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VIRTUAL REALITY IN ENGINEERING EDUCATION: APPLICATION OF SCENARIOS TO PRODUCTIVE LAYOUT

REALIDADE VIRTUAL NO ENSINO DE ENGENHARIA: APLICAÇÃO DE CENÁRIOS AO LAYOUT PRODUTIVO

REALIDAD VIRTUAL EN LA EDUCACIÓN DE INGENIERÍA: APLICACIÓN DE ESCENARIOS AL DISEÑO PRODUCTIVO

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ABSTRACT
This article discusses the teaching-learning methodologies associated with the use of virtual reality (VR) technologies applied to the development of concepts related to the productive layout. In this way, the main points about pedagogical approaches and their needs are presented, as well as the impact of the use of VR technologies and their applications, it is also discussed the opportunities to approach the referred content and focuses on in its application in the concepts of physical arrangement. Finally, an application model of the theme is elaborated with three layout scenarios applied to the productive process of manufacturing components, their characteristics, which, with some brief analyses, significant reductions of up to 54% among the applied models can be seen. Its breadth, applicability, feasibility for the educational context is also argued.

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Keywords: Virtual Reality in Engineering Education. Interactive Scenarios for Productive Layout. Educational Technology in Engineering.

RESUMO
Este artigo discute as metodologias de ensino-aprendizagem associadas ao uso de tecnologias de realidade virtual (RV) aplicadas ao desenvolvimento de conceitos relacionados ao layout produtivo. Dessa forma, são apresentados os principais pontos sobre abordagens pedagógicas e suas necessidades, bem como o impacto do uso de tecnologias de RV e suas aplicações. São discutidas também as oportunidades de abordagem do conteúdo em questão e o foco em sua aplicação nos conceitos de arranjo físico. Por fim, é elaborado um modelo de aplicação do tema com três cenários de layout aplicados ao processo produtivo de fabricação de componentes, suas características, que, com algumas breves análises, permitem constatar reduções significativas de até 54% entre os modelos aplicados. Sua amplitude, aplicabilidade e viabilidade para o contexto educacional também são discutidas.

Palavras-chave: Realidade Virtual no Ensino de Engenharia. Cenários Interativos para Layout Produtivo. Tecnologia Educacional em Engenharia.

RESUMEN
Este artículo analiza las metodologías de enseñanza-aprendizaje asociadas con el uso de tecnologías de realidad virtual (RV) aplicadas al desarrollo de conceptos relacionados con el diseño productivo. Se presentan los principales enfoques pedagógicos y sus necesidades, así como el impacto del uso de las tecnologías de RV y sus aplicaciones. También se discuten las oportunidades para abordar el contenido en cuestión y se centra su aplicación en los conceptos de diseño físico. Finalmente, se elabora un modelo de aplicación del tema con tres escenarios de diseño aplicados al proceso productivo de fabricación de componentes y sus características, que, tras un breve análisis, permiten observar reducciones significativas de hasta el 54% entre los modelos aplicados. También se argumenta su amplitud, aplicabilidad y viabilidad en el contexto educativo.

Palabras clave: Realidad Virtual en la Formación en Ingeniería. Escenarios Interactivos para el Diseño Productivo. Tecnología Educativa en Ingeniería.

Revista ARACÊ
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INTRODUCTION

The process of knowledge formation and learning takes place from the earliest years to the end of a human being's life and it is directly based on the action of the subject as a trainer of this learning and/or of his interaction with the environment in which he is involved (Werneck, 2006). According to Kaliská (2014), the formation of this knowledge can occur in several ways, such as: practicing, listening, visualizing, discussing, among others.

Applying these notions to current educational guidelines, it can be seen that among the various theories of pedagogical approaches, Gil, (2010) demonstrated that the cognitivist approach, which unites students and teachers through a process of greater interaction, gives priority to the student so that this become the centre of your learning process, actively, thus privileging mental processes and cognitive skills.

With this, the rapid expansion of the use of information and communication technologies (ICT), through digital media, has made the use of virtual reality (VR) techniques a disseminator of information, knowledge with global applicability (Martins, 2016). Despite this, there is a growing use of these technologies as a support in teaching, since these tools allow the breaking of geographic limits and enabling the presence and interaction at a distance, as well as, allowing the simulation of different environments in a similar way. to computer games, providing its user with the possibility of emulating a real experience (Cardoso et al., 2013; Guimarães & Martins, 2014).

Therefore, this need for constant and autonomous updating and learning combined with the high globalization of products, services and relationships becomes an engine for the development and use of more agile and active educational tools, in order to promote the formation of these citizens (Takeuchi & Nonaka, 1997), corroborating the approach and methodological practices mentioned above. In this context, a highly viable option is the use of virtual reality (VR) techniques, which generates this learning condition in a virtual environment, providing opportunities for the student's cognitive performance, in the training of production engineering professionals with the skills and abilities necessary (Anjos et al., 2020).

Anjos et al. (2020) present, in their study, the application of the use of virtual reality (VR) in areas of engineering education, whose results in the teaching-learning process have been growing in recent years. This already has applicability among the various areas of knowledge, such as: emergency simulations (Lerner et al., 2020), science teaching (Liu et al., 2020), development of children's skills in preschool (Lorusso et al., 2020), clinical

Revista ARACÊ
ISSN: 2358-2472

neuroanatomy (Elmansouri et al., 2020). However, the research shows that its use within production engineering had a total of 4 studies, at the time of the research, these studies being in the areas of: supply chain simulation (Chang et al., 2018), analysis of production flow (Laseinde et al., 2016), training of concepts and methods on lean manufacturing (Cudney et al., 2011; Gamlin et al., 2014).

Thus, bearing in mind the definitions presented on the formation of knowledge, the perception of the importance of teaching-learning environments with cognitive approaches, the opportunities for developing new methodologies with the application of virtual reality and its applications in production engineering courses , the importance of learning the concepts of physical arrangement, as well as the need to develop more studies in the area, since there are very few studies on the application of this tool within production engineering courses, there is a need to explore this , together with the theme, as a way of answering the question: What is the applicability and which concepts of physical arrangement (layout) can be developed with the use of virtual reality (VR) techniques, in the teaching-learning process for the area of production engineering?

This work aims to discuss assumptions of the model and application scenarios of virtual reality for teaching methodologies of physical arrangement with a focus on the identification and reduction of losses due to movement, to demonstrate the applicability of its use and how they support the development of knowledge.

This study is justified, first, in the small number of studies presented in the area, as well as in the importance of using these technologies in teaching-learning didactics, in the definition of pedagogical strategies and their impacts on the development of better able and prepared to work in the job market, improving competitiveness in companies (Anjos et al., 2020). For this, it is based on the facts shown, in which the use of these VR technology tools present positive results in the retention of the level of knowledge, in approximately 55% (Laseinde et al., 2016), corroborating the theory that the students learn more this way (Inayat et al., 2016). Therefore, this work will present the sections on theoretical framework, methods and materials, results, discussion of results and conclusion.

Revista ARACÊ
ISSN: 2358-2472

THEORICAL BACKGROUND

TEACHING-LEARNING APPROACHES TO THE APPLICATION OF VIRTUAL REALITY

Didactics needs to be committed both to cognitive issues and to the development of student thinking. In the teaching-learning process, it is necessary to train thinking subjects, capable of interpreting scenarios, information, and solving problems (Gil, 2010).

One of the approaches used is the cognitivist, which refers to the interaction between subject and object. In this approach, based on trial and error, research and problem solving, the student should be given the opportunity to carry out investigations and not simply receive formulas and nomenclatures. This strategy supports the development of autonomous, critical and creative thinking (Mizukami, 1992). In this cognitive approach, students need to participate strongly in their own learning, through research, experimentation, group work, stimulation of the challenge, development of reasoning and constant search for knowledge, as the answers are not ready and unique. To contemplate this investigative model, however, the teacher needs to work with didactic approaches that strengthen the investigative role of the student in his preparation to think (Gadotti et al., 1995).

The application of virtual reality has been supporting teaching-learning environments with the cognitivist approach. Virtual reality can create virtual environments that can be used in different ways. It is characterized by the interaction between man and machine in virtual environments (Lamb et al., 2018).

Schlemmer & Backes (2015) state that experiences with virtual reality bring new sensations and virtualization generates an environment very close to reality. This digital technology contributes to the concepts of presence and immersion, acting with interaction, acting directly on the students' cognitive issues, facilitating their understanding and interaction with the environment, being such concepts essential for learning.

Examples of the application of virtual reality in teaching-learning processes in various areas of knowledge, such as Anatomy (Shin et al., 2022) Medical emergency (Behmadi et al., 2022), Psychology (Huang et al., 2022), veterinary medicine (Vega-Garzón et al., 2022), primary education (Innocenti et al., 2019) and manufacturing processes (Chen et al., 2019)

Anjos et al. (2020) describes that the application of virtual reality in teaching-learning processes increases student learning rates and that the application of technology acts cognitively and accelerates the teaching-learning process. In 60% of cases, in engineering

Revista ARACÊ
ISSN: 2358-2472

education processes, the application of virtual reality generates greater learning for students and 96% positively impacts student satisfaction rates with the application of virtual reality in teaching-learning processes learning (Anjos et al., 2022).

LAYOUT OF PRODUCTION SYSTEMS

Production engineering is an area of knowledge derived from mechanical engineering, so they have a common focus, so much so that around the world, it is also known as industrial engineering or manufacturing engineering. In Brazil, ABEPRO (2008) defines the fields of activity of the engineer and presents them as: 1) Operations engineering and production processes; 2) Supply Chains; 3) Operational Research; 4) Quality Engineering; 5) Product Engineering; 6) Organizational Engineering; 7) Economic Engineering; 8) Work Engineering; 9) Sustainability Engineering; 10) Education in Production Engineering.

The physical arrangement or layout of the production system is a sub-item of operations engineering and production processes, and this subject is a key area for organizations, as this, being well designed and executed, acts directly on cost reduction. operations, in addition to resulting in increased productivity and process efficiency (CONFEA, 2014).

Other factors have a direct impact with the realization of a well-structured physical arrangement, such as: flow of materials and products improved with the reduction of handling time, ease of management and supervision, minimization of work accidents and the establishment of a more safe and stable (Slack et al., 2006; Sule, 2008).

Several authors describe that the physical arrangement is responsible for balancing the environment between the allocation of machines, equipment, materials and their functional use by people (Araujo, 2011; Muther & Wheeler, 2008; Slack et al., 2006). Corrêa & Corrêa (2007) describe the importance of studying and making strategic decisions about the physical arrangement of the operation, resulting in an increase in competitive advantages over the competition, as its application results in factors such as: space savings, reductions in unnecessary movements, inventory in process, manufacturing times, indirect costs, in addition to having a direct impact on perceived satisfaction, improvement in quality of life, among other ergonomic and occupational health factors. Another relevant factor is that the layout definition depends on and directly influences the flows of production systems, and must integrate all resources, materials and processing, in a logical and orderly manner in order to guarantee the productive efficiency of the applied medium (Caicedo et al., 2019).

According to Corrêa & Corrêa (2007), the way in which machinery and resources are organized within any company are basically divided into 4 models, namely:

1) Positional or fixed: when the product remains fixed, and the resources are arranged or taken to the place of production. For example: the construction of a ship or a building.
2) Functional or by process: when activities are grouped according to the functions performed. In this model, the material is moved to the processing locations. For example: Machining sector in a factory, department stores or the sectors of a hospital.
3) In line or by product: when processing requires a linear sequence of operations, with a high flow of products and standardization of these same items. In this model, the material is moved to the processing locations. For example: A car manufacturer, a foundry, or a chemical company.
4) Cellular: when different machines are grouped together to allow the production of small batches or medium batches of items with medium variety. This model is an intermediary between the arrangement by process and arrangement by product, also having the movement of material to the processing sites. For example: a manufacturing cell for a computer component or a maternity hospital in a hospital.

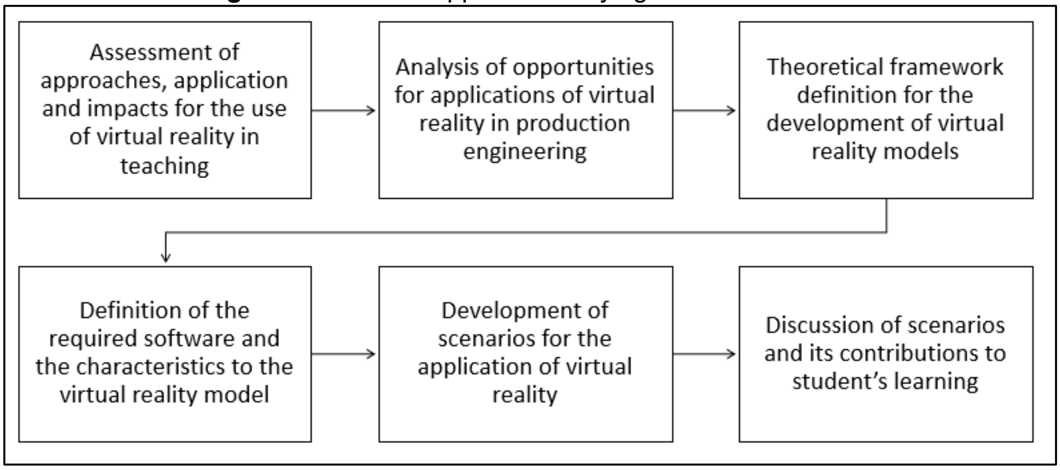
Observing what is described about layout, one can see the relevance of the theme for the formation of a production engineer, because analyzing the possibilities of a real simulation of the physical arrangement of a factory, this one uses expressive values for its realization, as well as, makes it necessary to analyze and calculate times and flows, hiring cargo handling companies (due to the weight of the equipment), changing the routines of workers, among other factors impacting the realization of the adequacy of a new space (Freitas et al., 2019).

METHOD

To carry out this study, the model presented Anjos et al. (2021), the steps will be organized and performed according to the scheme below, in Figure 1.

Revista ARACÊ
ISSN: 2358-2472

Figure 1 – Method applied in carrying out the research.



Source: Adapted from Anjos et al. (2021)

Steps 1, 2 and 3 are described in the introduction and theoretical background sections. Step 4 of the method was separated into two steps: definition of the model characteristics and which software to use, as shown below. A basic manufacturing model was proposed and, together with that, three scenarios will be proposed, referring to the types of productive arrangement (functional, cellular, fixed). These will have a combination of guidelines: physical arrangement of furniture and material/product/people movement since the model will focus on movement losses. Other factors such as the number of stations and degree of use will not be addressed at this time, as a way of simplifying the exercise. The indicators evaluated will be: distance travelled and delivery lead time, which can be verified through a spaghetti diagram (Werkema, 2011) and through the reports provided by the software itself. The movement of the part in the production process will be carried out by the operators themselves, in a walking way, with an average speed of 3.6 km/h or 1.0 m/s (Abril, 2021).

FlexSim® software (2021) will be used for the execution of the scenarios, as it has a robust interface and easy-to-use features, in addition to focusing on the scenario optimization test to find the best planning for them. The program allows the use of gadgets for immersion, such as viewing glasses or joysticks for moving and interacting with the virtual environment, as well as being used directly on the desktop, in a simpler way. In addition to the interaction tools with the program's interface, it is possible to register the process variables, as well as extract reports and graphs from the performed simulations, thus allowing the user to make a clearer comparison of the decisions made in choosing the models. The definition of the productive arrangement, as well as its simulated flow and the

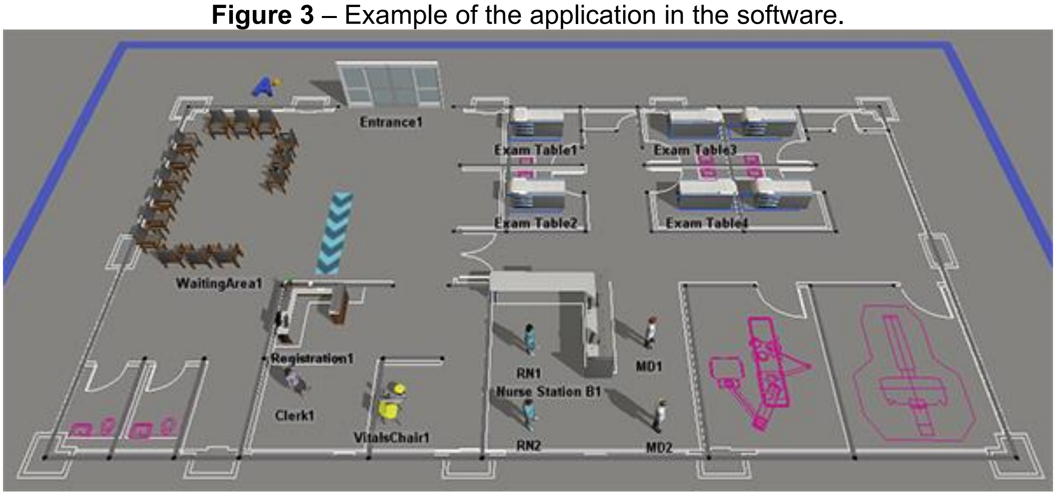
Revista ARACÊ
ISSN: 2358-2472

movement of materials and people can be verified in the images generated in virtual reality by the chosen software, as shown in Figure 2 and Figure 3.

Figure 2 – Layout model in the software.

Source: FlexSim (2021)

Figure 3 – Example of the application in the software.



Source: FlexSim (2021)

Step 5, on the proposals on the scenarios used to organize the physical arrangement, will be presented in the results section and, in step 6, the scenarios and their contributions are discussed in the results analysis section.

RESULTS

For the elaboration of a process model with defined rules, which will be applied in a physical arrangement analysis exercise with the focus of identifying losses due to excessive or unnecessary movement of materials. The defined model deals with the process of receiving four products from a supplier, which are identified with weight information and total

Revista ARACÊ
ISSN: 2358-2472

processing time for each material and weekly demand. The information is available in Table 1.

Table 1: Information of the parts applied in the model

Parts Information			
	Weight (kilograms)	Part processing time (seconds)	Weekly demand (units)
Part A	3,08	900	200
Part B	5,12	44460	60
Part C	4,30	1200	100
Part D	2,80	1380	50

The parts go through some processing steps (manufacturing), according to the scripts presented in Table 2. The parts are removed directly from the warehouse and, after ready, are taken to the final stock. The numerical sequence indicates the order of manufacturing steps.

Table 2: Information of the parts applied in the model

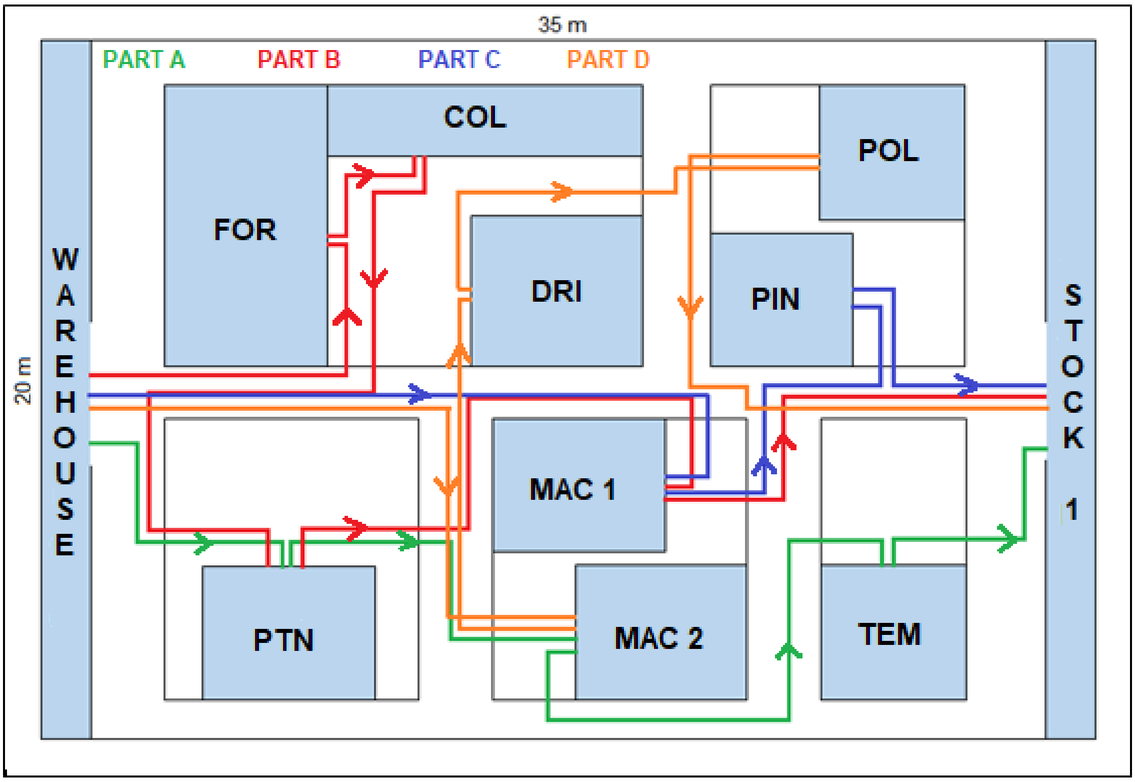
Parts manufacturing routine								
	Forging (FOR)	Cooling (COL)	Pre-Thinning (PTN)	Machining (MAC)	Drilling (DRI)	Tempering (TEM)	Painting (PIN)	Polishing (POL)
Part A	-	-	1º	2º	-	3º	-	-
Part B	1º	2º	3º	4º	-	-	-	-
Part C	-	-	-	1º	-	-	2º	-
Part D	-	-	-	1º	2º	-	-	3º

The purpose of applying this model is to demonstrate to the student the influence of the physical arrangement on the losses from material movement, so there is an intentional modification of these scenarios, with new provisions, so that these new provisions of machinery and their impacts can be verified. . For this, three scenarios of a factory measuring 35 x 20 m will be simulated. Among these scenarios, there is the movement of parts by the operators, according to the defined process. However, manufacturing-related movements, such as: placing and removing the part in the machine, measurements, among others of lesser impact, will not be considered. With this, the estimated movements are verified, given the dimensions of the factory. In the first model, the machines are separated

Revista ARACÊ
ISSN: 2358-2472

by similarities in their process, that is, similar processes are close together in a similar format to the functional one or by processes, as shown in Figure 4.

Figure 4 – Scenario 1 proposed to evaluate the impact of the layout on the indicators of distance travelled and material handled.



Considering scenario 1, there is a large movement of parts through the factory, the movement flow of these is disordered and they end up traveling longer distances, according to data estimated in Table 3.

Table 3: Estimated distance covered by each part

Scenario 1	
Part #	Travelled distance (meters)
Part A	54,5
Part B	89,5
Part C	53,0
Part D	80,5

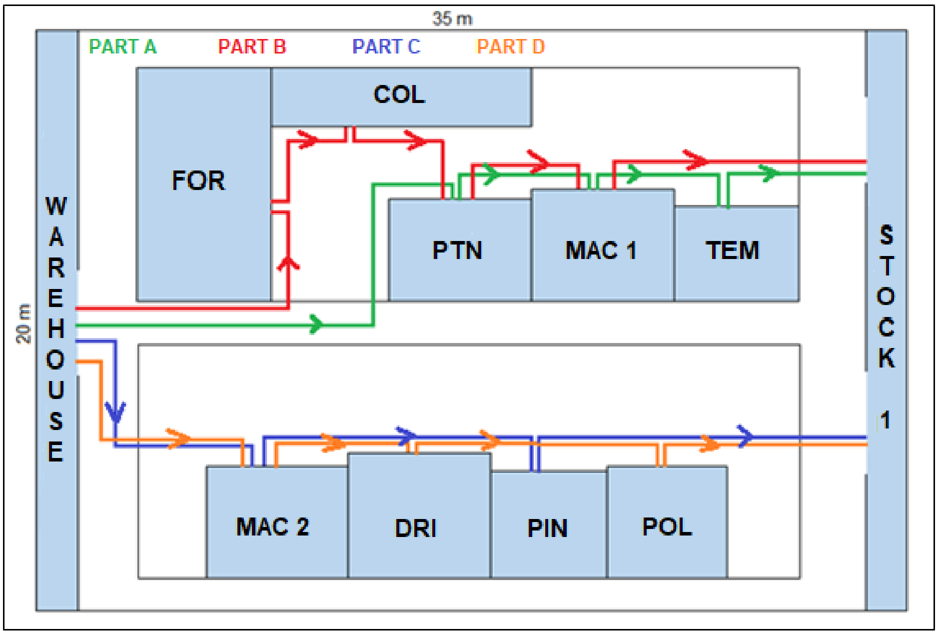
Revista ARACÊ
ISSN: 2358-2472

The virtual reality models applied with the information from scenario 1 can be seen in figure 5.

Figure 5 – Scenario 1 proposed in virtual reality.

In the second proposed scenario, the machines are arranged according to the sequence of the process to which the parts are subjected. The machines that carry out the processes at each stage are close together or together in a model with the logic of a layout arrangement by product or in line, as shown in Figure 6.

Figure 6 – Scenario 2 proposed to evaluate the impact of the layout on the indicators of distance travelled and material handled.



Revista ARACÊ
ISSN: 2358-2472

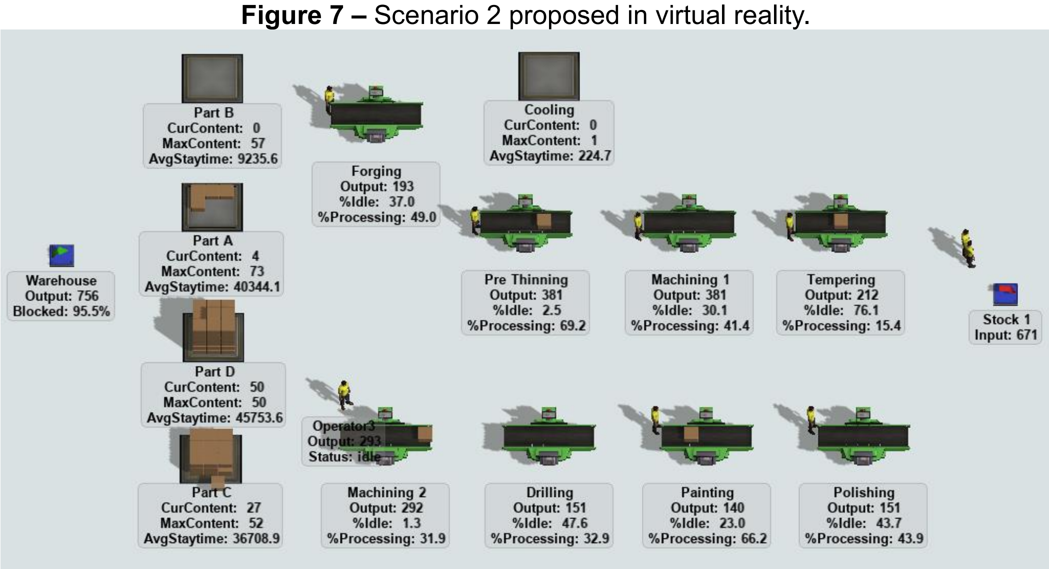
In scenario 2, the parts have a smaller movement between the processes, which is more organized and cohesive than the first one and the estimated distances covered by each part can be seen in Table 5.

Table 4: Estimated distance covered by each part

Scenario 2	
Part #	Travelled distance (meters)
Part A	44,5
Part B	49,5
Part C	44,0
Part D	42,5

The virtual reality models applied with the information from scenario 2 can be seen in figure 7.

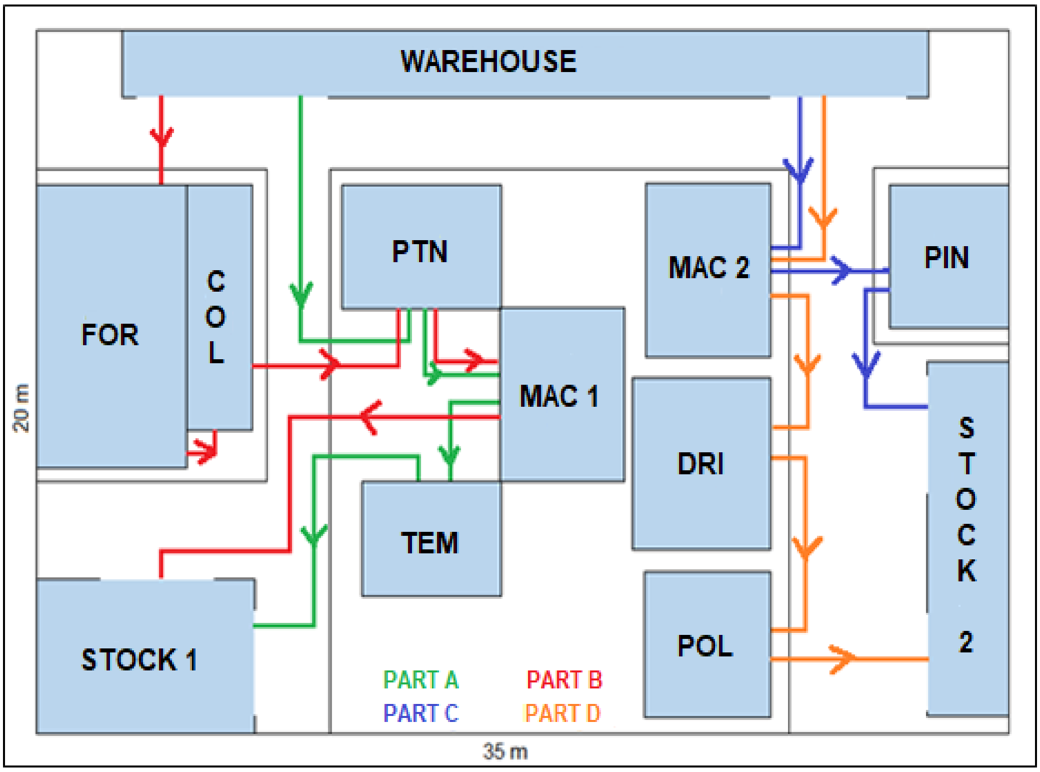
Figure 7 – Scenario 2 proposed in virtual reality.



In the third and last scenario, the inversion of the longitudinal direction of the previous scenarios was proposed, with the processes closer and with a cellular logic in a part of the production, as shown in Figure 8.

Revista ARACÊ
ISSN: 2358-2472

Figure 8 – Scenario 3 proposed to evaluate the impact of the layout on the indicators of distance travelled and material handled.



In scenario 3, the movement of parts was lower than in the longitudinal models, due to the processes being closer and, some, being grouped due to the low variability of products. The estimated distances covered by each part are shown in table 5.

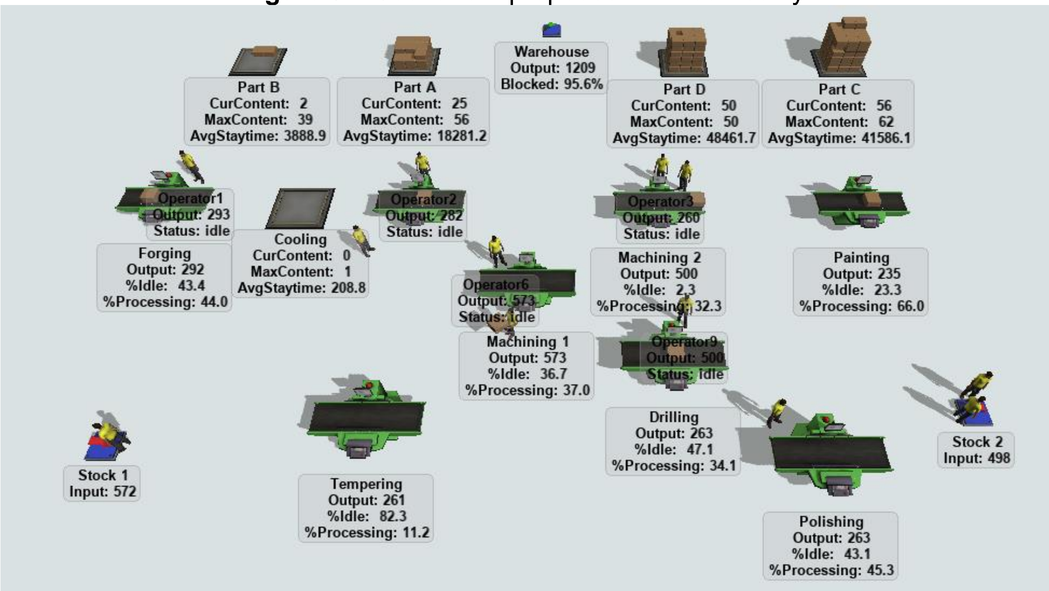
Table 5: Estimated distance covered by each part

Scenario 3	
Part #	Travelled distance (meters)
Part A	32,5
Part B	35,0
Part C	17,5
Part D	28,5

The virtual reality models applied with the information from scenario 3 can be seen in figure 9.

ISSN: 2358-2472

Figure 9 – Scenario 2 proposed in virtual reality.



The modelling of the scenarios in the FlexSim® software were assembled and meet the proposed models, so that the practical application of virtual reality is verified, which can be used directly in the classroom, with the possibilities of visualization of the simulation of the proposed experiments, including in first person, which allows the usability of the tool in an immersive way with the use of appropriate peripherals.

ANALYSIS OF RESULTS

For the purposes of movement analysis, the distance covered by the parts in the production process is evaluated, which varies greatly between the applied scenarios. Considering the weekly demand multiplied by the distance that a piece travels, the highest values are found in scenario 1, followed by scenario 2 and, finally, by scenario 3, which presented the lowest value of all, data presented in Table 6.

Table 6: Weekly movement of each part model

Total weekly movement per part model (meters)			
#	**Scenario 1**	**Scenario 2**	**Scenario 3**
Part A	10.900,0	8.900,0	6.500,0
Part B	5.370,0	2.970,0	2100,0
Part C	5.300,0	4.400,0	1.750,0
Part D	4.025,0	2.125,0	1.425,0
Average movement of parts per scenario	6.398,75	4.598,75	2.943,75

Revista ARACÊ
ISSN: 2358-2472

Considering an average of the values of each model applied, there is approximately a 28% reduction in distance from the first to the second scenario, 54% from the first to the third scenario and 36% from the second to the third scenario, or that is, it is possible to perceive that the readjustment of the layout impacts the distance travelled by the parts in the production model.

Another possible analysis is that the load can be verified to meet the weekly demand, which must be applied for ergonomic decision-making purposes. Table 7 shows the cargo handled by multiplying the weekly demand with the weight of each part.

Table 7 – Cargo handling to meet weekly demand.

Weight Moved of parts weekly (kilograms x meters)				
	Weight (kilograms)	Scenario 1	Scenario 2	Scenario 3
Part A	3,08	33.572,00	27.412,00	20.020,00
Part B	5,12	27.504,00	15.206,40	10.752,00
Part C	4,30	22.790,00	18.920,00	7.525,00
Part D	2,80	11.270,00	5.950,00	3.990,00
Average movement of weight per scenario	-	23.784,00	16.872,10	10.571,75

With the data presented in table 7, considering part A in scenario 1, and if the operator moved all the parts from the beginning to the end of the process, during a week he would be transporting approximately 33 tons.

In addition, there is a reduction in cargo handling of 56% from the first to the third scenario, 29% from the first to the second scenario, and finally, 37% from the second to the third scenario. So, with adequate analysis, one can obtain information that goes beyond the information of the production process, entering areas such as occupational health and ergonomics, which are inherent and essential to the formation of the production engineer.

When evaluating the processing time and weekly demand, available in table 1 and the speed of material movement, performed by the operators themselves, in a walking way, with an average speed of 3.6 km/h or 1.0 m/s (Abril, 2021), it is shown in table 8 to project the leadtime for manufacturing for the proposed scenarios.

Revista ARACÊ
ISSN: 2358-2472

Table 8 – Analysis of production leadtimes for the evaluated scenarios.

Leadtime of batches of manufactured parts			
	Scenario 1 time (hours)	Scenario 2 time (hours)	Scenario 3 time (hours)
Part A	655,6	544,4	411,1
Part B	830,5	790,5	776,0
Part C	180,6	155,6	81,9
Part D	75,1	48,7	39,0
Average lead time per production batch	435,4	384,8	327,0

Analysing the data presented in table 8, it generates the possibility of estimating the time these items take to be processed, it is also noticed a 25% reduction in the average time, between the first and the third scenario, 15% between the second and the second scenario. third scenario and 11% between the first to the second scenario. This analysis is relevant, because through this information it is possible to assess whether the company will be able to deliver the order to the customer, generates the possibility for the manager to make a decision about dividing its production capacity into another third-party company, new hires, or about the need of opening extra work shifts, an essential topic to be demonstrated and discussed in the classroom for students (Slack et al., 2006).

These scenario modelling can even be worked on in classes on other topics, such as Programming, Planning and Production Control (PPCP), Production Management, Manufacturing Processes, Cost Management, given the impact these changes have on the physical arrangement causes in the company, or in indicators.

If the teacher chooses to adopt characteristics of involvement without interactivity to expose the content, this becomes easier for the student to visualize, since he will be able to see the model in operation, he will be able to compare the values through the program reports, being able to perform future calculations to improve these indicators. If the teacher opts for an involvement model with interactivity (Guimarães & Martins, 2014), access to the program can be released to make changes to the proposed model, allowing the student to apply the theory to modify it and bring new solutions, corroborating the ideals of the cognitivist approach (Mizukami, 1992).

It is also interesting to note that in the applied cases, there were relatively simple processes, in which each piece went through only one process at a time. However, the teacher can continue adapting these models during the course, inserting other indicators, allowing the student to grow in his knowledge with new calculations and analysis of other

Revista ARACÊ
ISSN: 2358-2472

factors that will impact the physical arrangement of the components in the production, such as: more machines in the production system, a necessary new process, addition of new products in the scenarios, increase or reduction of the manufacturing plant, projects to reduce expenses and costs or proposing different product demands

CONCLUSION

The application of virtual reality, in these examples of layout organization, can clarify the student in a way that approaches the real, without having to invest, without visiting the experiment site, generates the possibility of changing the arrangement and positioning, thus ensuring an active and agile assimilation of the content, as well as reinforcing the multidisciplinary of the various disciplines studied.

With this, it can be concluded that the applicability of the concepts of physical arrangement in the teaching-learning processes, through scenarios, is total when applied in a physical environment simulation software, which regardless of the characteristics (involvement, immersion, interactivity) , can be worked on for didactic purposes in the classroom. Among the concepts of physical arrangement, it was seen that organizational architecture, process flow modifications, adaptation to production layout models, distances, production times, the flow of material movement and some of their impacts, which the future production engineer needs to be aware of and master for the exercise of his/her function.

Revista ARACÊ
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