Educational system in free software

Filipe Jaeger Zabala
PUCRS
Av. Ipiranga, 6681
90619-900 - Porto Alegre, RS, Brasil
55-51-3320-3531
filipe.zabala@pucrs.br

Thaísa Jacintho Müller
PUCRS
Av. Ipiranga, 6681
90619-900 - Porto Alegre, RS, Brasil
55-51-3320-3531
thaisa.muller@pucrs.br

ABSTRACT
This document presents a proposal to create a modular system in free software, specifically using the RStudio editor based on language R. Theoretical and applied foundations of Computing in Education are presented, with examples from different areas. Finally some preliminary results concerning the system development are presented, applied successfully in an extension course at the Pontifícia Universidade Católica do Rio Grande do Sul - Brazil.

Categories and Subject Descriptors
D.3.3 [**Applied Computing**]: Education – *Interactive learning environments.*

General Terms
Experimentation, Human Factors, Languages.

Keywords
Learning Objects, RStudio, Technology on Education.

1. INTRODUCTION
Information and Communication Technology (ICT) has revolutionised virtually every aspect of our life and work. Students unable to navigate through a complex digital landscape will no longer be able to participate fully in the economic, social and cultural life around them [23]. With its potential for interactivity and use of media, ICTs can contribute to the development of educational materials that will meet the new educational demands. Therefore, it is necessary training on authoring tools that enable the teacher to prepare their own educational materials, so that they are tailored to their needs and aspirations.

In other words, the spread of new technologies in the educational context has enabled the enrichment of teaching materials, which today tend to take a more interactive and a multimedia character. In addition to the development of more effective products, aimed at teaching situations and guided learning in a student's active role, the advent of the internet enables the spread and sharing developed resources.

The development of *Learning Objects* has been facilitated by access to authoring tools that no longer require a deep knowledge in areas such as design or programming. However, currently it is considered that a person interested in investing their time in the composition of educational materials must master the fundamentals of programming logic, in order to assert their aspirations without relying on purely visual environments. Thus, the basic elements of programming must be present when considering the development of a didactic material, allowing the designer to tailor the system to the user's needs.

On the other hand, it is also known that many students have gaps in basic knowledge of Mathematics when they enter the universities, which impairs their performance in subjects like Calculus and Statistics. Strategies are therefore needed, in order to help these students to expand their knowledge, whether the necessary prerequisites or the content of these disciplines. The use of technology as an ally in this process is an idea that has shown good results [21].

From this perspective it was decided to invest in a educational system which operates as a repository of Learning Objects. Both the educational system and the Learning Objects are written in R language [25] and RStudio environment [26], either under the GNU GPL license [10]. Section 2 sets out the theoretical framework, followed by the methodological procedures applied in free software in Section 3. Section 4 discusses the application of a survey planned by the authors for evaluation and automatic correction of Basic math questions in a short course. Finally, Section 5 presents the required guidelines in subsequent projects, as well as a channel with updates of the project status.

2. THEORETICAL FRAMEWORK
Regarding the nature of the proposal presented here, it is important to make considerations about the use of technology in education, especially with respect to Learning Objects. The intention is to promote meaningful learning, i.e., make the students expand their knowledge of certain issues of solid and permanent basis, allowing immediate application.

2.1 Information Technology and Mathematics Education
The use of information technology brings undeniable advantages to education, especially for mathematics education. However, in order to contribute to meaningful learning, it is essential that teachers feel safe to make use of technology, avoiding providing unplanned tools. In this regard, we highlight that “the use of new technologies in mathematics education require form teachers a critical rereading of their own practices. Without this rereading, the use of new technologies will have more devastating consequences than constructive” ([18] p.3, author’s emphasis).

For this reason, this proposal aims to provide conditions for the teacher – or even the student – strengthen its self-confidence and knowledge and take more initiative with the use technology, through online support materials and promoted discussions in undergraduate and graduate education. As stated by [3], “it is important to know where and when to use (or not) technologies. Therefore, it is important that teachers are prepared for these new

practices, after all play a prominent role in school integration to digital culture."

Furthermore, is emphasized the importance of the teacher in the construction of their own materials, becoming author and adapting its creations according to its needs and their students. Thus, the intention is to encourage teachers in this task, showing them that is feasible through the use of *authoring tools*.

> The authoring tools come facilitate the teacher's performance, they allow the creation of digital educational material without the teacher himself is a programmer, using structures and procedures already programmed, bringing them together, adding content and form of treatment to the data that depend on its pedagogical strategy ([9], p.394).

One can also think about the roles of teacher and student on technology. Relying on the [13] ideas, it is considered that the use of technological resources in education encourages the active participation of the student. In this approach, the teacher acts like a partner of student, instead a knowledge holder. However, the transition from traditional teaching method for teaching computer-aided requires adaptation by the teacher and the student. Both need to abandon the passive behavior, seek challenges and interact with agents in the classroom. It must be admitted entering a risk zone "in which we must constantly assess the consequences of proposed actions." ([4], p.57)

In continuation of this text, such prerogatives are followed to give support to the proposal, in order to contribute and serve as a reference for teachers and students who wish to promote learning through the use of technology.

2.2 Learning Objects

The concept of Learning Object is widespread in the educational world, especially in regard to the use of technologies. Thus, there are different definitions for the term, which were selected two very similar for use in this study.

According to [12], a Learning Object is defined as any entity that can be used, reused or referenced during learning supported by computer. It may contain various features, from the simplest, such as an independent text or video, or even more sophisticated, as a hypertext associated with a course, an animation with audio or more complex resources.

[32] points out that Learning Objects are small instructional components that can be reused in different learning contexts. He further states that LO should be self-explanatory, modular, aggregatable, digital, interoperable and reusable. Thus, each object should be a module with self-explanatory content, i.e., the student must be able to study alone, and these modules must be complementary, so that together form a more complete block content. Moreover, the author suggests that these materials should be digital and reusable in different situations and for different groups.

As an example of self-explanatory modules can be mentioned the videos found in Youtube channels. Figure 1 shows a series of videos on Calculus presented in Professor Leonard channel.

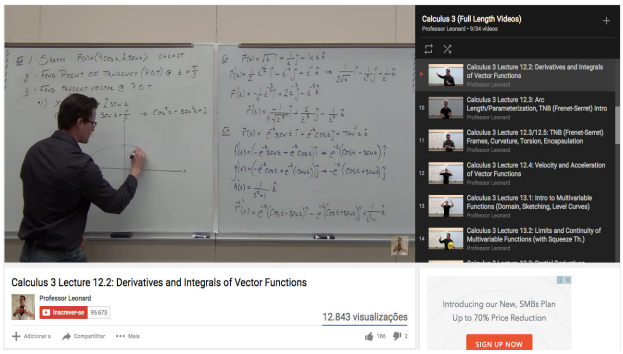

Figure 1: self-explanatory complementary digital blocks [24]

In the educational and business scope has been observed that the objects have been used on a large scale, being a very important resource for distance learning, but also serving as support in classroom teaching. These resources can be used to facilitate and qualify the processes of teaching and learning. Should be materials that motivate students through, for example, the presentation of problem situations, challenging and instigating your curiosity.

[20] draw attention to multimodal principles of instructional design, according to which the combination of verbal and nonverbal representations of knowledge content should, where possible, involve more than one mode. The same idea is presented by [29], with the argument that this combination makes the most efficient learning because human mental architecture has limited independent channels for processing information. Thus, the presentation of content only favor one mode, there will be more likely to overload the cognitive ability of the learner, which is why it is necessary to merge the modes and methods. That is, multimodality can be considered a way to minimize the risk of cognitive overload, which occurs when the instructional system requires a student processing capacity above its limits available [28]. With respect to learning styles, multimodality provides a gain of educational effectiveness, since the simultaneous use of verbal and non-verbal modes favors both those students who are more visual as those who are more verbal.

The principles presented by [27] are considered, which recommend be observed in the construction of digital educational materials:

- Multimedia principle – if the object integrate text and images and audio, will promote the construction of more effectively knowledge;

- Principle of Space Proximity – should be clear the relationship between images and words, if any. For this, the graphic similarity between them is essential;

- Principle of Temporal Proximity – images and words should be used simultaneously, not at different times, so that the content is better assimilated;

- Consistency principle – should not be used media that are not relevant to the subject, that is, your choice should be consistent with the educational goals;

- Modality Principle – the ideal is when the object has a story attached to an animation instead of written texts;

• Redundancy principle – besides the related animation narration, is sometimes also necessary to use a text to complement the content, even if it is characterized as redundancy;

• Principle of Individual Differences – considering that students have different ways of learning, these differences must be respected.

Finally, is important consider web standards like W3C. Such standards allow the access of persons with special needs and improve the user experience as a whole. Regarding the W3C Web Accessibility Initiative (WAI)[1] as support for social inclusion, we may consider alternative text for images, transcripts for podcasts and audio files, and all functionalities accessible via keyboard. The fulfillment of the items set out in the W3C is being incorporated gradually in the newer versions of the system.

The production proposed educational materials observe the above principles, since the intention is to create materials that are potentially significant in promoting learning.

2.3 Technologies and Significant Learning

When making a proposal to consider the importance of using technology to support teaching and learning processes, it is necessary to consider that the materials must enable meaningful learning. Learning significantly implies to relate, not arbitrary and substantive way, new information to others with which the student is already familiar [2]. Moreover, it is essential that the student expresses a willingness to learn that way.

According [19] (p. 1),

> **Meaningful learning** is the process through which new information (new knowledge) relates to **non-arbitrary and substantive** way (non-literal) to the cognitive structure of the learner. It is in the course of meaningful learning that the logical meaning of the learning material is transformed into psychological meaning for the subject.

Moreira also points out that there are two basic characteristics of meaningful learning: non-arbitrariness and substantiality. "Non-arbitrariness means that the potentially significant material relates to non-arbitrary manner with existing knowledge in cognitive apprentice structure." [19] That is, to ensure meaningful learning the student must have a foreknowledge of subsumptions[2].

The other feature is the substantivity, which Moreira defines as follows:

> **Substantivity** means that which is incorporated into the cognitive structure is the **substance** of new knowledge, new ideas, not the precise words used to express them. The same concept or the same proposition can be expressed in different ways through different signs or groups of signs, equivalent in meaning. Thus, meaningful learning can not depend on the **exclusive** use of certain **particular** signs. ([19], p. 2).

Based on these ideas, we can say that in addition to the need for the student to know the subsumptions, differentiated learning tools must created. In this sense, technology is a strong ally, since it brings many possibilities to produce potentially significant material. Webpages, applications, Learning Objects and other features can be created to promote interactivity, active participation and encourage the student in many ways.

2.4 Gamification

Gamification can be seen as a process of improvement in cognitive development made possible by a platform that encourages interaction and demonstration of individual skills in order to support its evolution [5,11]. This approach aims to (*i*) encourage the evaluation of different sources of information about a particular subject and (*ii*) apply the acquired knowledge. The results of the interaction provide data for the calculation of progress metrics used to evaluate and compare the platform users. The system should provide content considering the navigation and user performance to promote meaningful learning. Content can be in video format, questionnaires or casual games between activities. The progress metrics should be available in easily accessible panels, indicating the steps to be met to achieve higher levels.

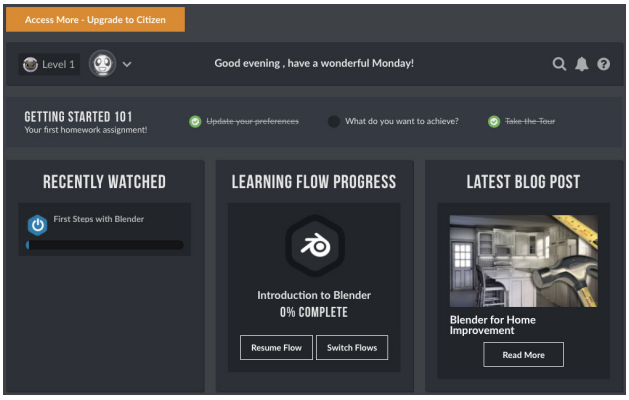

Figure 2: example of gamification [6]

Figure 2 shows a cgcookie.com site screen, a specialized platform in guided education. Operated by professionals from the visual arts, the environment has several features that encourage users to improve their performance, such as progress bars, suggestions of support materials and a ranking of the best scores.

3. METHODOLOGICAL PROCEDURES

The procedures adopted for the realization of suggested didactic proposal are presented. It should be noted that the technology used allows the Learning Object construction that meet the principles described in the previous sections. In practice are desired (*i*) the use of the material produced by any student and (*ii*) the disclosure of material production method for any interested party. In this case the focus is on postgraduate students working as teachers at different levels of education, which have specific needs that can be remedied by the proposed method.

3.1 Using R and RStudio

In addition to solid theoretical foundation, the creation of educational materials should follow the evolution of technology. Added to this, the tools must be accessible to teachers and students, preferably considering the costs of acquisition and maintenance of the software used. It is therefore considered the construction of an online educational platform in RStudio editor [26], which operates based on R language [25].

[1] https://www.w3.org/WAI/

[2] Necessary prerequisites for the acquisition of new knowledge.

R and RStudio are available under GNU GPL license [10], allowing the generated code can be read and implemented in major operating systems. Obtaining and installing both does not depend on administrator passwords or authorization of the purchasing department, being made within the user section. The combination of these two graphic and statistical analysis tools gives to the operator a compact but extensible system, which includes from reading and processing of data to interactive publishing tools. The association between packages allows to create documents with high standard diagramming [30,31], also responsive to user action. Currently there are more than nine thousand packages[3] available for immediate installation and operation.

There are some proposals that make use of R to support teaching. The project MOSAIC[4] [14] is a community of educators working to develop new ways to introduce Mathematics, Statistics, Computing and Modeling for students in colleges and universities. The researchers developed the *mosaic* package, designed to facilitate the teaching of these subjects using R, accessible via CRAN[5] and github.com. The statsTeachR[6] project is an open-access, online repository of modular lesson plans for teaching statistics using R at the undergraduate and graduate level. Each module focuses on teaching a specific statistical concept. The modules range from introductory lessons for Statistics and Computational Statistics to more advanced topics in Statistics and Biostatistics. It was officially launched in 2014 in the *New England Statistics Symposium*[7]. In addition to the modules, there are exercises with solutions and courses. It is evident, therefore, the applicability of the R and RStudio as tools in education.

The principle of the proposed system is its modularity, enabling the creation of blocks which add to the operating core. Publications based on R language result in a standardized content, facilitating the maintenance and collaboration throughout the projects. To ensure that the layout operate at a high level, the *markdown* package [1] was considered, a converter that allows to get an HTML code from plain text. The R Markdown syntax (.Rmd) allows text formatting, inserting R codes, tables, links and graphics, as well as the incorporation of the powerful language Latεχ [15,16]. The principle of *reactivity* from *shiny* package [7] offers interactive elements such as buttons and sliders to the user, allowing to observe the parameter variation results in charts, tables and text.

An interactive visualization example is presented by [17] as shown in Figure 3, which explains about the measure known as *Cohen's d* [8]. As the bar is slid, the parameters are instantly updated, allowing users to understand the impact of changes in measures of interest. This reactivity principle can be used in different contexts, presenting the student a clear understanding when there is variabilty, something difficult to explain in a static environment.

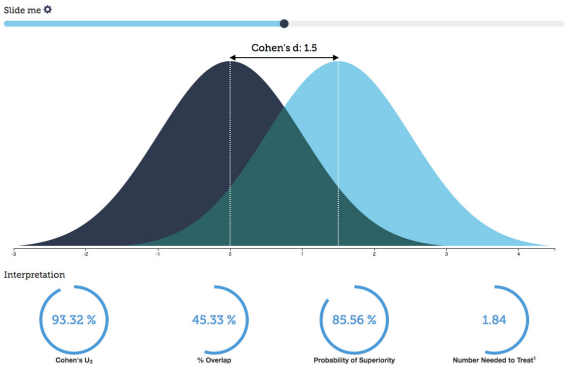

Figure 3: example of reactivity [17]

Thus, is advocated the use of R and RStudio for creating Learning Objects, once these open source tools allow the construction of interactive, multimediatic and multimodal materials. Such materials have the necessary characteristics to create potentially significant materials. The principles of gamification[8] are also observed, since it is possible to create a sequence of activities in which the student progress through several stages. In addition, a panel with their results must available to the user, which may indicate links to the contents that should be strengthened by the student.

3.2 Use of the material by the student

At first, it was thought to create a repository of materials for students who are studying basic disciplines of Statistics or Mathematics in their undergraduate courses. From the use of R and RStudio, an intuitive and easily accessible environment was conceived, where support materials and classes that enable interaction student are available. The environment offers modular units presenting the contents, so that each of them consists of a Learning Object.

The student can access the system with an username and password, in order to create an access log that allows to monitor the performance. The principles of gamification provide support to cognitive development, as well as objective metrics to evaluate each user interaction. Access to the environment followed by the implementation of the proposed tasks may compose the students grades, who get a score and a ranking according to their performance.

The content linked to Learning Objects are an extension of lecture notes and materials already used by teachers. Among the proposed materials is the *Momentinho Cultural* [33,34], a video channel of artistic and scientific content created in order to promote association between Arts and Science derived from the authors' classroom experience.

The system must meet the student needs, with constant feedback through a communication channel. This provides a connection between the teacher and the student, directing the creation of Learning Objects and creating an environment conducive to meaningful learning.

[3] https://cran.r-project.org/web/packages/

[4] http://mosaic-web.org/

[5] Comprehensive R Archive Network.

[6] http://statsteachr.org/

[7] https://www.hsph.harvard.edu/ness2014/

[8] Section 2.4.

3.3 Production of material in postgraduate school

Based on the idea that teachers should produce their own material, it was decided to work with students of the Postgraduate Program in Education in Science and Mathematics at the Catholic University of Rio Grande do Sul. These students are (or will be) teachers in different levels of education, and seek qualification in teaching practice.

Knowing the importance in using technology and Learning Objects in education, a discipline entitled "Learning Objects in Education in Science and Mathematics" was created. The proposal is, at first, educate students and teachers about the importance of this practice. For this, some basics of using technology in education are presented, as well as definitions and expected features of a Learning Object.

After the theoretical studies, the evaluation of Learning Objects is crafted, that is, ways to select already available materials are discussed. It is known that, with the advent of Web 2.0, where anyone can publish material on the network, a careful selection is important that, in fact, contribute to learning.

In a last step, after the theoretical research and material evaluation on the web, students of the Postraduate Program in Education in Science and Mathematics at PUCRS receive 8 hours of class on R language and RStudio computing environment. Its functionalities are presented through *demo*, a user-friendly interface to running some demonstration R scripts. Types of objects, main packages and basic commands are also discussed. There is a special emphasis on functions, so that the student understands the power and flexibility of these structures. Graphics concepts are developed, with subsequent availability of a standard module structure for inserting content. In Chart 1 is presented the basic template of a shiny application, discussed with the postgraduation students who make use of this tool.

```
library(shiny)
ui <- fluidPage()
server <- function(input, output) {}
shinyApp(ui = ui, server = server)
```

Chart 1: basic template of a shiny application

After learning the basics of the language and work with the given prototype, the postgraduate students are challenged to build a Learning Object directed to their students. Finally, they are then encouraged to test the materials with their students, making use of existing modules and composing new features. By having steep learning curve, the R language allows the postgraduate student soon contribute to the integration, organization and maintenance of the modules.

4. PRELIMINARY RESULTS

There are some ongoing projects of production and use of online materials created in RStudio. The approach started with the production of materials made by postgraduate students, which realized the importance of learning the programming fundamentals in R and have a tool to create learning objects for their classes.

An experiment was conducted in March 2016, when it was applied a survey test based on RStudio, in order to assess the level of students in Basic Mathematics, subsumptions for an extension course in Jurimetrics[9] [22,35]. The challenge was ensuring that law students had good performance when dealing with concepts required throughout the course. These law students in initial and continuing education are usually away from mathematics and its applications in their daily tasks. Based on the theory of meaningful learning [2] and on tests proposed in [21], it was found that people enrolled in the course should meet some prerequisites concerning the Mathematics area.

It was implemented the instrument through the shiny and markdown packages, presented in Section 3.1. Figure 4 shows an example of the survey question, that dealt with contents such as real numbers, operations and their properties, percentage, among other topics of Basic Mathematics.

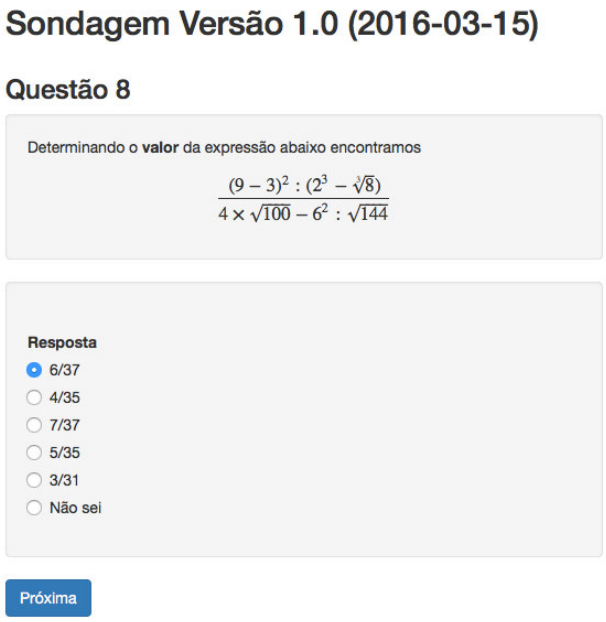

Figure 4: survey screen operating in RStudio [22]

All proposed questions on the test were multiple choice, and each response alternative was planned so that it was possible to identify the student's difficulties when the answer was incorrect. Thus, at the end of the questionnaire, it was shown on the correct and incorrect answers in each question, as shown in Figure 5. From incorrect or blank answers, the student was informed about what content should review. Intending to assist in this task, links to learning objects were available to facilitate the review of the

[9] Jurimetrics refers to the pursuit of harmony between legal and exact sciences, in order to bring greater predictability in the law using the current technology. Currently its foundations are often used in jurors selection and comparisons of DNA chains, being promising way for legislative drafting and construction of public policies [35].

contents involved and better monitor the course content. The Learning Objects in the extension course suggested to participants were properly selected and produced according to the principles presented in Section 2.2.

Figure 5: results presented to the user

The Learning Object illustrated in Figure 6 refers to the properties of the real number operations. It presents an interactive menu that allows the user to navigate freely, even when the arrows suggest an order. Moreover, all screens have been combined with different features, such as narration, written texts or images. The arrows at the bottom let you move forward and backward at the desired speed, providing immediate feedback.

Figure 6: Learning Object about real numbers

In the case of Jurimetrics course, it was observed a sactisfatory level among the students at the first test, averaging 7.8 with standard deviation 1.1. Anyway, the participants were faced with Learning Objects concerning the content of the questions marked incorrectly. From the evaluation and testimonies of the participants, became clear that once again Learning Objects contributed to the filling of possible gaps in learning subsumptions. Moreover, it was possible to test the tool created in RStudio, which proved to be quite effective and complied with the proposed objectives. The technology developed in this survey was the basis for the creation of the proposed system in this paper, in order to validate the proposed approach.

5. CONCLUSIONS AND FURTHER RESEARCH

Theoretical and applied framework to an online modular system for the production of interactive courseware is presented. The use of technology in education is proved to be adequate as an effective resource in meaningful learning from the considerations and experiments already carried out. In this regard, the Pontifical Catholic University of Rio Grande do Sul has, since 2009, investing in learning objects production. Many objects were built focused on content where students historically presentes gaps. But in recent years, it comes to considering changing the technology used in order to make it more affordable and minimize risks to be discontinued. Thus, materials produced with the use of R and RStudio gain more space in the composition of the institution repository. Due to the steep learning curve of the R language, it is possible that teachers masters the forementioned tools and became capable to build their own Learning Objects. With the mastery of basic programming tools, the educator becomes founder and director of the project, making it easy to upgrade working in teams considering the institutional repository.

Within the project is envisaged to assist the Learning Laboratory[10], responsible for the production and maintenance of Learning Objects designed to meet students seeking extracurricular support. Since many students entering the University presents gaps in basic education, Learning Objects built by graduate students provide support for work undertaken in LAPREN. The Learning Object databases becomes richer everyday, involving more content materials built with RStudio. As a next step, versions are considered in other languages such as Spanish, English and Chinese, considering the standards of W3C Internationalization (i18n) Activity[11]. Information and updates of the materials are available in filipezabala.com.

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