Teaching Statistics: An example of “How to" improve student's statistical skills by performing individualized assignments

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Sweave is a well known tool that allows to embed R code in LaTeX

The code can be evaluated and the resulting console output, figures and tables are automatically inserted into the final document. We applied this technique to create individualized assignments to students in four disciplines taught in two different universities:

- ✓ Human Nutrition (HN). University of LLeida, Spain.
- ✓ Medicine (ME). University of LLeida, Spain.
- ✓ Nursing (NU). Autonomous University of Barcelona, Spain.
- ✓ Occupational Therapy (OT). Autonomous University of Barcelona, Spain.

For each discipline we choose a clinical trial (CT) in some way appealing and related with the specific discipline (Figure 1). The main results of those CT were simulated to create an spreadsheet, one for each student of each discipline: 62 HN, 60 ME, 177 NU and 79 T0. (Figure 2-3)

Figure 2: Functions to simulate data

```
## to Simulate a random normal Continous variable
##########################################################
SimCon<-function(m, mean=, sd=, lolimit, uplimit, sdec)
    {
      if (sd^2>(mean-lolimit)*(uplimit-mean))
        {cat("The SD is too big to simulate data by a beta distribution\n")}
      else
        {
          x1<-mean
          x2<-sd^2
          x1<-(x1-lolimit)/(uplimit-lolimit)
          x2<-x2/(uplimit-lolimit)^2
          alpha<-x1*(x1* (1-x1)/x2-1)
          beta<-(1-x1)*(x1* (1-x1)/x2-1)
          temp<-rbeta(m, alpha, beta)
          temp<-round(lolimit+(uplimit-lolimit)*temp,sdec)
          return(temp)
        }
    }

# tpc<-SimCon(20,65,12,35,74,0)

## to Simulate a Categorical variable
#####################################
SimCat<-function(m, nprops)
    {
      props<-c(nprops, 1-sum(nprops))
      temp<-NULL
      for (i in 1:length(props)) {
          temp<-c(temp, rep(i,round(m*props[i],0)))
        }
      if(length(temp) > m) {temp<-temp[1:m]}
      if(length(temp) < m) {temp<-c(temp, rep(max(temp), m-length(temp)))}
      return(temp)
    }
# tac<-SimCat(200, c(20/100, 30/100, 35/100))

## to Simulate a Correlated variable
####################################
SimCor<-function(MyData, x, meanxy, sdy, lolimit, uplimit, sdec, scor)
    {
      mx<-MyData[, x]
      covxy<-sd(mx)*sdy*scor
      sbeta<-covxy/sd(mx)^2
      salpha<-meanxy-sbeta*mean(mx)
      sgred<-salpha+sbeta*mx
      sedgred<-sd(sgred,na.rm=TRUE)
      smeangred<-mean(sgred,na.rm=TRUE)
      covygred<-sedgred*sedy*scor
      sedxesid<-sqrt(sedgred^2*sedy^2-2*covygred)
      secor<-(
          if (sedxesid^2>(0-(lolimit-min(sgred)))*((uplimit-max(sgred))-0)) {
      !cat("The Cor. c/or the SD of 'y' is to big to simulate data by a beta distribution\n")}
          temp<-rep(NA,length(mx)) )
          else
          {
            x1<-0
            x1<-sedxesid^2
            x1<-(x1-(lolimit-min(sgred)))/((uplimit-max(sgred))-(lolimit-min(sgred)))
            x2<-x2/(uplimit-max(sgred))-(lolimit-min(sgred)))^2
            alpha<-x1*(x1* (1-x1)/x2-1)
            beta<-(1-x1)*(x1* (1-x1)/x2-1)
            temp<-rbeta(length(mx), alpha, beta)
            temp<-round((lolimit-min(sgred))+(uplimit-max(sgred))-(lolimit-min(sgred)))*temp,sdec)
          }
      temp<-as.data.frame(cbind(sgred, secor))
      temp<-with(temp, sgred+secor*c)
      temp<-round(temp, sdec)
      return(temp)
    }

# bmi<-SimCor(MyData, "age", 27.4, 4.6, 17, 40, 1,0.7)
```

Figure 3: Making data

```
rm(list=ls())
source("C:/JVila/DseB/simulV01.r")

## Loading students names
#########################
students<-scan(what="character", sep="\n")
Silvio Berlusconi
David Cameron
Stephen Harper
Naoto Kan
Dmitry Medvedev
Angela Merkel
Barack Obama
Nicolas Sarkozy

## Initializing .CSV with the expected results
##############################################################
write.table(file="C:/JVila/DseB/expect.csv", cbind("Student", "Answer01", "LowLimit01",
"Uplimit01", "Answer02"), sep="/",append = FALSE, col.names = FALSE, row.names=FALSE)

## Starting loop
################
set.seed(123)
for (k in 1:length(students)) {
## making data
##############
makeData<-function(){
    # id
    lowerlimit<-1900 # select minimun number of registers
    uplimit<-2200    # select maximun number of registers
    dat<-as.data.frame(seq(1, round(runif(1,lowerlimit,uplimit),0) , 1))
    names(dat)<-"id"

    # group
    group<-rbinom(nrow(dat), runif(1,0.45,0.52))
    dat<-as.data.frame(cbind(dat, group))

    # Sense of vulnerability
        # group ==1
        vul1<-SimCon(sum(dat[group==1), 13.1, 16.3, 0, 100, 0)
        # group ==2
        vul2<-SimCon(sum(dat[group==2), 23.6, 25.8, 0, 100, 0)
    vul<-c(vul1, vul2)
    dat<-as.data.frame(cbind(dat, vul)) ## be sure it works (i.e no missings!!)

    # Physical discomfort (moderately correlated with Sense of vulnerability:
    # r== 0.45 for group ==1 & r==0.50 for group ==2)
        # group ==1
        dis1<-SimCor(dat[dat$group==1,], "vul", 17.2, 17.8, 0, 100, 0, 0.65)
        # group ==2
        dis2<-SimCor(dat[dat$group==2,], "vul", 30.4, 26.8, 0, 100, 0, 0.50)
    dis<-c(dis1, dis2) ## be sure it works (i.e no missings!!)
    dat<-as.data.frame(cbind(dat, dis))

    # Sense of loss of control (poor correlated with Sense of vulnerability:
    # r== 0.03 for group ==1 & r==0.07 for group ==2)
        # group ==1
        los1<-SimCor(dat[dat$group==1,], "vul", 17.7, 23.6, 0, 100, 0, 0.03)
        # group ==2
        los2<-SimCor(dat[dat$group==2,], "vul", 23.1, 27.1, 0, 100, 0, 0.7)
    los<-c(los1, los2) ## be sure it works (i.e no missings!!)
    dat<-as.data.frame(cbind(dat, los))
    return(dat)
}

dat<-makeData()
while(sum(is.na(dat$dis))>0) {dat<-makeData()}
## Sweave
#################
setwd("C:/JVila/DseR")

  # Questions
Sweave("Quest.snw")
shell("pdflatex Quest")
file.copy("Quest.pdf", paste("Quest/Q_",students[k],".pdf", sep=""), overwrite = TRUE)
file.remove("Quest.snw")
file.remove("Quest.log")
file.remove("Quest.pdf")
file.remove("Quest.tex")

  # Answers
Sweave("Answer")
shell("pdflatex Answer")
file.copy("Answer.pdf", paste("Answ/A_",students[k],".pdf", sep=""), overwrite = TRUE)
file.remove("Answer.snw")
file.remove("Answer.log")
file.remove("Answer.pdf")
file.remove("Answer.tex")
## Storing expected answer
#########################
write.table(file="C:/JVila/DseB/expect.csv",
            cbind(students[k], anO1, loanO1, upanO1, anO2),
            sep=",",append = TRUE, col.names = FALSE, row.names=FALSE )

## Storing data
###############
write.table(file=paste("C:/JVila/DseB/csv/", students[k],".csv", sep=""),
            dat,
            sep=",",append = FALSE, col.names = TRUE, row.names=FALSE )
}
```

Data were similar but different for each student in the discipline. So each student received an spreadsheet with his/her particular data and a PDF with his/her name and id. The PDF consists on 50th questions to apply on his/her spreadsheet covering all material taught during the course.

Questions and the way to solve them were exactly the same in each discipline students, but conclusions could be: the same, similar or absolutely different depending on his/her data.

Questions consist on open questions that requires to calculate a figure (i.e. a Student-t statistic) as well as multiple choice questions. The answers for the late were randomly ordered. So not only conclusions could be different, even if the conclusion was the same, the choice could be a different item. (Figure 4-5).

Student were advised to fulfil the 50 answers in a free and open-source e-learning software platform (Moodle or Sakai, depending on the university).

By the deadline of delivery, each student received a detailed answer, of course personalized with his/her name, not only showing what the correct answer was but with a completely detailed explanation how to get the answer or, in the multiple choice questions, why we consider not correct the remainder answers. (Figure 6)

Figure 6: Example of answer received after delivery (question 1)

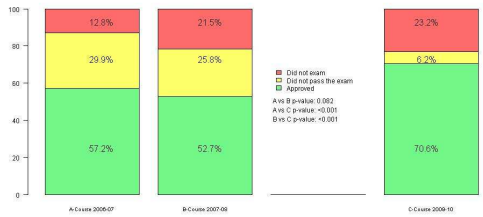
1. To calculate the standard deviation (SD) of Sense of vulnerability for stirrups group:

$$\begin{aligned} SD &= \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{X})^2}{(n-1)}} \\ &= \sqrt{\frac{(21-24.1)^2+(2-24.1)^2+\ldots+(0-24.1)^2+(1-24.1)^2}{(1060-1)}} \\ &= \sqrt{\frac{718369.3}{1059}} = 26 \end{aligned}$$

Is expected you answer 26, but any value between 25.5 and 26.5 will be considered correct.

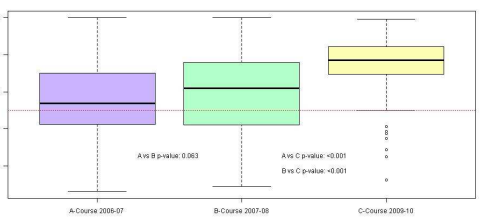
At the end of the quarter students did a final exam. We compare the results of the final exam in each discipline, applying the new system against historic exams performed in 2006-07 and 2007-08. Exams were made with the same teachers and solved for similar students but not using individual assignments method. Results were extremely dramatic: As example, in NU discipline the final exam was done and approved for 57.2% of 187, and 52,7% of 186 students in the academic course 2006-07 and 2007-08 respectively, while 70.6% of the 177 students approved the exam in 2009-10 course (Figure 7).

Figure 7: Exam results by period



Although the percentage of students who did the exam was fairly similar, the ones who did the exam, got higher marks: Mean (SD): 5.50 (1.94), 5.99 (2.12) and 7.43 (1.54) and approved a higher percentage: 65,6%, 67.1% and 91.9% (courses 2006-07, 2007-08 and 2009-10 respectively). (Figure 8)

Figure 8: Students marks by period



Students were asked about strengths and weaknesses in relation to assignment. The results of this analysis, got from open questions of the type “positive / negative” about the assignment with qualitative research methodology, has led to descriptions and interpretations of the experience of the student in learning statistics on a context of innovation. It has also identified those aspects of the subject more vulnerable and susceptible of being improved in future courses.

Figure 1: An example of Clinical trial choose for nursing

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Research BMJ

Improving women's experience during speculum examinations at routine gynaecological visits: randomised clinical trial

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Fig 2 Positioning of women with draping for examination without stirrups (drawn by Jordan Mastrodonato)

Table 2 Main outcome measures (mean (SD) score on 100 mm visual analogue scale) in 197 women examined with or without stirrups

Outcome	No stirrups	Stirrups	Difference (95% CI)
Sense of vulnerability	13.1 (16.3)	23.6 (25.8)	−10.5 (−16.6 to −4.4)
Physical discomfort	17.2 (17.8)	30.4 (26.8)	−13.2 (−19.7 to −6.8)
Sense of loss of control	17.7 (23.8)	23.1 (27.1)	−5.4 (−12.6 to 1.8)

Figure 4: Example of SNW file with 1 open an 1 multiple choice question

```
\documentclass[a4paper,titlepage,12pt]{article}
\usepackage{longtable}
\usepackage{english]{babel}
\usepackage{ansinew]{inputenc}
\usepackage{a4paper,top=2cm,bottom=2cm,left=2cm,right=2cm]{geometry}
\usepackage{multicol}
\usepackage{pdftex]{graphicx}
\usepackage{epsfig}
\usepackage{amssymb,amsmath}
\usepackage{c:/jvila/Sweave}

\begin{document}
\begin{center}
\begin{Large}
\textbf{BIOSTATISTICS} \\
\end{Large}
\vspace{0.4cm}
Assignment to: \textbf{\Sexpr{students[k]}} \\
Deadline: July $24^{th}$ 2010
\end{center}
\vspace*{0.7cm}
\begin{enumerate}

% q01
<<results=hide,echo=false>>=
mevul0<-round(with(subset(dat, group ==1), mean(vul)),1)
mevul1<-round(with(subset(dat, group ==2), mean(vul)),1)
medis0<-round(with(subset(dat, group ==1), mean(dis)),1)
medis1<-round(with(subset(dat, group ==2), mean(dis)),1)
melos0<-round(with(subset(dat, group ==1), mean(los)),1)
melos1<-round(with(subset(dat, group ==2), mean(los)),1)

sdvul0<-round(with(subset(dat, group ==1), sd(vul)),1)
sdvul1<-round(with(subset(dat, group ==2), sd(vul)),1)
sddis0<-round(with(subset(dat, group ==1), sd(dis)),1)
sddis1<-round(with(subset(dat, group ==2), sd(dis)),1)
sdlos0<-round(with(subset(dat, group ==1), sd(los)),1)
sdlos1<-round(with(subset(dat, group ==2), sd(los)),1)

vul<-t.test(vul~group,data=dat)
vuldiff<-round(vul$estimate[1]-vul$estimate[2], 1)
vullo<-round(vul$conf.int[1], 1)
vulup<-round(vul$conf.int[2], 1)

dis<-t.test(dis~group,data=dat)
disdiff<-round(dis$estimate[1]-dis$estimate[2], 1)
dislo<-round(dis$conf.int[1], 1)
disup<-round(dis$conf.int[2], 1)

los<-t.test(los~group,data=dat)
losdiff<-round(los$estimate[1]-los$estimate[2], 1)
loslo<-round(los$conf.int[1], 1)
losup<-round(los$conf.int[2], 1)
@

\item
Next table is made using your spreadsheet with simulated data from Seehusen D et at.
\begin{table}[ht] \small
\begin{center}
\begin{tabular} {l c c c}\\
\hline
\multicolumn{4}{l}{\textbf{Table 1}  Main outcome measures (mean (SD) score on 100 mm visual } \\
\multicolumn{4}{l}{analogue scale) in \Sexpr{nrow(dat)} women examined with or without stirrups.}\\
&&&\\
\textbf{Outcome} & \textbf{No stirrups} & \textbf{Stirrups} & \textbf{Difference (95\% CI)}\\
\hline
Sense of vulnerability  & \Sexpr{mevul0} (\Sexpr{sdvul0}) & \Sexpr{mevul1} (\textbf{NA})  & \Sexpr{vuldiff} (\Sexpr{vullo} to \Sexpr{vulup})\\
Physical discomfort  & \Sexpr{medis0} (\Sexpr{sddis0}) & \Sexpr{medis1} (\Sexpr{sddis1}) & \Sexpr{disdiff} (\Sexpr{dislo} to \Sexpr{disup})\\
Sense of loss of control & \Sexpr{melos0} (\Sexpr{sdlos0}) & \Sexpr{melos1} (\Sexpr{sdlos1}) & \Sexpr{losdiff} (\Sexpr{loslo} to \Sexpr{losup})\\
\hline
\end{tabular}
\end{center}
\end{table}
\
\\
Note that the standar deviation of Sense of vulnerability for stirrups group is missing (Non Available). What is this value?\\
\begin{footnotesize}
Note: The answer is expected to be a figure with 1 decimal.
\end{footnotesize}
\vspace{0.5cm}

% q02
<<results=hide,echo=false>>=
ar02<-"No statistically significant differences at 0.05 level were observed between the group assigned to Stirrups and the group of No Stirrups"
br02<-"The group assigned to Stirrups presented significantly (p \\$\\leq\\$  0.05) higher values"
cr02<-"The group assigned to No Stirrups presented significantly (p \\$\\leq\\$  0.05) higher values"
dr02<-"The group assigned to Stirrups presented significantly, at 0.05 level, higher values"
er02<-"The group assigned to No Stirrups presented significantly, at 0.05 level, higher values"
choi02<-sample(c(ar02, br02, cr02, dr02, er02))
@
\item
According to Difference (95\% CI) for Sense of loss of control, which of the following answers is correct?
\begin{itemize}
\item{1.} \Sexpr{choi02[1]}
\item{2.} \Sexpr{choi02[2]}
\item{3.} \Sexpr{choi02[3]}
\item{4.} \Sexpr{choi02[4]}
\item{5.} \Sexpr{choi02[5]}
\end{itemize}
\begin{footnotesize}
Note: The answer is expected to be an integer between 1 and 5.
\end{footnotesize}
\end{enumerate}
\end{document}
```

Figure 5: Example of a question that:

- ✓ requires to calculate a figure
- ✓ and a multiple choice question

1. Next table is made using your spreadsheet with simulated data from Seehusen D et at.

Table 1 Main outcome measures (mean (SD) score on 100 mm visual analogue scale) in 1936 women examined with or without stirrups.

Outcome	No stirrups	Stirrups	Difference (95% CI)
Sense of vulnerability	12.8 (16.1)	22.5 (NA)	-9.7 (-11.6 to -7.8)
Physical discomfort	17.4 (17.6)	30.4 (26.7)	-13 (-15 to -11)
Sense of loss of control	17.8 (23.8)	23.9 (27.9)	-6.1 (-8.4 to -3.8)

Note that the standar deviation of Sense of vulnerability for stirrups group is missing (Non Available). What is this value?
Note: The answer is expected to be a figure with 1 decimal.

2. According to Difference (95% CI) for Sense of loss of control, which of the following answers is correct?
   1. No statistically significant differences at 0.05 level were observed between the group assigned to Stirrups and the group of No Stirrups
   2. The group assigned to Stirrups presented significantly, at 0.05 level, higher values
   3. The group assigned to No Stirrups presented significantly ($p \leq 0.05$) higher values
   4. The group assigned to Stirrups presented significantly ($p \leq 0.05$) higher values
   5. The group assigned to No Stirrups presented significantly, at 0.05 level, higher values

Note: The answer is expected to be an integer between 1 and 5.