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Using Educational Game in Civil Engineering: Making Pavement Design Fun with "Dimensione"

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ABSTRACT

This work aims to present and discuss the results of including an active educational alternative - board game DIMENSIONE, created by the authors - to evaluate its impact on teaching and on the student's learning process in Paving subject part of the civil engineering career at the Federal University of Alagoas. The students used the game and evaluated it by answering a questionnaire. The students' responses were analyzed, allowing to conclude that 63% of the students observed improvements in motivation, user experience, and knowledge after using DIMENSIONE as a complement to the learning process in Pavement subject. This game is expected to be implemented in more universities and that it will be able to make teaching the method for projecting pavements more efficient and fun.

KEYWORDS

Pedagogical games. Pavement design. Higher education. Civil engineering. Active learning.

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Uso de Jogo Educacional na Engenharia Civil: Tornando o Dimensionamento de Pavimentos Divertido com o Jogo “Dimensione”

RESUMO

Este trabalho teve como objetivo apresentar e discutir os resultados da inclusão de uma alternativa educacional ativa - o jogo de tabuleiro DIMENSIONE, criado pelas autoras – de modo a avaliar o seu impacto no processo de ensino e aprendizagem dos alunos da disciplina de Pavimentação do curso de engenharia civil da Universidade Federal de Alagoas. Os alunos utilizaram o jogo e o avaliaram com uso de questionário. Foi realizada uma análise sobre as respostas dos alunos que permitiu concluir que 63% destes observaram melhora nos aspectos motivação, experiência do usuário e conhecimento após utilizar o DIMENSIONE como complemento do aprendizado na disciplina de Pavimentação. Espera-se que este jogo seja implementado em mais universidades e possa ajudar a tornar mais eficiente e divertido o ensino do método de dimensionamento de pavimentos.

PALAVRAS-CHAVE

Jogo pedagógico. Dimensionamento de pavimentos. Educação superior. Engenharia civil. Aprendizagem ativa.

Uso de Juego Educacional em Ingeniería Civil: Faciendo el Diseño de Pavimentos Divertido con “Dimensione”

RESUMEN

Este documento tiene como objetivo presentar y discutir los resultados de la inclusión de una alternativa educativa activa, el juego de mesa DIMENSIONE, creado por las autoras, con el fin de evaluar su impacto en el proceso de enseñanza y aprendizaje de los estudiantes del curso de pavimentación parte de la carrera de ingeniería civil en la Universidad Federal de Alagoas. Los estudiantes usaron el juego y lo evaluaron usando un cuestionario. Se realizó un análisis de las respuestas de los estudiantes, lo que nos permitió concluir que el 63% de ellos observó una mejora en la motivación, la experiencia del usuario y el conocimiento después de usar DIMENSIONE como complemento al aprendizaje en la disciplina de Pavimentación. Se espera que este juego se implemente en más universidades y pueda ayudar a que la enseñanza del método de dimensionamiento del piso sea más eficiente y divertida.

PALABRAS CLAVE

Juegos pedagógicos. Dimensionamiento de pavimentos. Educación superior. Ingeñeria civil. Aprendizaje activo.

1 Introduction

This article proposes to present the design and application of DIMENSIONE a game whose main objective is to teach its participants (civil and transport engineering students' pursuing pavement design credits), to design pavements by Eng. Murilo Lopes de Souza method, also known as DNIT method, the primary pavement design method used in Brazil.

The study wasmotivated by the implementation of educational practices that encourage students to get involved in the learning process. With the advent and popularization of digital technologies, it is increasingly challenging to capture students' attention with traditional teaching practices; thus, the teacher is required to increase the use of dynamic strategies linked to the learning process. It is necessary to involve the student in the learning process through active teaching methodologies.

In this way, in addition to presenting a proposal for inserting a board game created specifically for the pavement course context, the present research proposes to answer to what extent has the game DIMENSIONE reached the goal of increasing motivation, learning experience and acquired knowledge by students during the classroom process. This assessment was made based on the questionnaire model proposed by Savi et al. (2010) and adapted by Lima and Melo (2013).

In Brazil, in the field of road education, several initiatives have been consolidated regarding the use of games and recreational activities in the classroom in different regions of the country. Garcia (2017) from the Federal University of Rio Grande do Sul - UFRGS reported "Ponto de Partida" project experience, whose objective was to enable students to act as engineers (coordinating, carrying out studies and projects and supervising) in a playful-real-didactic environment. Lima and Melo (2013) exposed the experience of using nine different games developed by civil engineering students at the Federal University of Paraíba – UFPB, the games' themes varied between intersections, overtaking lanes, drainage, geotechnical study, and earthworks. Moraes (2018), in her master's dissertation from Federal University of Espírito Santo - UFES, described the development and evaluation of a board game that simulated a road network with real construction problems, where the student needed to manage the project and build one of the highways.

It is also essential to mention similar initiatives in the general field of Transport engineering. In this context, Silva et al. (2013) analyzed the adequacy of a participatory methodology based on company games, "TECON Game," to the syllabus of the Port's technical course at Itaguaí's Federal Center of Technological Education. Bernardinis et al. (2015) narrate about the design of a card game for teaching-learning processes at Transport Systems course for Civil Engineering Undergraduate Students at Federal University of Paraná - UFPR and De Paula (2016) who conducted an exploratory study on games in humanitarian logistics in her Master thesis at the State University of Maringá, PR.

There is no example of a board game in the literature whose objective was to teach students how to design pavements using DNIT's method. Thus, this article aims to narrate the experience of developing and applying the board game at the Federal University of Alagoas - UFAL. We expected that, upon learning about the initiative, other teachers would seek to use the game with their classes; thus, we could contribute to a less rigid and more fun and effective engineering teaching.

The following section conceptualizes games and their use as a pedagogical tool, section three explains about the emergence of the idea, the conception and stages' to be overcome by the participants, as well as elucidates about application mechanisms' and learning result evaluation. Section 4 narrates the results and analysis, and section 5 reports the conclusions.

2 Conceptualizing Games and its Adaptations for its Use as a Pedagogical Tool

Games, both digital and analog, are being increasingly used as one of the teaching methods in different courses and varying education levels. The game can attract students and provide the learning of specific content in a relaxed way. These adaptations proposed by teachers seek to approach the playful experiences that are part of the students' imagination without, however, encompassing all the complexity that surrounds game development.

As an object of study, the game has been discussed by several areas with names such as Huizinga (1971), Caillois (1958), Suits (1978), Avedon & Sutton-Smith (1981), Salen & Zimmerman (2003) among the references of which today is known as Game Studies. Game Studies is a field of research that seeks to bring together the discussions around the theme, the main approaches and studies that encompass not only how to produce games, but also how to understand them.

Its complexity can be gauged when trying to find a definition of what "game" and "play" are. In a brief search, it is possible to notice that there is no consensus on the game's nature capable of being brought together in a protocol definition. Its variations surround both the goal for the game's development and even the unfolding of the user's playing experience. Seeking a more comprehensive and pragmatic definition, we have the thought of Jasper Juul defining that:

> A game is a formal system based on rules with a variable and quantifiable result, where different outcomes are attributed by different values, the player exerts effort to influence the result, the player feels connected to the result, and the consequences of the activity are optional and negotiable (JUUL, 2003)

That is, for developing a game some elements are needed such as: i) a set of fixed and pre-defined rules, even if they are variable; ii) results of the interaction between the player and game that are variable and quantifiable; iii) valuing these results in a way

that encourages engagement; vi) this engagement creates a link between the player, and; v) an outcome that is only obtained through the player's effort who faces negotiable consequences. To promote this interaction, the development team must establish the mechanics that will compose the game.

> Mechanics are the essence of what games are. It is the interactions and relationships that remain when all aesthetics, technology and narrative are removed (SCHELL, 2008).

The interaction and linking promoted by the gaming process tend to increase the user's engagement concerning the procedures therein. This characteristic has been widespread among educators who have come to see pedagogical potential in games, expanding the student's involvement in the learning process.

2.1. The Game as a Pedagogical Tool

Educational games, unlike other games, privilege some characteristics of the playing process because, in addition to the game's goal, there is also a pedagogical goal. The game's objective is what determines who the winner at the end; the educational purpose sought by the teacher is a result of the student-game interaction.

In DIMENSIONE's project case, the pedagogical objectives were defined, and some dynamics were proposed, with this educational objective always set as a priority. The mechanics developed maintained the pedagogical target specified in the previous stage, generating characteristics that are representative of games, such as, for example, to stimulate group engagement, promoting a bond between the player and the result obtained through an effort by the student player.

We sought to enhance the game's characteristics by working on the concept, mechanics, rules, objectives, materials, as well as aspects related to verbal and non-verbal language. Full understanding of the game (logically and visually) was also ensured, creating mechanisms that promote the player's interest, whether for aesthetic reasons, game dynamics, amongst others.

It is important to note that in this experience, more than working on the complexity of the game or its graphical interface, the main objective was to allow teaching pavement design playfully, making the process more pleasant and efficient.

3. Dimensiones's Project

3.1. Preliminary Studies: The Emergence of the Idea

The idea of creating a game that taught how to design asphalt pavements using DNIT's method arose from the author's willingness to implement active methodologies in the classroom, from her taste for board games, coupled with the participation in a course called "Digital Technologies and Active Methodologies" promoted by the

Federal University of Alagoas, where the first prototype of the game was developed. After that, the research group Laboratory of Experimentation in Design was also involved. In the present work, we discuss the third version of the game, which was designed as a board game, divided into three distinct phases and the second version, that was used by students of the 2018.2 semester and who answered the questionnaires.

3.2. Projects: Game Design and Development

The game (Figure 1) was designed to be used in the classroom. Ideally, each group should have a box containing the three projected phases, so that each stage is played individually and in sequence, varying the time of each stage according to the student group performance.

Figure 1. Image of DIMENSIONE's box and cards

Source: the authors

The product of the game is to obtain the pavement layers' design according to DNIT's method. The "victory" in the game is associated with fulfilling the journey, with no competition between participants being proposed here. Some competitiveness mechanics were designed but were not implemented due to the level of complexity that would be achieved, deviating the process from the defined pedagogical objective.

3.2.1 Stage 0: Selection of the City and Section

Before starting the game, the students had to draw at random the "Excerpt" card that determined the highway's extension, class and geography, and the "City" card referring to the city with information about precipitation, a climatic factor, and the subgrade's CBR. Examples of these cards can be seen in Figure 2.

Figure 2. Examples of excerpts and city maps

Source: the authors

These cards guaranteed variability to the game and the final pavement design projects, in addition to giving playful elements by referring to items that permeate the universe of university students such as parties, course materials, friendship, security in the city, and music.

3.2.1 Step 1: Traffic Studies

At this stage, students should initially calculate the number "N", equivalent number of passages of standard axles on the road. The game presented a sequence of cards containing the instructions for the calculation, which is preceded by the determination of the factors VT (Traffic Volume), FE (Axel Factor), FC (Load Factor), and FR (Climatic Factor). First, participants should make the traffic expansions for the project period (VT) from a card containing traffic data time series for buses, medium trucks, and heavy trucks from 2005 to 2016 and then calculate the FE and FC following the card's formulas and instructions. Examples of the cards used can be seen in Figure 3.

Figure 3. Calculating N

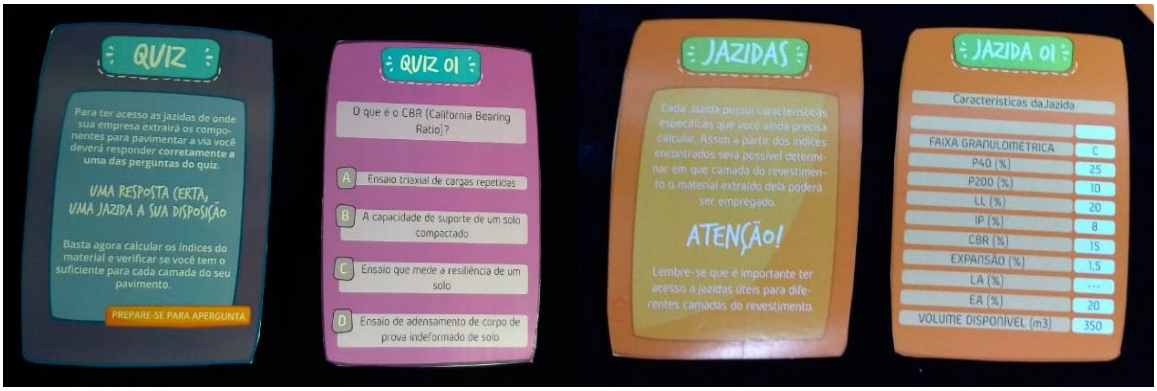
Source: the authors

Traffic studies' step is the longest and most complex stage of the game and usually lasts around 10 hours/class. Besides calculating the elements, students had to determine and explain their decisions because the answers could vary. For example, they could vary according to the sample expansion selected method and the standard axis calculation method.

3.2.2 Step 2: Ore Deposit Selection

In the deposit's selection phase, participants should draw cards from a Quiz, and if they answered the question correctly, they would be entitled to draw a deposit card, the graphical representation can be seen in Figure 4. The deposits are made of materials that have characteristics that determine if their ideal application in different pavement layers, these being Base, Sub-base, or Subgrade Reinforcement layers. The students then had to define for which layer the card's material could be used, and they had to repeat the process to obtain deposits whose material could be used in each of the layers mentioned. The definition of the deposit material characteristics is done by calculating some indexes. The game's phase 2 also brings instructions on this calculation.

Figure 4. Example of Quiz cards (left) and deposit cards (right).



Source: the authors

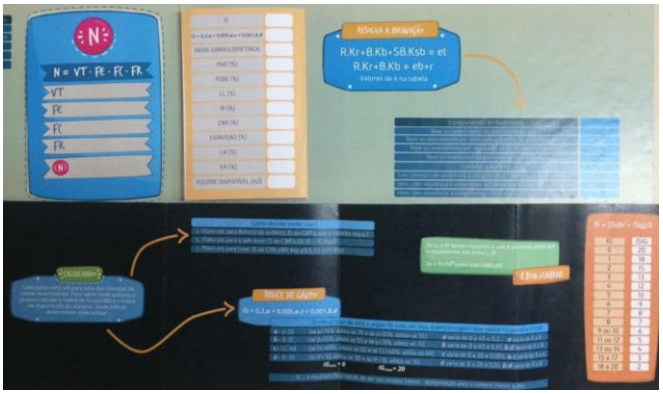
Moving to the next stage was allowed once the team obtained at least one deposit that could be used for each pavement layer according to DNIT's rules expressed in one of the game's inserts.

3.2.3. Step 3: Pavement Design

The third stage corresponded to pavement layers design and rescues the calculations developed in the previous actions. At this step, participants should determine the layers' thickness. Such thickness varies according to the N number (step 1) and the layer thickness according to the subgrade's CBR at the city card (step 0) and the deposits' CBRs cards (step 2).

They should also calculate the total volume of material needed according to the layer, lane width, and road section length. If the material available in the deposits obtained was not sufficient to build the layers, the players should return to step 2 (ore deposits) and get material in quantity and quality necessary for the construction of each layer. Figure 5 shows the board and instructions for the pavement design calculations.

Figure 5. Pavement Design



Source: the authors

In the end, students should deliver a report explaining step by step how each stage of the game was fulfilled and what results were obtained in the design. Besides, they should clarify the decisions made by them, since each situation needed to be analyzed, choosing the viable engineering solutions within the scenario created by the game.

3.3. Validation and Evolution of Game Prototypes

Although the previous topic describes the third version of the game, for its conception, two validation steps were carried out before it. “DIMENSIONE” was applied twice in two preliminary versions and had adaptations derived from the classroom using experience. The first experience took place 2018.1 term (version 1) and the second 2018.2 term (version 2). The first version contained the definition of the steps to be developed, but there was still no mechanics, and the resource for transmitting information was still very rudimentary, without a more elaborate graphical interface.

Version 2 used cards (for cities, sections, and deposits) in addition to structuring the Quiz, it also had a graphical interface closer to version 3 (current version). Larger graphic schemes were used to guide the calculation process, in the form of a basic infographic. This version already followed the mechanics and dynamics described in item 2.2. The analyzes in the next sections referred to the second version application in 2018.2 and were fundamental for the third version development, as well as for validating the results obtained with the proposal. At the end of the semester, students answered an online questionnaire about playing the game and how it influenced in aspects such as motivation, gaming experience, and knowledge acquisition.

3.4. Game Assessment

A questionnaire proposed by Savi et al. (2010) and adapted by Lima and Melo (2013) was used for the game assessment. Chart 1 lists the aspects, parameters, and questions asked, grouped according to motivation, user experience, and knowledge. Regarding motivation, questions related to increased attention, relevance, confidence in learning, and satisfaction degree when playing were evaluated. In the user experience aspect, the game's immersion ability, the challenge degree, the feeling of competence, the ability to increase social interaction and gameplay were considered. Finally, the strength of the game to increase the level of knowledge acquired was evaluated.

Chart 1. Assessment questionnaire

Parameter	Question
Motivation	
Attention	There was something interesting at the beginning of the game that captured my attention.
	The game's interface design is attractive
Relevance	I liked the game so much that I would like to learn more about the subject it covered.
	I could relate the content of the game to things I've seen, done, or thought.
	The game content will be useful to me.
Confidence	The game had so much information that it was difficult to identify and remember significant points.
	The content of the game is so abstract that it was challenging to keep an eye on it.
	I couldn't understand a good deal of the game's material.
Satisfaction	Completing the game exercises gave me a sense of accomplishment.
	I learned things from the game that were surprising or unexpected.
	I felt good to complete the game.
User experience	
Immersion	I didn't notice the time passing while playing.
	I felt more in the game environment than in the real world.
	I tried hard to have good results in the game.
	There were times when I wanted to give up the game.
	I felt encouraged to learn from the game.
Challenge	I liked the game and didn't feel anxious or bored.
	The game kept me motivated to continue using it.
	My skills gradually improved with overcoming the challenges.
	The game offers new challenges at an appropriate pace.
	This game is suitably challenging for me; the tasks are neither too easy nor too difficult.
Ability/competence	I quickly reached the objectives of the game.
	I felt competent.
	I felt that I was making progress during the game.
Social Interaction	I felt that I was collaborating with other colleagues.
	In-game collaboration helps learning.

Gameplay	The game supports social interaction between players. I like using this game for a long time. When it ended, I was disappointed that the game was over. I would play this game again. Some things in the game pissed me off. I was hoping the game would end soon. I found the game a bit still.
Knowledge	After playing, I can remember more information related to the theme presented in the game. After playing, I can better understand the themes presented in the game. After playing, I feel that I can better apply the themes related to the game.

Source: the authors

Questions 1.6, 1.7, 1.8, 2.4, 2.20, 2.21, and 2.22 were classified as unfavorable, and their values were inverted for the calculation.

4. Results and Analysis

The following analyzes detailed how the game was evaluated by students of Pavement Design course for civil engineering students in the 2018.2 term at the Federal University of Alagoas. The results are detailed in Table 1.

4.1 Motivation Aspect

The motivation aspect was considered positive by 87% of the students regarding attention, meaning that the participants found the interface attractive. 60% of students approved the relevance and confidence delivered by the game. 54% showed satisfaction when playing and being able to complete a playful activity.

4.2 User Experience Aspect

Regarding the user experience aspect, 45% considered themselves immersed in the reality of the game while playing. 60% characterized the game as challenging, 60% managed to perceive its progress throughout the game in a positive way, 59% believed that the game improved social interaction with colleagues, and 55% evaluated the gameplay well. It is worth mentioning that it is a preliminary version and that it was still being tested when we made the evaluations.

4.3. User knowledge Aspect

Regarding knowledge, 86% considered that they were able to better understand the themes related to the game, remember more information, and better apply the knowledge acquired with the activity developed.

Table 1. Game's general assessment

Aspect	Assessment				
	Negative		Neutral	Positive	
	Strongly	Slightly		Strongly	Slightly
Motivation					
Attention	0%	0%	13%	48%	39%
Relevance	2%	9%	30%	30%	30%
Confidence	1%	14%	26%	40%	20%
Satisfaction	0%	12%	33%	33%	21%
User Experience					
Immersion	5%	13%	28%	37%	18%
Challenge	0%	11%	29%	41%	19%
Ability/competence	0%	9%	31%	46%	15%
Social Interaction	4%	16%	22%	35%	24%
Gameplay	1%	14%	31%	35%	20%
Knowledge					
	0%	1%	14%	51%	35%
Total	**1%**	**10%**	**26%**	**39%**	**24%**

Source: the authors

Looking at the questionnaires' results, we believe that the game fulfilled its proposal and proved to be a useful tool for teaching and active learning with playful elements.

5. Conclusion

Active methodologies are essential for efficient learning. This article showed the students' perception after using the DIMENSIONE game for teaching DNIT's pavement design method. The idea of creating the game arose from the implementation of educational practices that encouraged students to get involved in the learning process.

The students' feedback was very positive, with students that had not attended the course yet reporting they were eager to play the game on the following semester. The evaluation with those who have already played, 63% agreed with improvements in motivation, user experience, and knowledge, and only 11%, on average, disagreed with these aspects.

By disseminating this experience, the authors hope to encourage other teachers to seek using games and active methodologies in the classroom, contributing to a funnier, less rigid, and more effective way of teaching engineering.

As future contributions, this game could be improved, for example, by also including a concrete pavement design method or by adding more stages of the process, as the average transport distance, for example. At the last level, the game could encompass the entire pavement design course.

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