

# RANDOM EXAMS USING SWEAVE

**D.S. Gómez, J. Mulero, M.J. Nueda, M.D. Molina, A. Pascual**

*Department of Statistics and Operation Research, University of Alicante (SPAIN)*  
*dani.gomez@ua.es, julio.mulero@ua.es, mj.nueda@ua.es, aurora.pascual@ua.es,*  
*mariola.molina@ua.es*

## Abstract

The adaptation of the Spanish University to the European Higher Education Area (EEES in Spanish) demands the integration of new tools and skills that would make the teaching- learning process easier. This adaptation involves a change in the evaluation methods, which goes from a system where the student was evaluated with a final exam, to a new system where we include a continuous evaluation in which the final exam may represent at most 50% in the vast majority of the Universities.

Devising a new and fair continuous evaluation system is not an easy task to do. That would mean a student's learning process follow-up by the teachers, and as a consequence an additional workload on existing staff resources.

Traditionally, the continuous evaluation is associated with the daily work of the student and a collection of the different marks partly or entirely based on the work they do during the academic year. Now, small groups of students and an attendance control are important aspects to take into account in order to get an adequate assessment of the students. However, most of the university degrees have groups with more than 70 students, and the attendance control is a complicated task to perform, mostly because it consumes significant amounts of staff time. Another problem found is that the attendance control would encourage not-interested students to be present at class, which might cause some troubles to their classmates.

After a two year experience in the development of a continuous assessment in Statistics subjects in Social Science degrees, we think that individual and periodical tasks are the best way to assess results. These tasks or examinations must be done in classroom during regular lessons, so we need an efficient system to put together different and personal questions in order to prevent students from cheating.

In this paper we provide an efficient and effective way to elaborate random examination papers by using Sweave, a tool that generates data, graphics and statistical calculus from the software R and shows results in PDF documents created by Latex. In this way, we will be able to design an exam template which could be compiled in order to generate as many PDF documents as it is required, and at the same time, solutions are provided to easily correct them.

Keywords: Continuous assesment, random test, free software.

## 1 INTRODUCTION

*"In the decade up to 2020 European higher education has a vital contribution to make in realising a Europe of knowledge that is highly creative and innovative... Europe can only succeed in this endeavour if it maximises the talents and capacities of all its citizens and fully engages in lifelong learning as well as in widening participation in higher education."*

*Ministers responsible for Higher Education in the countries participating in the Bologna Process, Leuven/Louvain-la-Neuve Communiqué, April 2009 [1]*

In Spain, the Bologna process has become synonymous with the reform of degree structures. The years following the signing of the Bologna Declaration stimulated widespread and ongoing debate. The adaptation of the Spanish University to the European Higher Education Area (EEES in Spanish) demands the integration of new tools and skills that would make the teaching- learning process easier.

This involves structural systemic, programmatic and procedural changes that ensure real benefits on the ground, to students, to staff, to the economy and to society more widely.

The evaluation method, which goes from a system where the student was evaluated with a final exam, to a new system where we include a continuous evaluation in which the final exam may represent at most 50% in the vast majority of the Universities, are also affected by this new education system.

The subject Statistics in Social Sciences was introduced in 2010-11 academic course in Alicante University. The number of students in these classes is around 90. Table 1 summarizes the punctuation weights applied since the first course. For further information, see [2].

First year continuous evaluation was divided in three items: partial exams (30%), participation (10%) and a task in group (10%). After this experience we noted that the task in group was not a good idea for several reasons. Firstly, not everyone involves in the same way as we could see that final marks did not correspond with the mark of the work. Secondly, correcting all the works was highly time-consuming for teachers and this was not productive because it was difficult to give feedback to the students. Therefore, in the second course (2011-12) we decided to remove this task and focused efforts in evaluate participation giving to this part 20% of the final mark. Furthermore, we made the effort of encouraging students to participate in the subject as it is described in [3] and [4]. We prepared news to read and to comment, debates, exercises, videos, etc. After this experience we have noted that students involved in the subject get the best marks in partial and final exams. However, evaluating participation is not easy and sometimes can be unfair. Moreover, preparing and evaluating all these tasks imply high workload. We also have noted that students respond better to exams than to this type of work: a high number of students do the exams and prepare them meanwhile only a few students participate in the other tasks. After this experience, we consider that partial exams must be considered the best way to continuous evaluation.

TYPE	DESCRIPTION	2010-11	2011-12	2012-13
<b>CONTINUOUS EVALUATION</b>	2 partial exams	30%	30%	50%
	Participation: - Individual exercises - Virtual participation - Presential participation	10%	20%	-
	Task in group	10%	-	-
<b>FINAL EXAM</b>	Final exam with all the contents	50%	50%	50%

**Table 1: Evaluation weights.**

## 2 PURPOSE

As we mentioned before we consider that partial exams are the best way to evaluate the continuous assessment. These exams must be done in classroom during regular lessons and with the control of only one teacher. Therefore, we need an efficient system to put together different or random questions in order to prevent students from cheating.

Designing different exams can be made in different ways. We propose putting the same questions changing only the data. This option is appropriate for our subject because the aim is to assess if the students understand the process of obtaining results. And it is also fair for students because all of them will have the same difficulty degree.

### 3 METHODOLOGY

After a two year experience in the development of a continuous assessment in Statistics subjects in Social Science degrees, we think that individual and periodical exams are the best way to assess results. These exams must be done in classroom during regular lessons and with the control of only one teacher. Therefore, we need an efficient system to put together different or random questions in order to prevent students from cheating.

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Making different exam models in statistics is also highly time-consuming due to it requires a lot of calculations. Lecturers are usually familiarized with the use of LaTeX and R, why not use both at once?

The tools are the following:



- **LaTeX:** As we can read in the official website (<http://www.ctan.org/tex/>), "TeX and associated programs such as LaTeX is a system for computer typesetting, for placing text on a page. It is well known for its skill with mathematical and scientific text and other difficult typesetting jobs: long or intricate documents, and multilingual works." This software is totally free and is available for many operating systems. We also need the corresponding software to view pdf files (usually, adobe acrobat reader) and a LaTeX editor. There are a lot of free editors, but we work with WinEdt.

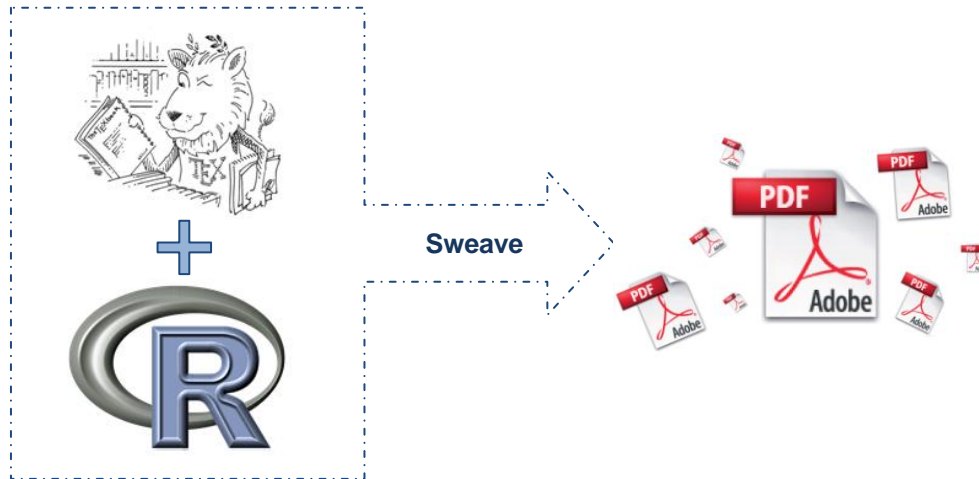
The advantages of LaTeX are that

- It's free.
- It's available for many machines.
- LaTeX files are ASCII and are portable. Because they're ASCII it's easy to discover how someone achieved an effect.
- You can use the editor of your choice (I sometimes use Word).
- The typesetting's better, especially the maths.
- Style changes are neater in LaTeX. Style files for many periodicals exist. Many Word users don't use styles or templates, and there's a limit to what can be done.
- LaTeX is extensible.
- LaTeX's floats are no more awkward than Word's anchored frames, and the latter don't always work well.



- **R:** "R is a free software environment for statistical computing and graphics. It runs on a wide variety of UNIX platforms, Windows and MacOS". It is free and we can download it in <http://www.r-project.org/>.

- **Sweave:** Sweave is a function in the statistical programming language R that enables integration of R code into LaTeX documents. The purpose is "to create dynamic reports, which can be updated automatically if data or analysis change" (<http://www.stat.uni-muenchen.de/~leisch/Sweave/>).



Sweave combines LaTeX with R, therefore it presents all the previous advantages.

Moreover,

- We can save time because there is no need to copy numbers, tables and graphics by hand into documents.
- We do not have to repeat the process to create different models of exams.

### 3.1 PROCESS OF MAKING RANDOM EXAMS

The design of suitable questions is an arduous task that can be simplified by using a sort of random exams generated by R and LaTeX. The steps are the following:

1. **Create an Rnw file with LaTeX.** We create a new file in the LaTeX editor with the structure of a complete LaTeX document, we write the text, and we save it with Rnw extension which combines both formats. The .rnw looks basically like a TeX file, except, where you've included R-code.

Now, we can insert in it some R-code, as follows:

```

\documentclass[a4paper]{article}
\begin{document}

<<options>>=
R code
@

<<options>>=
R code
@

\end{document}

```

The R-code has to be place in a environment opened by <<options>> and closed by a @.

Some options are the following:

- `echo`: Print code in document? (True)
- `print`: Prints all results? (False)
- `fig`: Is there a figure to print? (False)

- o pdf: logical (True), indicating whether PDF figures shall be generated. Ignored if fig=False.
- o Further information in [7].

2. **Compile with Sweave in R.** To generate a .tex file the following sentence must be executed in the workspace in R:

```
Sweave("Example.Rnw")
```

This generates a unique tex file with the name: Example.tex, where the R code is replaced by the corresponding data, figures and computations.

To generate different tex files corresponding to different exams the following sentences must be executed as many times as model exams are required:

```
Sweave("Example.Rnw", output="Example_A.tex")
Sweave("Example.Rnw", output="Example_B.tex")
...
```

3. **Compile with pdflatex.** Finally, we open these files in the TeX editor and we compile with pdflatex in order to generate the pdf files.

### 3.2 EXAMPLE

Next, we describe the process to generate random exams with a particular example. Let us imagine that we need to design an exam, but we have an small classroom and a lot of students. In this case, it would be interesting to have several models of exams in order to prevent students from cheating.

The process can be illustrated by Figure 1.

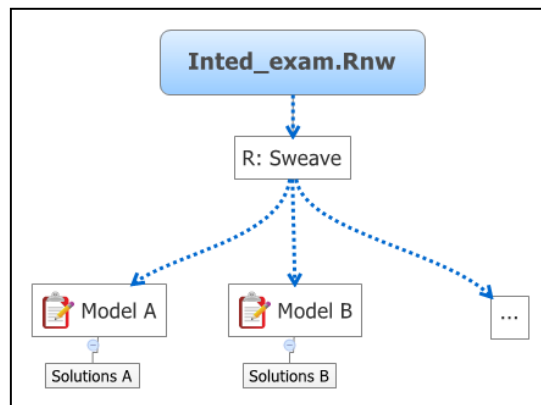


Figure 1. Example process.

The first step is to create the code in LaTeX which included some R code. In general, it is possible to include all the available commands in R. For example, as it can be observed in Table 2, we can generate samples or include figures with the following codes, respectively:

<pre>&lt;&lt;echo=FALSE&gt;&gt;= B&lt;&lt;-rbinom(20,6,0.4) names(B)&lt;-rep(c(""),length(B)) B @</pre>	<pre>&lt;&lt;fig=TRUE,echo=FALSE,width=4,height=4&gt;&gt;= plot(X,Y,col=2) @</pre>
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<pre> \documentclass[a4paper,11pt]{article} \usepackage{Sweave} \usepackage[latin1]{inputenc} \usepackage[a4paper]{geometry}   \geometry{hmargin={3cm,3cm},height=21cm}  \title{Statistics Exam \Valencia. INTED 2013 \ Model A \date{}}  \begin{document} \setkeys{Gin}{width=0.6\textwidth} \maketitle  \begin{enumerate}  \item From the following data sample:  &lt;&lt;echo=FALSE&gt;&gt;=   B&lt;&lt;-rbinom(20,6,0.4) names(B)&lt;-rep(c(""),length(B))   B   @  \begin{enumerate}   \item Group the data in an appropriate frequency table.   \item Draw an appropriate graphic.   \item Calculate the mean and the variance.   \item Calculate the median and the interquartilical range.   \item Calculate the variation coefficient.   \item Find a 95\% confidence interval for the mean. \end{enumerate}  \item From the following data:  &lt;&lt;echo=FALSE&gt;&gt;=   X&lt;-round(rnorm(10,5,2),0) b&lt;-round(runif(1,1,5),2) a&lt;-round(runif(1,0,5),2) Y&lt;-round(a+b*X+rnorm(10,5,2),0) DATA&lt;&lt;-rbind(X,Y) colnames(DATA)&lt;-rep(c(""),ncol(DATA))   DATA   @  \begin{enumerate} \item Draw the dispersion diagram. \item Find <math>a</math> and <math>b</math>, the regression coefficients of the model: <math>Y=a+bX</math> \item Is there linear relationship between <math>X</math> and <math>Y</math>. Justify the response. \end{enumerate} \end{enumerate}  %% </pre>	<pre> \newpage \vspace*{-2cm} \begin{center}   \textbf{\large{SOLUTIONS}} \end{center}  \textbf{PROBLEM 1}  As it is a discrete variable, there is no need of making intervals and the most appropriate graph is a barplot. \begin{center} &lt;&lt;fig=TRUE,echo=FALSE,width=4,height=4&gt;&gt;=   barplot(table(B))   @ \end{center}  \vspace{-1cm} \begin{minipage}[t]{0.5\textwidth} &lt;&lt;echo=FALSE&gt;&gt;=   source("tabla_frec.R")   tabla.frec(B)   @ \end{minipage}  \begin{minipage}[t]{0.5\textwidth} &lt;&lt;echo=FALSE&gt;&gt;= sol1 &lt;- c(mean(B), var(B), median(B), quantile(B,probs=0.75)- quantile(B,probs=0.25), sd(B)/mean(B),t.test(B)\$conf.int[1],t.test(B) )\$conf.int[2]) sol1 &lt;- round(sol1, 4) sol1 &lt;- matrix(sol1,length(sol1),1) rownames(sol1) &lt;- c("Mean","Variance","Median", "Interquartilical Range", "Variation Coefficient", "95% C.I.low limit","95% C.I.upper limit") colnames(sol1)&lt;-"" sol1   @ \end{minipage}  \vspace{1cm} \textbf{PROBLEM 2}  \vspace{-0.5cm} \begin{minipage}[c]{0.6\textwidth} &lt;&lt;fig=TRUE,echo=FALSE,width=4,height=4&gt;&gt;=   plot(X,Y,col=2)   @ \end{minipage}  \begin{minipage}[c]{0.3\textwidth} &lt;&lt;echo=FALSE&gt;&gt;= sol2 &lt;- c(summary(lm(Y~X,data=as.data.frame(t(DATA)) ))\$coef[1],summary(lm(Y~X,data=as.data.frame e(t(DATA))))\$r.squared) sol2 &lt;- round(sol2, 4) sol2 &lt;- matrix(sol2,length(sol2),1) rownames(sol2) &lt;-c("a","b","R-squared") colnames(sol2) &lt;- "" sol2   @ \end{minipage}  \end{document} </pre>
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**Table 2. Inted\_exam.Rnw.**

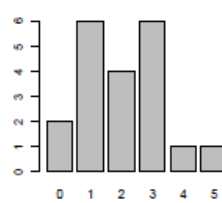
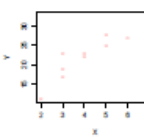
Then, we open R, charge the Sweave package and compile the following instruction:

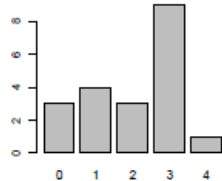
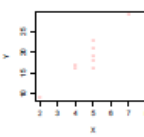
```
Sweave("Inted_exam.Rnw", output="Model_A.tex")
```

In case we want to obtain another model of this exam, we can also compile

```
Sweave("Inted_exam.Rnw", output="Model_B.tex")
```

Each one of these codes in R generates one file Model\_A.tex and Model\_B.tex, respectively, and if we compile with pdflatex, we obtain the following pdf's:

<p style="text-align: center;">Statistics Exam Valencia. INTED 2013 Model A</p> <p>1. From the following data sample:</p> <pre>1 3 1 1 3 3 3 2 1 3 1 0 5 1 4 3 2 2 0 2</pre> <p>(a) Group the data in an appropriate frequency table.          (b) Draw an appropriate graphic.          (c) Calculate the mean and the variance.          (d) Calculate the median and the interquartilical range.          (e) Calculate the variation coefficient.          (f) Find a 95% confidence interval for the mean.</p> <p>2. From the following data:</p> <pre>X 3 6 2 3 4 5 7 4 3 5 Y 23 27 11 19 23 28 33 22 17 25</pre> <p>(a) Draw the dispersion diagram.          (b) Find <math>a</math> and <math>b</math>, the regression coefficients of the model: <math>Y = a + bX</math>          (c) Is there linear relationship between <math>X</math> and <math>Y</math>. Justify the response.</p>	<p style="text-align: center;">SOLUTIONS</p> <p><b>PROBLEM 1</b> As it is a discrete variable, there is no need of making intervals and the most appropriate graph is a barplot.</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>f1</th> <th>fri</th> <th>F1</th> <th>Fri</th> <th>Mean</th> <th>2.0500</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>2</td> <td>0.10</td> <td>2</td> <td>0.10</td> <td>Variance</td> <td>1.7342</td> </tr> <tr> <td>1</td> <td>6</td> <td>0.30</td> <td>8</td> <td>0.40</td> <td>Median</td> <td>2.0000</td> </tr> <tr> <td>2</td> <td>4</td> <td>0.20</td> <td>12</td> <td>0.60</td> <td>Interquartilical Range</td> <td>2.0000</td> </tr> <tr> <td>3</td> <td>6</td> <td>0.30</td> <td>18</td> <td>0.90</td> <td>Variation Coefficient</td> <td>0.6424</td> </tr> <tr> <td>4</td> <td>1</td> <td>0.05</td> <td>19</td> <td>0.95</td> <td>95% C.I. low limit</td> <td>1.4337</td> </tr> <tr> <td>5</td> <td>1</td> <td>0.05</td> <td>20</td> <td>1.00</td> <td>95% C.I. upper limit</td> <td>2.6683</td> </tr> </tbody> </table> <p><b>PROBLEM 2</b></p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <tbody> <tr> <td>a</td> <td>7.3611</td> </tr> <tr> <td>b</td> <td>3.6759</td> </tr> <tr> <td>R-squared</td> <td>0.8544</td> </tr> </tbody> </table>	f1	fri	F1	Fri	Mean	2.0500	0	2	0.10	2	0.10	Variance	1.7342	1	6	0.30	8	0.40	Median	2.0000	2	4	0.20	12	0.60	Interquartilical Range	2.0000	3	6	0.30	18	0.90	Variation Coefficient	0.6424	4	1	0.05	19	0.95	95% C.I. low limit	1.4337	5	1	0.05	20	1.00	95% C.I. upper limit	2.6683	a	7.3611	b	3.6759	R-squared	0.8544
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<p style="text-align: center;">Statistics Exam Valencia. INTED 2013 Model B</p> <p>1. From the following data sample:</p> <pre>3 3 0 1 4 2 1 3 3 3 1 3 3 3 3 1 2 0 0 2</pre> <p>(a) Group the data in an appropriate frequency table.          (b) Draw an appropriate graphic.          (c) Calculate the mean and the variance.          (d) Calculate the median and the interquartilical range.          (e) Calculate the variation coefficient.          (f) Find a 95% confidence interval for the mean.</p> <p>2. From the following data:</p> <pre>X 5 5 5 4 2 4 8 5 5 7 Y 18 23 21 16 9 17 26 16 19 29</pre> <p>(a) Draw the dispersion diagram.          (b) Find <math>a</math> and <math>b</math>, the regression coefficients of the model: <math>Y = a + bX</math>          (c) Is there linear relationship between <math>X</math> and <math>Y</math>. Justify the response.</p>	<p style="text-align: center;">SOLUTIONS</p> <p><b>PROBLEM 1</b> As it is a discrete variable, there is no need of making intervals and the most appropriate graph is a barplot.</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>f1</th> <th>fri</th> <th>F1</th> <th>Fri</th> <th>Mean</th> <th>2.0500</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>3</td> <td>0.15</td> <td>3</td> <td>0.15</td> <td>Variance</td> <td>1.5237</td> </tr> <tr> <td>1</td> <td>4</td> <td>0.20</td> <td>7</td> <td>0.35</td> <td>Median</td> <td>2.5000</td> </tr> <tr> <td>2</td> <td>3</td> <td>0.15</td> <td>10</td> <td>0.50</td> <td>Interquartilical Range</td> <td>2.0000</td> </tr> <tr> <td>3</td> <td>9</td> <td>0.45</td> <td>19</td> <td>0.95</td> <td>Variation Coefficient</td> <td>0.6021</td> </tr> <tr> <td>4</td> <td>1</td> <td>0.05</td> <td>20</td> <td>1.00</td> <td>95% C.I. low limit</td> <td>1.4723</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td>95% C.I. upper limit</td> <td>2.6277</td> </tr> </tbody> </table> <p><b>PROBLEM 2</b></p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <tbody> <tr> <td>a</td> <td>3.5667</td> </tr> <tr> <td>b</td> <td>3.1667</td> </tr> <tr> <td>R-squared</td> <td>0.8287</td> </tr> </tbody> </table>	f1	fri	F1	Fri	Mean	2.0500	0	3	0.15	3	0.15	Variance	1.5237	1	4	0.20	7	0.35	Median	2.5000	2	3	0.15	10	0.50	Interquartilical Range	2.0000	3	9	0.45	19	0.95	Variation Coefficient	0.6021	4	1	0.05	20	1.00	95% C.I. low limit	1.4723						95% C.I. upper limit	2.6277	a	3.5667	b	3.1667	R-squared	0.8287
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## 4 CONCLUSIONS

*“Let us change our traditional attitude to the construction of programs: Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to humans what we want the computer to do.”*  
Donald E. Knuth, 1984

Lectures are challenged to effectively use new technology in ways that both take advantage of the unique characteristics of new technology.

The main purpose of this paper was to design random exams in Statistics subjects by using LaTeX and R jointly. This idea emerged as a result of several circumstances: Our experience as lecturers in Statistics subjects indicates that partial exams are the best way to evaluate continuous assessment.

- Different exams in Statistics subjects implies a lot of computations.
- The same questions with different data is a good way to be fair with students.
- There exist a tool in R named Sweave that generates documents with different data by using Latex and R.
- Lectures involved in Statistic subjects are familiarized with the use of LaTeX and R.

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