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DEVELOPMENT AND RECEPTIVITY OF AN DIDACTIC GAME (SERIOUS GAME) FOR TEACHING OF INDUSTRIAL FACILITY LAYOUT

Miguel Augusto Lobon Ruiz

Abstract: This study had the general objective of verifying the acceptance of the active methodology: game-based learning, through the development of the ar➔fi board game, supported by serious games design methods. Structured as action-research, the study is divided into two phases, in the first phase, data for game development is collected through a focus group, with the participation of students from two schools, in the second phase, the technique of content analysis, supported by the atlas.Ti 8 software, is used to analyze the answers to open-ended questions, the aim is to understand the students' perception of the educational objectives of the game. As a result, the game's construction is achieved in first phase with intense participation of the focus groups. In the second phase, a strong connection is established between the approval of the game as an instructional tool to support teaching, with the experience of the game in representing a facility layout system, where students could experiment and see the results of their actions, thus creating a meaningful learning opportunity. It is concluded that the ar➔fi game meets the premises of serious games design, and it is identified that the students recognized other important aspects of the game, such as: collaborative, dynamic, motivating, and fun, among other categories.
Keywords: Game-based learning; active teaching methodologies; serious games; facility layout.

INTRODUCTION

The General National Curriculum Guidelines for Technological Level Professional Education describe the need to promote teaching methodologies that go beyond the content model in order to promote the effective reduction of evasion and that develop in the student, in addition to technical, behavioral and social skills (BRAZIL, 2002).

In compliance with these guidelines, in the State of São Paulo, the Centro Paula Souza (CPS), creator and maintainer of the Fatecs, demonstrates this concern over the last few years, with the continuous offer of debates, seminars and training to teachers regarding the use of the active learning methodologies.

In the active methodology, the teacher must assume a role of facilitator and no longer content, proposing teaching techniques that lead students to the development of personal and professional skills, working collaboratively in the search, elaboration and solution of problems, using interdisciplinarity for this of the contents. Among the most used techniques are: problem-based learning, project-based learning, flipped classroom, collaborative learning, game-based learning, etc. (CAMARGO; DARUS, 2018).

Game-based Learning is increasingly present as an educational tool, with educational games (serious games) digital or analog (card games, paper games, board games, etc.) it is possible to work on educational content through the various game mechanics, motivating students in a playful way to solve problems and challenges, following rules and objectives in the search to achieve the best results or victory. Through games, students develop group work skills, overcome challenges, deal with failure and seek self-learning (BACICH, LILIAN; MORAN, 2017; TASPINAR; SCHMIDT; SCHUHBAUER, 2016).

Board games have long been found in applications at all levels of education, such as the classic Beer Game, created in the 1950s by the Massachusetts Institute of Technology (MIT), which simulates the behavior of a supply chain and even today surprises its creators with the involvement of students (DIZIKES, 2013).

The project for the facility layout of installations is similar to a toy for assembling

"puzzle" figures, where the problem is to position machines and equipment in the correct positions in order to obtain a continuous flow of products, with the shortest crossing times and lowest internal transportation costs, in addition to observing building, facility and regulatory restrictions. Therefore, it must be conducted by a professional who has, in addition to technical skills, also behavioral skills, to deal with the pressure of deadlines and responsibilities, and social skills, such as ease in interpersonal relationships.

These characteristics are too complex for students to assimilate only with theories, and taking students to visit real cases would be to observe a static moment of an action that involves several stages of design, planning and execution.

Within this context, this research had the general objective of verifying the acceptance of a board game, by technology graduation students, as an active methodology in teaching and learning the concepts of facility layout. Thus, the research sought to answer the following research question:

Is the board game, developed with the concepts of the game-based learning methodology, an instructional tool accepted by technology graduation students as a support for teaching and learning the concepts of facility layout?

And to help answer this question, the research had as a specific objective the development of a board game, the game called "AR➔FI", built collaboratively with the students, applying the iterative design the game was being improved session by session. session with the data collected from the interactions between the players (students) and the mediator (author of this research) through the focus group data collection method.

LITERATURE REVIEW

GAME-BASED LEARNING – GBL

According to PLASS; HOMER; KINZER (2015) the use of games as a means of learning presents an interaction of several characteristics of different theoretical aspects, such as motivational, cognitive, affective and sociocultural.

The motivational characteristic of games, created by numerous artifices in game mechanics, to reward and encourage players to continue playing for long periods is one of the most pointed characteristics for the effectiveness of games as a means of learning (LAMERAS et al., 2017).

This engagement of students to remain is presented on the cognitive aspect (mental processing), the behavioral aspect (posture and gestures) the affective aspect (emotions) and the sociocultural aspect (social interactions in a given context). In a game, the objective of these aspects is to lead the student to a cognitive process for effective learning (PLASS; HOMER; KINZER, 2015).

SERIOUS GAME DESIGN

According to Schell (2008), most games are composed of a tetrad of fundamental elements, where the meaning of each element plays a very important role in creating a game experience:

1. Mechanics: mechanics contain the rules, objectives of the game, number of players, or other elements that define the conditions of the game.
2. History: the history is a sequence of events connected linearly or not, pre-defined or created during the game, of the most varied themes and objectives.
3. Aesthetics: Aesthetics define the look and feel of the game and are an important element in stimulating the senses and supporting the story.
4. Technology: technology is any

resource that supports mechanics, where aesthetics is presented and the story can be told.

Kalmpoutzis (2018), adapting Schell's model, with the introduction of the pedagogical element, adapts the model to create game-based learning experiences. And in the same way, the designer of educational games must now try to balance all these elements in order to create captivating, motivating experiences that make people acquire new knowledge.

THE ITERATIVE DESIGN

According to Salen and Zimmerman (2012) iterative design is a process in which game design decisions happen with the experiences of playing the game itself. The necessary number of iterative cycles for the final development of the game is related to the complexity of the game and the return offered ("*feedback*") by people selected to participate in game test sessions ("*playtest")*.

FACILITY LAYOUT

The facility layout of an operation or process determines its appearance, that is, how its transforming resources are physically allocated and how its facilities are arranged. The facility layout also determines how products, people or services flow through the operation, and must support the operating strategy adopted by the company (SLACK; BRANDON-JONES; JOHNSTON, 2015).

Planning an facility layout involves decisions on how the transforming resources in an operation must be physically arranged, which can be machines, people, equipment, storage, and handling equipment, etc. Facility layout definitions are present in the operation of services, such as: restaurants, hotels, hospitals or in the manufacture of products in transformation and manufacturing industries. facility layout planning of processes within the operation has a direct impact on handling and storage costs, production costs and the productivity of machines and people (KRAJEWSKI; RITZMAN; MALHOTRA, 2009).

According to Heragu (2016), the facility layout must: Minimize the costs of transporting raw materials and finished products between the various departments; Be safe and preventive regarding the risks of accidents in the operation; Meet the legal requirements and standards of operation, work safety and ergonomics; Provide a suitable environment for the operation; Facilitate the flow of information and communication between people involved in the operation and Maximize the use of the area, mainly in the facility layout of warehouses and deposits.

The facility layout must generally minimize the extent to which materials and products flow through the operation's processes and must be clear to all involved. The flow is directly related to the type of manufacturing process and the volumes and varieties produced (SLACK; BRANDON-JONES; JOHNSTON, 2015). There are five general types of facility layout: product layout or line layout, fixed position layout, process layout or functional layout, cell layout or technology-based cluster layout, and hybrid layout.

METHODOLOGY

As a research method, Action Research was selected as a general approach for this research. According to Martins; Mello; Turrioni (2014, p. 183) "one of the qualitative research methods considered appropriate for use in Production Engineering".

Data collection took place in two moments, the first one during the construction of the AR➔FI game, using Focus Groups, which is a data collection method used in qualitative research in all fields of knowledge, which consists of gathering a small group of 3 to 10 people to debate, guided by a moderator, on a

certain topic (YIN, 2016).

For the construction of the game, the students were organized into two groups, the first group (initial group) with 20 students, for the development of the game, students from Fatec de Itatiba who had already attended the factory project discipline were selected and, therefore, had prior knowledge of the content covered by the game, facilitating the narratives that could improve the game throughout the sessions. The other group (table group) formed by 20 students from Fatec de Jundiaí, for game testing sessions with minimal interference from the moderator, in order to test the written rules and gameplay.

In the second moment, at the end of the sections, in order to investigate the students' perception in relation to the problem of this research, three open questions were applied individually to the participants of the initial group and the table group, in order to deepen the knowledge of the subject. collective feeling about the AR➔FI game:

Question 1: What did you think of the game to learn about layout?

Question 2: Do you think that through this game you can learn the concepts more easily?

Question 3: According to your view, does this game contribute to learning the topic of facility layout?

In question 1, we tried to understand how the students perceived the game, in relation to its elements and the experience of playing. In question 2 if the students recognized and accepted the game as an instructional tool and in question 3 if there was a connection between the experience of playing and the instructional objectives.

The "content analysis" technique was used to analyze the answers to the questionnaire about the students' perception of the game's proposal and its use as a tool to help them learn the content covered by the AR➔FI game.

According to Bernardes, Muniz and Nakano (2019) "In content analysis, a deductive strategy, the researcher questions data to substantiate previously defined ideas, arising for example from the theoretical review". This analysis technique is based on the interpretation of the meaning of the content of a message, a response to a questionnaire or an interview in written or oral form, and through the creation of "coding units" that represent this same meaning (hermeneutics) in other answers.

To identify the codes, which are the words and expressions that are most repeated and stood out in the responses of the 25 respondents to the questionnaire, and the codification of citations (excerpts from the answers), the use of the qualitative analysis software Atlas.ti was used., for the possibility of obtaining an academic license for this study.

Table 1 shows the definitions of codes used in the analysis.

PROVISIONS ON ETHICS IN THIS RESEARCH

Participants were guaranteed anonymity, privacy and confidentiality of the information collected. The research was approved by the Research Ethics Committee Professor Robison Baroni of UNITAU – ``Universidade de Taubaté``, under opinion number 3,395,920.

RESULTS AND DISCUSSION

THE DEVELOPMENT OF THE AR➔FI GAME

Five focus group sessions were held to develop the AR➔FI board game, which started with a prototype, with simple game mechanics present in commercial games made for leisure and entertainment.

The initial prototype of the game was presented to the "starter group" for discussion and collection of students' impressions about the components, game mechanics

Code	Comment
Learning	It shows the respondent's perception of the game to facilitate the learning of the theme.
Approval	Evidences in the response the statement, or interpretation, regarding the approval of the game for educational purposes
Well elaborated	Indicates that game elements created an enjoyable gaming experience.
Collaborative	It shows the respondent's perception of identifying the mechanics of the collaborative game
Difficulty	Salienta as dificuldades encontradas na experiência do jogo.
Dynamic	Denota que houve uma percepção do jogo sempre apresentar novos problemas.
Interesting	Denota a percepção do respondente sobre o jogo como ferramenta de ensino.
Ludic	Evidencia a compreensão do respondente para a experiência de aprendizagem por meio do jogo.
Keeps the focus	Indicates that the game experience keeps players focused.
Motivator	Indicates that the game experience keeps players interested.
Synthesizes a complex system	It shows the respondent's perception of the game's ability to represent complex systems.

TABLE 1: Codes and definitions. Source: The Author

FIGURE 1 – First to fourth sessions. Source: The Author

FIGURE 2 – Fifth session. Source: The Author

and rules. The proposed improvements were implemented and tested in the next session, and so in the three subsequent sessions. The beginning group (Figure 1) tested and improved the game until its finalization.

In the fifth and last test carried out with students from the "table group" (Figure 2), four teams were formed to carry out the game session. As a result, a single comment about leaving the game rules with more pictures to facilitate understanding.

Ando also regarding the results of this fifth test are shown in Figure 3. (Colored lines were drawn on the photos of the solutions presented by the teams to represent the different distances covered by the pieces in each proposal). To find out the transportation costs, the teams played the game, managing the production of manufactured parts, based on the known average demand for each product. With data on the quantity of manufactured parts to compose each product served, the distances traveled by each manufactured part and the defined transport cost between sectors, each team calculated the total cost of the proposal.

The results of all teams, and the overall ranking by calculating the transportation cost per manufactured product are shown in Table 1.

The presentation of the results to the teams was another important moment of the test, an opportunity for them to discuss the adopted strategies, those that worked or not. At this moment of reflection, known as "debriefing", the professor conducts a contextualized discussion of the results with the actual practice of a facility layout project.

According to Kalmpoutzis (2018, p. 56, our translation) "It is during the debriefing that players realize that the skills they have acquired while playing can be used in other contexts and the knowledge they have gained can be applied in different ways".

With this last test, the ability of the AR➔FI game to enable numerous layout configurations and different results was demonstrated, depending on the players' skills in teamwork, problem solving and resource management.

ANALYSIS OF THE QUESTIONNAIRE

A sample of 25 quotes from the coding result, out of a total of 164 quotes (excerpts from answers), from the 25 answers to each question, is shown in Chart 2, which maintains the formatting of the report extracted from the Atlas.ti software 8. The pair citation order refers to the question number and sequence of citations, the numbers in parentheses refer to the beginning and end of the citation, relative to the number of characters in the answer text.

Table 2 shows the number of times each code was assigned in all citations in the answers to the three questions.

In the answers to question 1 "What did you think of the game to learn about facility layout ?" the codes Learning (11x), Interesting (13x) and Synthesizes a complex system (15x) stand out.

And in question 2 "Do you think that through this game you can learn the concepts more easily?" and 3 "According to your view, does this game contribute to learning the topic of facility layout?" the codes Learning (13x and 9x), Approval (22x and 25x) and Synthesizes a complex system (9x and 14x, respectively in the 2nd and 3rd question) stood out. The analysis shows that the students' perception of the game facilitating learning is in the answers, in the vast majority, linked to the game's characteristic of synthesizing the facility layout system of an installation, and for the same reason question 2 and 3 have the most of approval.

This is an important feature of board games pointed out by Castronova (2015), with its moving parts and the combination of different game mechanics, to explain or discuss

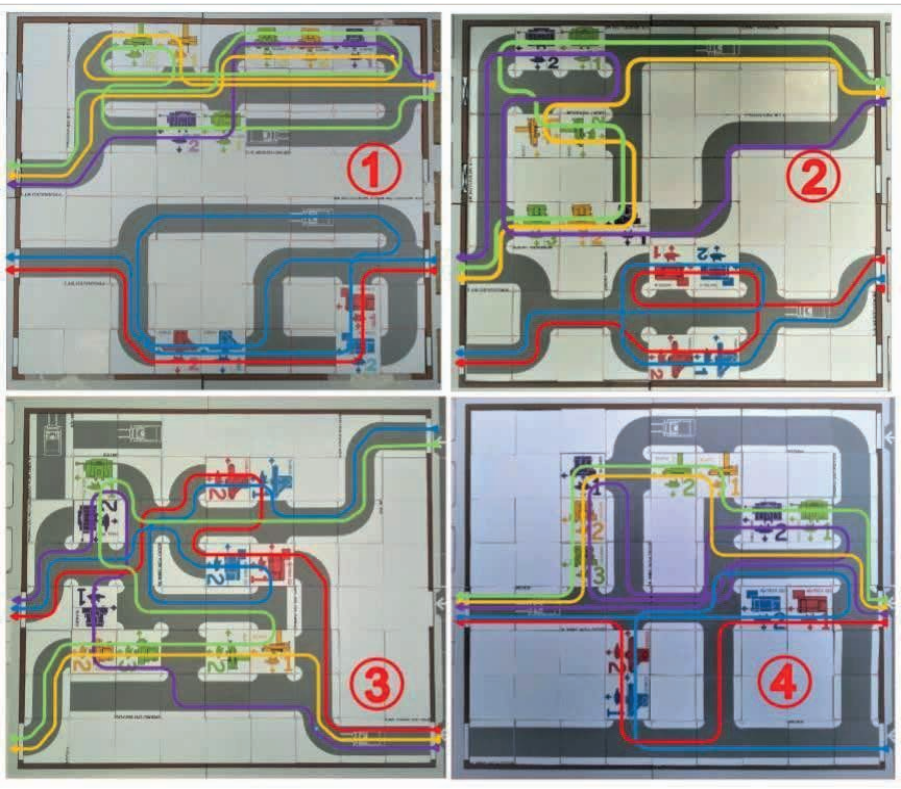

FIGURE 3: facility layout solutions by groups, with the number of teams. Source: Author

	GRAND TOTAL OF MANAGEMENT POINTS	TRANSPORTATION COST BETWEEN SECTORS	CLASSIFICATION GENERAL
TEAM 1	144	$ 13.110,00	1º
TEAM 2	112	$ 12.360,00	3ª
TEAM 3	128	$ 12.905,00	2º
TEAM 4	27	$ 15.630,00	4º

TABLE 1- Results and ranking of teams

Source: The author

QUESTIONS / CODES	• Learning	• Approval	• well crafted	• Collaborative	• Difficulty	• Dynamic	• Interesting	• Ludic	• Keeps the focus	• Motivator	• Synthesizes a complex system
What did you think of the game to learn about physical arrangement?	11	3	2	1	3	3	13	2	1	2	15
Do you think that through this game you can learn the concepts more easily?	13	22	0	2	0	3	0	3	2	0	9
According to your view, does this game contribute to Learning the topic of physical arrangement of facilities?	9	25	2	1	0	1	0	1	1	0	14

TABLE 2: Coding Summary

Source: The author

Citations:

1:10 The game presents the concept of layout in a practical way (633:700)- 1 Codes:○ Synthesizes a complex system

1:11 one can see the bottlenecks found and possible for the realization…… (730:818) - 1 codes:○ Learning

1:12 didn't even know what facility layout was and how it worked (941:992) -1 Codes:○ Learning

1:14 I really liked (1005:1016) -

1 Codes:○ Approval

1:15 I found the shape quite interesting (1019:1053) -1 Codes:○ Interesting

1:16 the game holds the player's attention. (1063:1097) - 1 Codes:○ Stay focused

1:17 The game showed us in a practical way (1108:1142) - 1 Codes:○ Synthesizes a complex system

1:18 importance of planning the layout, the physical arrangement; for efficiency pr…… (1146:1278) - 1 Codes:○ Learning

Citations:

2:40 in a more relaxed way (1558:1587) - 1 Codes: ○ Ludic

2:41 Makes the class more dynamic (1601:1627) - 1 Codes: ○ Dynamic

2:42 development and in game form is more attractive for young people (1638:1705) - 1 Codes: ○ Ludic

2:43 possible to have a brief notion of the concepts taught in class through the j…… (1754:1827) - 1 Codes: ○ Learning

2:44 all theoretical concepts are applied during the game in a fixed way…… (1844:1942)- 1 Codes: ○ Learning

2:45 theory learned in the classroom. (2043:2076) -1 Codes: ○ Learning

2:47 we can interact more spontaneously by testing and learning n…… (2235:2317) - 1 Codes: ○ Collaborative

2:48 concepts that can be applied virtually to the decision whether it is…… (2115:2199) - 1 Codes: ○ Synthesizes a complex system

2:49 helping her a lot with the didactics presented. (2319:2362) -1 Codes: ○ Learning

Citations:

3:31 is a good way to show how the implementation works in practice…… (658:745) - 1 Codes:○ Synthesizes a complex system

3:32 this game was in a didactic way (761:797)- 1 Codes:○ Learning

3:33 because you can observe in practice the concepts of arrangement f…… (917:992) - 1 Codes:○ Synthesizes a complex system

3:34 contributed in that it exemplified in practice an arrangement system…… (1008:1097) - 1 Codes:○ Synthesizes a complex system

3:35 where the layout had to be done as efficiently as possible. (1100:1170)- 1 Codes:○ Learning

3:36 used the game with an example in the presentation of subjects, such as te…… (1288:1381)- 1 Codes:○ Synthesizes a complex system

3:37 very well crafted game (1413:1436)- 1 Codes:○ Well-crafted

3:38 and easy access to knowledge of the topic addressed. (1438:1488) -1 Codes:○ Learning

TABLE 2- Quote coding sample. Source: The author

problems of complex systems in a simplified way. Game-based learning brings experience in doing, and allows failure, which in addition to being fun is educational, because students do not only see the mistakes, but how they happened, leading to an understanding and a systemic view.

This association is evident in the answers, of how a small representation of a facility layout system can lead to the understanding and questioning of the real problems encountered in practice.

The unprecedented application of the board game for teaching facility layout concepts appears in the "Interessant" code, which also demonstrates, in a way, an approval of the game as an instructional tool.

Games-centered contextualization offers an alternative to seek learning in a motivating environment that is already known to current generations who grew up in a society of communication and games (WIGGINS, 2016).

According to Bacich, Lilian; Moran (2017, p. 21), "The most relevant active learning is related to our lives, our projects and expectations".

FINAL CONSIDERATIONS

The present work presented as general objective: to verify the students' acceptance of the game-based learning methodology. To achieve this objective, the AR➔FI Game was developed, addressing theoretical concepts of facility layout, through the iterative design method with the participation of students, in focus group sessions, where the collected data updated, through fixes and improvements, the versions of the game, from the initial prototype to its finalization.

Fulfillment of the general objective was initially verified in the game's test sessions, mainly in the fifth session, where the AR➔FI game was unknown to the students, and where the students' speeches showed a receptivity for the proposal. But, to better analyze this perception of the students, some open questions were applied in the form of a questionnaire and the result analyzed using the content analysis method, with the support of the ATLAS.ti 8 software, verifying that the majority of the students approved the game as an instructional tool because they associated the experience of the game, of allowing a synthesized construction of a facility layout and in it being able to verify the result of their actions, with the learning of incorporated theories. This result goes against the concepts of active methodologies.

It is concluded, based on what has been exposed, that the AR➔FI board game, developed based on the theory of game-based learning, is a tool to support the learning of the topic of facility layout, for the development of skills and skills that only practice allows, and which was very well received by the students of the two undergraduate technological courses that participated in the research.

At the moment, a patent application for the AR➔FI game (BR2020200103496) has been filed and as a suggestion for future work: verify the game's contribution to improving the learning of the topics covered, which would require a longitudinal study.

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