Multiple choice parameterized exercises in Logic*

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Abstract

The first contact of students with logic is not straightforward since they are not familiar with its notation and with logical thinking. For this discipline to become more attractive and in order to avoid this intimidating first contact, interactive didactic tools can be useful. In the University of Aveiro there exists a group of teachers developing an interactive platform that provides students some guidance in their independent study in several courses. We propose and describe the use of this platform as a complement for teaching the logic course of Mathematics Department in this University.

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1 Introduction

Logic is taught in several departments in the University of Aveiro. Usually, for students, it is not easy to start learning logic because this domain of mathematics is completely unfamiliar in their knowledge background in Portugal. Therefore, we need didactic material, but there exists few exercises in literature for our mathematical logic syllabus and almost all of it is in English language. Furthermore, the theoretical framework of logic that we can find in literature, is introduced with different notations, what makes the study difficult. Indeed, logic requires a special vocabulary with its respective notation and a way of thinking that students have never contacted before. Hence, we have looked for attractive tools to teach logic. We want to propose exercises in Portuguese language that will be linked with a theoretical textbook containing uniform notation and all of this in an interactive fashionable form.

In the Mathematics Department of the University of Aveiro, in Portugal, there exists a group of teachers who are developing two systems, the first MEGUA (Mathematics Exercises Generator, University of Aveiro) [1] allows teachers to construct multiple choice parameterized exercises in a shared cloud environment and the second system SIACUA (Sistema Interativo de Aprendizagem por Computador, Universidade de Aveiro) [5] is used by students to learn. From the authoring tool, teachers send their exercises to the students learning system.

In the first section, we present our motivation to construct interactive exercises using this platform. Then we explain all the software that we need and how we use it. In third section, we give two examples of multiple choice exercises, constructed in MEGUA, with

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detailed answer used for logic. Next section shows some advantages in using these tools for teaching logic, from the point of view of students and teachers. Afterwards, we describe some difficulties that we have met to implement multiple choice parameterized exercises about logic. Finally, we conclude by suggesting improvements to the platform for better teaching.

2 Motivation

In the University of Aveiro in Portugal, there exists an interactive platform already used in Calculus subjects, that propose multiple choice questions with a detailed answer and truth/false exercises (without resolution) for students. They are also developing exercises for College and Secondary School with the support of school teachers.

Before implementing this kind of project for logic subject, we made a short survey to check if this interactive platform is really efficient for students. The survey was distributed to a population of about three hundred students and contains thirteen questions, one of them is an open question in order to give them the opportunity to describe the advantages and disadvantage of this platform. A study throughout this survey reveals that students often use this platform and consider that multiple choice exercises with detailed answer are more useful rather than truth/false exercises without any detailed explanation of the correct solution. Furthermore, all of them recognize that it is crucial to have an interactive platform like this allowing independent study instead of only PDF materials for download. Moreover, most of them want to use this platform in their partial assessment and consider that it promotes their learning. The presentation of a detailed answer of exercises is the most important element, in the point of view of students, since it clarifies doubts and allows them to independently answer other similar exercises. The platform gives information about their evolution in the different topics. These topics are shown as a tree of concepts we have previously defined. For students, it is important to know immediately if they answered correctly the multiple choice question, and in the future, they would like that the platform suggests exercises according to their knowledge and mistakes. Finally, almost all students would like that other disciplines use this platform.

Taking into account the results of this survey and our concern to diversify tools for teaching logic, we are creating, in the platform, parameterized exercises for logic in the context of the syllabus teaching in Mathematics Department of University of Aveiro, that is, History of logic, in particular Aristotle syllogism and paradox, Classical Propositional Logic and First-Order Logic. Moreover, we want to propose a new didactical component, different from the traditional one, in the sense that we are making a lot of exercises available in a variety of types, where we suggest a detailed answer.

3 Platform description

The platform is composed of: authoring system (MEGUA) and student learning system (SIACUA).

The first allows an author to write and run exercises in the cloud. We are using Sage Notebook [3] which allows anyone to create, collaborate on and publish interactive worksheets. In each worksheet, we can write code using Python language, the Sage Mathematics library and other software included in Sage [4] which is a free open-source mathematics software. Coding with this type of environment is very easy, it is not necessary to have a training in programming. It is easy to find in the internet several short examples to program for HTML, LaTeX and Python, what is enough for writing exercises. The library that allows exercise

authoring, MEGUA [1], is an open-source software [2]. MEGUA borrows from Sagemath the Sage Notebook tool for editing online and sharing work with others. Exercises are created and edited as Sagemath notebook worksheets. Sagemath also gives an extensive library of mathematical routines that help calculations in each exercise.

MEGUA package was created aiming the authoring of parameterized problems which is one of our objectives. Indeed, we can take a classical exercise and parameterize it, so that we obtain several exercises in few minutes which assess the same notion in logic. Each exercise is characterized by a summary, a problem, a multiple choice part, and a detailed answer for the exercise. Each author (or project) has his own database of parameterized exercises and can share each exercise with other authors for collaboration. We can choose a set of questions from a database and print them to create a small textual study book or a paper exam, with or without resolution.

The other principal software, SIACUA [5], is an experimental project which implements a Bayesian user model. Each user is associated to a Bayesian network that includes initial study concepts map which is updated after each evidence of knowledge (or no knowledge) of the student. Exercises which are created in MEGUA are generated randomly by the author and few of them are selected and sent to this website [6]. This software allows student to solve interactively all exercises created in Sage Notebook by teachers and gives them some feedback about their progress. Indeed, they can know how much times and when students were connected, and evidently what they answered. This software is crucial in our viewpoint, because Sage Notebook is interesting in creating parameterized exercises and obtaining many questions in few time, but it is more helpful for teachers the possibility to make available, throughout internet, these exercises for student learning.

Both systems MEGUA and SIACUA are being developed at the University of Aveiro. The computer system is described in detail in [7].

4 Examples of parameterized exercises in logic

Syllogism is a part of our program in logic and we give here an example of how to create a multiple choice parameterized exercise about this subject. We want to check if students can deduct a valid conclusion given two premises using Venn diagram. In figure 1, we show the statement of the exercise, two premises and one question, and we give four choices ("escolha" in Portuguese) where the first is always the correct and the remaining ones are false before the system shuffles answers for students. In system MEGUA, the first choice is the correct one, then the choices are randomly ordered in SIACUA and four of them, always including the correct one, are presented to the student. In figure 2, we show a detailed answer of the exercise by using a Venn diagram and the corresponding valid conclusion. It is easily to parameterize this type of exercise substituting the words "seagulls", "cows" and "fly" by others. The difficulty level and the objectives of the question remain the same.

In some exercises we parameterize connectives of logic, formulas, inference rules, etc. Some parameters are numbers and can be chosen from a predetermined set of numbers, some parameters can be nones, expressions, functions and even a set of symbols like $\vee$, $\rightarrow$, $\wedge$, the connectives symbols used in logic.

For some kind of exercises this parametrization can be more difficult. We present an example where the aim is to evaluate if students can translate sentences in natural language to Mathematical formulae, more precisely in formal logic, and find the solution using Classical Propositional Logic. In figure 3, we show the statement of the exercise and the four choices. We present, in figure 4, a detailed answer for the exercise giving a translation of the text

using propositional variables and the respective truth table from which we have the solution of problem.

5 Advantages in using the platform

This platform allows an independent study using only computers and internet. Before answering an exercise in logic, students can look at theoretical contents in PDF format. Thus, they can at anytime and anywhere study their course without printed paper. Furthermore, this platform may be a principal tool for working students. Indeed, they do not spend much time in the university and consequently, sometimes, they do not have printed content that teachers transmit in classes. Since, we may access this platform at distance, it may be used as a tool for teaching logic in any country of Portuguese language.

Moreover, the presentation of a detailed solution is very important for students. They can test their own knowledge by answering correctly the proposed question and, in that very moment, see a proposed correct answer made by the teacher. This fact is new, because there exists on the internet and books lots of multiple choice or true/false exercises in logic but rarely they offer a detailed solution. The aim to solve exercises is to check if students are understanding all mechanisms of logic being taught and this platform is a frame to evaluate this notion.

One of the advantages for teachers is that, although the time spent to construct interactive exercise is long, in the future they save time because they are creating a database that contains theoretical lessons in PDF format and many exercises. Each teacher can fill this database with new parameterized exercises and can share it. In addition, this platform allows to keep in the cloud all exercises that are created. In other words, exercises are not stored in one computer for only one teacher, they are reachable for all teachers they want to invite to collaborate on their construction.

6 Difficulties of implementation

Generally, a "classical" question is formulated as a question where student must prove or solve something. The main difficulty that we are confronted with is how to reformulate a question in multiple choice question formulation with only one true choice and the three others false. Sometimes the construction of such an exercise is very complex. In some exercises, we ask, which one is the wrong answer instead of asking for the correct answer, as usual. For instance, which of the following expressions is not a formula in Classical Propositional Logic? Or which of the following inference rules is not a derived inference rule of the system? In these cases, student has two possibilities: he can find a proof of the correct answers and obviously the remaining one is false, or he can obtain directly the answer that is not correct.

The main difficulty, that we find, is how we can parameterize some exercises with different detailed solutions, depending on the parameters. We think that it is for this reason that we can find lots of interactive exercises in internet but without detailed solution. In spite of this difficulty, we keep present the detailed solution, otherwise the exercise is not complete in our point of view, and do not offer a complete independent study solution.

7 Conclusions and Future Work

We present a platform to learn logic in an interactive way. It offers a place for students (and teachers) where they may find all the information, theoretical-lessons, exercises and

explanations about logic as taught in the University of Aveiro. This system permits self assessment for students with feedback about students knowledge progress.

On the future, we expect to diversify the type of exercise suggested, other than the current multiple choice type, for example, exercises where it may be possible to have several correct answers and not only one. Indeed, with this kind of exercise, students must analyze each answer independently. Therefore the difficulty of the same exercise is higher and it reduces the probability to find the correct answer by elimination of the others.

Moreover, we want to improve platform suggestion of exercises according to the evolution of knowledge of the student and its difficulties, towards an individual and adapted learning. Furthermore, teachers may have better feedback of the student's knowledge and may recommend other material to study according to their skills.

Due to the simplicity of programming, needed for creating exercises in the platform, teachers may propose students to create one exercise of logic using directly the system. This idea presents two advantages. One is that we can augment the database of exercises with the collaboration of students. The other is to propose high level concept themes for students. Indeed, students must think to construct the exercise in several ways. They write a question, in which all of the information must be complete, then they propose several choices as possible answers, in which only one is correct but the others must be according to the possible error that students usually do so that the correct answer is not trivial. And finally, they propose a detailed answer for the problem. We believe that if a student acquires all these notions, that are necessary for the construction of an exercise, we have the proof that he knows very well the topic in study. This is the same as, if a student explains the notions to another student and the second achieves correctly the problem and the solution, then the first student really knows this topic of logic.

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Consider the following statements:

All seagulls can fly.
Some cows cannot fly.

Which is a possible conclusion to obtain a valid syllogism?

Escolha:
Some cows are not seagulls.

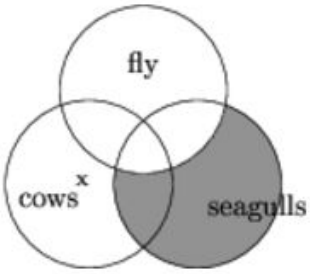
Escolha:
No cows are seagulls.

Escolha:
All seagulls are cows.

Escolha:
Some seagulls are cows.

Figure 1 Syllogism

We use Venn diagram:



We have a X in a part of circle of cows which is not in seagulls.
Thus we conclude that there are some cows that are not seagulls.

Figure 2 Detailed resolution of Syllogism

Four individuals are suspected of committing a crime.
Only one of them committed the crime.
During the interview by the police, they stated as following:

Arthur: It was Joseph who committed the crime .
Joseph: It was James who committed the crime.
Gabriel: I did not do.
James: Joseph lies when he says that I was.

If only one of these statements is true, who is the criminal?

Escolha:
Gabriel

Escolha:
James

Escolha:
Joseph

Escolha:
Arthur

Figure 3 Translation and Resolution

Considering the following propositional variables:

a	Arthur is the criminal
j	Joseph is the criminal
g	Gabriel is the criminal
t	James is the criminal

We have the following representation:

It was Joseph who committed the crime	j
It was James who committed the crime	t
I did not do	$\neg g$
Joseph lies when he says that I was	$\neg t$

Since only one statement is true, we have the following cases to analyse:

	j	t	$\neg g$	$\neg t$
case 1	1	0	0	0
case 2	0	1	0	0
case 3	0	0	1	0
case 4	0	0	0	1

Cases 1 and 3 can not occur because, with the same valuation,
a formula cannot be tautology and contradiction.
In case 2, variable t has valuation 1, thus James is criminal.
Moreover, variable $\neg g$ has valuation 0, so variable g has valuation 1, thus Gabriel is criminal.
But there is one and only one of them criminal, therefore we also eliminate this case.
In case 4 we have:
Variable j has valuation 0, thus Joseph is not criminal.
Variable t has valuation 0, thus James is not criminal.
Variable $\neg g$ has valuation 0, so variable g has valuation 1, thus Gabriel is the criminal.
This is also compatible with the last statement.

Evaluating all cases, if only one statement is true, the criminal must be Gabriel.

Figure 4 Detailed resolution of Translation and Resolution