DSLEP (Data Structure Learning Platform to Aid in Higher Education IT Courses)

Estevan B. Costa, Armando M. Toda, Marcell A. A. Mesquita, Jacques D. Brancher

Abstract—The advances in technology in the last five years allowed an improvement in the educational area, as the increasing in the development of educational software. One of the techniques that emerged in this lapse is called Gamification, which is the utilization of video game mechanics outside its bounds. Recent studies involving this technique provided positive results in the application of these concepts in many areas as marketing, health and education. In the last area there are studies that covers from elementary to higher education, with many variations to adequate to the educators methodologies. Among higher education, focusing on IT courses, data structures are an important subject taught in many of these courses, as they are base for many systems. Based on the exposed this paper exposes the development of an interactive web learning environment, called DSLEP (Data Structure Learning Platform), to aid students in higher education IT courses. The system includes basic concepts seen on this subject such as stacks, queues, lists, arrays, trees and was implemented to ease the insertion of new structures. It was also implemented with gamification concepts, such as points, levels, and leader boards, to engage students in the search for knowledge and stimulate self-learning.

Keywords—Gamification, Interactive learning environment, Data structures, e-learning.

I. INTRODUCTION

THE advances in technology over the last five year have brought the emergence of new methods to improve many society aspects such as economy, health and education. Among the last, the development and utilization of applications to aid in the educational process. Some of these are encountered in higher education IT courses which draw the attention of researchers.

Some studies were realized and aimed to minimize the evasion of students between those courses. Also the creation of tools to aid students in programming lessons, as these have a higher failure rate, according to [1]. As for the Data Structures lessons which is also an important subject to IT courses.

This happens because the main focus involve concepts of non trivial algorithms that are utilized in many systems, as stacks, queues, trees and etc. Improving the learning process of this subject is crucial to enhance the formation of professionals in this area [2].

To achieve this, researchers have been creating tools to aid the understanding and learning process ([3], [4],[5], [6]). Their works created learning environments that are similar to computer games, which are precursors to the game based learning methods.

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Games are also influencing this area through gamification, which can be defined as the utilization of game mechanics outside its bounds, to enhance user engagement [7] [8] [9]. Some authors explains that these mechanics are already implemented in educational area [10] however are not well-optimized to engage students.

This work demonstrates the development process of a Data Structure Learning Platform (DSLEP). It will cover basic concepts seen on data structure lessons, as stacks, queues, trees, lists and arrays, through interactive tasks. Besides these activities were also implemented gamification concepts to enhance the engagement of the users.

Some of these concepts that are involved in the system are: user profiles, experience points, levels, leader boards and achievement rewards [7] [9]. Those mechanics, as well as other data structures, will be unlocked as the player progress through the activities in the system.

This paper is divided as follows: Section II describes some concepts involving gamification in education through motivation theories followed by Section III which demonstrate some related works.Section IV follows describing the project, architecture and tools utilized in the system and Section VI describes the results obtained by implementing it.Finally on Section VI there are the conclusions, discussions and future works of this project.

II. GAMIFICATION

The concept of gamification consists in utilizing game mechanics outside of its bounds with the perspective to improve user engagement [7] [8] [9]. The term emerged in 2008, however only in 2010 it came to prominence [11].

It is possible to find some work reporting successful cases in areas as economy, marketing and health [7],[8]. According to [7] the utilization of these concepts must be well planned in order to obtain a positive effect and to not let the users get addicted to it.

He also focus on three major areas that are directly affected by Gamification in education: cognition, emotional and social. This happens because these areas influence the success or failures in a students academical progress [12].

The cognition area comprises the interactions of the user with the systems. As the games have a set of rules, the user is stimulated to learn these through experimentation, trial and error. During classes, the student may become reticent since the chances of failure are generally higher [7] [13].

These methods of experimentation generates the emotional transformation, as the user is compelled to overcome his

challenges in a game. The transformation occurs by changing a positive emotion into a negative one and vice versa. For example, when frustration becomes pride after overcoming an obstacle inside the world of the game.

The social area is explored through the interactions which are made inside the game. As the player progresses their virtual avatar need to make choices that will influence in their actions and the others around them. [13] and [7] also states that the user may identify himself as a scholar while "playing" the school game which most of the doesn't feel like it.

These theories can be reinforced through the studies of motivation by [14]. Those describes that in order to increase engagement, three major areas must be discussed: Autonomy, Mastery and Purpose.

Autonomy is when the person has control over their decisions and actions. Mastery is the intrinsic motivation which occurs when this person learns something new. As for Purpose, it is the necessity to create bounds with something externally to fulfil an internal need.

Another theory to enforce the ones described previously is the Flow proposed by [15]. This creates a relation between a person's skills and the size of the problem. The author argues that it must have a balance between these two metrics for the person be engaged with the task. In Fig. 1 there is a graph to represent this theory.
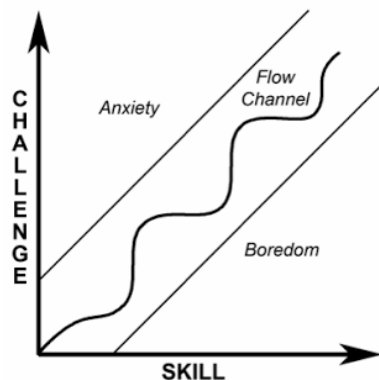

Fig. 1 Flow Management [15]

If the problem is bigger than the skills, the person becomes frustrated however if the skills are higher, then this person may feel bored. In this theory proposed by [15] a good learning method stays in the "Flow" section of the graph (Fig. 1) where the difficult raises with the skills of the learner.

III. RELATED WORKS

Empirical studies about gamification in education have emerged in the last five years. [1] realized a study with two groups, to analyse the influence of badges in users performance. The environment consisted in creating and answering questions from one group to another, one of them gained badges as they succeed and the other didn't.

The results affirmed that the number of answered questions were higher in the badges group. Then the author concludes

that the addition of badges in educational systems can steer better results related to students performance.

This conclusion can also be seen in the work of [16]. The author observed a Q&A (Questions and Answers) site, which implemented rewards through badges. The focus of this work was the correct method to implement this system and see how this method can influence on the changes in users behaviour.

Further on the gamification studies, [17] performed a study to demonstrate the healthy competition benefits through activities involving game development. The study was realized with a "Introduction to Computer Science" lesson in a group of undergraduate students. As a result of this study, a majority of the students decided to enter Computer Science courses.

Among those studies to engage the participation of students in classes, [18] created a system with points and rewards to Computer Science freshmen. The focus was to increase the interactions between those students, proposing challenges which could only be finished through combined teamwork as the tasks involved searching various locations of the campus.

Some of those awards were related to the students final grade. This method mobilized the entire class and also some veterans. As a positive result, there was a 92% of approval between all the classes that utilized this method.

IV. DEVELOPMENT

The development of this system began by identifying the subject which would be focused. To this end, a survey of the IT courses curriculum was conducted. Altogether 60 curriculum were collected from all regions and states of Brazil. After the survey, began the analysis stage, which sought not only the contents to be addressed, but also the workload of each discipline.

As a final result you can see that the concepts of lists, stacks, queues and trees appear more than 95 % on the curriculum analysed. Beyond that, the analysis of the workload of this course showed that the national average for Brazil is 100.06 hours, with the Southeast region with the highest average (122.1 hours) and the Midwest region with the lowest average (84.2 hours). Table I is possible to display the top 10 topics on menus. Moreover, Table II shows the separated region workloads.

TABLE I
TOPICS WITH THE HIGHEST PERCENTAGE OF
INCIDENCE ON CURRICULUM

Concepts	Percentage of Appearance
Queue	100,00 %
Stack	100,00 %
List	100,00 %
Tree	96,67 %
Search	75,00 %
Dynamic Storage	73,33 %
Graph	70,00 %
Files	51,67 %
Hashing	50,00 %
Complexity of Algorithms	43,33 %

After the identification of the topics, began the contextualization phase, which consisted in creating activities

TABLE II
WORKLOAD BY REGION

Region	Average Workload (hours)
Midwest	84,2 h
North	91 h
Northeast	102,3 h
Southeast	122,1 h
South	100,7 h

to cover the concepts of these structures. Each activity contains two general tasks, which consists in an interactive tutorial for the basic concepts and an exclusive task, to exemplify those subjects in practice. The implemented activities are explained in the next section.

In the next phase, named Planning, it was decided how the system would behaviour through the student experimentation and the gamification concepts. At first the system contains only one structure, however as the player progresses, through finishing tasks, more will be unlocked. In the planning phase, it was also designed the behaviour of the touch controls. As for the gamification concepts, a brief explanation can be seen below:

- Experience Points: Gained by finishing tasks
- Levels: Gained by collecting experience points
- Leaderboards: Utilized to measure the community progress
- Achievements: Unlocked by finishing special tasks
- User Profile: Used to see statistics of the utilization of the platform

The Implementation phase consisted in the materialization of the system. It was developed in Scirra Construct 2 game engine, which allows to export the game files directly to HTML 5. Also Clay.IO plugin for Construct 2 was used to implement the gamification concepts, such as player profiles, points, leader boards and achievements. And finally Ludei Cloud Compiling to export the project to an Android Application Package File (APK) so it may runs as a native application in this OS devices.

V. RESULTS

The DSLEP is divided by Data Structures, seen in the majority of lectures on this subject in IT courses. Each structure is unlocked by the player progression as he levels up, which occurs when he achieves a certain number of points by doing the activities in each structure.

By unlocking new structures, the student is exposed to new concepts and new activities associated with them. The user may also unlock achievements by fulfilling tasks related to specific structures activities. A few examples of possible achievements can be seen in Fig. 2.

In each system sub-menu contains the explanation tutorial and the activities associated with it (Fig. 3). The tutorial explains how the main algorithms of that structure works.

In the activities menu are the general and specific tasks of each subject. The general activities are found within every structure while the specific are associated with only one. The general and specific activities developed and implemented are the ones below:
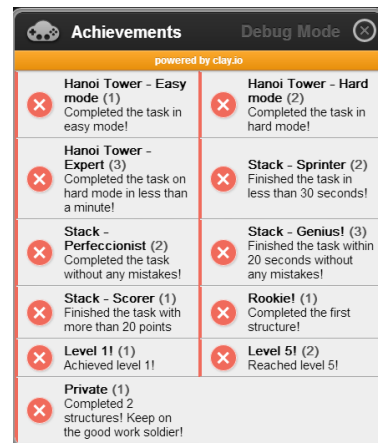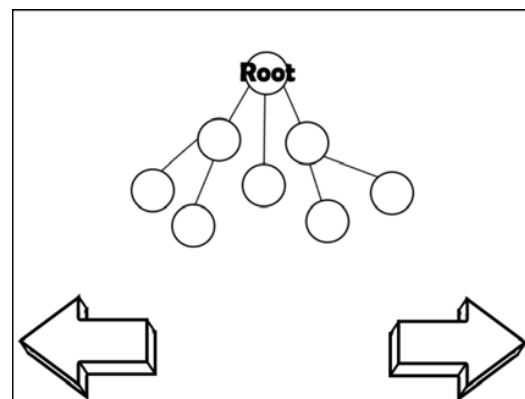

Fig. 2 Achievements

Fig. 3 Rotational Menu

- Classifying the Arrays
- Tower of Hanoi
- Stack ship
- Queue Race
- List Snake
- Balanced Tree
- Tree Traversal Methods

As for the major areas defended by [7] the cognition is affected by the interaction with an intuitive environment and it set of rules, so the player may navigate through the developed tasks. The continuous utilization provides a quick feedback and also allows to visualize the emotional transformation of the students, as for example a negative emotion turning into a positive one.

As for the social area, the system is integrated with a user profile, where he may be able to measure his progress. A set of leaderboards is implemented so the player is able to compare its results with others. Also he may be able to post their results to social networks as twitter and facebook.

A. Activities

The activities implemented in the system address the following structures and topics:

Structure	Concepts
Arrays	Types
Stack	Pop/Push
Queue	Insert/Remove
List	Insert in front/back
Rooted Trees	Balanced Binary Tree and Traversal Methods

Classifying the Arrays Activity: The Arrays task consists in organizing the geometric shapes in their respective lines. The task begins with random geometric shapes falling from the screen, the user may allocate them to one of the three presented lines.

After the first reallocation, the user will be capable of filling that line with the geometric shape allocated with it e.g. If the user allocates a green triangle to the first line, that line will be able to store only triangles of the same color (Fig 4).
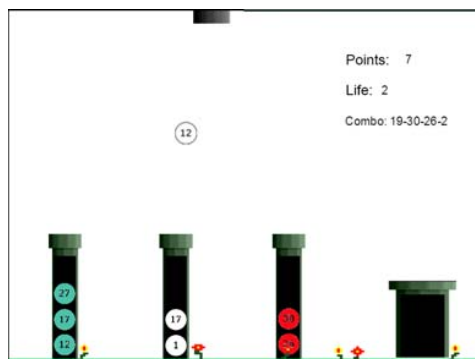

Fig. 4 Array Activity

This activity is proposed for the player to understand that an array can be capable of holding one type of element, after it initialization. On the Fig. 4 can be seen the implemented activity with its functionalities. The user sum points to the score as he fill and array with it correct elements.

Tower of Hanoi: This activity is a virtualization of the classical problem Tower of Hanoi. The user must pass the discs from one pine to another. However one smaller disc can't be above a bigger one. This activity is used to demonstrate the basic stack algorithms: Pop and Push.

The user may pop a disc from a pine stack and push it in the desired one (as seen on Fig. 5), following the problem logic. He may also unlock achievements by finishing the activity in less than 1 minute or with less than ten movements.

The Fig. 5 demonstrate the Tower of Hanoi activity. The user is able to select a disc from a pine to Pop, and push it in the desired pine by clicking on it. The text box PUSH or POP are highlighted as the action occurs.

Stack Ship Activity: The second stack activity is similar to the Array task. The user controls a stack through drag n' drop and random values will fall from the top of the screen. A random sequence will be generated and the user must complete it, in the stack, with the correct values.
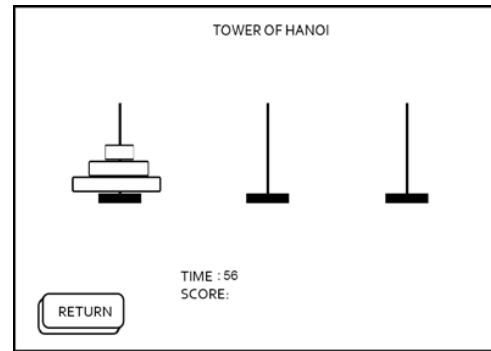

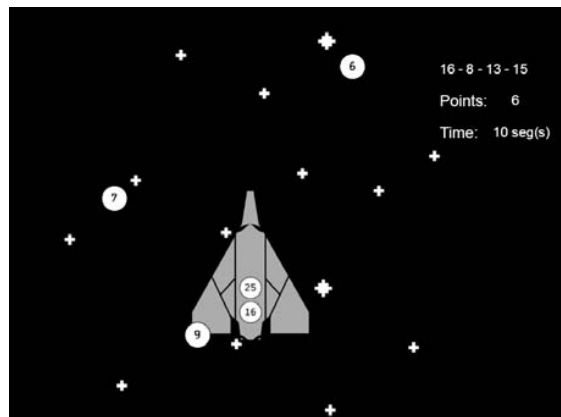Fig. 5 Tower of Hanoi Stack Activity

Fig. 6 Stack Activity

To Push a number in the stack it is necessary that the player touches the desired value with the structure. He may Pop the value by tapping the POP button, as seen on Fig. 6. The activity finishes when the stack overflows or underflow.

Queue Race: The queue race activity simulates a race game where the user controls a Queue car. The road is filled with numbers which the player must pass trough in order to gain points. A random sequence is generated in the beginning of the activity which add extra points to the user score.

The basic Insert algorithm is implemented obeying the "FIFO" (First In First Out) method, as seen in the Queue concepts. The points grabbed by the car are stored in the first position of the queue. If the player hit the Turbo button, the value stored is then released as seen in the queue Remove algorithm, this also allows the user to accelerate the car to grab more points (Fig. 7).

In the Fig. 7, the activity is demonstrated with the implemented functionalities. The user can control the car through the touch controls and push the Remove button to activate the Turbo. He may unlock achievements related to the points obtained as also the number of sequences completed.

List Snake: The List Snake activity represents the List data structure. The user controls a snake simulating a double linked list, with head and tail. Random numbers will be generated through the screen and the player must get them in order to sum points.
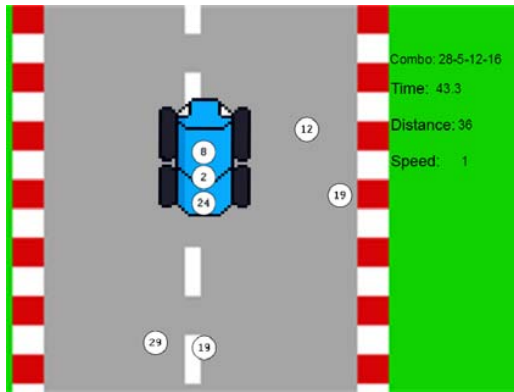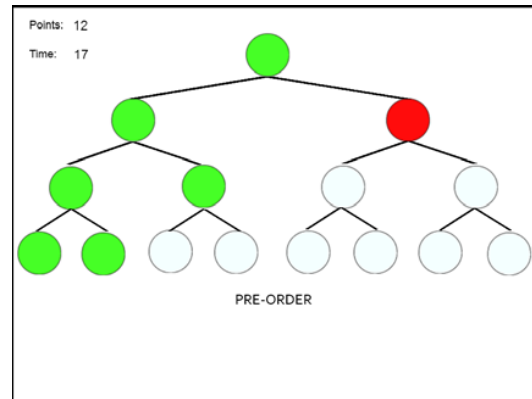
Fig. 7 Queue Race Activity

The user may be able to get the numbers through the Insert in Front or Insert in Back algorithm, by grabbing a ball with the Head or Tail of the snake. The activity ends when the two extremities collide.

Balanced Tree: The Balanced Tree activity simulates the Balanced Binary Tree insertion method. It begins with a random root node and random numbers will be generated, the user must click on the correct position to insert the value.

A countdown timer will also be presented to the user, if he chooses the correct answer the system add 2 seconds to the timer. The user must complete the tree before the timer runs out. To generate new values, the player can click on the Generate button (Fig. 8).
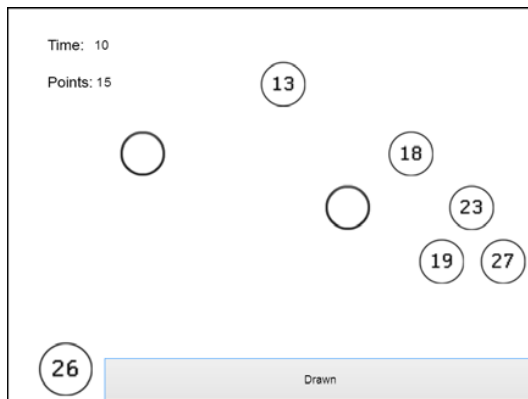

Fig. 8 Binary Balanced Tree Activity

The Fig. 8 demonstrate the implemented functionalities of this activity. The user is able to control de snake through the touch controls. He also may be able to unlock new achievements related to this activity.

Tree Traversal Methods: This is another Tree data structure related activity. The objective is to make the correct traversal method which is randomly generated as the user push the Start button. The countdown timer mechanic work the same as the Balanced Binary Tree Activity, where the user sums 2 seconds to each correct answer, and loses seconds to each wrong one (Fig. 9) .

Fig. 9 Tree Traversal Method Activity

In the Fig. 9 it is demonstrated the implemented functions of this activity. The user may tap the Start button to initiate and generate a random Traversal Method. After the method is generated, the player may touch the correct traverse method to gain points. The activity finishes when the user completes the tree or the timer reaches zero.

B. Evaluation

The evaluation of the system is based on the work performed by [19]. The author described a method divided in four phases, to evaluate and analyse applications with gamification concepts, which are described below:

Identification of the Main Objective: The purpose in gamifying a learning environment in Higher Education IT Courses is to engage and aid students in acquiring of knowledge for data structures concepts.

Identification of the Transversal Objectives: The secondary objectives includes the satisfaction of the students with the proposed method. By gamifying this system it is expected that the players develop a sense of aware of what are the important topics to learn about this subject.

Selection of Game Mechanics: The game mechanics chosen to be included in the system are divided in the three aspects of human motivation (autonomy, competence and relation), as cited by [14].

- Autonomy: profile, alternative activities, notification control.
- Competence: positive feedback, optimal challenges, intuitive controls, points, levels, leader boards.
- Relation: groups, connection to social networks.

Analysis of the Effectiveness: The analysis of the DSLEP will be measured through a questionnaire, validated by a Likert scale. This contains fifteen questions that will verify mainly the satisfaction of the user by utilizing the system.

VI. CONCLUSIONS

This paper presented the development of the DSLEP application which is an Interactive Learning Environment to aid students in Data Structure lessons in higher education IT courses. Some gamification concepts were applied to enhance engagement of the users.

The system consist in a set of activities to contextualize the concepts of the structures covered by it. All of the activities and their mechanics were planned to be running in mobile devices. The gamification concepts as points, leader boards, achievements and others, may provide a immediate positive feedback to the users, which may engage them.

The DSLEP was also planned to be easily extensible, so new activities and structures may be implemented in future works. This work aims to improve the understanding of the related subject and also to engage students to develop a sense of self-taught. In future works it is planned to analyse the effectiveness of the system in a practical situation, using the evaluation method cited previously.

In comparison with the last paper published about this project [20], the implementations of the mobile application with HTML 5 were successful and more activities were added. With a mobile version, the project is accessible to a large amount of users and not limited only to IT courses students, but also people who would like to understand Computer Data Structures. Also, more activities were added to the application.

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