Survival models play a key role in Actuarial Science, especially in the life contingencies field. The complexities of some of these models, when applied to human lifetimes, make them a particularly difficult topic for students to learn, as well as for educators to teach. Using the new capabilities of modern web browsers and JavaScript frameworks, a graphical interactive simulator has been developed which eases the study and analysis of actuarial survival models. This interactive graphical tool is integrated into a series of guided activities that allow students to experiment with confidence within a contextualized environment, fully adapted to the professional competences demanded by the actuarial profession. The results of a dedicated survey reveal that students who used this simulator considered that it significantly facilitated their comprehension of the most complex features of actuarial survival models. Amongst the characteristics of the simulator investigated in the survey, regarding their effects on understanding and learning, the best valued ones by the students were the possibility of experimenting and the interactivity. Furthermore, another relevant finding was the students’ perception of a less boring learning experience when using the simulator.

Keywords: Simulation, survival models, actuarial.

1 INTRODUCTION

Survival models play a key role in Actuarial Science, especially in the life contingencies field. The complexities of some of these models, when applied to human lifetimes, make them a particularly difficult topic for students to learn, as well as for educators to teach. Since the nineties, there is a growing research area of developing new resources and methods to improve Statistics learning performance, in an attempt to take advantage of the possibilities that new technologies provide in this regard [1], [2], [3], [4], [5]. Many of these efforts are based on using computer-based simulations to facilitate the understanding and allowing experimentation in real time. Significantly, most of the literature states positive effects over performance and understanding when using computer simulation based resources in Statistics learning [6], [7], [8], [9]. Moreover, finance and insurance sectors are demanding new and more specialized skills [10], [11], due to the changing technical and technological market environment [12], thus requiring the adaptation of the educational resources to these new conditions in this specific academic area.

Following this approach, and integrated into a Pedagogical Innovation Project at the University of Málaga, an interactive online simulator of lifetimes based on actuarial survival models has been developed to enhance the learning experience of the students at the MSc in Actuarial Science. The general project has a broader nature and makes use of the experience of the involved lecturers using innovative strategies and resources in the Actuarial study programs at the Universidad de Málaga, in several areas like new technological resources [13], [14], models of assessment [15], creativity [16], transversality [17], [18] and professional competences [19].

The graphical interactive simulator has been developed using the new capabilities of modern web browsers and JavaScript frameworks, in an attempt to ease the study and analysis of actuarial survival models. JavaScript open source libraries are the new technological paradigm in this area, which is progressively substituting the previous one based on Java applets, as several studies confirm. In the simulator, a visual animation shows the generated lifetimes and several graphic windows present the main features of the model, like the expectation of life at several ages, the curve of deaths, the modal age at death and conditional annual mortality rates. The parameters of the model are user modifiable, generating real time modifications of all the graphical windows. This interactive graphical tool is integrated into a series of guided activities that allow students to experiment with confidence within a contextualized environment, fully adapted to the professional competences demanded by the actuarial profession.

The aim of this paper is to describe the main features of the simulator and the results of its application in the last academic year, by means of a dedicated survey. Section 2 presents the methodology used...
in the development of the simulator and its main characteristics. The results of survey conducted in 2016 are analysed in section 3. Finally, the main conclusions of this study are reported in section 4.

2 METHODOLOGY

A blended strategy is followed in the course of Survival Models (in the MSc program at the University of Málaga), combining in-classroom activities with online resources, to facilitate the integration of diverse learning styles. Previous experiences in the Project where the course is involved [20], [21] revealed that the best valued resources by our students were the online and interactive ones, and they demanded more tools of this type, being the main reason for developing the new simulator. Therefore, the interactive simulator in integrated into a varied set of activities in the Survival Models course.

The main technological feature of the interactive simulator is the use of JavaScript framework to take advantage of the capabilities of modern browsers, that allow a high level of interactivity and powerful graphical visualisations. Thus, the multiplatform code is interpreted by the browser in each device, either a computer or laptop or a tablet or iPad.

The interactive simulator is embedded in a web page with several graphical panels, which also contains the text of the activity. The first panel (Fig. 1) includes the parameters of the stochastic survival model, in our case the Heligman-Pollard model. Parameters are user modifiable in real time with the big icons, generating modifications all the remaining graphical panels. To ease the use and understanding of the simulator, the specification of the model is also included in this panel.

The second panel (Fig. 2) shows an animation of the lifetimes simulated by the model. Each lifetime is represented by a point at the age at death. Two controls labels indicate the age at death of the last simulated lifetime and the cumulative number of simulated lifetimes. In order to get more interactivity, three big icons have been added to control the animation. By clicking them it is possible to pause, continue or restart the animation.

![Figure 1. Interactive parameters panel.](image)

\[
\frac{q_x}{1 - q_x} = A(x + B)^C + De^{-E[Ln(x) - Ln(F)]^2} + GH^x
\]
There is a third graphical panel that shows three key functions of the survival model (Fig. 3): the empirical curve of deaths, the empirical survival function and the conditional annual mortality rate by age (in a log scale). The three functions are estimated with the simulated deaths and change at the same rhythm as the animation goes on. In order to provide some additional information of the simulation, the empirical curve of deaths also includes the estimated modal age at death and the empirical survival function shows the estimated life expectancies at some ages (x=10, 20, ..., 110 years). Moreover, the graphical representation of the conditional annual mortality rates includes the continuous function of the model (in red colour) to have a visual assessment of the difference between the simulation and the simulation.

Each activity that makes use of the interactive simulator is contained in a dedicated web page, which are included into a series of experiments adapted to the actuarial uses of survival models. Some of them use real demographic data in order to have a contextualised experience.

In addition, all the activities are provided in English and Spanish to ease the development of one of the transversal skills included in all the courses of the MSc in Actuarial Science at the Universidad de Málaga.

3 RESULTS

A survey was carried out to have an assessment of the opinions of our students about the usefulness and satisfaction with the interactive simulator we have developed. The survey was conducted at the end of the course in the last academic year, 2016-2017, with a demographic profile of 36% women, 64% men and an average age of 26.2 years (sample size= 44).
Students who used the simulator were asked about their opinion related to the usefulness of their experience with the simulator for enhancing the learning process, using a Likert scale in the interval (1-5). The general opinion about the usefulness of the simulator is highly valued (with a sample mean of 4.51), what constitutes a very good result from the point of view of the pedagogical use of this resource. Apart from the overall opinion, they were also asked about four different characteristics of the simulator (Table 1). The highest sample means correspond to interactivity and experimenting (4.79, 4.56). This result is an indication of the interest of our students in educational resources that allow experimenting, especially if it is done via interactivity, which are precisely the main characteristics of the interactive simulator. Furthermore, the other two features, graphics and online availability, also exhibit high sample means (4.47 and 4.37), though below the overall mean.

<table>
<thead>
<tr>
<th>Table 1. Opinions about usefulness for learning concepts.</th>
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<tbody>
<tr>
<td><strong>Mean</strong></td>
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<tr>
<td>Interactivity</td>
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<tr>
<td>Experimenting</td>
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<td>Online availability</td>
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<td>Graphics</td>
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<td>Overall</td>
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</table>

In order to develop future strategies and resources in our project, there are also several general aspects of the simulator use we were interested in. Table 2 shows the means and standard deviations of the answers. Firstly, the majority of the students gave the maximum value to the item ‘I would recommend it to my peers’, resulting in a sample mean of 4.7, which we consider a very good result regarding the students’ perception about the quality and usefulness of the simulator.

But the most interesting result in this set of questions corresponds to the highest mean, 4.73, of the item ‘it made the learning process less boring’. This result, along with the high means of items related to usefulness for the learning process, mentioned above, reveals that this kind of educational resources that are 'less boring', at the same time that being 'serious' and highly analytic, can produce a relevant positive effect over the learning process.

Moreover, the mean score of the item ‘easy to use’ showed a relatively high mean score (4.27), but below the remaining items. This result may be a warning of the need of some adjustments in future versions of the simulator that ease its use.

<table>
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<th>Table 2. Opinions about the simulator.</th>
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<tbody>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>I would recommend it to my peers</td>
</tr>
<tr>
<td>It made the learning process less boring</td>
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<tr>
<td>It was easy to use</td>
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</tbody>
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Finally, the satisfaction with the experience using the interactive simulator was assessed in the survey with five questions related to particular aspects of experience and one question about the overall satisfaction (measured in the same scale as the remaining questions). Fig. 4 shows the mean scores of these six questions. There is little variation in the sample means of the five particular aspects, all of them greater than or equal to 4.5. However, interactivity and visualisation show slightly higher means. Therefore, the features of the simulator that generate the greatest satisfaction amongst our students are those related to interaction and visual elements.

The last question in the survey, about the overall satisfaction with the experience, was valued with a mean score of 4.6. This is a very good result, bearing in mind that the course in Survival Models has a highly technical content, and it is also coherent with the outcomes of the project discussed above.
CONCLUSIONS

Survival models play a key role in Actuarial Science, especially in the life contingencies field. The complexities of some of these models, especially when applied to human lifetimes, makes them a particularly difficult topic for students to learn as well as for educators to teach. New approaches to Statistics learning recommend using technological interactive resources that allow experimenting and simulating for a better understanding of concepts. Within this context, a particularly useful type of educational resource has been developed in this project combining interactivity, simulation and online availability, specifically for a course in Survival Models in the MSc program on Actuarial Science at the University of Málaga.

The interactive simulator of lifetimes has been designed bearing in mind the experience of the team of lecturers in previous projects that involve interactive graphical resources [22], [23], but also incorporating the new capabilities of modern web browsers and JavaScript frameworks. This technological choice allows an easy access from a wide variety of devices, regardless of the operating system.

In addition, to get better results, the simulator is integrated into a series of contextualised activities to ensure a full adaptation to the professional context where the concepts will be applied. The activities encourage experimenting with the simulator, taking advantage of its interactive features, which have been highly valued by the students.

The analysis of the results of a dedicated survey reveals that students that used this simulator considered that it significantly facilitated their comprehension of the most complex features of actuarial survival models. Within the characteristics of the simulator investigated in the survey, regarding their effects on understanding and learning, the best valued ones by the students were the possibility of experimenting and the interactivity. Furthermore, another relevant finding was the students’ perception of a less boring learning experience when using the simulator.

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