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GAMES IN HIGHER EDUCATION: A GAME PROPOSAL ON PRODUCTION ENGINEERING CONCEPTS USING A COGNITIVE TEACHING-LEARNING APPROACH

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ABSTRACT
The general objective of this article is to propose a game to apply teaching-learning concepts of production engineering to higher education students. This proposal addresses concepts of takt-time, production costs, and layout organization and supports a more dynamic and interactive learning process. This work is justified because it is based on constructing a cognitive teaching-learning environment for students with interactive visualization of academic concepts and the world of work.

Keywords: Engineering education, games, teaching-learning process, higher education, Production Engineering.

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INTRODUCTION

During academic training, teachers and students face challenges to ensure that the knowledge presented in class is absorbed, especially in content where the relationship with reality is essential. Given that the difference in students' life experiences is explicit, some have never had contact with the world of work, while others are mature in their activities. Therefore, it is necessary for teachers to seek new teaching strategies to develop a better cognitive environment.

According to Kaliská (2012), students learn in different ways, such as listening, viewing, practicing, and discussing. In the same way, different ways of teaching can be adopted, for example, using demonstrations, discussions, exercises, or lectures.

Regarding the way of teaching, Malheiros (2012) explains that methods are the paths defined by the teacher to facilitate learning. Furthermore, when addressing active teaching-learning methodologies, Borges and Alencar (2014) state that using these methodologies can favor the student's autonomy, awakening curiosity and stimulating individual and collective decision-making arising from the essential activities of social practice and in the student's contexts. Regarding the different approaches in the teaching process, according to Mizukami theory (1992), the cognitivist approach is one of the five teaching-learning approaches, where the others are traditional, behaviorist, humanist, and sociocultural. In the cognitivist approach, teaching is based on trial and error, research, investigation, and problem-solving, prioritizing the student's development, offering freedom of action, and proposing work with concepts. Thus, it can be concluded that receiving and constructing knowledge is decisive for the student's performance and professional development. Examples of cognitive teaching include Business administration (Motta; Quintella, 2012), literature (Medeiros et al., 2016), production planning and control (Filha et al., 2017), innovation management (Filho; Schröter, 2018), chemistry (Pontes et al., 2020), among others. Based on these and other studies, we sought to gather data and information to answer the following research problem: What are the characteristics and criteria for developing a game and using it in teaching-learning processes to be applied to production engineering concepts, with an active teaching methodology bias and generating a cognitive environment? The general objective was to develop a game with a cognitive approach to enhance students' learning on production engineering topics. The study is justified in the organizational field by the contributions it will bring to students and future employees or employers, with better preparation for the organizational environment. In the academic field,

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it provides a way to increase student performance and add a significant amount of knowledge to teachers. Finally, it is justified in the social field based on Freire's words (1987): "Education does not change the world. Education changes people. People change the world."

THEORETICAL BACKGROUND

The theoretical basis of this research includes concepts and knowledge of teaching-learning environments and cognitive teaching-learning environments.

TEACHING-LEARNING ENVIRONMENTS

According to Mizukami (1992), five types of teaching-learning approaches are organized: traditional, behaviorist, humanist, cognitivist, and socio-cultural. Based on this, each approach is classified into twelve items, in addition to the main representatives for the author: general characteristics, man, world, society-culture, knowledge, education, school, teaching-learning, teacher-student, methodology, evaluation, and final considerations.

Based on this information, a clear line of differentiation can be established between the approaches proposed by Mizukami, essentially using the role of the teacher in the learning process, as shown in Board 1.

Board 1 - Role of the teacher in each approach

Differences between types of approaches depending on the teacher's role	
Approach	**Role of the teacher**
Traditional	Transmitting knowledge is considered the most important thing, so the student is a receiver.
Behaviorist	Plan, develop, and monitor the teaching-learning system, controlling the student's path.
Humanist	It facilitates student learning closely, aiming at freedom and self-development.
Cognitivist	He assumes the investigator, researcher, and advisor role, seeking to structure teaching based on trial and error, research, investigation, and problem-solving.
Sociocultural	It proposes action and critical reflection, creating conditions for the analysis and production of culture.

Source: Based on Mizukami (1992)

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Cognitive teaching-learning environments

For the cognitive approach, it is essential that the student experiment to learn, thus relating acquired knowledge with experiences and practices in their way, making it possible to structure and develop their intelligence, moving towards self-control and autonomy. Since the act of experimenting cannot occur by watching the teacher do it or by doing something previously determined, one can only learn to experiment, in fact, by doing it for oneself, being active, doing it with one's own characteristics and in one's own time, according to Piaget (1949, apud Munari, 2010).

Piaget was the first psychologist to conduct a systematic study of cognitive development. In his theory of cognitive development, he explains how a child builds a mental model of the world, moving away from the idea that intelligence is intrinsic by nature and thus considering development as a process related to biological maturation and interaction with the environment. According to Piaget's theory, the mental level determines how didactic situations should be presented; that is, there are notions or stages that depend on others; therefore, if they are not structured, they compromise cognitive development. For Piaget, the construction of knowledge is the achievement of equilibrium, which is the adaptation of the subject to the object between assimilation and accommodation. From this, the “psychogenetic” method was presented, the term used for a pedagogy based on Piaget (Santos, 2017) and based on four lines, demonstrated in Board 2.

Board 2 - Four lines of the psychogenetic method

Psychogenetic method	
Lines	**Description**
1. Problem Situation	Challenge to research, discovery, and invention. It is an imbalance.
2. Group Dynamics	The group is the most stimulating environment, which builds solidarity while preserving individuality.
3. Awareness	Becoming aware of the mechanisms you use to carry out an activity is your way of building social awareness.
4. Assessment	It is an ongoing diagnostic process that assists and guides development.

Source: Adapted from Santos (2017)

Although Jean Piaget places biological maturation and interaction with the environment as the main factors in development, for Jerome Bruner (1966), man depends on techniques to realize his humanity in his theory of evolutionary instrumentalism, also known as developmentalism. He considers the influence of the cultural and social context in the process and highlights language as a factor that contributes to greater interaction with the cultural environment. For Bruner, learning by discovery occurs when the student is provided with all the necessary tools to discover for himself what he wants to learn. Henri Wallon (1975) also places the concept of affectivity as one of the central factors in development, with the sense that the human being is affected by both internal and external sensations. Kanakana-Katoomba and Maladzhi (2019) point out that the cognitive teaching-learning environment should consider different methods, such as an integrative approach, experimental learning, problem-based learning, case-based learning, project-based learning, inquiry-based learning, and competency-based learning.

In the view of Mestrinho and Cavadas (2018), using the integrative approach brings life to the teaching-learning process, where the central value of the integrative approach is its ability to allow students to learn about the origin of life, the evolution of life, and the future of life and humanity, solving problems related to real life.

According to Bates (2015), experimental learning allows students to put into practice what they have learned, for Mestrinho and Cavadas (2018), it is shaped by the vocational aspect, especially in areas where practice and theory are strongly intimate, such as engineering, electricity, electronics, and mathematics, thus offering a possible experience for those who do not yet have it.

In problem-based learning, Bates (2015), Tsai, Shen, and Lu (2015), students receive predefined tasks to solve problems according to what was taught, where the teacher plays a coordinating role to ensure the teaching-learning environment and is normally carried out in groups, this method is most used in areas such as science, engineering, and technology.

For Mestrinho and Cavadas (2018), case-based learning can be used when addressing complex and interdisciplinary topics, where students have the freedom to appropriate the teaching-learning environment and discuss possible solutions, in which technology can provide an online environment for this.

When talking about project-based learning, it can be assumed that it concerns case-based learning. However, Bates (2015), Mestrinho, and Cavadas (2018) cover a more extensive plan, addressing real challenges and helping give meaning to manual work.

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Inquiry-based learning for Soudien (2010) and Kaen (2017) resembles project-based learning, where instructors take control, and Bates (2015) students take the lead in choosing research topics.

USE OF GAMES IN HIGHER EDUCATION

According to Haydt (2006), playing is a natural and playful activity for human beings. People play for the simple pleasure of doing so. Using games as a teaching tool, the teacher creates a motivating environment that allows students to actively participate in the teaching-learning process, enabling them to assimilate experiences and information and incorporate attitudes and values.

In this same perspective, Fialho (2007) explains that exploring the playful aspect can become a facilitating technique for several activities, such as elaboration of concepts, reinforcement of content, sociability among students, creativity, and a spirit of competition and cooperation. Items that, for Fialho, make the learning process transparent so that knowledge absorption is a natural consequence of the activity.

For Haydt (2006), games are exciting activities that start with a voluntary effort, as justified by the items shown in Board 3.

Board 3 - Items of attractiveness for the use of games in teaching

Reasons for using games in teaching according to Haydt (2006)	
Item	**Description**
a)	It corresponds to a natural impulse of the student, whether they are a child or an adult. In this sense, it satisfies an inner need, as humans have a playful tendency.
b)	It absorbs the player intensely and completely, creating an atmosphere of enthusiasm since two elements coexist in the game: pleasure and spontaneous effort. This aspect of emotional involvement makes the game an activity with strong motivational content, capable of generating a state of vibration and euphoria.
c)	It mobilizes mental schemes to trigger and activate psychoneurological functions and mental operations, stimulating thought.
d)	It integrates the affective, motor, and cognitive dimensions of personality. As a physical and mental activity that mobilizes functions and operations, play activates the motor and cognitive spheres and appeals to the affective sphere as it generates emotional involvement. The being who plays and plays is the one who acts, feels, thinks, learns, and develops. Therefore, like artistic activity, play integrates the motor, cognitive, affective, and social aspects.

Source: Adapted from Haydt (2006)

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According to Alves, Minho, and Diniz (2014), a great effort is needed to develop this engaging educational strategy that promotes learning. Based on this, they described a step-by-step process for creating this type of application, as shown in Board 4.

Board 4 - Steps to create a game as an educational strategy

How to create a game with a focus on learning		
Step	**Action**	**Description**
1	Interact with games	It is desirable that the teacher seeks to have some experience with games and on different platforms to experience the logic of the games and understand the different mechanics.
2	Know your audience	Analyze the characteristics of your audience, in the case of this work, they are Production Engineering students.
3	Define the scope	Define which areas of knowledge will be involved, the topic that will be addressed, the skills that will be developed, the associated content, and the attitudes and behaviors that will be enhanced.
4	Understand the problem and context.	Reflect on which everyday problems can be explored with the game and how the problems relate to the content studied.
5	Define the mission/objective.	Define the mission of the gamified strategy and analyze whether it is clear, achievable, and measurable. Check whether the mission aligns with the skills that will be developed and the proposed theme.
6	Develop the game's narrative.	Think about what story you want to tell. Analyze whether the narrative is in line with the theme and context. Check whether the metaphor makes sense to the players and the strategy's objective. Think about whether the story has the potential to engage your audience. Consider the aesthetics you want to use and whether it reinforces and consolidates the story.
7	Defina o ambiente, plataforma	Define whether your audience will participate from home or a specific environment, whether the classroom environment, digital environment, or both will be used. Identify the main interface with the player.
8	Define tasks and mechanics.	Determine the duration of the gamified educational strategy and the frequency with which your audience will interact. Define the mechanics and check whether the tasks enhance skills development and align with the narrative. Create rules for each task.
9	Define the scoring system.	Make sure the scoring is balanced, fair, and diverse. Define the rewards and how the ranking will be done (location, frequency of exposure).
10	Define the features	Plan the strategy agenda in detail, defining the resources needed each day. Analyze your involvement in each task (whether the scoring will be automatic or whether you will need to analyze the tasks).
11	Review the strategy	Check whether the mission is compatible with the theme and is aligned with the narrative. Consider whether the narrative has the

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		potential to engage players and is consistent with the tasks. Check whether the tasks are diverse and feasible and have clear rules. Check whether the scoring system is well structured and the rewards are motivating and compatible with the audience. Check whether all resources are secured and the agenda is appropriate for the audience.

Source: Adapted from Alves, Minho, and Diniz (2014).

According to the introduction to this work, games have several applications as a teaching mediator. In a study by Lozza and Rinaldi (2017) on using games for learning in higher education at a university center in Curitiba-PR, interesting data about a specific discipline were collected. Through a questionnaire answered by professors who teach the content, all the professors interviewed considered the traditional teaching resources used for teaching research insufficient and saw active methodologies, emphasizing using games, in a positive light. Regarding the students, when asked about the use of any game for educational purposes during all their years at school, 68.89% said that they had already carried out some activity in this sense, however, when they were asked specifically about higher education, only 37.79% said that they had already received classes with this type of methodology and 95.56% said that they would like the method to be used during classes, demonstrating good acceptance by the students. Furthermore, the research yielded a pedagogical proposal for applying a digital game and the direction of active methodologies for the discipline studied at the educational institution.

Another research that adds important information to this work was carried out by Paccola et al. (2014), where they improved “The Boat Game”, a game that simulates the production of a boat factory and proposes engineering and production management concepts related to productivity, quality, and costs, among others, such as takt time (Pantaleão et al, 2003), which also included a value stream mapping in the game, in addition to being applied at three different times, unlike the application of Pantaleão et al. (2003). To improve the game, problem-based learning was used, which, according to Echavarria (2010), has the following common principles: the student is the active agent of learning, where they have autonomy to use their experiences and interests in the process, researching the problem, proposing a solution and defending it through technical arguments, in addition to the work being carried out in a team; the teacher is the guiding agent, acting as a tutor and the problem is the starting point of the learning process, which interacts with real-life situations.

Another example of research can be seen on Board 5.

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Board 5 - Example of the use of games in higher education

Examples of the use of games as a teaching tool in higher education		
Authors	**Objectives**	**Results**
Filho *et al.*, 2018	This research is characterized as a case study in which the development and application of a didactic game on innovation management in related disciplines was carried out.	The research showed that using educational games in higher education can effectively contribute to teaching and learning. The students' testimonies about the classes were positive, and the result was a better understanding of the entire process related to innovation management.
Filha *et al,* 2017	Se buscou demonstrar a aplicabilidade dos jogos Lego® como ferramenta pedagógica no processo ensino-aprendizagem no ensino superior.	A aplicação da dinâmica com os brinquedos de montar Lego® com os alunos de graduação do curso de logística da Universidade X, mostrou-se adequada ao ensino da disciplina Planejamento e Controle da Produção (PCP), sendo que esta dinâmica passou a ser um recurso de ensino adicional dentro do curso de logística.
Quirino *et al,* 2017	Identificar em que medida o uso de jogos é percebida como importante e útil pelos professores e pelos alunos no contexto educacional, permitindo melhorar a qualidade dos processos de aprendizagem através do uso de um simulador.	O uso dos jogos educacionais pode ser facilitador na aprendizagem, o discente consegue visualizar a teoria na prática. Acredita-se que o uso de simuladores desenvolve aspectos técnicos e comportamentais, integrando equipes e desenvolvendo lideranças com emoção e entusiasmo.

Source: Adapted from Alves, Minho, and Diniz (2014).

Based on these and other studies, the use of games in the teaching-learning environment can be potentialized in the search for better student results and awakening greater interest among those involved in the proposed content.

METHODOLOGIES

The game's construction is based on six stages, as shown in Figure 1.

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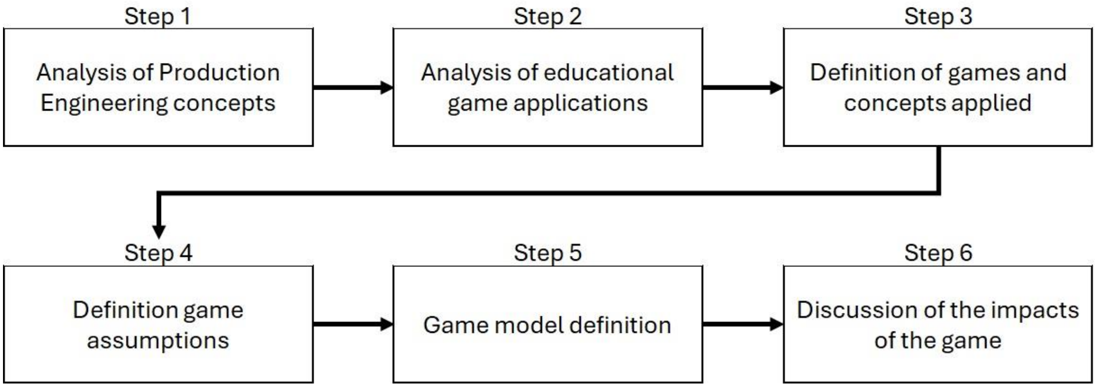
Figure 1 - Stages defined for the game's construction



Source: Development by Authors (2024)

Stage 1: The first stage is in section 4.1, where we seek to analyze the literature on Production Engineering concepts.

Stage 2: After analyzing these Production Engineering concepts, section 4.2 analyzes literature on the application of games as a teaching tool in developing students' knowledge and skills.

Stages 3 and 4: In section 4.3, we seek to define which game will be applied, as well as the concepts that will be contemplated and the assumptions of the game.

Stage 5: In the fifth stage, the game model is developed and is organized in section 4.4.

Stage 6: In the last stage, we discuss the impacts of the game on the development of knowledge about the subjects proposed by the activity; this stage is found in section 5.

ANALYSIS AND INTERPRETATION OF RESULTS

According to Swales and Feak (2004), the discussion of results section is the point in the text where the author changes focus, leaves the description of the methodology, and goes back a few steps to have an overview of the data and put them into perspective in the study. Therefore, in this chapter, analyses and interpretations will be carried out according to the theoretical basis presented in the second chapter of this research.

ANALYSIS OF PRODUCTION ENGINEERING CONCEPTS

Production and process management, as a subject studied during the Production Engineering course, involves several interrelated and constantly improved concepts, as the market demands that new practices be incorporated together with techniques already consolidated in the business environment, thus proposing a differential and competitive

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advantage between businesses. Takt time is among the related subjects. To understand it fully, it is necessary to identify differences with other concepts, such as cycle or lead time. This may occur because these are concepts that are generally discussed traditionally without an appropriate environment for the construction of the students' knowledge and are subjects that involve common themes, given that they deal with productivity and units of measurement that mark time, often making it difficult for students to distinguish between these subjects. However, it should be noted that these are elements used to develop a strategy, planning, and indicators, among others, and if they are not fully mastered, they can distort fundamental analyses in search of good results in the production process and consequently in the business. Therefore, an alternative is to use a game with a cognitive approach to actively build this knowledge by the student to improve the quality of absorption, understanding, and structuring of the content.

DEFINITION OF THE GAME, ASSUMPTIONS AND APPLIED CONCEPTS

To create the game, we sought to use LEGO, a toy based on parts that fit together, allowing for different ways of assembling these parts, in which the teacher does not need prior knowledge of game mechanics and is easy to understand and apply. To create the game, we considered that Production Engineering students at the end of the course should be prepared to implement, operate, improve, and maintain production systems that involve different resources and predict and analyze results. In this sense, the game's narrative is the simulation of a factory's production in the classroom, where the raw material is LEGO parts. Given this, the areas of knowledge involved are related to production and process management, with the theme dedicated to takt time, seeking to use experimental and problem-based cognitive approaches so that the student can build their own knowledge, where the teacher will apply teaching based on trial and error, research, investigation, and problem-solving.

DEVELOPMENT OF THE GAME MODEL

Therefore, the game seeks to bring students into a real situation in which the concepts are seen in practice and analyzed by them. The goal is for students to structure their knowledge in practice and, through experimentation, be able to master the concept of takt time and differentiate it from cycle time and lead time. In addition, students must work in groups as active agents, and the teacher acts as a co-advisor. In this sense, the game

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will be applied in five phases. In the first part, the objective is for students to simulate production and focus on timing production times. In the second phase, the teacher, in the manager role, must pass on to the students the activity as a problem related to takt time, according to the information in section 4.3.5. In the third phase, it is time to evaluate the processes based on a systemic view by mapping the value stream. In the fourth phase, students discuss possible improvements to be made to the current state of manufacturing. From there, they must develop a plan with improvements and implement the changes in the fifth and final stage, according to Figure 2.

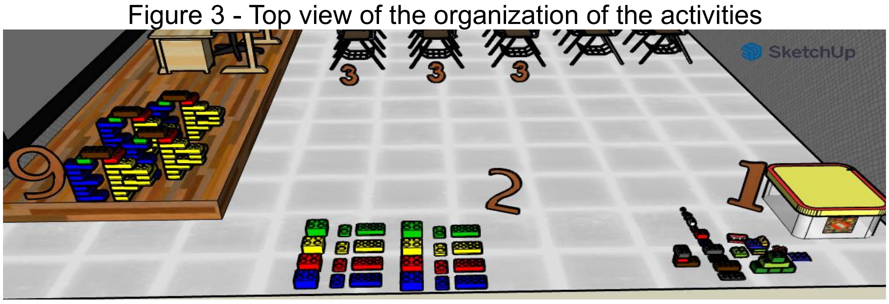
Figure 2 - Game application steps

Step 1	Step 2	Step 3	Step 4	Step 5
Measure the times of each process when executing activities	Calculate takt-time	Mapping the current state of the game	Discussion with students about which processes can be improved	Implement the changes

Stage 1 of the game application: instruction on the production processes

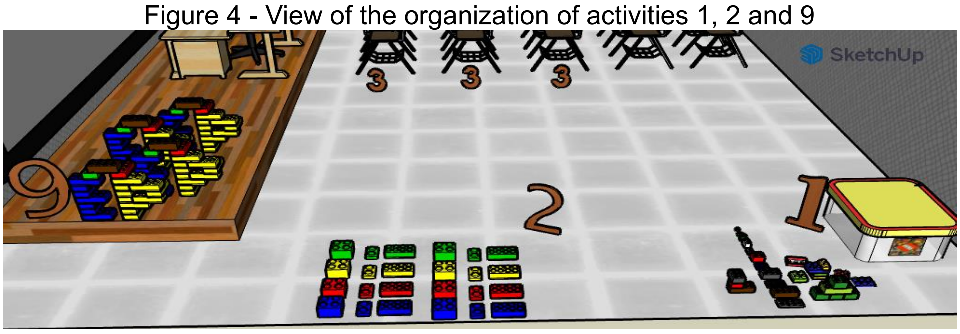
This section describes the activities for the development of the game during the activity. The estimated time and number of people were assumed so that an example could be created for demonstration purposes. The organization of the activities can be seen in figures 3, 4 and 5.

Figure 3 - Top view of the organization of the activities



Source: Development by authors (2024)

Figure 4 - View of the organization of activities 1, 2 and 9



Source: Development by authors (2024)

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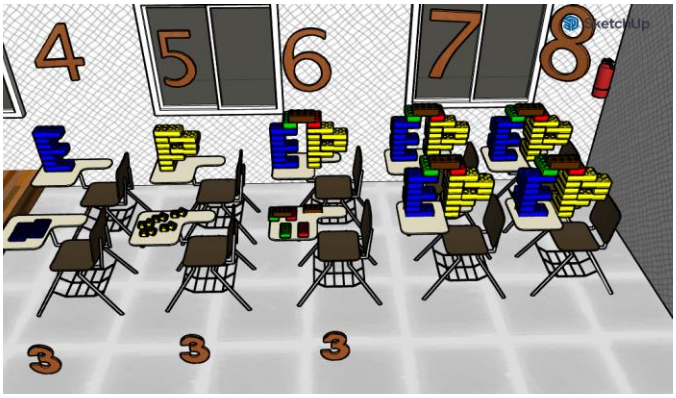
- Activity 1 - Receiving inspection
    - Action: separate and count the parts by color and size.
    - Estimated time: 3 minutes
    - Number of operators: 1 person
- Activity 2 - Inventory
    - Action: store the separated parts and enter them into the inventory.
    - Estimated time: 1 minute
    - Number of operators: 1 person
- Activity 3 - Preparation of raw materials
    - Action: remove the necessary parts from stock and transfer them ○ physical to start production.
    - Estimated time: 1 minute
    - Number of operators: 1 person

Figure 5 - View of the organization of activities 3, 4, 5, 6, 7 and 8



Source: Development by authors (2024)

- Activity 4 - Production E
    - Action: assemble part E.
    - Estimated time: 20 seconds
    - Number of operators: 1 person
- Activity 5 - Production P
    - Action: assemble part P.
    - Estimated time: 30 seconds
    - Number of operators: 1 person

- Activity 6 - Joining letters
  - ○ Action: join the two letters to form the product.
  - ○ Estimated time: 25 seconds
  - ○ Number of operators: 1 person
- Activity 7 - Resting process for 40 seconds
  - ○ Action: place the assembled product on rest for 40 seconds. ○ Estimated time: 45 seconds
  - ○ Number of operators: 1 person
- Activity 8 - Quality control
  - ○ Action: check if all steps were completed, count the number of pieces and the color of Production E, there should be 7. Count the number of pieces and the color of Production P, there should be 10 and a different color from Production E. When joining the two letters, you should check if the colors of the 3 pieces are different from those used in the letters and that there is no repetition.
  - ○ Estimated time: 1 minute
  - ○ Number of operators: 1 person
- Activity 9 - Stocking
  - ○ Action: pick up the finished pieces and put them in stock.
  - ○ Estimated time: 1 minute
  - ○ Number of operators: 1 person

Stage 1 of the game application: instructions for assembling the product

o The letter E must be made of 7 LEGO pieces.

o The letter P must be made of 10 LEGO pieces of a different color than the letter E;

o Both must be the same height and always fit one piece at a time during assembly.

o They must be joined by three different colors than those used in the letters without repeating them.

o In the first stage, activities 4 and 5 must be carried out in sequence, one after the other.

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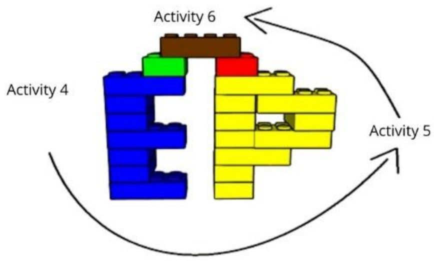
Figure 6 - Product assembly



Source: Development by authors (2024)

Stage 1 of the game: number of people

In order for the game to be carried out, ten people are suggested, namely:

- one manager (teacher) who can propose problems to the game and make adaptations, as well as demand solutions from the students;
- one person responsible for the warehouse: responsible for activities 1, 2, and 9;
- five people for the production processes: responsible for activities 3, 4, 5, 6, and 7;
- one person responsible for quality: responsible for activity 8;
- two people responsible for timing.

Stage 1 of the game: cycle time and lead time

After the students have familiarized themselves with the game and all the activities have been explained, they must repeat the production process until all the times are recorded during the observation of the students responsible for timing the processes. Therefore, students must have encountered something similar to Table 1.

Game application step 1: cycle time and lead time

After familiarizing the students with the game and explaining all the activities, the students should repeat the production process until all the times are recorded during the observation of the students responsible for timing the processes. Therefore, the students should have found something like Table 1.

Table 1 - Cycle time and lead time simulation

Cycle time and lead time simulation				
Activity	Cycle time			
	Measure 1	Measure 1	Measure 1	Time average
Activity 1	2’50”	3’10”	3’	180”
Activity 2	1’05”	1’	55”	60”
Activity 3	55”	1’05”	1’	60”
Activity 4	21”	19”	20”	20”
Activity 5	29”	31”	30”	30”
Activity 6	24”	25”	26”	25”
Activity 7	45”	45”	45”	45”
Activity 8	4’03”	4’	3’57”	60”
Activity 9	1’	55”	1’05”	60”
Lead time	-	-	-	540” = 9’

Source: Development by authors (2024)

At this point, the teacher must ensure that students have understood the concepts of cycle time and lead time by observing the processes in practice, thus enabling the game to continue.

Stage 2 of the game application: takt time

With stage 1 completed and the student's understanding of cycle time and lead time, the manager should propose the following situation where the demand forecast for the month is 110 units of the product, considering that the company works 22 days per month and that the work shift lasts 30 minutes, where during this time there is a 5-minute coffee break and another 5-minute break for cleaning the premises. Based on the previous data, propose the calculation of takt time.

- About the work routine:
  - 30-minute shift;
  - 5-minute coffee break;
  - 5-minute cleaning of the premises at the end of the workday.

Table 2 - Calculation of net operational time for takt time

Operational Time	
Activity	Time
Half hour shift	30 minutes
Coffee	5 minutes
Cleaning	5 minutes
Net operating time/day	20 minutes

Source: Development by authors (2024)

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Considering the monthly demand of 110 units and that there are 22 working days in a month, we have that five units must be produced each day, therefore:

Takt time = time available for production/demand

Takt time = 20 minutes / 5 units

Takt time = 4 minutes per unit; a finished product must be produced every 4 minutes.

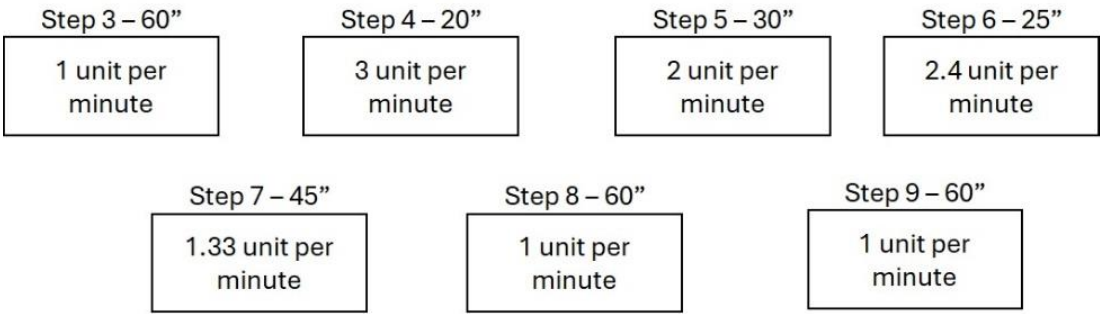
Based on the proposed problem, students reinforce the concept of takt time and identify the difference in cycle time and lead time.

Stage 3 of the game application: production mapping

In this stage, students must gather information to be discussed in the next stage. They can perform the current stage in several ways, including mapping the value stream, analyzing the processes that add value to the product, mapping the factory layout, and calculating costs according to the data listed below. From this, students are expected to construct information similar to that found in the current section, thus fostering the next stage of the game.

This information can highlight the production system's imbalance, starting from Figure 9, which considers the ratio of units per minute of activities 3 to 9. This cycle can be called production lead time because it is the time used to transform raw material into a product.

Figure 7 - Activities with cycle time



Source: Development by authors (2024)

When addressing costs, the following data can be used:

- About the sale of the product:
  - Sales price: $1,300 per unit;
  - Sales tax of 10%;
  - Commission paid to sellers of 2%;
  - Estimated annual sales of 1,296 units.

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● Raw material (LEGO pieces):

○ Price of pink color: $15 per unit;

○ Price of blue color: $15 per unit;

○ Price of white color: $20 per unit;

○ Price of yellow color: $20 per unit;

○ Price of other colors: $25 per unit. ● About labor:

○ Production operators were considered direct costs involved in activities 3, 4, 5, 6, and 7, where the value is $30 per minute. In addition, the value of the variable cost and expense per product is $10;

○ Operators of the other activities are included in other fixed costs and expenses, where the annual value is $64,800.

With this, students develop information to be questioned and discussed in the next stage about executing the activities and the costs involved, as in tables 3, 4, and 5.

Table 3 - Data for calculating EP product costs

Data for calculating EP product costs					
Selling price un	Variable costs and expenses per unit	Commissions paid to sellers	Sales Taxes	Annual fixed costs and expenses	Sales estimate for the year
$1300	Raw material $380 + direct labor $450 (3'*$30*5) + $10 other variable costs = $840	2%	10%	64.800$	1296 un

Table 4 - Calculation of the contribution margin of the EP product

Calculation of the contribution margin of the EP product	
Unit contribution margin	%
=1300$ - 840$ - (1300$ * 0,02) - (1300$ * 0,1) = = 304$	23,38

Tabela 5 - DRE do produto EP

DRE statement for the EP product using the variable costing format for the estimated sales quantity	
Gross revenue	= 1300$ * 1296 un = 1.684.800$
Taxes	= 1.684.800$ * 0,1 = 168.480$
Commissions	= 1.684.800$ * 0,02 = 33.696$
Variable costs	= 840$ * 1296 un = 1.088.640$
Net revenue	= 1.684.800$ - 168.480$ - 33.696$ - 1.088.640$ = 393.984$
Fixed costs and expenses	= 64.800$
Net profit	= 329.184$

In addition, the following suggested indicators facilitate assessments and comparisons:

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● Check the amount of in-process inventory;

● Cost of in-process inventory = (amount of in-process inventory + quantity in shipment) x production cost;

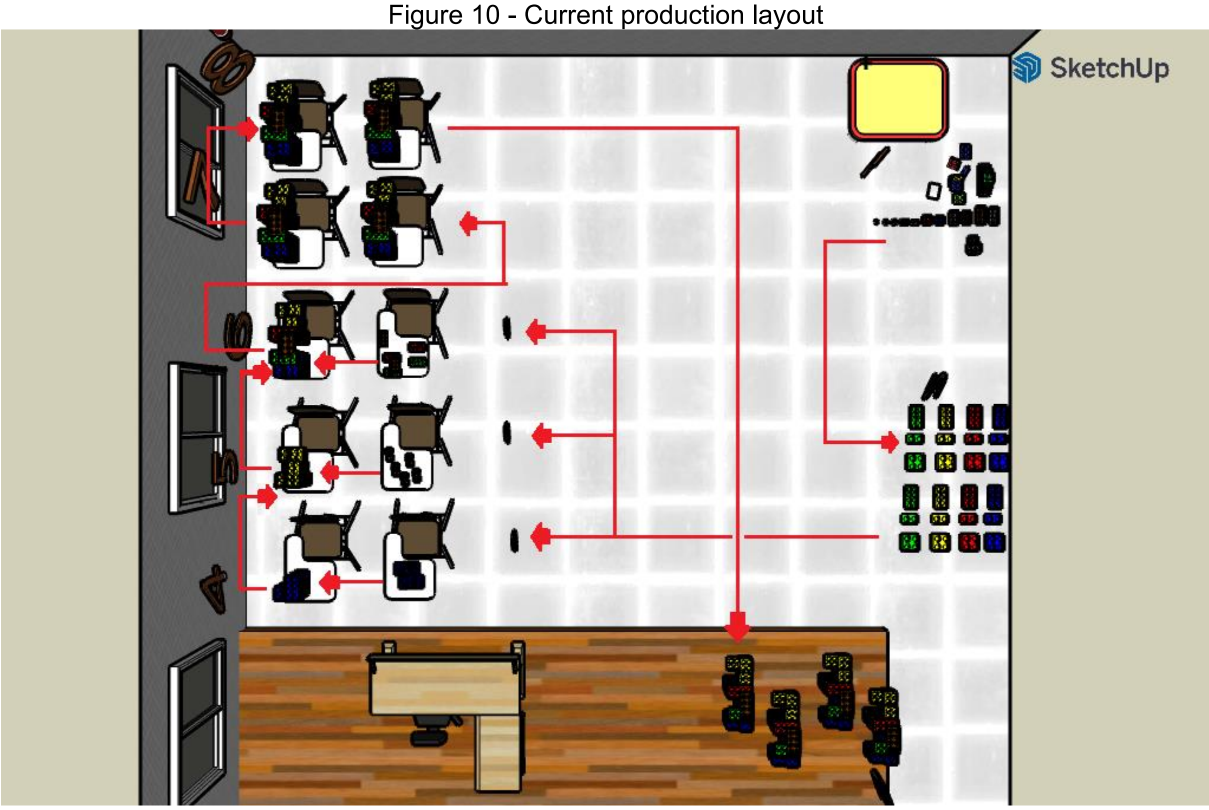
● Cash generation = sales - raw material expenses;

● Rejection rates = quantity of defective products / total quantity produced;

● IROG = (Takt time/cycle time) or (quantity produced / production capacity).

As for the organization and sequence of activities, in addition to the number of operators, Figure 10 allows the visualization of the production layout and is intended to provide better discussions on these subjects.

Figure 10 - Current production layout



Etapas 4 e 5 da aplicação do jogo: discussão e implementação

A partir do mapeamento do estado atual da produção e do cálculo de custos, os alunos irão discutir sobre possíveis melhorias na finalidade de fazer um mapeamento do estado futuro para otimizar processos e custos, discutindo as informações construídas pelos discentes na seção anterior, as quais podem ser o layout de produção, o modo de desenvolver algum processo, balanceamento, entre outros, além de selecionar e organizar as cores das peças que são a matéria-prima para produção do produto com um menor custo, sendo que a ideia para diminuir os custos da matéria-prima se baseia em substituir

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as peças amarelas utilizadas na letra P por peças da cor rosa e também mudem duas cores das peças que são utilizadas para juntar a letra P com a letra E, utilizando uma peça de cor branca, outra de cor amarela e por fim uma qualquer cor que ainda não tenha sido usada.

DISCUSSION OF RESULTS

Based on Mizukami's (1992) vision, which is based on authors such as Piaget and Bruner, the game seeks to foster the possibility of learning on one's own through teaching based on trial and error, research, investigation, and problem-solving in which the student is provided with tools that enable them to experiment to learn, thus making, in their way, the relationship between acquired knowledge and experiences and practices, making it possible to develop their intelligence, using the environment of the game model and its application in more than one phase to structure teaching. Furthermore, the game's development uses mainly two approaches that are present in the classification of Kanakana-Katoomba and Maladzhi (2019), the experimental and the problem-based, thus creating a combination to have students put into practice what was learned theoretically and also solve problems according to what was taught, creating an environment in which the teacher can conduct and structure the teaching, playing the role of manager and where students are the builders of their knowledge, where they are practitioners, analysts and holders of the power to provide solutions.

The concepts of takt time, cycle time, and lead time are related to a production system, according to Alvarez and Antunes Jr (2001) and Tubino (2000). Therefore, the game's proposal with a cognitivist approach is that they are taught in this context, providing a relationship of how and why such definitions are applied. The game's first stage proposes that students interact with the environment to understand the activities and time themselves, thus creating first contact with their organization. From this point on, the concepts become evident, including their differences, because when carrying out the activity, students can reinforce the definitions according to the execution and visualization in practice. In the second stage, a problem proposal about takt time is presented. In this sense, students can understand the relationship between the concept and the demand, which had only been addressed in the previous stage, thus building another part of the knowledge. When the third stage is indicated, in addition to reinforcing the definitions that were explained previously, there is a deepening of the information, starting from a grouping of experiences such as inventory in the process, number of operators in the production process, costs, productivity, production layout, among others that can be discussed and that seek to highlight problems fundamentally through the concepts seen so far. When the student is inserted into an environment similar to that found in companies, this is the moment in which the student is challenged to think and propose changes, thus practicing the new concepts and activating previous learning. Based on this, the fourth stage is carried out in groups, where students share their understandings and exchange information, consequently broadening the students' vision in relation to problems and solutions. Finally, in the last stage, students put into practice what they planned, thus realizing possible mistakes, difficulties, successes, or facilities.

FINAL CONSIDERATIONS

At the beginning of the research work, it was found that during the academic training of students, teachers are required to seek new teaching strategies to provide a better cognitive environment, since there are subjects that require a relationship with reality so that the knowledge being presented is absorbed more easily and efficiently, considering that students do not have any professional experience. For this reason, games were used as a teaching tool. From this, the research had the general objective of developing a game with a cognitive approach to enhance students' learning on production engineering topics. Given this, it is observed that the objective was met because the work managed to build elements for developing a game with a cognitive environment focusing on production and operations management and takt time, which are topics in production engineering. As for the specific objectives, the first objective was to identify concepts and practices of the cognitive teaching approach, which was achieved, thus serving as support and as a guide in defining the stages for the game's development. The second objective was also achieved, as concepts enabled the context of the activity and involved production engineering with a focus on production and operations management, which took time. In addition, it was found that the third objective was also achieved, given that a game model was developed as a methodology for developing production engineering concepts, being production and operations management and taking time.

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RESEARCH LIMITATIONS

Given the strategic basic research method with descriptive characteristics and bibliographic procedures, with a qualitative approach and deductive method of the main authors consulted, which are Mizukami, Piaget, Kanakana-katumba and Maladzhi, Corrêa and Corrêa, Iwayama and Haydt, the work could be carried out with a broader search in the bibliography, as well as involving more concepts related to the teaching of production engineering, in addition to carrying out activities closer to the students, for example using questionnaires on preferences for forms of game applications for educational purposes. It is also worth noting that the lack of application of the game hinders the analyses, which should be effectively validated, given that the research was carried out during a pandemic and that the time to carry out the work was limited.

SUGGESTIONS

The game seeks to provide examples of applications that can be carried out. Still, it is worth noting that the teacher should not limit himself to them and use them to propose more challenges to the students through adaptations made by the teacher when planning the execution of the game. Here are some topics that can be worked on: takt time, lead time, cycle time, value stream mapping, costs and expenses, kanban, 5s philosophy, production layout, poka yoke, quick tool change, 5W2H, PDCA cycle, five whys, Ishikawa diagram, scatter diagram, Pareto diagram, flowchart, histogram, check sheet, control charts, quality indicators, document management, economical purchase lot, safety stock, demand forecasting, among others. In addition, the study can also be applied in the professional environment as a strategy for in-service training and team training.

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