at Universidad Privada del Norte, Universidad Científica del Sur, and Universidad Tecnológica del Perú. Moreover, he is an international lecturer in Argentina and the U.K. (E-mail: sbeltozar@cientifica.edu.pe).

Enrique Díaz-Vega holds a degree in Applied Mathematics, Master in Higher Education and University Research and PhD in Educational Sciences, in addition to several professional certificates, and currently is working as a university professor and doing research work with a team of highly qualified teachers, a member of the College of Mathematicians of Peru, with research interest in the area of engineering and education (E-mail: enrique.diaz@upn.edu.pe).