DEVELOPMENT OF LEARNING OBJECTS AND THEIR APPLICATION IN TEACHING AND LEARNING DATA STRUCTURES AND THEIR ALGORITHMS

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Abstract: *In the courses of information technology area, there are many difficulties in the teaching and learning process of Algorithms and Data Structures. Learning objects (LOs) as images, videos, animations and other digital resources have such characteristics that can benefit the educational process of these disciplines. Not only presential classes but also new formats of online courses may be favored by the use of LOs in virtual learning environments. In this context, this article aims to present the results from the development of LOs for simulating operations with linear list, stack and queue, stored in a Website built as a repository, as well as its evaluation by students of Computing Engineering and Software Engineering. This issue is also discussed in the article the technologies used in the development of this educational tool.*

Keywords: *Algorithms teaching methodology. Distance education. Animations.*

1. INTRODUCTION

The teaching and learning process of algorithms and data structures presents a great difficulty, which is to understand how is the practice from the theory. According to Scalco (2006), the abstraction of concepts is a great difficulty of the students, since they fail to realize immediately as the graphical representation of a flowchart or the words of a source code may turn into a computer program.

Teaching in general can benefit itself by the computer use. According to Oliveira et al. (2011), the use of a computer together with the blackboard, chalk and textbooks, along with the teaching-learning methodologies and the teachers, has been facilitating the acceleration of the teaching-learning process by providing students interaction with the content through animations, views and checks available during the use of these educational softwares.

According to Krämer (2005), the concept of LOs (learning objects) emerged in the late 1990s, with the motivation to reduce the development cost of digital educational content and its maintenance, by means of modularization and reusability. The author points out that learning objects offer a new way to create and mediate educational content in terms of smaller learning units that are self-sufficient, which can be reused in several contexts and pedagogical situations and can be grouped into coherent sets of digital learning content .

There are several definitions to LOs. According to Braga (2014), animations, as well as images, videos and others digital resources can be considered learning objects. And for Audino and Nascimento (2010), the reference to LOs is associated to computer use and Internet.

From a learning object repository on the Internet, students can analyze information and learn at their own pace outside the classroom, according to Gilley (2001). Besides that, the Internet provides an appropriate means for reuse and sharing of educational materials. This aspect of the global network significantly expand the possibilities of interaction not only in traditional teaching (presential) but in distance learning, which according to Santos and Leite (2010), is the physical separation between teachers and students, focusing on self-learning and collaborative learning.

In this context, this article aims to present the results obtained from the development of LOs for the simulation of operations with lists, queues and stacks, deposited in a Website built as a repository. This article also presents the aspects related to technologies used in its construction, as well as the prospect of students in information technology area that used educational tools.

2. ISSUES RELATED TO THE TEACHING AND LEARNING PROCESS OF ALGORITHMS AND DATA STRUCTURES

The learning of algorithm and data structure is essential for information technology courses, because is the base for the development of computer programs. The domain of this knowledge requires the development of logical reasoning, from which you can model the solution of problems in the form of algorithms and set the mode of data organization. Evasion problems in the field of computer courses as well as courses in algorithms and programming have stimulated discussion on the various aspects involved in these issues, given their importance.

Santos and Costa (2006) discuss the importance of good teaching of algorithms and programming fundamentals in undergraduate courses such as Computer Science and Information Technology, as well as they present an analysis of computing teaching methodologies approaching problems and solutions. The authors highlight the use of tools for teaching algorithms, data structures and programming, such as the use of tutorials, educational software and environments for the development of animations.

Giraffa and Mora (2013) present various studies related to evasion in higher education, especially in Computer Science courses. The authors point out that one of the reasons for the withdrawal is the difficulty encountered by students with the content and skills necessary in algorithm's discipline. The authors, in their work, sought to find what are the perspective of the student in this process, through a qualitative analysis, with the development of a case study. The research results showed that factors that teachers think as more impactful, such as pre-requisites related to mathematics content, logical thinking and ability to solve problems are not perceived by students as the most impactful. For students, factors associated with lack of time and the difficulty in understanding enunciation from exercises appear as the most relevant for the evasion of the discipline. The authors conclude that there is no single factor that influences the maintenance or evasion of the student, and that research should be extended to strengthen the indicators found. However, they point out that the conduct of teachers can help to mitigate the problem in different ways, for example, the use of various materials and media.

Silva et al. (2009) also discuss aspects related to educational programming, algorithms and data structures in higher education courses in Computer Science. The authors listed several reasons for the high rates of failure in these disciplines and related possible solutions presented by different authors, for example, the use of

computational tools to implement animations of algorithms and data structures. As for programming teaching in courses in distance mode, the authors emphasize the need to implement focused methodologies in that reality.

3. LEARNING OBJECTS (LOs)

In the literature, there are many definitions of learning objects, more or less comprehensive, or used in specific contexts. For Wiley (2000), a learning object is any digital resource, considered a "small instruction object", which can be reused in different learning contexts. Still, Wiley (2000) highlights that such objects are available on the Internet and can be used by individuals simultaneously.

More specifically, McGreal (2004) states that LOs are sometimes defined as being educational resources that can be employed in technology-supported learning. With appropriate metadata descriptions, they can be modular units that can be assembled together to form lessons and courses. A LO can be based on an electronic text, a simulation, a Website, a .gif graphic image, a Quicktime movie, a Java applet, JavaScript application or any other resource that can be used in learning.

According to Braga (2014), learning objects are deposited in a variety of locations, such as Internet sites, in generic repositories, in multimedia libraries (as YouTube), or in specialized repositories, which contain pedagogical information, which means an increase of reusability of this educational resource.

Schwarzelmüller and Ornelas (2006) discuss different concepts of learning objects and their use in the teaching-learning process, especially within learning environments used in distance education. The authors suggest a concept for learning objects consistent with the principles of cyberculture:

> Reusable digital educational content developed to support the learning process that stimulate reasoning and critical thinking involving new teaching approaches to digital technologies and the epistemological principles of cyberculture (SCHWARZELMÜLLER; ORNELLAS, 2006, p.9).

Therefore, a learning object may be considered any digital entity used for educational purposes.

There is a great challenge in the sense of produce reusable learning objects with quality. The main feature of a LO is the reusability that is associated with granularity. Granularity refers to the lower part of the object with all the essential information of a theme. This implies that an object must be compact, but must also contain a sufficient amount of knowledge for a relevant learning (BRAGA et al., 2012).

According to Braga et al. (2012), beyond reuse, learning objects should promote effective learning and quality. Based on different theories, the authors present the LOs quality characteristics: pedagogical teaching skills, availability, accessibility, accuracy, reliability, ease of installation, portability, interoperability and accessibility.

It appears that is not easy to build LOs that perform all reuse and quality characteristics. Furthermore, it is important to highlight the technical issues arising from the dynamic advancement of computer technology. This fact makes LOs to have a short lifespan, often by becoming incompatible with the operating environments used.

4. DISTANCE LEARNING AND THE USE OF LOs

Technology is responsible for mediating most of the actions concretized in the current daily information society and boosts the production and dissemination of information. In the last years, due to this combination between technology and information, debates and initiatives related to the self-archiving of information, the collaboration and open access have been increased and reached educational resources to support teaching (SILVA et al., 2010).

It is evident the revolution that technology is making on ways to organize and disseminate information, and in the educational field, allows the provision of courses in various models.

For some time the distance learning is used in society, even before they have a large number of people connected to the Internet. In this case, discipline's modules were distributed by mailbox, rendering unnecessary the presence of students in the classroom, and hence its name: distance learning.

With the popularity of the Internet, new opportunities and new ways to apply distance learning were raised, such as virtual learning environments (VLE). Currently, the VLEs are essential to the functioning of distance learning because they enable the different activities in this educational format. According to Santos and Leite (2010), in distance education the teacher's role becomes being the mediator and facilitator, while the student becomes the subject of learning, being a co-author in this process.

Santos and Leite (2010) propose the development of learning objects based on the dimensions of education - interactivity, cooperation, autonomy, affection/desire and cognition/metacognition - to be used in distance education. For the authors, in distance education learning objects developed from this perspective can be boosters of learning networks. That is, living and experience with a particular object the student can socialize his findings with the other participants of the learning community, so that each can bring their contribution aimed at collective construction of knowledge.

Silva et al. (2010) in their work address the learning objects in the context of the information society, in which new scenarios distance education emerges as an opportunity to improve the attendance of the educational needs of the population and society and, in this perspective, the creation and the provision of learning objects contributes to the effective achievement of this objective.

Furthermore, LOs could help the education in many ways, and a good application would be in distance learning, because in this case students need to learn much more by themselves.

5. ASPECTS OF DEVELOPMENT

In this section, we describe the materials and methods used in the development of learning objects for the simulation of operations with lists, stacks and queues, as

well as a Website to serve as a repository of these objects. This methodology also includes performing an evaluation of the tool by students and professors in the field of information technology.

5.1 Selection of tools for Web animation development

The choice of the tool was made from conducting a comparative study of available technologies for the development of Web animations. The researched technologies - Adobe Flex, JavaFX, Java Applet and JavaScript - have several specific features, such as graphical interface load time, accessibility to the user, among others. JavaScript showed promise from the analysis due to its wide compatibility and interaction with various Web technologies, and it not depends on license for its use (DIJKSTRA et al., 2015).

5.2 Development of animations

For the development of animations were selected three data structures: linear list, stack and queue, which are fundamental to the learning algorithms and programming at undergraduate in the information technology area.

Regarding the scope of the animations, were chosen the most important operations on the selected data structures. For the linear list, insert, delete and search operations were implemented. For queue and stack, push and pop.

The animations were developed in order to provide an effective learning and quality for the use of students, as suggested by Braga et al. (2012). For this, it was considered aspects related to viewing and clarity, such as use of colors, buttons to control operations, display messages and callouts, button to control the speed of animation, among others. Moreover, it was considered as the most important aspect the precision and reliability of the animations.

5.3 Website development

For the construction of the Website, it were used languages for Web development. The production of the site pages was done through the HTML (HyperText Markup Language) text markup language. To set the display texts written in HTML, the CSS (Cascading Style Sheets) was used. Finally, for the establishment of user interaction/application, we used the JavaScript programming language, which is the standard script language for HTML.

The Website was modeled in a "responsive" way to be compatible with different screen sizes, fitting in smartphone display area, tablets and PCs. Therefore, considering that the Website is a support tool for professors and students, this feature allows the site to be viewed in different ways and in different contexts.

5.4 Evaluation of the proposed tool

In order to evaluate the proposed tool, a questionnaire was developed with eight multiple-choice questions. The questions discussed aspects related to users from the use of the tool, such as experience with Web animations; prior knowledge about the data structures: linear list, stack and queue; perception about usefulness of the tool

in learning; perception of ease and usability of the tool; motivation to use the tool in their studies; motivation to use tools for simulation of other data structures.

The questionnaire was created using Google Forms tool, which allows you to create online forms. The tool has the advantages of being free, allowing remote access by the browser, allowing sharing the document to edit and follow up their development and application and presenting the results in an organized manner.

For the questionnaire, it was selected a group of students of the Software Engineering and Computing Engineering courses at the State University of Ponta Grossa, with or without knowledge of the data structures included in the animations.

6. RESULTS AND DISCUSSION

The Website was developed using responsive design technique that keeps the visual characteristics of the site open in full screen on different devices, as shown in Figure 1. The Website is housed on a server in the IT Department at State University of Ponta Grossa[1].

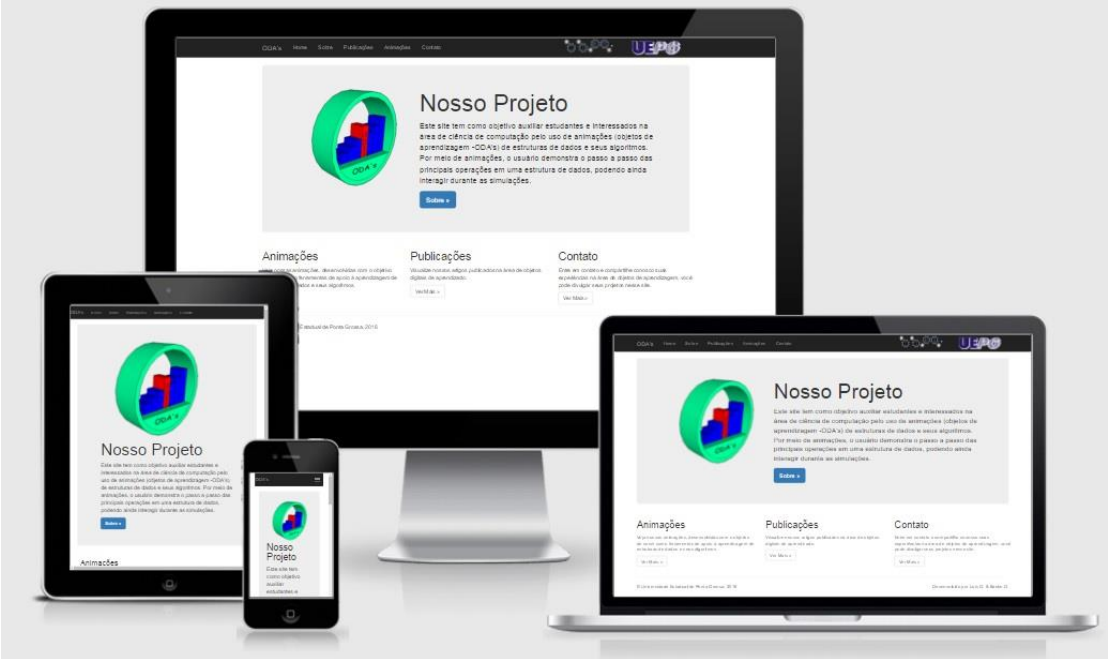

Figure 1: Main page of the developed Website in different devices
Source: The authors

The Website was designed more broadly to accommodate not only the LOs developed for linear list, stack and queue, but also other relevant and pedagogical information. Therefore, in its continuity, the Website can accommodate LOs to other data structures such as trees and spreading tables, for example, to assist effectively algorithms and data structures disciplines.

The Website has a page that provides initial information and provides access to sub-pages. The sub-pages provide access to: animations of the linear list, stack and queue; information about the project and the team involved in it, and publications

[1] The Website is available in: http://deinfo.uepg.br/~oda.

related to this research. There is also the possibility of user's contact with the team through a box for message routing.

The sub-pages of the LOs developed for linear list, stack and queue have a similar format, containing:

- A brief description of the data structure.
- A button interface to perform the operations and control the speed when the animation is played.
- A panel that allows display in pseudo-code, the description of data structure and algorithms for each operation.

The set of complementary information to the animation was designed because it is fundamental to the learning process of the data structures.

During the execution of the animation, messages are displayed related to the operation that is being performed. Figure 2 shows a screenshot of animation for linear list, and the right side of the panel displays the algorithms in pseudocode.

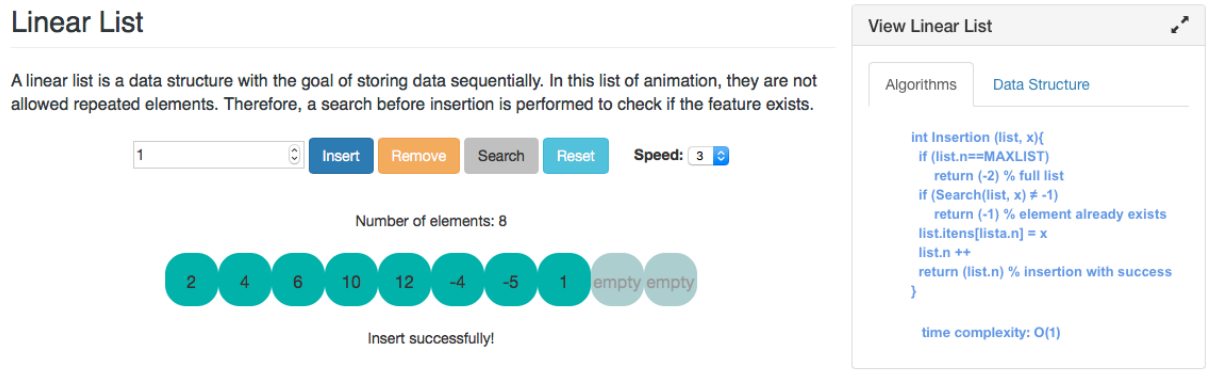

Figure 2: Screenshot of animation for linear list
Source: The authors

The Website developed was presented to students and professors of Computing Engineering and Software Engineering courses, after visiting and using the animations, they answered a questionnaire. In total, 27 people participated in the survey. Table 1 summarizes the group's answers to the quiz questions.

Table 1 - Summary of answers related to the survey questions

QUESTION	SUMMARY OF ANSWERS
Have you ever used any type of animation to help you study?	Yes - 74,1% No - 25,9%
Did you already know the definitions of the data structures linear list, queue and stack?	Yes - 96,3% No - 3,7%
Do you believe that the use of animations facilitates learning?	Yes - 100% No - 0%
Do you want to use these animations as a support for your studies?	Yes - 70,4% No - 29,6%

Rate the difficulty of performing the tasks in your first use of the animations.	Very Hard - 0% Defiant - 0% Regular - 40,7% Easy - 59,3%
Rate the usability of the animations.	Very intuitive (great) - 48,1% Intuitive (good) - 51,9% A little confusing at first (regular) - 0% Unintuitive (terrible) - 0%
Would you like to use animations for learning other types of data structures and their algorithms?	Yes - 96,3% No - 3,7%
In your opinion, what was missing or does it need to be improved in the animations? *	Suggestions for the design of the animations

* Open question

From the answers it was observed that the vast majority (96.3%) of the participants have knowledge of linear list, stack and queue. However, 25.9% of participants said they never used any kind of animation in their studies.

These data demonstrated that there are in the evaluated group individuals which have knowledge about the linear list, stack and queue data structures, but they had not used animations yet until the time of the survey.

When asked if they intend to use these animations as support for their studies, subjects answered affirmatively, in the ratio of 70.4%. However, 100% of respondents believe that the use of animations facilitates learning, and 96.3% said they would like to use animations for learning other types of data structures and algorithms.

Regarding the difficulty of using the tool in its first use, the answers showed that subjects had no difficulty, because 59.3% considered easy and 40.7%, regular, totaling 100% of opinions.

In the same way, the usability of the animations was evaluated positively, being that 48.1% felt great and 51.9% good, totaling 100% of opinions. This result, in particular, demonstrated that human-computer interaction of the animations was satisfactory.

The last question of the questionnaire, open character, received only nine responses from a total of 27 participants. Briefly, there are suggestions for the design of animations, such as use of color and size relative to the screen.

Ultimately, the data obtained from the questionnaire showed that the developed tool provided an encouraging data for the continuation of the project with the development of LOs for different data structures.

7. FINAL CONSIDERATIONS

Learning objects can significantly contribute to the teaching and learning process, allowing the student to use these resources in different environments and contexts in his own time and according to his needs. Learning objects also provide a rich experience to promote interactivity through which the student constructs and reconstructs knowledge. In this context, the student occupies the center of the process of teaching and learning, motivated to advance the field of knowledge and develop skills.

In the area of algorithms and data structures in particular LOs contribution is very significant because it allows the student, through the reusability, reaching the mathematical logical thinking level required for modeling problems, because he can realize how much he knows about it. In addition, the use of LOs provides the setting of learning, for his participation and interest in the topic presented, consolidating learning.

In distance education, the LOs are even more interesting, because in this educational model the student is the protagonist, leaving him drive his learning from virtual learning environments. In addition, the experience gained by the student in the use of LOs can be shared with colleagues and professors in a collective process of knowledge construction.

Preliminary results obtained and reported in this study showed that there was a very positive response from the students regarding the use of LOs for learning types of data structures, as linear list, stack and queue and their algorithms. In this way, we intend to continue to work, including LOs for different data structures and algorithms on the site of the repertoire developed for it. These materials will be used in classes of Computing Engineering and Software Engineering courses of the State University of Ponta Grossa (UEPG). Similarly, we intend to use these tools in the Bachelor's Degree in Computing of the UEPG, offered in the distance model.

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