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Gamification in accounting education using artificial intelligence algorithms

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Abstract

Objective: To analyze the applicability of a game incorporating AI-based models, developed for the Business Budgeting course at a Brazilian public university.

Method: Data were collected from secondary sources related to the game. Descriptive statistics and the Mann-Whitney test were used for analysis.

Results: The findings describe the game's operation, the strategies used to develop AI-based models, and a comparison between student performance and that of the models. The analysis demonstrated the effectiveness of the strategies and highlighted student engagement in decision-making. The game's design enables the development of skills such as leadership, initiative, persistence, adaptability, collaboration, and critical thinking. Moreover, the detailed game description offers educators a foundation for replicating it and adopting an innovative active learning methodology.

Contributions: The study underscores the relevance of gamification in Accounting education and the integration of AI, which enhances the complexity and realism of decision-making activities. It proposes a novel approach to accounting education that combines gamification and AI to foster more innovative and effective classroom learning.

Keywords: Accounting Education; Gamification; Artificial intelligence (AI) Algorithms.

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1 Introduction

Gamification refers to the use of game elements in non-game contexts (Woodcock & Johnson, 2018). Rincon-Flores and Santos-Guevara (2021) highlight that, in education, gamification functions as an active methodology aimed at enhancing student engagement in the teaching-learning process. This approach has gained increasing attention in the literature (Gupta & Goyal, 2022), with its benefits recognized as extending beyond knowledge acquisition. According to Dicheva et al. (2015, p. 1), "The use of educational games as learning tools is a promising approach due to the games' abilities to teach and reinforce not only knowledge but also important skills such as problemsolving, collaboration, and communication," which are essential for meeting the demands of the 21st-century job market (Durso et al., 2019; Levant et al., 2016).

Despite the growing number of gamification experiences and their various benefits reported in the literature (e.g., Alves, 2019; Durso et al., 2019; Reginato et al., 2022; Del Sent et al., 2023), discussions on the use of Artificial Intelligence (AI) algorithms in the gamification process—particularly in accounting education—remain scarce. However, AI has been used in games more broadly for decades (Mitchell, 1997). Notably, AI algorithms are becoming increasingly relevant in the daily work of accounting professionals, contributing to several areas of practice and producing promising results, as highlighted in studies such as Lopes (2019), Moll and Yigitbasioglu (2019), and Qasim et al. (2020). Moreover, several authors have emphasized the role of AI in business contexts, particularly in what is referred to as "algorithmic management" (Mateescu & Nguyen, 2019; Moreira, 2022), which encompasses the use of AI in various control and management accounting processes (Schildt, 2017; Avelar et al., 2022; Oliveira & Avelar, 2023).

Thus, addressing this gap in the literature, this article presents an analysis of the applicability of an AI-based game developed for the Business Budgeting (BB) course at a Brazilian public university. Specifically, the study aimed to: (a) describe how the game functions; (b) explain the operation of the AI algorithms used in the game; (c) compare the performance of the models developed from different algorithms among students; and (d) discuss the implications of AI-based games in the teaching-learning process in Accounting, as well as their role in preparing students for an environment where this technology is increasingly present.

The relevance of this research lies primarily in its reflections on the use of AI in the educational context, particularly in the training of accounting professionals. Moreover, by proposing the development of an AI-based game within an accounting course, the study seeks to foster deeper student engagement and contribute to the development of practical and cognitive skills essential for professional practice in today's job market. Finally, the use of an AI-based tool in the education of future accountants also helps increase students' familiarity with this type of technology, which is becoming increasingly integrated into the profession's daily routines.

2 Literature Review

2.1 Gamification in the educational context

The literature on the use of games for educational purposes highlights that one of the main benefits of gamification in the classroom is the significant increase in student motivation, particularly intrinsic motivation (Hamari et al., 2016; Oliveira et al., 2023). This is because games inherently stimulate interest and curiosity, creating a challenging and enjoyable learning environment (Hamari et al., 2016). Game elements that foster a sense of progress and achievement can encourage students to persevere through the challenges of the learning process, leading to greater classroom engagement (Gupta & Goyal, 2022).

Furthermore, the rapid feedback provided during gameplay plays a crucial role in the teaching-learning process (Ahmed & Sutton, 2017). Receiving immediate information about what was correct or incorrect helps students remain engaged in the educational process and enhances their classroom performance (Oliveira et al., 2023). In addition to benefiting students, continuous feedback allows instructors to monitor performance throughout the learning process, enabling timely interventions to support and improve student outcomes (Christopoulos & Mystakidis, 2023).

Another important aspect of gamification is the creation of an immersive educational environment. The literature emphasizes that using games in the classroom enables students to reach a psychological state of deeper engagement with the task at hand, which enhances concentration and, in turn, supports the teaching-learning process (Pereira et al., 2022). The immersion provided by games allows students to experience abstract concepts in a concrete and practical manner, facilitating knowledge comprehension and retention, as well as skill development (Levant et al., 2016). For these benefits to be realized, the game must offer a realistic simulation of the real world (Santos-Souza & Azevedo Ferreira, 2020). However, this requirement does not exclude the inclusion of playful elements characteristic of games. On the contrary, the playful nature of games can further motivate students to engage with the tasks, contributing to a successful educational experience (Hamari et al., 2016).

Furthermore, one of the key benefits of using simulation in educational games is the opportunity for students to test different strategies to achieve objectives without the risk of real-world consequences (Reginato et al., 2022). Gamification also promotes meaningful learning by contextualizing content within engaging narratives, encouraging students to connect new knowledge to their personal experiences and the world around them (Reginato et al., 2022). In this context, by enabling students to apply theoretical concepts in practical situations, gamification fosters a deeper and more enduring understanding of the teaching-learning process (Santos-Souza & Azevedo-Ferreira, 2020).

In recent years, advances in AI have broadened the applicability and benefits of gamification in the educational context (Tolks et al., 2024). The integration of AI into educational games has enhanced elements such as student engagement, personalized learning experiences, and the delivery of immediate and more precise feedback (Alenezi, 2023). AI enables tailoring challenges to individual student profiles, rendering game scenarios more complex, dynamic, and effective (Bennani et al., 2022). When properly structured, AI can therefore contribute to making gamified strategies even more appealing and better aligned with contemporary pedagogical needs.

Some studies in the accounting field have evaluated the use of gamification strategies for educational purposes, supported by different technological infrastructures. Levant et al. (2016), for instance, examined the role of business simulations in developing students' soft skills across various countries. The authors found evidence that such skills can indeed be fostered through business simulation games, although ethnic and cultural differences influenced the extent of the benefits observed. Similarly, Durso et al. (2019) analyzed the contribution of a business simulation course to the skill development of accounting students. Their findings indicate that participants perceived the development of several competencies through the gamified simulation, including curiosity, leadership, initiative, persistence, adaptability, collaboration, and critical thinking.

Alves (2019), in turn, examined the applicability of a game designed for teaching Cost Accounting. The author developed Easy Cost, a game that simulates the industrial process of a clothing company, and applied it in two colleges located in different Brazilian states. The results suggest that the game contributed to significant learning by capturing students' attention and promoting integration and enjoyment during the learning process. Similarly, Santos-Souza and Azevedo-Ferreira (2020) sought to identify the contributions and limitations of using business games to teach Management Accounting in Brazil. Their findings indicate varying levels of student engagement, which limited the achievement of learning outcomes for all participants.

Reginato et al. (2022), on the other hand, examined the transfer of learning and the development of interpersonal skills through the use of business simulation software in a gamified Accounting course. The results indicated that the software enabled students to acquire knowledge applicable to real-world situations. Participants also reported developing interpersonal skills through the course, particularly collaboration and adaptability. Finally, Del Sent et al. (2023) investigated how the effects of gamification influence the engagement of Brazilian students in undergraduate Accounting programs. The authors concluded that the game contributed to fostering critical and reflective learning among Accounting students.

Although the literature emphasizes the importance of games in the teaching-learning process, and recent studies—such as those mentioned above—have examined this phenomenon within the accounting field, there are no investigations specifically focusing on the integration of games with AI-based tools. As Mitchell (1997) noted, AI algorithms have been applied in games for decades; however, their use in educational contexts remains underexplored, with several gaps yet to be addressed (Wang et al., 2024). Therefore, considering the increasing presence of AI-based models in everyday life, it is essential to discuss their implications for the educational and managerial training of Accounting students.

2.2 Artificial Intelligence (AI) and Business Management

AI is described in the literature as a machine or system capable of learning, reasoning, and simulating cognitive tasks similarly to a human being, but with greater speed and accuracy (Jarrahi, 2018). Russell and Norvig (2013) define AI as a field of study encompassing various subfields, including Machine Learning (ML), which employs algorithms that enable machines to improve their performance through example-based learning, particularly in pattern recognition and prediction tasks. Among the main ML algorithms, the most prominent are k-nearest neighbors (KNN), Random Forest (RF), and Artificial Neural Networks (ANNs).

KNN is a distance-based algorithm founded on the premise that similar observations are likely to share similar attributes. As noted by Nwaganga and Chapple (2020), predictions or classifications are made by using the attributes of the most similar observations from the training phase. RF, in turn, is defined by Burguer (2018) as a collection of decision tree models built from multiple random subsets of the training data. Each model generates an expected result based on its subset, and these results are then aggregated to produce a final decision. Finally, Burguer (2018) explains that ANNs are understood as a set of equations used to compute an output value.

The application of various AI algorithms, such as those mentioned above, spans multiple fields, including medicine, marketing, personnel selection, investments, and accounting (Schildt, 2017; Shrestha et al., 2019). These technologies have been used in the accounting context to automatically identify calculation rules and tax classifications, classify documents for tax and accounting purposes, identify areas of audit concern, analyze the behavior of performance indicators, and identify tax and labor risks, among other uses (Moll & Yigitbasioglu, 2019; Lopes, 2019; Qasim et al., 2020).

Currently, AI-based solutions play an increasingly significant role in performing complex management tasks that were once the exclusive domain of humans, often demonstrating superior performance (Raisch & Krakowski, 2020; Borges et al., 2021). In this context, Grønsund and Aanestad (2020) highlight that AI has impacted both the nature of work and the way organizations are structured. Moreover, there is a growing adoption of algorithm-based management aimed at increasing efficiency and reducing costs (Mateescu & Nguyen, 2019).

As noted by Moreira (2022), the use of algorithms in management is promising. However, the adoption of AI also presents challenges and ethical considerations. Issues such as data privacy, algorithmic bias, and the interpretability of AI models must be carefully examined and addressed to ensure that AI implementation benefits organizations in an ethical and responsible manner (Borges et al., 2021; Cardon et al., 2021). Nonetheless, Schildt (2017) emphasizes that middle management, traditionally responsible for Management Control (MC), is increasingly expected to be replaced by algorithms. According to the author, management at this level is becoming a predominantly technological process, with minimal or no human intervention. This level of management has traditionally encompassed the main MC tool grounded in Accounting: the BB.

2.3 Business Budgeting (BB)

Although various definitions of budgeting exist, there is broad consensus that it plays a fundamental role within the Management Control System (MCS) of organizations. In the context of Management Control (MC) practices, the budget represents the materialization of planning and control through the development of a detailed plan that encompasses all stages of operations over a defined future period (Pedreti & Diniz-Maganini, 2023). It functions as a critical tool for resource allocation, coordination, control, and the communication of organizational strategies (Mucci et al., 2021).

Dal Magro and Lavarda (2015) emphasize that one of the key objectives of budgeting and its preparation process is its motivational function, as it encourages managers to develop solid and well-structured plans. Additionally, the budget serves as an effective communication tool, enabling the organization to clearly and accurately convey its expectations to managers. The literature also highlights that budget-related judgments may be prone to error though. As noted by Lima Filho et al. (2010), the complexity and uncertainty inherent in budgetary activities might increase the likelihood of cognitive biases, even among experienced professionals. Furthermore, Moraes et al. (2022) suggest that the more involved an individual is in the budgeting process, the greater the potential for the emergence of such biases.

Budgeting is often a challenging and complex task for managers, typically characterized as a time-consuming process (Oliveira, 2018). Garrison et al. (2013) emphasize that the forecasts used in budget preparation require statistical models and tools to enhance accuracy and ensure that the budgeting process is properly conducted. In response to a dynamic market and the ongoing global digital transformation, MC and its tools—such as budgeting—have undergone significant modernization. Brognoli and Ferenhof (2020) argue that digital transformation, understood as the integration of digital technologies and data analysis with intelligent processes, is a phenomenon that demands attention and serves as a key driver in the transformation of organizations.

In this context, from an educational perspective, the use of a game incorporating AI algorithms into BB allows students to engage with current market practices. Additionally, it enables the simulation of complex and dynamic scenarios, making the educational experience more realistic and enriching. Finally, the use of AI in the educational setting allows for personalization of the game, adapting challenges and feedback based on students' progress and individual needs, thereby promoting more effective and engaging learning.

3 Methodology

According to the classification by Cooper and Schindler (2003), this is a descriptive and documentary study that adopts both qualitative and quantitative approaches. Secondary data were collected from the game guidelines provided to students, reports detailing the decisions and outcomes achieved by student groups in each round over the four semesters during which the game was implemented (from the first semester of 2022 to the second semester of 2023), and the code and databases used to develop the models based on different AI algorithms.

The game guidelines provided to participants were analyzed to describe the tool's dynamics and the main decisions made by the student groups. The key recurring decisions were found to include: production quantity, unit pricing, personnel hiring, loan and interest payments, marketing expenditures, sales commissions, and the hiring of market consulting services. These decisions are scored based on a set of criteria, with the primary objective being the achievement of a long-term goal—either maximizing the company's return or its market share. Further details on the decisions and outcomes are presented in subsection 4.1.

The reports detailing the decisions and outcomes of the student groups were analyzed, and the data were tabulated and processed using MS Excel spreadsheets. The analysis focused on the main decisions the students made, as outlined in the game manual, as well as the outcomes related to the long-term objective. A total of 103 decisions were recorded, along with the corresponding long-term outcomes (whether achieved or not), including macroeconomic variables that influence these results within the game, such as inflation and Gross Domestic Product (GDP) variation.

To develop models based on AI algorithms, data from previous rounds of the game were initially processed to make them suitable for algorithmic use. As all AI algorithms require metric data, normalization was applied in accordance with the approach presented by Nwanganga and Chapple (2020). The dataset was divided into training and test sets for model estimation, following the procedures described by Burguer (2018) and Lantz (2019). In line with their guidelines, approximately 80% of the data was allocated for training and 20% for testing.

In general, the model development process followed the step-by-step approach proposed by Ferreira et al. (2021) for forecasting in finance using AI: (1) collecting input data; (2) transforming and selecting the data; (3) training the model; (4) optimizing the parameters; and (5) evaluating the model's performance. Note that the process was conducted in multiple stages, addressing the main decisions sequentially: Production, Price, Commission, and Marketing. Data related to GDP and inflation were used as initial inputs, with the output of each stage serving as the input for the next. Specific details regarding the development of models based on each algorithm are provided in subsection 4.2.

To optimize the parameters and select the models, the root mean squared error (RMSE) metric—calculated using the test data—was employed to assess model performance (Equation 1), with a focus on its ability to predict the achievement of the long-term objective. RMSE is a widely used measure in AI-based models developed for category-specific prediction tasks (regression), such as the phenomenon examined in this study (Nwanganga & Chapple, 2020).

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{\left(\left| value_{real} \right|_i - \left| value_{predicted} \right|_i \right)^2}{n}} \quad (1)$$

Quantitative data were analyzed using descriptive statistics and the Mann-Whitney test. All data processing and analysis were conducted using spreadsheets and R software, with the support of the following packages: A Grammar of Data Manipulation (dplyr); Breiman and Cutler's Random Forests for Classification and Regression (randomForest); Evaluation Metrics for Machine Learning (Metrics); Classification and Regression Training (caret); Create Elegant Data Visualisations Using the Grammar of Graphics (ggplot2); Misc Functions of the Department of Statistics, Probability Theory Group (e1071); Read Excel Files (readxl); and Training of Neural Networks (neuralnet).

4 Results

4.1 Description of how the game works

The game is initially titled SIPROJEN-AI, an abbreviation for "*Simulador de Processo Orçamentário baseado em Jogos de Empresas do Núcleo X*" [Business Game-Based Budget Process Simulator by Núcleo X]. Note that "X" is used as a pseudonym to avoid identifying the research center responsible for developing the game. Additionally, the acronym "AI" is included in this version to reflect the incorporation of artificial intelligence, which was not present in the game's previous version. The game is presented as an assessment activity to be completed by students over a few weeks in the Business Budgeting (BB) course, during the second half of the semester, after students had been introduced to the entire budget preparation process.

The game involves making periodic decisions for a hypothetical company that sells product Y in market Z, based on a previously defined long-term Decision Objective (DO), as well as the preparation of a budget, following the concept proposed by Pedreti and Diniz-Maganini (2023). Note that product Y is homogeneous, meaning there is no differentiation between competing companies. The product is measured in liters and requires raw material X for its production.

During a predefined number of rounds (typically four), students are required to make quantitative decisions based on historical data and future projections, in order to quantify the company's economic and financial activities, as highlighted by Mucci et al. (2021). It is important to emphasize that the assumptions are discretionary, reflecting the participants' strategies and objectives, in accordance with what is outlined by Garrison et al. (2013).

In each round, students must make the following decisions: (a) Quantity to be produced (in liters) – ranging from 1 to 10,000; (b) Unit price (in R$) – ranging from R$ 0.01 to R$ 10,000.00; (c) Hiring of personnel (number of employees) – may include positive values (hiring) or negative values (firing); the minimum number of employees is zero, and there are no additional costs for hiring or firing; (d) Payment of loans and interest (in R$) – minimum of R$ 0.00; only loans from previous periods may be repaid; (e) Marketing expenses (in R$) – minimum of R$ 0.00; (f) Sales commission for salespeople (in percentage) – ranging from 0% to 100%; (g) Acquisition of machinery (number of units) – minimum of zero; (h) Market consultancy service (yes or no) – if selected, a report is provided with descriptive statistics of the main decision variables of the competing companies for that period.

It is worth noting that, according to neoclassical economic theory (Besanko et al., 2012), the demand for each company in market Z is primarily influenced by its price. In this case, the lower the price, the greater the quantity demanded tends to be. However, the percentage of commission and marketing expenditures also has a significant positive influence on sales. It is important to highlight that demand decreases sharply for prices above R$ 1,000.00.

In addition to the decisions mentioned above, players must establish the DO in the first round, which will remain valid for all subsequent rounds. The DO can be one of the following: (i) DO1 – Maximize market share (in terms of quantity sold); or (ii) DO2 – Maximize return on assets (ROA). Maximization means that the value used as a reference for the DO in a given period must always be higher than that of the immediately preceding period. Additionally, players are evaluated based on their ability to generate profit in the period, and if they achieve the highest value among all players for the selected DO in a given round, they receive an extra point. Students are also presented with several assumptions regarding production characteristics, macroeconomic variables, and payment terms, along with a balance sheet from the immediately preceding period.

Furthermore, the average price charged by companies is assumed to be R$400 per unit during period X0. The average marketing expenditure in that period was R$50,000, and the average sales commission was 5%. Note that disbursements related to these expenditures occur within the same period. Companies are also required to use the moving weighted average cost method to value their finished product inventories. In this regard, it is assumed that, after estimating the quantity to be produced, all raw materials are purchased and the entire production is completed before any units are sold. Therefore, there is no raw material or work-in-process inventory remaining at the end of each period. Additionally, all costs are allocated to the products, regardless of the quantity produced. With respect to loans, they are automatically contracted at the beginning of each period if the company does not have sufficient cash to meet its financial commitments.

Furthermore, it is worth noting that the company initially has three machines, with a total production capacity of 1,500 liters per period. Each machine was acquired at R$50,000.00 and is depreciated on a straight-line basis over five periods, with no residual value. The company may purchase additional machines during the game at the same unit price, with payment made in cash. Any newly acquired machine becomes operational in the same period in which it is purchased, thereby increasing the company's production capacity. If the production for a given period exceeds the installed capacity, the company must outsource machine hours from other companies, which charge R$45.00 per liter processed.

Before each round, estimated information on GDP and inflation for the period is presented. Inflation directly affects the cost of raw materials, while GDP impacts market growth. Companies are distributed based on the number of participants, and decisions for companies not managed by human players are controlled by different AI algorithms and incorporated into each round. Additionally, two initial rounds are conducted to familiarize participants with the game. After these training rounds, all company data is reset to the initial conditions of X0. Decisions must be submitted via a link provided by email no later than 11:59 p.m. on the date set by the instructor of the BB course. Each player receives a report of their company's results by email after the end of each round.

Based on the previous operational descriptions, SIPROJEN-AI is designed to provide a highly immersive environment for students, aiming to foster a psychological state of deeper involvement and concentration, while enhancing knowledge comprehension and retention, as emphasized by Levant et al. (2016) and Pereira et al. (2022). Furthermore, in line with Reginato et al. (2022), the game enables students to test different courses of action to achieve objectives without facing the negative consequences that such decisions might entail in real-world scenarios. In this context, SIPROJEN-AI serves as a budgeting laboratory, allowing students to experiment with various strategies based on the knowledge acquired in the course. Additionally, the rapid feedback provided after each round helps students stay engaged in the learning process, which tends to improve their performance, as reported by studies such as Ahmed and Sutton (2017) and Oliveira et al. (2023).

Thus, the design of SIPROJEN-AI has the potential to foster the development of various skills identified in prior studies in the accounting field (e.g., Durso et al., 2019; Alves, 2019; Reginato et al., 2022), including interpersonal relationships, curiosity, leadership, initiative, persistence, adaptability, collaboration, and critical thinking. Additionally, the inclusion of initial training rounds enables students to become more familiar with the game, aligning with Durso et al. (2019), who found that familiarity with online tools and perceptions of software usability were positively and significantly correlated with students' views on the development of essential skills for the 21st-century job market. This feature also helps mitigate the risk of low student engagement, as noted by Santos-Souza and Azevedo-Ferreira (2020).

4.2 AI – Based Models

AI algorithms were employed in the development of SIPROJEN-AI to create a non-human player capable of competing with groups formed by Accounting students. The primary objective of introducing AI as a competitor is to prevent the formation of cartels among groups, a practice that could unduly influence the outcomes of game rounds. Additionally, the inclusion of AI contributes to a more immersive and dynamic environment, making the competition more challenging and engaging. This strategy is intended to enhance student engagement while reinforcing the teaching-learning process, thereby providing a richer and more motivating educational experience. Finally, the use of AI in the classroom also helps students become more familiar with tools that are increasingly present in professional accounting practice (Moll & Yigitbasioglu, 2019; Lopes, 2019; Qasim et al., 2020), in light of the growing role of algorithmic management in contemporary management control (Avelar et al., 2022; Oliveira & Avelar, 2023; Schildt, 2017; Mateescu & Nguyen, 2019).

The first model developed for SIPROJEN-AI was based on the KNN algorithm. This is a simple algorithm that operates as follows: (1) it receives and stores a training dataset in which each observation consists of a set of independent variables and a corresponding dependent variable; (2) when a new observation needs to be classified, the algorithm identifies the "k" nearest observations in the training set, where proximity is measured by the distance between variable values; (3) the class of the new observation is determined based on the classes of these "k" nearest neighbors, using a majority voting approach. In this case, since the algorithm was used for regression purposes, the learning process remains similar; however, instead of applying majority voting, the predicted value for the new observation is calculated as the average of the dependent values of the k-nearest neighbors, as described by Burguer (2018).

To measure the distance between observations, the Euclidean distance of the variables of each observation is usually used. Mathematically, this distance refers to a straight line between the coordinates of two points in a multidimensional space (Nwanganga & Chapple, 2020). To select the "k" value, an essential parameter of this algorithm, for each decision, values between 1 and 10 were tested, following the approach highlighted in Nwanganga and Chapple (2020). The aim was to select the best k considering the bias-variance trade-off highlighted by Lantz (2019).

In turn, the model generated based on RF combines the results of the different trees, according to the prediction objective (regression in this case). This is an ensemble learning approach. According to Nwanganga and Chapple (2020), ensemble learning assumes that it may not be possible to find the optimal set of parameters for a given model and, even if it were possible, the model might not be able to capture all the patterns underlying the data. Thus, instead of focusing on optimizing the performance of just one model, several weak and complementary models are used to develop a more effective and powerful model (a process called bagging). According to Nwanganga and Chapple (2020), RF includes not only a selection of subsets of training data, but also a random selection of attributes. To select the number of trees to be considered, an essential parameter of the RF algorithm, values between 1 and 30 were tested for each decision.

Regarding the last algorithm used, ANNs, Lantz (2019) highlights that these networks model the relationship between a set of inputs and outputs using a model based on our knowledge of how the biological brain does this. According to the author, while the biological brain uses a network of interconnected cells (biological neurons) to provide a vast learning capacity, ANNs use a network of artificial neurons to solve challenging problems. In this sense, Faceli et al. (2021) highlight that the concept of deep network, linked to deep learning, refers to an ANN that has at least two intermediate layers, which contributes to increased performance.

To select the architecture to be considered, the ANN algorithm was configured to use neurons across four layers, thereby enabling deep learning, as described by Faceli et al. (2021). Table 1 presents the optimized parameters used in the developed models. Accordingly, the best parameters for the ANN, RF, and KNN models were selected based on the specific decisions in each category: Production, Price, Commission, and Marketing.

Table 1
Optimized parameters used in the model

Algorithm	Decision	Best parameters for models
RNA	Production	2 layers with 1 neuron each
	Price	1 layer with 1 neuron
	Commission	4 layers with 3 neurons each
	Marketing	4 layers with 3 neurons each
RF	Production	13 trees
	Price	6 trees
	Commission	1 tree
	Marketing	9 trees
KNN	Production	8 nearest neighbors
	Price	6 nearest neighbors
	Commission	2 nearest neighbors
	Marketing	6 nearest neighbors

4.3 Comparison of AI model decisions and performance

The decisions and performance of students and SIPROJEN-AI in the same games were compared. Only data from student groups that selected DO2 (i.e., maximizing ROA) were included in the comparison, as this subset provided a larger volume of available data. Table 2 presents the descriptive statistics for the main decisions made by both the students and the AI-based models.

Table 2
Student decisions *versus* SIPROJEN-AI by category

Decision	Gamer	Statistics					
		Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Production	Students	816.00	950.00	1,000.00	1,033.61	1,050.00	1,320.00
	SIPROJEN-AI	1,021.51	1,054.95	1,097.55	1,103.73	1,158.42	1,195.02
Price	Students	421.50	430.00	457.31	477.43	479.75	675.00
	SIPROJEN-AI	427.00	436.14	445.37	446.07	452.72	475.42
Commission	Students	4.00%	6.00%	7.00%	6.88%	7.25%	10.00%
	SIPROJEN-AI	6.13%	6.88%	7.27%	7.18%	7.33%	8.50%
Marketing	Students	33,743.50	52,000.00	55,000.00	52,304.83	57,500.00	65,000.00
	SIPROJEN-AI	47,165.25	49,436.80	51,804.96	52,011.68	54,732.69	57,096.11

There is no major discrepancy between the two groups of players. Students appear to invest more in Marketing than SIPROJEN-AI; however, the Mann-Whitney test revealed no statistically significant differences. The same applies to the other decisions. Table 3 also presents the findings on performance outcomes for both groups: students and SIPROJEN-AI. Although it is not possible to state that the AI-based models achieved statistically different results in relation to the DO, they did not incur losses in any period. Moreover, no statistically significant differences were found between the groups based on the Mann-Whitney test.

Table 3
Student performance *versus* SIPROJEN-AI

Results	Gamer	Statistics					
		Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Profit	Students	2.00	4.00	4.00	3.67	4.00	4.00
	SIPROJEN-AI	4.00	4.00	4.00	4.00	4.00	4.00
ROA	Students	1.00	2.00	2.00	2.33	3.00	4.00
	SIPROJEN-AI	2.00	2.00	2.00	2.25	2.25	3.00
Extra point	Students	-	1.00	1.00	1.22	1.00	4.00
	SIPROJEN-AI	-	-	0.50	0.63	1.00	2.00

The applicability of AI-based models in the game is evident, as they achieve performance levels comparable to those of students who study the budgeting process during the course and complete training rounds to become familiar with the tool. By competing directly with students—who are aware of the AI's presence—these models not only prevent the formation of cartels and other opportunistic behaviors aimed at inflating scores (as previously discussed) but also encourage students to develop a deeper understanding of this type of intelligence and its increasingly common role in everyday professional life.

4.4 Discussion

This study presents a range of implications from academic, professional, and educational perspectives, particularly within 21st-century accounting education. First, it offers an innovative contribution by applying gamification as a teaching methodology in accounting education. Although some studies have explored this topic (e.g., Levant et al., 2016; Alves, 2019; Santos-Souza & Azevedo-Ferreira, 2020), the literature remains limited, despite the well-documented benefits of this approach. Gamification promotes leadership, initiative, persistence, communication, collaboration, adaptability, integration, and critical and reflective learning, as noted by Alves (2019), Durso et al. (2019), Reginato et al. (2022), and Del Sent et al. (2023). Therefore, this study reinforces the value of gamification in the context of accounting education and underscores its potential advantages.

Furthermore, this study explores gamification within the broader context of artificial intelligence, incorporating algorithmic models based on AI. In doing so, it offers an innovative contribution and expands on the findings of previous research, such as Alves (2019), Reginato et al. (2022), and Del Sent et al. (2023). The results emphasize the importance of integrating AI into educational games to promote student interaction with this technology, fostering awareness of both its potential and limitations. The game's premises are grounded in a social context where the use of AI algorithms is already documented in the routine activities of accounting professionals, as highlighted by Lopes (2019), Moll and Yigitbasioglu (2019), and Qasim et al. (2020). SIPROJEN-AI specifically addresses issues related to management control in the face of the rise of algorithmic management, as discussed by Mateescu and Nguyen (2019), Moreira (2022), and Oliveira and Avelar (2023). In this regard, Schildt's (2017) assertion is particularly relevant, as it anticipates the replacement of human middle management by intrinsically technological processes. These findings reinforce the importance of preparing accounting professionals for these emerging scenarios.

The study's proposal and findings align with the competencies and skills expected of graduates from undergraduate Accounting Science programs (bachelor's degree), as outlined in CNE/CES Resolution No. 1 of March 27, 2024, which established the new National Curricular Guidelines for this field (Ministry of Education, 2024). SIPROJEN-AI corresponds to several of the competencies and skills described in the resolution, particularly the requirement that students "understand how information technology contributes to data analysis and information generation" (free translation). Within this competency, the following skill is especially relevant: "develop the ability to implement and use contemporary technologies such as big data, data analytics, data visualization, and artificial intelligence [AI] within the scope of accounting information systems" (free translation). Therefore, SIPROJEN-AI is not only aligned with current societal demands but also with the directions set by the new curricular guidelines for accounting education.

Furthermore, the detailed operation of SIPROJEN-AI and the parameters of the estimated models support its reapplication in other educational settings, contributing to the replicability of this study. The game's rules can be reused or adapted to different educational contexts, and through programming, new AI strategies can be integrated into the game to enhance its design. Thus, the findings of this study provide instructors with a foundation for implementing an innovative, active learning methodology in their courses.

Thus, this study provides a relevant contribution to accounting education by addressing an active methodology that employs models based on AI algorithms—whose benefits are widely reported in the literature—in the context of the growing and widespread adoption of this technology across various areas of Accounting. The application and adaptation of games such as SIPROJEN-AI offer a valuable foundation for both replication and enhancement, significantly supporting the training of 21st-century accounting professionals in line with the expectations of the market, educational institutions, and society at large.

5 Conclusions

This study aimed to analyze the applicability of a game (SIPROJEN-AI) that incorporates models based on AI algorithms. The game was developed for the Business Budgeting (BB) course at a Brazilian public university. Data were collected from the guidelines provided to students, reports detailing the decisions and outcomes of student groups in each round, as well as the codes and databases used to develop the models based on various AI algorithms.

A detailed description of how SIPROJEN-AI works was presented, which simulates the management of a fictitious company in a competitive market. In this context, participants make specific strategic decisions related to production, pricing, commission, and marketing. Subsequently, the AI algorithms used (KNN, RF, and ANN) were briefly described, highlighting their characteristics and operation. Then, a comparison of the models developed from these algorithms was presented, demonstrating their effectiveness in predicting students' decisions based on historical data and future projections. Finally, a discussion was presented regarding the implications of games using AI in the teaching-learning process in Accounting.

The results highlight significant contributions on several fronts. Initially, the importance of gamification in the context of Accounting education stands out. By transforming theoretical concepts into a simulated game, gamification makes learning more engaging and motivating for students. Also noteworthy is the integration of AI in SIPROJEN-AI, which adds an additional layer of complexity and realism. By controlling companies not assigned to human players, AI algorithms simulate the competitive behavior of rival firms, challenging participants to make better strategic decisions, more closely replicating real-world market dynamics and providing students with a more authentic and applicable learning experience.

Note that the detailed presentation of the SIPROJEN-AI process facilitates its replication in different educational contexts, potentially enhancing student engagement through mechanisms such as challenges, competition, and rapid feedback. This can promote greater knowledge retention in the classroom and support the development of essential skills for training accountants, in line with the new curricular guidelines for the Accounting Sciences program. Finally, this study offers a proposal for Accounting education that integrates gamification and AI, presenting an innovative and effective approach that prepares students for real-world challenges and equips them with key competencies for their professional careers.

Some limitations should be noted though. The study was restricted to a single course within a specific educational context, which limits the generalizability of the findings. Moreover, the analysis focused primarily on comparing student outcomes with those of AI algorithms, without exploring qualitative aspects of student engagement. Future research is suggested to apply the game and replicate the study in other management-related courses (with appropriate adaptations) and educational institutions, to more comprehensively assess the applicability and benefits of gamification and AI. Additionally, further investigations using qualitative approaches could explore students' perceptions and engagement with SIPROJEN-AI, offering deeper insights into its impact on the teaching-learning process.

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