TrilhEdu: Visualization of Educational Content Through Learning Trails Using Graphs and Gamification

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Abstract. *Visualizing learning trails aims to present educational content that enhances understanding students' progress and needs. This process, however, encounters challenges related to complexity, quality, and consistency of content, as well as interpretation, personalization, and presentation of information in the context of a Pedagogical Course Project. This paper introduces TrilhEdu, a gamified web system that organizes content into learning trails visually represented by graphs. The system prioritizes students, enabling analysis of their progress and potential paths within a trail while allowing trail administrators to simulate and monitor student progress. User evaluations indicated that TrilhEdu provided a positive and motivating experience.*

1. Introduction

The Internet provides a significant insertion of teaching and learning in information systems, facilitating communication between different areas of knowledge. Based on this, pedagogical resources are being inserted into new software and systems to be used on devices such as computers, cell phones, and tablets to complement learning and expand virtual learning environments (Ramos et al. 2015; Lima et al. 2017).

Games are not only a source of entertainment but are also used in various contexts, such as learning (Lima et al. 2017). Gamification, the integration of game elements into non-game contexts, enriches the learning process, making it more dynamic, engaging, and motivating, while also facilitating learning (Ribeiro 2012). Examples of gamified learning systems include Duolingo, which uses points, progress bars, and levels for language learning, and MeuTutor, which applies similar elements to teach Brazilian elementary and high school subjects (Santos et al. 2021).

Learning trails are a sequence of content that enable intellectual development and skills related to Course Pedagogical Projects (CPPs) in the higher education environment (Tafner et al. 2012). According to (Ramos et al. 2016), identifying and proposing trails by educators is still a study factor, as in general, research focuses on learning trails as an independent form of the system, just as a method of analyzing student data. In this way,

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the student cannot benefit from using learning trails for their study, and it is impossible to verify the best paths to take to achieve students' objectives within the course.

It is proposed a web system, called TrilhEdu, capable of organizing and presenting curricular components in CPPs through a visual representation of learning trails using graphs visualization and gamification. Therefore, TrilhEdu can be used to represent learning trails for an entire undergraduate course to a specific class topic. The hypothesis is that the learning trails combined with the gamified model positively influence the process of designing the trails (for teachers) and the learning process (for students), offering a motivating and satisfying experience. The methodology of this work involved specifying, designing, implementing, and evaluating a gamified web system for visualizing learning trails through graphs. Two evaluation stages were conducted: one with users in *Administrator* or *Teacher* roles and another with users in a *Student* role. Questionnaires were administered to gather users' perceptions of their experience with the system. The responses were then analyzed to determine whether the visualization of learning trails aided content organization and whether gamification increased participant motivation.

It was found that TrilhEdu provided users with a good visualization experience of learning trails through an easy and intuitive interface, promoting a new way of viewing the content of a learning trail. Moreover, gamification components included in the system generated motivation in students to complete content in order to obtain rewards.

This paper is structured as follows: Section 2 covers the theoretical background; Section 3 details the modeling and development of the TrilhEdu Web System; Section 4 discusses the evaluation method and results analysis; finally, Section 5 presents conclusions and suggestions for future work.

2. Background

In recent years, various learning approaches have emerged, from traditional methods to flipped classrooms and the use of Artificial Intelligence (Lage et al. 2000; Bishop and Verleger 2013; Luckin and Holmes 2016; Holmes et al. 2023). A learning environment is a space where learning occurs, utilizing tools, collecting information, and fostering interaction among participants (Wilson 1995). Among these environments, the Virtual Learning Environment (VLE) stands out. A VLE facilitates online course management, student registration, and evaluation, serving as a content repository and a platform for communication between educators and learners (Ninoriya et al. 2011).

A learning trail, or learning path, is a sequence of course components organized to meet specific learning goals, fostering students' intellectual development and skills (Fung et al. 2011; Tafner et al. 2012). However, designing and understanding these trails presents challenges, particularly in visualizing complex educational data, ensuring data quality, and creating adaptable, user-friendly interfaces (Dede 2011; Duval 2011; Siemens and Long 2011; Dawson et al. 2014; Duin and Pedersen 2023).

Graph theory emerges as a solution for presenting learning trails. Graph theory is an area of discrete mathematics that studies the relationship between objects in a set. Therefore, it is possible to map content within a learning trail through graphs to obtain a more precise and satisfactory visualization of the relationships between the contents of the path, as demonstrated by (Ramos et al. 2016), demonstrating positive results, such as real-time monitoring of a student in a VLE by teachers.

Gamification further enhances VLEs by boosting student motivation and engagement, providing educators with better tools for guiding and rewarding students through a fun experience (Lee and Hammer 2011). The gamification use game design elements to tap into intrinsic motivation, offering a more rewarding experience than traditional methods (Deterding et al. 2011; Hunter and Werbach 2012; Pansera et al. 2016).

Several works in the literature address different ways of presenting content in virtual environments. (Ramos et al. 2016) present an LPGraph plugin that identifies and visually represents Moodle students' learning paths based on their activities and accesses. (Vicente and Souza 2018) present a visualization model of their academic trajectory using gamified dashboards through the Graphon Unifei application, using gamification in order to improve the visualization of the student's academic trajectory, together with a persistence mechanism based on graph theory, presenting positive and acceptable evaluations by students.

The TrilhEdu Web System is distinguished by its student-focused design, providing clear visualizations of learning trails and offering benefits such as rewards for progress. It also enables administrators to simulate and monitor student progress, recommending tailored content. This study gathered evidence on student satisfaction with using such systems to follow instructor-recommended learning trails.

3. TrilhEdu Web System

The TrilhEdu system aims to offer a model for visualizing educational content through learning trails based on graphs and student-focused gamification. Figure 1 shows the architecture view of the TrilhEdu system.

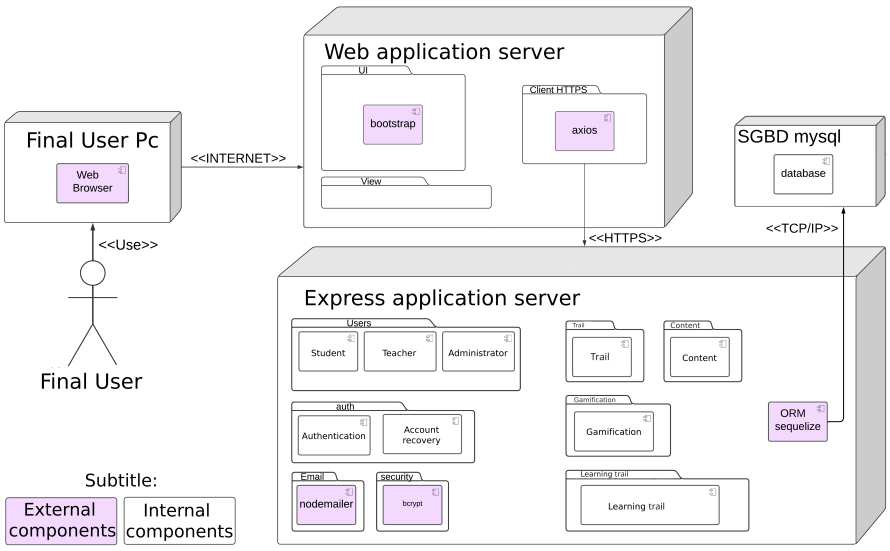

Figure 1. Physical view of the TrilhEdu system architecture.

The TrilhEdu system is built on a three-layer client-server architecture. The web application provides user interfaces accessed through the user's (teacher or student) web browser, while the express application server handles back-end functionalities like user management, authentication, learning trail management, gamification settings, email notifications, and data encryption. The data is stored in a decoupled database.

The *Content* component stores the set of educational contents selected by the instructor, while the *Trail* component organizes these contents into learning paths for students. The *Learning Trail* component is responsible for the graph-based modeling and visualization of these trails. The *Gamification* component enables instructors to incorporate gamification elements into the learning process. User management is handled by the *Users* component, allowing profiles as *Student*, *Teacher*, or *Administrator*. Students are the system's primary user, accessing and engaging with the trails, while teachers create and manage trails and content. Administrators oversee the entire system, including all trails, content, courses, and users.

The architecture incorporates various third-party libraries, including Bootstrap (Gaikwad and Adkar 2019), Material UI (Boduch 2019), Axios (Rawat and Mahajan 2020), and Cytoscape.js (Franz et al. 2016) on the front-end; and Express (Brown 2019), Sequelize (Felipetto and Basso 2020), nodemailer, and Bcrypt (Santos 2015) on the back-end. Regarding technologies, TrilhEdu is entirely deployed in the cloud infrastructure. The front-end was developed using React.js framework, the back-end was implemented using Node.js and the Database Management System (DBMS) used was MySQL. Heroku was used to serve the back-end and database, and Netlify was used to serve the front-end.

3.1. Learning trails modeling and visualization

A graph-based model was implemented in TrilhEdu to visualize learning trails using the *Breadth-First Search* (BFS) algorithm (Figure 2). BFS explores the graph level by level, starting from an initial node and systematically visiting adjacent vertices before moving to more distant ones (Santos and Ferreira 2021).

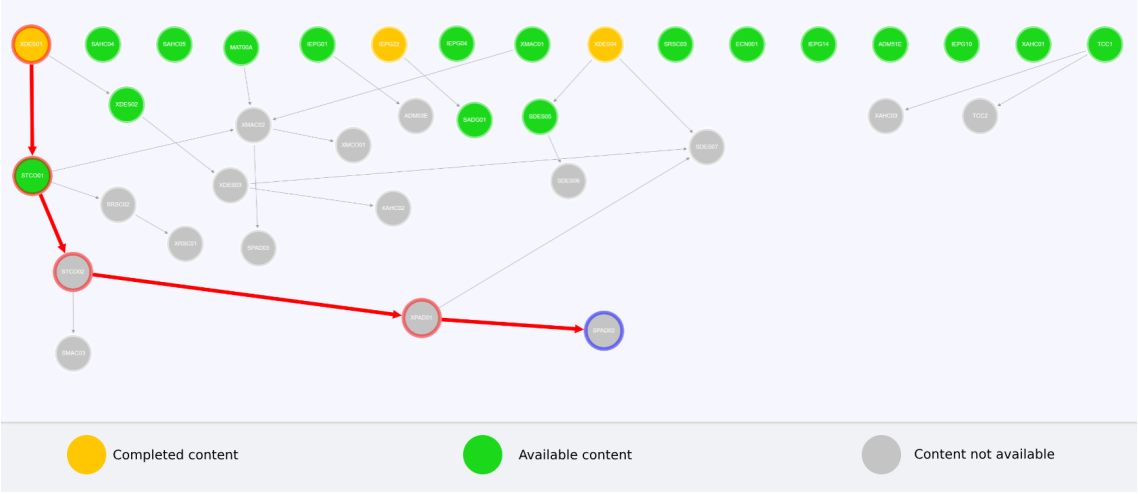

Figure 2. Example of graph visualization of a learning trail.

Trail and content creation are managed by *Teacher* or *Administrator* profiles, while *Students* can view and sign up in available trails. After signing up for a trail, the student can view all the content of that trail and sign up for it if they have the prerequisites for that content, which is set when it is created or edited. After registering for a trail, students can access the "Learning Trails" screen, where the system automatically displays the trail's graph. An example of this visualization is depicted in Figure 2. If subscribed to multiple trails, users can filter their view to select the desired trail.

In the graph, trail content is represented by vertices in different colors: yellow for completed content, green for available content, and gray for unavailable content, each color chosen for its psychological impact (Gelles 2020). As students progress, the graph updates to reflect completed content. The system also allows filtering to highlight the best path to specific content within a trail, with a blue-bordered vertex indicating the target and red-bordered vertices forming the path, as represented in the Figure 2. Users can toggle the visibility of edges, which represent prerequisite connections between content, for a tailored visualization.

An additional feature for *Administrator* users is the ability to simulate a *Student*'s learning trail. This allows administrators to see completed, available, and unavailable contents of the student, helping to guide them on their educational journey.

3.2. Gamification

The gamification model in TrilhEdu was designed to create an engaging and motivating learning experience by incorporating elements identified by (Hunter and Werbach 2012). These elements include avatars (virtual character representations), badges (symbols of achievement), competition (challenges between players), achievements (task completions), consequences (outcomes of actions), virtual currency (used to purchase virtual goods), ranking (leaderboards), and rewards (benefits for accomplishments). To achieve these objectives, the following items were proposed based on (Hunter and Werbach 2012): a credit model as a form of virtual currency, acting directly as a form of achievement, reward, and consequence; a model of energy, also acting as a form of achievement and consequence; a store model in which the user can exchange their virtual currencies, purchasing avatars, virtual animals and badges that will be linked to their user profile, and a ranking model, aiming to generate competitiveness.

The TrilhEdu credit system functions as a virtual currency representing the cost of content access. When creating content, the creator assigns a credit cost based on its difficulty, which also plays a role in the gamification aspect. Credits can be earned through enrolling in or completing content within a trail.

In this system version, the student does not need to purchase credits; instead, they receive a set amount upon enrolling in a trail. If a student lacks sufficient credits, they cannot access specific content. Students are rewarded with the invested credits plus a bonus upon completing content, depending on the content's difficulty. Additionally, their energy level increases, provided it is below the maximum value of $10,0$. This reward system can be compared to student performance indices in a school: when they complete the subjects they are enrolled in, the index increases; otherwise, it decreases. To implement the gamification element *Consequence*, if the student fails content, they will be penalized by not receiving back the invested credits, and their energy level will be reduced. Reward and penalty values were adopted according to the content difficulty, as shown in Table 1.

A store model was implemented to enable users to spend their credits on avatars, virtual animals, and unique profile names. Each item has a designated credit value, allowing users to acquire items within their available credit limit. An image of part of the store in the TrilhEdu system and an example of a user profile with active items can be seen in Figure 3. In this example, the character items, animals, and badges that a user with 50 credits can and cannot acquire are shown, along with their values and active items.

Table 1. Reward and penalty values for content difficulty.

Difficulty	Reward	Penalty
Low	120% of invested credits and increase of 0.2 energy points	Decrease of 1.5 energy points
Medium	150% of invested credits and increase of 0.6 energy points	Decrease of 1.0 energy point
High	180% of invested credits and increase of 1.0 energy point	Decrease of 0.5 energy points

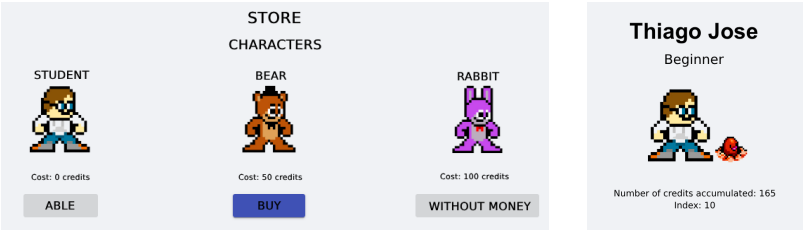

Figure 3. Example of the store and user profile in the TrilhEdu system.

A ranking model was developed to foster competition to showcase the top 10 users with the most accumulated credits. These credits reflect the total earned through completing trails and content, distinct from the current credits used for store purchases. This system encourages users to earn credits and stay at the top ranking. Additionally, users can click on any bar in the ranking to view the corresponding user's profile, promoting interaction and further enhancing the competitive spirit.

4. Evaluation of the TrilhEdu System

To evaluate TrilhEdu's user satisfaction, two questionnaire-based surveys were conducted, following the guidelines in (Kitchenham and Pfleeger 2008). The first survey focused on teachers' satisfaction with using TrilhEdu to manage learning trails, offering insights for system improvements. The second survey targeted students' satisfaction. The surveys addressed key system aspects across categories like **trail and content**, **learning trails**, **gamification**, and **general aspects**. Questions are listed in Tables 2 and 3, respectively.

The teacher questionnaire included 12 questions — 9 multiple-choice and 3 open-ended. The student questionnaire comprised 16 questions, with 13 multiple-choice, 1 comment field, and 3 open-ended questions. The multiple-choice questions used a five-point Likert scale, with **1** indicating the lowest satisfaction and **5** the highest. All participants agreed to the free and informed consent terms and authorized the use of collected data. No personal information was asked, so all answers were anonymous.

Finally, content from two undergraduate courses was integrated into TrilhEdu, based on the pedagogical projects of Information Systems and Computer Science programs at a Federal University, serving as the basis for user interaction.

4.1. Teachers satisfaction with TrilhEdu

Three teachers participated in the study, each attending a 30-minute remote meeting where the system's key features were introduced. They then interacted with TrilhEdu and respond to the questionnaire. Table 2 presents that over 60% of responses rated most aspects of the system as good or excellent (levels 4 or 5). Two respondents (66.7%) were neutral regarding the low amount of information provided in the trails visualization.

Table 2. Satisfaction with TrilhEdu aspects from the teachers' perspective.

Category	System Aspect	Level of Satisfaction				
		1	2	3	4	5
Trails and contents	The facility of creating trails and content	0.0%	0.0%	0.0%	33.3%	**66.7%**
	Visualization intuitiveness	0.0%	0.0%	0.0%	33.3%	**66.7%**
	Information provided in the view	0.0%	0.0%	**66.7%**	33.3%	0.0%
Learning trails	Experience while viewing	0.0%	0.0%	0.0%	**66.7%**	33.3%
	Experience while viewing a simulation	0.0%	0.0%	0.0%	33.3%	**66.7%**
Gamification	The usefulness of the system for a teacher in gamifying course content	0.0%	0.0%	0.0%	33.3%	**66.7%**
General aspects	Ease of account creation and system access	0.0%	0.0%	0.0%	**66.7%**	33.3%
	Simplicity in creating and managing users	0.0%	0.0%	0.0%	33.3%	**66.7%**
	User-friendliness of the system interface	0.0%	0.0%	0.0%	0.0%	**100.0%**

The open-ended questions addressed difficulties, suggestions for improvement, and whether participants would recommend TrilhEdu. One user reported no issues, another suggested more information, and a third recommended streamlining the *Teacher* profile access process. Suggested improvements included adding floating tooltips for content and enhancing content management features. Lastly, all users indicated they would recommend the system to teachers or students.

According to participant feedback, the TrilhEdu system interface was rated as excellent, with ease of account creation, system access, user management, and creation of trails and content. Visualizing trails and content was intuitive, although participants suggested displaying more interactive information. The system was beneficial for gamifying content within a trail for teachers, but both the visualization and simulation of learning trails, while providing a good user experience, have room for improvement.

4.2. Students satisfaction with TrilhEdu

Thirty-two students participated in the survey, following a scripted sequence of instructions before interacting with the system and completing a questionnaire. Table 3 shows that most students rated the system as good (4) or excellent (5) across all 13 evaluated aspects, showing satisfaction. While most users reported no difficulties, some mentioned issues with finding trails and content, filtering, and mobile usability. Suggestions for improvement included adding navigation icons, enhancing the interface and registration model, using distinct colors for active content, improving search functions, providing more content information, increasing accessibility, expanding store collectibles, and refining the reward system based on content duration and difficulty. Despite these suggestions, all respondents indicated they would recommend the system.

Overall, all respondents would recommend TrilhEdu, reflecting a positive experience. Participants found the system visually appealing, intuitive, and user-friendly. Account creation, system access, and content exploration were straightforward. The system's gamification elements effectively motivated students, though suggestions were made to display more dynamic information for better content progression.

Table 3. Satisfaction with TrilhEdu aspects from the students' perspective.

Category	System Aspect	Level of Satisfaction				
		1	2	3	4	5
Trails and contents	The facility of the entry process	0.0%	6.3%	9.4%	37.5%	**46.9%**
	Visualization intuitiveness	0.0%	3.1%	18.8%	37.5%	**40.6%**
	Information provided in the visualization	0.0%	12.5%	12.5%	**37.5%**	**37.5%**
Learning trails	Experience while viewing	0.0%	0.0%	21.9%	28.1%	**50.0%**
	New way to view trail content	0.0%	9.4%	12.5%	21.9%	**56.3%**
	Introduction of a new way to visualize paths to content	0.0%	3.1%	12.5%	31.3%	**53.1%**
	Support in decision-making for content progression	0.0%	6.3%	25.0%	28.1%	**40.6%**
Gamification	Motivation from credits earned after completing trails or content	3.1%	6.3%	15.6%	18.8%	**56.3%**
	Credits and energy points earned after content completion	6.3%	6.3%	15.6%	28.1%	**43.8%**
	Motivation to earn more credits from ranking display	9.4%	12.5%	18.8%	6.3%	**53.1%**
	Incentive to earn credits for purchasing characters, animals, and tags	0.0%	9.4%	15.6%	15.6%	**59.4%**
General aspects	Ease of account creation and login	0.0%	0.0%	6.3%	12.5%	**81.3%**
	User-friendliness of the system interface	0.0%	0.0%	3.1%	37.5%	**59.4%**

5. Conclusions

Identifying content trails within Course Pedagogical Projects poses challenges due to the complexity, quality, and consistency of content, as well as the interpretation and presentation of information. This paper proposed TrilhEdu, a web system that visually organizes and presents educational content from CPPs using learning trails and gamification.

TrilhEdu underwent two evaluation stages, initially involving users with profiles of *Administrator* and *Teacher*, and subsequently focusing on users with a *Student* profile. From a qualitative-quantitative analysis of the results obtained in the research, it was possible to conclude that TrilhEdu provided users with a good viewing experience of learning trails through an easy and intuitive interface, thereby promoting a new way to visualize the contents covered in a specific path. The inclusion of gamification in the system, linked to the completion of trails and content and the presentation of a user ranking, motivated users to earn credits effectively, achieving the expected results.

In future work, it is intended to carry out new tests and new analysis models, compare experimental groups and control groups with a larger sample, highlight their differences in learning and engagement, and explore new technological models with the intention of complementing gamification and improving users' educational experience.

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