Proposal of Method for Converting a Physical Card Game to Digital for Logical Reasoning Competencies on the Data Structure Subject

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Abstract— This paper presents a methodology to transpose a physical game into digital and an application to a case study. The main goal of this research is to confirm that digitalization helps working-class students to learn even having less time to study and experiment. The students developed a digital version of a traditional card game. The research bolsters the idea of first understanding the actual game concepts by analyzing and manipulating a physical card game. Using these concepts, students apply their results to examine the data structures perceived in the card game. Later, students develop the same card game using a conventional algorithm. Afterward, the development takes place in the virtual environment, using the Java programming language - we inherited the choice for Java from top hierarchies. We developed the method for transposing the physical game to a digital version before applying this case study. Using this method, students could work and understand each of the data structures concepts. In the end, each student extrapolated its applicability, trying to solve society’s problems. As a bonus, students also researched strategies for logical reasoning and critical thinking. Both are necessary for card game resolution and personal and professional development. The results presented show that the students who learned data structures developing this method were able to apply the concepts in the course's evaluations, in their work, in their homes, in their daily lives, and their personal lives. Some students' self-motivation led them to change their social position such that they found themselves improving their quality of life and those around them.

Keywords—logical reasoning, Data Structure, card game, education.

I. INTRODUCTION

Data Structure is one of the fundamental courses for students of college education in the field of Computing, as according to Cormen, Leiserson, Rivest and Stein [1], algorithms are within the heart of computing and data structures assist in the way of storing and organizing data to facilitate access and amendments.

However, there is a debate about the teaching-learning process of the concepts of Data Structures, as students find it difficult to understand data structures because they need both abstract thinking and problem-solving skills. A common factor considered is that many of the students end up observing ready-made solutions without understanding the behavior of the data structures, this is an important factor to be considered by educators in college technology courses in the search for new ways to make the teaching-learning process of the Data Structure subject more attractive, motivating, and interesting for students [2].

Academic experiences in the Data Structure subject, such as those presented by Correia, Garcia and Olivete Jr. [3], Fang, Du and Li [4] and Dicheva, Hodge, Dichev and Irwin [2], verify the difficulty for students to understand concepts such as Recursion, Stack, Queue and Linked List. With the advancement and innovation of technology, and the need for effective learning, the use of digital games as a tool to facilitate student learning has grown [2] [5] [6].

Educational researches have demonstrated a series of approaches, such as active learning, effective feedback, development of computational thinking, providing opportunities to practice, offering support tools to explore and visualize concepts, can help students of Data Structures courses in the teaching-learning process [7]. And, many of these approaches present principles and strategies aligned with the functionality offered in the construction of digital games [2].

Besides, as noted by Bottino, Earp and Ott [8], Hainey, Connolly and Boyle [9], Pereira, Silva, Piconez and Zimmer [10] and Lionmas, Altanis and Retalis [11], educational digital games, as they are related to educational didactics, besides being a support tool to understanding of knowledge, assist in cognitive development and social interaction.

The central problem described in this article is the difficulty of learning the concepts of Data Structure subject by the students of Computing. Traditional teaching-learning models do not usually show good results as presented by Correia, Garcia, Olivete Junior, Brandi and Cardim [3] and Dicheva, Hodge, Dichev and Irwin [12], which suggests a new approach. This approach must consider two important factors: the difficulty of abstraction, related to a lack of logical reasoning competencies for part of the students [12] [13]; and learning is more effective when the concepts and contents are exercised by students [12] [14].

Considering the previous researches and the hypothesis that educational digital games can enhance the learning process, this work's main objective was to employ games to improve the performance and results of the teaching-learning process for students of Data Structures. To reach this aim, the Solitaire Project was developed as a method of building a digital game applied in an educational context. This digital game was inspired by the traditional card game Klondike Solitaire.

The project has been applied in two consecutive semesters employing action research and data triangulation to generate qualitative results to determine the effectiveness and improvements of the Solitaire Project's method. The
understanding and mastery of the concepts of Data Structures were evaluated throughout the project.

The method developed for transposing a physical game to a digital version was applied in this case study. Applying this method, made students able to work and understand each of the data structures concepts. In the end, each student was able to extrapolate its applicability to solving society's problems.

II. RELATED WORK

The learning of Data Structure concepts through the construction of digital games was presented by Ferrari, Ribeiro, Dias and Falvo [15]. In this case, only the study of the concepts of intermediate and final card stacks, based on an adaptation in the FreeCell card game, was applied to the digital game, not presenting a method for the construction of the game, suggesting only tips for which steps to follow.

The Snake game, in which a snake eats screen elements and increases its length, is used for applying only the Queue concepts in the studies of Ferrari, Ribeiro, Dias and Falvo [15], without presenting the method of building the game.

The manipulation of ready-made digital games can be used as a way of motivating students to learn the concepts of Data Structures. Zhang, Atay and Caldwell [16] present the study of the Linked List concept in the Space Traveler game, similar to the Snake game, where the spacecraft’s ‘orbs’ represent the nodes of a linked list with the insertion and removal operations.

Zhang, Atay, Smith, Caldwell and Jones [17] present the concept of Recursion in the game Recursive Runner to find the numbers of the Fibonacci sequence and to calculate the factorial of a natural number, using the concept of Recursion in the game's walkthrough.

Kaur and Geetha [18] present a custom-built gamified application named “Play and Learn DS”. The manipulation of Stack in phase two of the application and Queue in phase three of an application.

The construction of educational applications by students who are future teachers was studied by Krimberg, Ribeiro, Sonego and Behar [19]. In this study, it was observed that the development of digital applications considering the pedagogical, technical, and interactive criteria provides that educational materials have more significant potential to obtain new forms of learning.

Dicheva, Hodge, Dichev and Irwin [20] present an educational game development effort to teach the concept of Stacks as part of the Data Structure Subject. Dicheva notes that the teaching-learning process through game development integrates active, problem-based systems and interactive learning that is combined with motivational strategies.

The Solitaire Project addresses the concepts of recursion, Stack, Queue and Linked List in a single card game Klondike Solitaire presenting the method of building the game, so that the student can make the proper connection of the concepts being applied in the game. The concepts are applied to the game under implementation are card shuffling, card stacks and the deck from which the cards are drawn.

In Solitaire Project, students create their own digital game; thus, human-computer interaction, user interface, strategies and gamification are developed according to each student's skills. The critical thing in this project is that the concepts of Data Structures are mastered from the game's logical construction.

III. METHODOLOGY

The Solitaire Project promotes the experimentation of the Recursion algorithm's concepts, in addition to the concepts of Stack, Queue and Linked List of the Data Structures subject, by converting the traditional Klondike Solitaire card game in its digital version in Java.

A. Student Profiling

Two semesters, two classes of students, one with 99 students and the other with 80 students had their knowledge of Data Structures evaluated by action research and data triangulation. Table I presents some information of these students.

![Table I. Students Information](image)

The target group is made up of students from the Data Structure subject, from college education courses in Computer Engineering and Computer Science at a private university with previous knowledge of sequence, decision, multiple-choice, repetition, sub-algorithms, vector manipulation and routines.

Most students are between 20 and 40 years old and have already passed the Algorithms course or already have basic knowledge of algorithms or the Java programming language.

According to the results of the university students' profile questionnaire, they are mostly from classes C and D, are students from public schools in basic education, and have parents with high school studies when completed. Their grades in national exams such as ENEM (national high school exam) and their social conditions allowed them to receive scholarships in governmental assistance programs such as 'Quero Bolsa'. Evasion is approximately 60%. Live on the outskirts and take between 90 to 120 minutes on the university-residence commute.

Few have automobiles or motorcycles for this commute. Most chose the computer course because it provides a good salary, and when they start working, they start to help the family financially.

Regardless of the social class of the students who took part in this research, the students notice the need for a qualification to enter the labour market with a position that allows them to be in a more comfortable condition. What motivates them most to play a student role is the qualification for a better position in the labour market.

Solitaire Project is designed to provide greater motivation for those students who dedicate part of their time to work, part of their time to family, and part of their time to studies. As such, it is a method that simplifies traditional education for student-centered education and takes into account their prior knowledge and allows the student to be the protagonist of the teaching-learning process, with a mediating educator who helps him organize ideas with planning, with questions, with
knowledge, suggesting paths, guidance, and direction, as defended by Freire [21].

Once the protagonists of the knowledge to be developed in the Data Structures subject, they come to understand their position in front of the university, their capacity in the face of professional challenges, their family challenges and balances and their role as citizens who provides services to society helping to solve everyday problems.

B. Material

The Solitaire Project combines the learning of the concepts of Data Structures from the construction, by the students themselves, of a digital game based on the traditional card game Klondike solitaire.

The solitaire chosen between card and board games, in previous research with students of this research, the results showed greater motivation when learning is performed through games. Most of them already knew the strategies of the solitaire game, and they felt comfortable in manipulating this game to study the concepts of Data Structures.

The solitaire game also has, in its initial structure, the arrangement of the cards so that the concepts of Data Structures can be understood, manipulated, and studied. To later be converted to your digital version of the logic game.

In the Solitaire Project, students use the physical cards to handle and manipulate the Klondike solitaire game and understand the concepts of Data Structures, so that they can begin to understand the logical rules of the development of the algorithms involved for the creation of the digital game that is implemented in Java language.

The educational objectives of the Solitaire Project are to learn some of the Data Structures and algorithms that support the data structure manipulation algorithms, such as the following and presented by Drozdek [21].

1. Recursion. It is a programming model in which a subroutine can call itself. Although not a data structure, it is a computational algorithm strategy used to manipulate data structures.

2. Stack. It is a linear data structure in which data is accessed from only one end, so that the last to be stored is the first to be accessed.

3. Queue. It is a linear data structure in which data is accessed from both ends so that the first one that is stored is the first to be accessed.

4. Linked List. It is a set of nodes and links in which data is stored on the nodes that are connected by the links.

The surveys were carried out in the university computer labs. The decks, computers, mouses, monitors, and computer programs used had the same settings and characteristics.

C. Solitaire Project Method

In Solitaire Project, in the construction method of the digital game Klondike Solitaire, students follow a sequence of steps to understand the concepts of Data Structures, the development of algorithms, the implementation in the Java language, and the integration with the Klondike Solitaire game logic.

In the physical Klondike Solitaire card game, a traditional 52-card card game is used with four suits (Hearts, Spades, Diamonds, and Clubs) and thirteen numbers (A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, and K).

When students develop the Klondike Solitaire digital game, the cards are registered in a Node structure with a number, a suit, and a status (open or flipped). They are then stored in an array and shuffled recursively.

Subsequently, 24 of these cards are stored in a Queue structure, and the remaining 28 cards are placed in seven Linked Lists. The player must create strategies to send all the cards, one by one, in an increasing numerical sequence, to the four Stack structures.

Figure 1 exemplifies the illustration of the data structures used in the Klondike Solitaire card game, as well as, where the concepts of Stack, Queue, and Linked List are associated with the card game.

During the development of the Solitaire Project, students were introduced to the theoretical concepts of data structures that were used to create each stage of the Solitaire Project.

Fig. 1. Stack, Queue and Linked List in Klondike Solitaire

The following are the Solitaire Project steps and the moment when the concepts of Data Structures are being developed.

In the first contact with the Solitaire Project, students need to explore the game in its traditional form, to be able to plan and, later, execute the construction of the digital version. Exploring is done in three stages, corresponding to three face-to-face sessions, as shown in Figure 2.

Fig. 2. Discover, Plan and Execute

At first, students manipulate the physical cards to understand the game and its rules, think about how they can develop an interface and a human-computer interaction with the virtual game they are going to build, thinking about the elements that make up a card and play the physical game.

Once the students understood the game and observed the elements with the physical game, they developed the card's structure and build the vector Game with 52 positions.
This construction is performed with algorithms in pseudocode and later in the Java language in one step with a face-to-face session.

In the Solitaire Project, four face-to-face sessions are dedicated to the construction of computational thinking that involves Recursion, as shown in Figure 3.

![Recursion](image)

**Fig. 3.** Recursion

First, students use the physical game to understand the procedure for shuffling the cards, considering that these cards are in a 52-position array.

They place the cards side-by-side and in sequential order, considering that each has a position from 0 to 51. They choose two random numbers from 0 to 51 and exchange these position cards.

The process is repeated for students to observe that these iterations result in the cards shuffling. At this point, the concept of Recursion is introduced.

Subsequently, the students develop the recursive algorithm to shuffle the cards in pseudocode, then in the Java language, and perform individual tests to verify that the developed algorithm behaves as expected.

For the development of the Stack concept's computational thinking, the Solitaire Project proposes four classes: manipulating stacks in the physical game, algorithm development, Java development and tests execution.

Students separate the physical game in the four card suits and understand how they can be handled in the suit stacks, according to the rules of the game.

Once students understand the operations involving the Stack concept, they develop the pseudocode algorithms, later in the Java language, and finally perform the necessary tests to verify that their algorithms are correctly performing the Stack operations.

Another four face-to-face sessions are focused on the development of the computational thinking of the Queue concept and proposes four classes: manipulating queues in the physical game, algorithm development, Java development and tests execution.

Once more, they return to the physical game, select some cards that represent the game's Queue and handle them to understand the operations involved in the Queue concept.

Once students understand the concepts of Queue, they develop the unique algorithms in pseudocode and, later, in the Java language.

And, to finalize the construction of the Queue knowledge, they performed the necessary tests to check for possible inconsistencies in their algorithms and, if necessary, repairs to the algorithms are performed.

For the construction of computational thinking that involves Linked Lists, the Solitaire Project dedicates five classes: manipulating Linked List in the physical game, algorithm development in two classes, Java development, and tests execution.

For the learning of Linked List, students manipulate the physical game and understand the operations that involve the concept of Linked List.

At the time of the development of the pseudocode algorithms, the students return to manipulating the physical game to remember the operations.

Subsequently, they develop the algorithms in the Java language and perform the necessary tests to correct any inconsistencies they find.

Once the algorithms that involve the data structures have been developed, the method assumes that students need to understand and build the algorithms of the logical operations of the game manipulation between the algorithms of the data structures.

For this, the Solitaire Project proposes five classes: manipulating logical operations in the physical game, algorithm development in two classes, Java development, and tests execution. Students return to the physical game to manipulate and understand the operations between data structures.

They later developed the algorithms of these logical operations of manipulating the game in pseudocode and the Java language. Students perform the tests necessary to eliminate the possible inconsistencies that may appear in these algorithms.

After all the algorithms of the operations involving the game data and logic structures have been developed, students need to integrate these algorithms for the functioning of the digital game.

For this development, the method assumes that they need six classes, as shown in Figure 4.

![Logical Reasoning](image)

**Fig. 4.** Logical Reasoning

First, students go back to manipulating the game with the physical cards to understand how the connections between data structures and logical operations happen.

With the help of the physical game, they develop the game integration algorithms in pseudocode and, later, in the Java language.

Once the digital game is complete, students perform individual tests on their digital game and then test their colleagues' digital game collaboratively.

And, the inconsistencies presented for both tests are discussed as a way of exchanging experiences and eliminated.

Students were invited to share the learning collectively at the end of the development of each of the data structure in the Solitaire Project. At that time, some specific activities of the developed in the Solitaire Project were requested. Each of the
students went to the whiteboard to record their learning, discussing, and showing different solutions.

At a later moment, some specific activities of data structures were requested; however, this time, playing cards like the Solitaire Project. This time, the students had to adapt the learning obtained in the development of the Solitaire Project with a new card game. Colleagues collaborated and cooperated with suggestions and tips, showing the similarity with those that had already been developed in the Solitaire Project.

And, in a third moment, the specific activities of data structures were related to any situations other than playing cards. This time, the students had to adapt their learning, understanding, and associating the knowledge learned in the Solitaire Project. Again, colleagues collaborated and cooperated with suggestions and tips, presenting the adequacy of the knowledge learned from data structures in new day-to-day situations.

D. Conversion with Data Triangulation

The research-action approach is being considered to understand reality in its context and assimilate the impact of the construction of digital games as a learning strategy and since digital games are inserted in the social environment of students.

Action research [22], in its immersion, considers an academic environment surrounded by cultural, social and, economic issues of the participants. During the research period, students and educators were pedagogically better influenced in the teaching and learning process.

The research carried out data triangulation within the observation and data collection procedures through records of the educator's and students' performance. The presence of an apprentice stimulus mediator caused internal, socio-cultural, and pedagogical interconnections.

The factors in the experiences of mediated learning are the apprentice, his colleagues and the educator who have different experiences and who have crucial influences on the development of the individual as a human being. Human and cultural mediators are responsible for sharing broad and meaningful cultural elements of the objects and events of students' direct or lived experience by students [23, 24].

Qualitative diagnostic survey questionnaires, individual interviews, and focus groups were used as instruments of data collection. And, later, individual, and written exams of transcription of the knowledge learned.

The interviews that took place were always formal and informal when the research took place with students.

The results were used to prepare and execute the Solitaire Project to develop the competencies and skills of logical reasoning and the teaching of Data Structure.

The individual interviews took place during the first class and before the Solitaire Project's application, meeting the students, understanding their needs, motivation and, the context in which they live, so that the experiments could be adapted.

Informal interviews were also conducted with educators, teachers, and coordinators of the University Computing courses for an initial survey and recognition of the research field. Focus groups are a qualitative research technique for data collection and are used when there is an absence of numerical measures and statistical analysis. They are a type of group assessment on a subject in which discussions favor the understanding of the phenomenon observed and directed by a mediator, who was the author of this work. The objective is to verify students' feelings, perceptions, attitudes, and ideas on the subject, clarifying personal points of view, encouraging the collection of valuable information.

A field diary, with records in an electronic spreadsheet was part of the data collection, continuously, to have a more significant record of the results obtained in each stage of the research. The diary helped to adjust the data triangulation from the experiments and inter reflections about what was collected in conjunction with other techniques used to understand the researched experiment.

The game defined for the construction in its digital form was the Klondike solitaire that was used freely in its physical version.

During the two semesters in which the experiment was carried out, students were instructed to use the physical game during the activities. The students were assisted, followed, and motivated through the interaction facilitated by the two weekly classes in the semester.

Data collection involved interviews during classes, field diaries filled out for each class and, focus groups with monthly discussions.

Students presented adequate responses to the concepts of Data Structures and, encouraged to explain the answers in the focus group experience, clear to the other students. These data allowed a finding that the student understood the concept and how he came to the answer presented.

E. Assessment

In each face-to-face class, students were interviewed, and the interview results were mapped and recorded on electronic spreadsheets. The situations in which the development of the algorithm precedes and succeeds and, in which the use of the physical game served as support for the understanding of the concept, were recorded.

The students' observations recorded include their motivation, permanence until class was over, arrival before the beginning of the class, exchange of messages among themselves and with the educator, and outside of class period.

The motivational factor, the understanding, the time of execution of the tasks, the connection with the resolution of personal, professional, and society problems were also evaluated.

Both classes performed written assessments at the end of each period, with open and discursive questions that assessed the quantitative and qualitative knowledge of data structures that each of the students in each class presented to have developed.

For each concept of Data Structure, some questions were developed for analysis: understanding of the concept assimilated by the student; understanding the manipulation of the concept; the ability to develop algorithms using the concept; understanding of performing tests, checking for possible errors and improvements in the algorithm with the applied concept; computational application; the application to
solve problems at work; the application to solve problems in the family environment; the application to solve personal problems; and application to solve society's problems.

Also, students discussed the advantages, disadvantages, and applications of learning through the Solitaire Project.

For a qualitative result, however, without values that make up the final grade of the exam, the students presented professional and everyday situations in which they could observe the concepts of the Data Structure being employed.

Although written and individual evaluations of quantitative results have been carried out, these results have not been explored in detail here, as it is not the focus of this section, however, all the values that prove the improvement in learning through quantitative results are stored and tabulated in spreadsheets.

 Learning was assessed according to the scores obtained in theoretical exams. In this way, when students manipulate data structures in the Solitaire Project, they learn, even when they play the digital games developed by their colleagues.

One last aspect observed was the game's graphical interface, since students were concerned with developing interfaces like the digital games of the Klondike solitaire game found on personal computers and the internet. However, the graphical interface could be developed after the game was created.

IV. RESULTS

It was possible to observe that the learning of Data Structure concepts was better assimilated when developed with the Solitaire Project.

The Linked List and Recursion were the most difficult concepts to learn by looking at student averages, grades from 0 to 10, for each Data Structure concept in Table II.

<table>
<thead>
<tr>
<th>TABLE II. AVERAGE GRADES OF WRITTEN EVALUATIONS</th>
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</thead>
<tbody>
<tr>
<td>Recursion</td>
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<tr>
<td>-----------</td>
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<tr>
<td>1st sem.</td>
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<td>2nd sem.</td>
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</tbody>
</table>

The students reported that, although they developed the same algorithms, they can now interconnect the concepts for the same purpose to make the game run instead of applying them in isolated exercises.

The students understood that, from the theoretical studies of the pseudocode algorithms, it was possible to reproduce the contents in the Java language with the computational resources and apply it to a functional product.

The students realized that, with the need to solve a problem or achieve a goal that was to make the game run, they developed abilities to reveal errors and create strategies to solve them, which did not happen when they developed isolated exercises to fix each of them the Data Structure concepts.

The students reported that to apply the Solitaire Project, they had to understand the project as a whole to then define the development strategies and their connections with the concepts of Data Structure because if some part of the project was not logically defined and structured to be developed, the whole project could be compromised, as the game might not run properly.

The students realized how much they can share knowledge among themselves, because the different data structures were applied in different ways within the project, without loss of application and within the suggested scope.

In this way, students helped each other in detecting errors and improving each project, creating a collaborative environment between them, acting as the professor, the coordinator, and collaborator instead of the holder and transmitter of knowledge, allowing, according to Ponce [25], a democratic and solidary academic coexistence for the construction of a humanitarian, democratic and mutual respect knowledge.

During the application of the Solitaire Project, the learning information of Data Structure concepts was analyzed. A more in-depth observation was made with students who failed the Data Structure using the Solitaire Project.

Some students reported that part of the difficulty of maintaining a face-to-face attendance due to conflicts between work and study hours and commute times, losing the interaction and learning to build knowledge of the concepts of Data Structure. One way to solve this problem would be the possibility for the attending students to report the steps developed in each stage and share with the absent students.

Some students reported the need to develop parallel activities for solving different exercises to fix the concepts of Data Structure to certify the concepts. In this way, exercises such as stacks for browsing the web, queues for printing control, linked lists in bank services passwords, among others, can be requested from students optionally for the maintenance and review of the concepts to perform the written exam.

A. Discussion of Results

During two semesters before Solitaire Project's application, some specific activities, involving the development of simple games, were applied and developed by the students. Examples of these games are the Tower of Hanoi, Chess, Magic Cube, Snake Cube, among others.

The students realized that they were more involved in learning and felt much more motivated when the activities involved games. They even reported that they studied how to solve the games before the activities were realized. They studied the games outside of the classroom so that they arrived ready to develop the resolution using the data structures.

As it was noticed greater motivation and better learning through games, the idea arose to develop a project, of a semester, in which students could digitally develop a game applying some of the data structures and algorithm concepts.

In a survey with students, there was a greater interest in games involving playing cards. Logic games, especially card games, are part of the students' daily life. Its form, communication, and formalization made learning of data structures more effective than traditional teaching methods.

When the activities realized were those developed in the Solitaire Project, the students were able to solve them without any difficulty. When the activities performed were similar in the context of playing cards, based on few analyzes and discussions, the students were able to complete the activity based on a few analyses and discussions. And, later, when the
activities were in a different context from playing card games, students based on the cooperation, dialogue, and comparison of previous activities, were able to perform the activity, applying the knowledge already learned.

In this case, what was observed is the transcendence of transferring what was learned to their everyday situations and to the society they pertained. It happened when a student presented a solution to optimize his work or when a student presented a solution to improve the performance of the company in which he works, and when a student presented a solution to improve a society concern.

A student who works with document archiving, realized that the documents were organized in an alphabetical manner. Using the concepts of Linked List, inserting the documents into Stack, alphabetically and different from how the student used to archive; which was the order of the arrival of the documents, he would be able to file the documents in a shorter period because instead of opening the files by the letter of the document, he started to open the files in alphabetical order. This insight allowed him to significantly optimize the time as he opened the files in alphabetical order, and incoming documents, which had the letter the student had already filed, were stacked to be organized later. The student adopted this strategy because there was no priority in filing documents.

The student stood out for his agility in filing documents and his superiors asked him to develop an archiving manual so that other professionals who performed the same task could use the same strategy. Subsequently, the student was asked to verify which manual and slow processes of the department that he worked in to apply the knowledge learned to optimize the time to accomplish these tasks.

At the end of the Solitaire Project, a student had an insight when making a mental analogy with the data structures learned from the production mats, and he presented a proposal for the pharmaceutical industry in which he works. He develops solutions to optimize the systems that operate the machines to guarantee product quality and reduce losses.

A student who develops technology solutions for a company, thought about how he can use the knowledge learned in the Data Structure Subject for environmental sustainability. He is very concerned with the environment and the country's hydro structure for the collection of water that can be used for human consumption. He reported that he would use the concepts of data structures to propose a solution and participate in entrepreneurship contests to promote his idea.

A group of students of the Solitaire Project adapted the card game to put tips and questions about the game as an auxiliary resource, which was out of the scope of the project. They used the learning of binary searches for a question to be found more quickly in case they used a linear search for the question. In this case, the ordering concepts utilized at the beginning of the project and discussed with students were used.

What has been learned with the development of the Solitaire Project? What were the strategies used for the development of the Solitaire Project? Why is the content learned important? Where can this content be applied to solve everyday problems? Questions like these, proposed by students allowed them to analyze and reflect. The student found himself in situations of his social context, which could be improved or resolved by applying the contents he learned in Data Structure.

Since knowledge was built on a stable, mediated, collaborative, collective and mainly motivating basis, the meaning of learning was also constructed so that each student could replicate the knowledge learned reasonably and within the formality of programming languages, to solve problems of his daily life or society. They were starting from the theoretical and applying in practice.

All students reported that, with the Solitaire Project, the learning dynamics allowed for a greater involvement, with collaboration promoting a sense of competence in the project. The logical reasoning promoted by a student or a group of students was analyzed, shared, and discussed. This reasoning was then put into practice to verify the results after the paths were chosen when a path reached a result that was different from what was expected, a new analysis, discussion of the results, and the commitment of each one to find the appropriate solution transformed each student's feeling of competence in the project.

It was remarkable that the students, at each content developed and each stage of the advanced process in the Solitaire Project, started to have more confidence in participating, collaborating, and analyzing together to have the best result.

One of the students reported that at the end of the project, he was able to analyze his projects and verify, analyze, and look for other ways to find satisfactory solutions to the result of these projects. He reported that before he was frustrated when he tried, and the results achieved were far from the projected objective. Now he observes, shares the results, seeks for opinions, analyzes, and traces another way to find the desired solution. He said that the way the professor mediated observations, analysis, and strategies in choosing algorithms for the development of data structures for Solitaire Project, helped him understand why he failed with the results of his projects.

One of the students reported that he started to have a better professional performance after participating in the Solitaire Project. He said that before, he simply performed what was asked, finished, and left. He stopped questioning, analyzing, and checking whether the results were compatible with the ideal. He noted that for everything that happened at Solitaire Project, the professor just listened and made the students find the solutions. The professor conducted it to the students in a way that they needed to analyze and forecast the results, even before realizing the task. When the student started to perform these simple tasks, it was perceived by the superiors that the results were improving qualitatively.

One student reported that he felt entirely cornered at the beginning of the project by his shyness and fear of making mistakes. When he started to realize that everyone was there playing the same game, that everyone was there learning and that the difference is that some who had a little more advanced knowledge had more ideas, however, in the end everyone was working towards a single development goal of the Solitaire Project for effective learning of the concepts of Data Structure. “The professor encouraged everyone to participate, and at my turn, I sweated and refused at first, but the professor told me to express just one idea or an example where we could go to find the desired solution, I gave an example that I found silly and to my surprise, the professor said, but that's it! And
she used my example, to show how the expected result could be achieved.” From that day on, the student began to participate more effectively in the project with outstanding results.

One student said he had difficulties working on team projects, as he had a perception that tasks were divided into teamwork, and the result had no connection that contributed to the proposed final goal. He realized that he was developing the Solitaire Project, as the project's stages were performed with collaboration of all students in the class mediated by the professor. That the groups only met to realize what had already been built collectively. The groups created their strategies based on what had already been planned for all students. The groups only inserted particularities that they considered being a differential, which enhanced the results. However, all the results of all groups reached the objectives.

One student reported that when they validated the Solitaire Project, and the professor asked the groups to exchange their projects, he realized how much each project had its particularity, styles, different trends among them. Even if the projects had been developed altogether, collaborating, exchanging ideas, opinions, improving, one helping the other. The designs themselves, the product, were all different. They reached the same goal, but each with its particularity, enclosing each of the members of each group particularities. At this point, the student realized how much the existing differences were valued.

One student realized that his choices could contribute positively or negatively, but that they should be exposed to be analyzed and discussed in a group, as all other students did, and they did not complain when noticing that their proposal was not the best for that moment. The professor showed that an idea even an inappropriate idea for that project could be used successfully in another type of project, or another situation, or another perspective. This discovery motivated the student to present his ideas, unblocking his fear of exposing his ideas, and increasing his confidence because his ideas could always be used successfully in different ways, in other situations. However, he needed to analyze and understand the best way, the best place, and the application of his ideas at the best time.

One student reported that the professor managed to deftly manage the situation of a group that wanted to personalize the image of the suits, with ones susceptible to erotic scenes. The professor said that each group could personalize their project in the way they best perceived. That they should analyze who the target audience was, how it could be observed and commented on by society, what impact it could generate for the group, if there could be investors for this type of customization, among others. She did not decide for the group, and she made the group reflect on deciding according to the answers they found.

One of the students reported that his relationship with family members improved, as he started to organize small things better at home. He realized that when he shares information with family members, he hears suggestions and analyzes. He began to practice what the professor did in the classroom, the same questions were asked, and family members were asked about a simple objective, which was to organize their college material. This behavior does not mean that he needs to follow the recommendations, but they helped him to analyze the alternatives that went unnoticed and often useful. And that way he managed to organize his clothes, shoes, college materials, schedules, among other things.

V. CONCLUSION

Based on the application of the Solitaire Project, the students of the Data Structure subject learned to organize their ideas by manipulating the cards, to plan the actions connecting the concepts of Recursion, Stack, Queue, and Linked List, learned in theory, with the implementation in Java language and collaborative development to understand the rules of the game.

This practice allowed students who applied the Solitaire Project to get the highest grades in the written exams, as well as the highest pass rate in the Data Structure Subject compared to students who developed learning in the traditional method.

Furthermore, students discussed with colleagues about concepts, ideas, problems, and simple strategies brainstorming with other students, allowing collaboration. They played games developed by colleagues, an exciting experience to observe other solutions and gain knowledge.

It was possible to notice an extrapolation of the concepts being applied outside the academic and computational context. And, despite all the qualitative results observed, some students from university's college education courses work in areas that are not related to Computing and, some others are not able to enter the labor market in the computing area.

Although it is not the scope of this document, it was observed that there is a prejudice against the student's education and social class to enter the labor market. Some students are not working in the area they graduated from university. It was noticed that when a student from classes C and D starts college, he positively impacts the family, changing the behavior of family and friends, encouraging academic training and registered work.

The students' location interferes with academic attendance because on rainy days, the surroundings of their homes flood and stop them from being able to commute to university. For many students, the crime and violence surrounding their homes prevented them from staying in school until the end of class.

On days of soccer matches and Fridays, the absences were noticeable, which allows an understanding that the social reality in which the student lives interferes in his academic life. Perhaps, it is necessary to change the reality in which the student is immersed for him to leave the condition in which he finds himself.

The students of classes C and D become change agents, since once they allow the academic change to provide them with better living conditions, the reality of the environment also changes. When knowledge is learned, he can extrapolate learned concepts out of the course, whether for home, work, and life. This type of project that leads to meaningful learning, can propose a study to verify the need to be built on the first day of the educator's class together with the students, as it is a proposal where the curriculum is dynamic and can undergo changes during the course trajectory.

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