Universität Innsbruck

A One-for-All Exams Generator: Written Exams, Online Tests, and Live Quizzes with R

Achim Zeileis

http://eeecon.uibk.ac.at/~zeileis/

Overview

- Motivation and challenges
- R package **exams**
- Exercises
- Exams
  - Combination of exercises
  - PDF output
  - HTML output
  - **Moodle**, **OLAT**, **ARSnova**, . . .
- Discussion

Motivation and challenges

Motivation:

- Introductory statistics and mathematics courses for business and economics students at WU Wien and Universität Innsbruck.
- Courses are attended by more than 1,000 students per semester.
- Currently: Several lecturers teach lectures ($\sim$500 participants) and tutorials ($\sim$150 participants) in parallel.

Strategy:

- Individualized organization of learning, feedback, and assessment.
- The same pool of exercises at the core of all parts of the course.

Motivation and challenges

	Learning	**Feedback**	**Assessment**
Synchronous	Lecture	Live quiz	Written exam
	Live stream	(+ tutorial)	
Asynchronous	Textbook	Self test	Online test
	Screencast	(+ forum)	

Motivation and challenges

	Learning	**Feedback**	**Assessment**
Synchronous	Lecture	Live quiz	Written exam
	Live stream	(+ tutorial)	
Asynchronous	Textbook	Self test	Online test
	Screencast	(+ forum)	

Challenges:

- *Scalability:* Randomized dynamic exercises required for feedback/assessment.
- *Feedback:* Support for complete correct solutions.
- *Flexibility:* Automatic rendering into different assessment formats.

R package exams

Tools chosen:

- R for random data generation and computations.
- LaTeX for mathematical notation.
- LaTeX or Markdown for text formatting
- `Sweave` or **knitr**/**rmarkdown** for tying everything together.

Exercises:

- Dynamic templates if R code is used for randomization.
- Each exercise is a single file (either `.Rnw` or `.Rmd`).
- Contains question and (optionally) the corresponding solution.

R package exams

Answer types:

- Single choice and multiple choice.
- Numeric values.
- Text strings (typically short).
- Combinations of the above (cloze).

Output:

- PDF – either fully customizable or standardized with automatic scanning/evaluation.
- HTML – either fully customizable or embedded into any of the standard formats below.
- **Moodle** XML.
- QTI XML standard (version 1.2 or 2.1), e.g., for **OLAT**/**OpenOLAT**.
- **ARSnova**, **TCExam**, **LOPS**, . . . (**Blackboard** under development).

Exercises

Exercise templates: Either `.Rnw` files composed of

- R code chunks for random data generation within `<<>>=` and `@`.
- Question and solution descriptions contained in `\begin`/`\end` pairs for `{question}`/`{solution}`.
- Metainformation about `extype` (numeric, multiple choice, ...), correct `exsolution`, a short `exname`, etc. `\extype{mchoice}`, `\exsolution{01001}`, ...
- Question and basic metainformation is mandatory – everything else optional. Insertion of data elements with `\Sexpr{...}`.

Alternatively: `.Rmd` files with

- Code chunks: ```` ```{r} ... ``` ````.
- `Question`/`Solution` sections with `=======` markup.
- `extype: mchoice`, `exsolution: 01001`, ...
- Insertions: `` `r ...` ``.

Exams: Combination of exercises

Idea: An exam is simply a list of exercise templates. For example, using statistics exercise templates contained in **exams**.

```
R> myexam <- list(
+    "boxplots.Rnw",
+    c("confint.Rnw", "ttest.Rnw", "tstat.Rnw"),
+    c("anova.Rnw", "regression.Rnw"),
+    "scatterplot.Rnw",
+    "relfreq.Rnw"
+  )
```

Draw random exams:

- First randomly select one exercise from each list element.
- Generate random numbers/input for each selected exercise.
- Combine all exercises in output file(s) (PDF, HTML, . . .).

Exams: Combination of exercises

Interfaces: `exams2pdf()`, `exams2html()`, `exams2moodle()`, `exams2qti12()`, `exams2nops()`, `exams2arsnova()`, ...

Workhorse function: Internally, all interfaces call `xexams()` that handles (temporary) files/directories and carries out four steps.

1. *Weave:* Each `.Rnw`/`.Rmd` exercise is weaved into a `.tex`/`.md` file. Default: `xweave()` which calls `Sweave()` or `knit()`.
2. *Read:* Each resulting `.tex`/`.md` file is read into an R list with question, solution, metainformation. Default: `read_exercise()`.
3. *Transform:* Each of these exercise-wise list objects can be transformed, e.g., by converting LaTeX text to HTML or Markdown to LaTeX etc. Default: No transformation.
4. *Write:* The (possibly transformed) lists of exercises can be written out to one ore more files per exam in an output directory. Default: No files are written.

Exams: Combination of exercises

Usage:

- A single exam popped up in a PDF viewer:

```
R> exams2pdf(myexam, template = "exam")
```

- Multiple PDF/NOPS exams written to an output directory:

```
R> odir <- tempfile()
R> exams2nops(myexam[-(2:3)], n = 3, dir = odir)
```

- Multiple replications in a single Moodle XML file in output directory:

```
R> exams2moodle(myexam, n = 3, dir = odir)
```

Exams: PDF output

R University
Statistics Exam 2016-02-17 **Exam ID 00001**

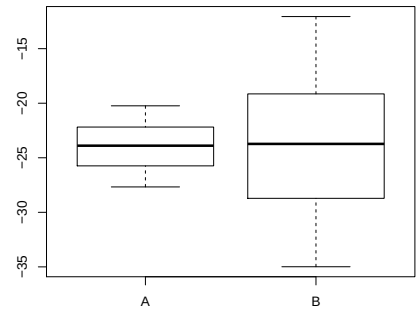
Name: _____

Student ID: _____

Signature: _____

1. (a) ☐ (b) ☐ (c) ☐ (d) ☐ (e) ☐
2. ☐☐☐☐☐☐ . ☐☐☐
3. ☐☐☐☐☐☐ . ☐☐☐
4. (a) ☐ (b) ☐ (c) ☐ (d) ☐ (e) ☐
5. (a) ☐ (b) ☐ (c) ☐ (d) ☐ (e) ☐

1. In the following figure the distributions of a variable given by two samples (A und B) are represented by parallel boxplots. Which of the following statements are correct? *(Comment: The statements are either about correct or clearly wrong.)*



   (a) The location of both distributions is about the same.
   (b) Both distributions contain no outliers.
   (c) The spread in sample A is clearly bigger than in B.
   (d) The skewness of both samples is similar.
   (e) Distribution A is about symmetric.

2. A machine fills milk into 500ml packages. It is suspected that the machine is not working correctly and that the amount of milk filled differs from the setpoint $\mu_0 = 500$. A sample of 226 packages filled by the machine are collected. The sample mean $\bar{y}$ is equal to 499.7 and the sample variance s^2_{n-1} is equal to 576.1.

   Test the hypothesis that the amount filled corresponds on average to the setpoint. What is the absolute value of the t test statistic?

3. For 49 firms the number of employees X and the amount of expenses for continuing education Y (in EUR) were recorded. The statistical summary of the data set is given by:

	Variable X	Variable Y
Mean	58	232
Variance	124	1606

   The correlation between X and Y is equal to 0.65.

   Estimate the expected amount of money spent for continuing education by a firm with 60 employees using least squares regression.

4. The following figure shows a scatterplot. Which of the following statements are correct?

Exams: PDF output (NOPS)

R University

Exam 2016-02-17

Personal Data

Family Name:

Given Name:

Signature:

checked

Registration Number

0 1 2 3 4 5 6 7 8 9

In this section **no** changes or modifications must be made!

Scrambling 0 0

Type: 005

Exam ID: 16021700001

Please mark the boxes carefully: ☒ Not marked: ☐ or ■

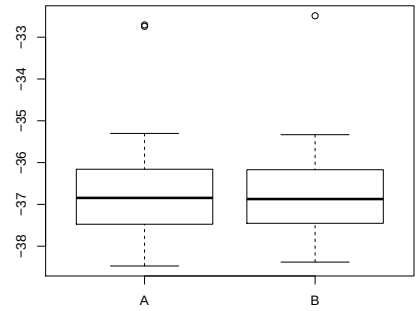
This document is scanned automatically. Please keep clean and do not bend or fold. For filling in the document please use a **blue or black pen**.

Only clearly marked and positionally accurate crosses will be processed!

Answers 1 - 3

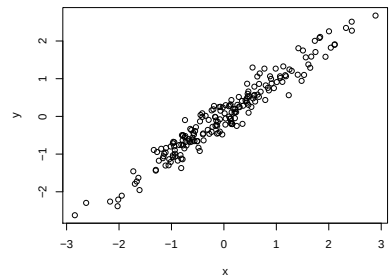
	a	b	c	d	e
1	☐	☐	☐	☐	☐
2	☐	☐	☐	☐	☐
3	☐	☐	☐	☐	☐

1. In the following figure the distributions of a variable given by two samples (A und B) are represented by parallel boxplots. Which of the following statements are correct? *(Comment: The statements are either about correct or clearly wrong.)*



(a) The location of both distributions is about the same.
(b) Both distributions contain no outliers.
(c) The spread in sample A is clearly bigger than in B.
(d) The skewness of both samples is similar.
(e) Distribution A is about symmetric.

2. The following figure shows a scatterplot. Which of the following statements are correct?



(a) The slope of the regression line is about 1.
(b) The standard deviation of Y is at least 6.

Exams: HTML output

File Edit View History Bookmarks Tools Help

Exam 1

file:///tmp/RtmpjjlbQz/file2c8d10dbc901/plain1.html

DuckDuckGo

Exam 1

1. **Question**

   In Figure the distributions of a variable given by two samples (A und B) are represented by parallel boxplots. Which of the following statements are correct? *(Comment: The statements are either about correct or clearly wrong.)*

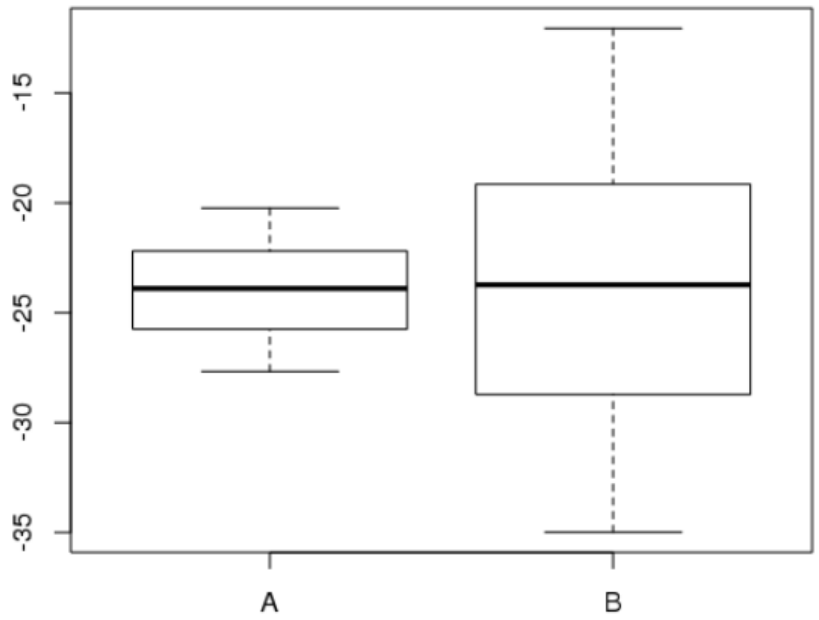


Figure 1: Parallel boxplots.

a. The location of both distributions is about the same.
b. Both distributions contain no outliers.
c. The spread in sample A is clearly bigger than in B.
d. The skewness of both samples is similar.
e. Distribution A is about symmetric.

Exams: Moodle XML

File Edit View History Bookmarks Tools Help

JSS Quiz

138.232.202.120/mod/quiz/attempt.php?attempt=2

DuckDuckGo

R exams course

You are logged in as Nikolaus Umlauf (Logout)

Home ► Rexams ► 20 November - 26 November ► JSS Quiz ► Preview

Quiz navigation

1 2 3 4 5

Finish attempt ...

Start a new preview

Navigation

Home
- My home
  - Site pages
  - My profile
  - Current course
    - Rexams
      - Participants
      - Reports
      - General
      - 20 November - 26 November
        - JSS Quiz
          - Info
          - Results
      - 27 November - 3 December
      - 4 December - 10 December
      - 11 December - 17 December
      - 18 December - 24 December
      - 25 December - 31

Question 1

Not yet answered

Marked out of 1.00

Flag question

Edit question

In Figure the distributions of a variable given by two samples (A und B) are represented by parallel boxplots. Which of the following statements are correct? *(Comment: The statements are either about correct or clearly wrong.)*

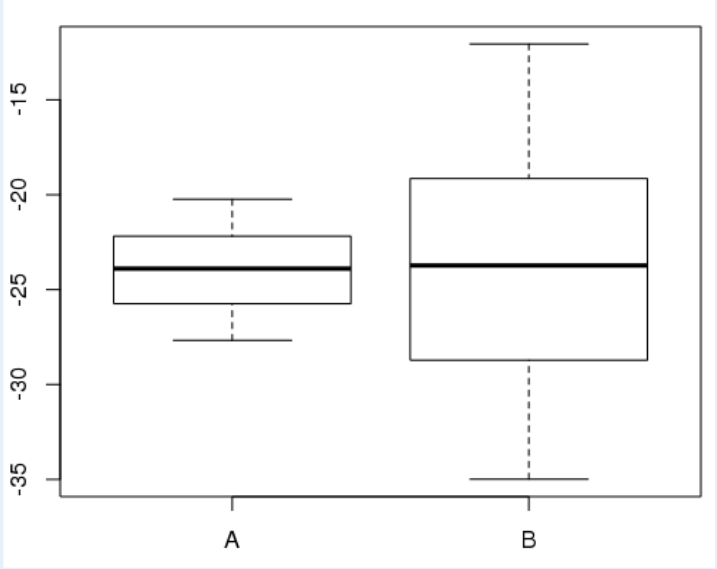


Figure 1: Parallel boxplots.

Select one or more:

- a. The location of both distributions is about the same.
- b. Both distributions contain no outliers.
- c. The spread in sample A is clearly bigger than in B.
- d. The skewness of both samples is similar.
- e. Distribution A is about symmetric.

Exams: QTI

File Edit View History Bookmarks Tools Help

OLAT - OLAT: Course templat...

138.232.202.96:8080/OLAT-LMS-7.6.0.0/auth/1%3A6%3A1000020776%3A1%3

DuckDuckGo

Print Help Log out

Home | Groups | Learning resources | Group administration | User management | Administration | gui_demo | OLAT: Course...

qti12

Finish test

Actual score: 0 / 5

qti12

1. Exercise
1.1. Question 0
2. Exercise
2.1. Question 0
3. Exercise
3.1. Question 0
4. Exercise
4.1. Question 0
5. Exercise
5.1. Question 0

Still 1 attempt(s).

Question

In Figure the distributions of a variable given by two samples (A und B) are represented by parallel boxplots. Which of the following statements are correct? *(Comment: The statements are either about correct or clearly wrong.)*

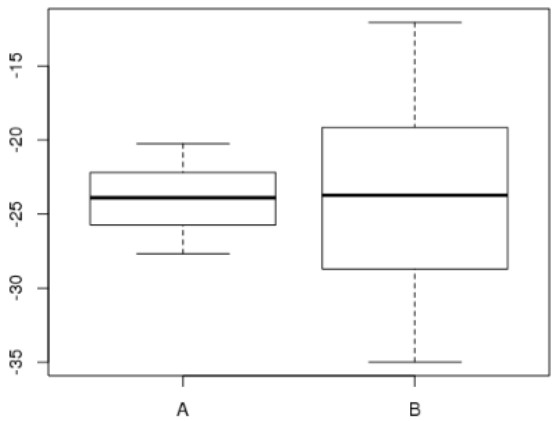
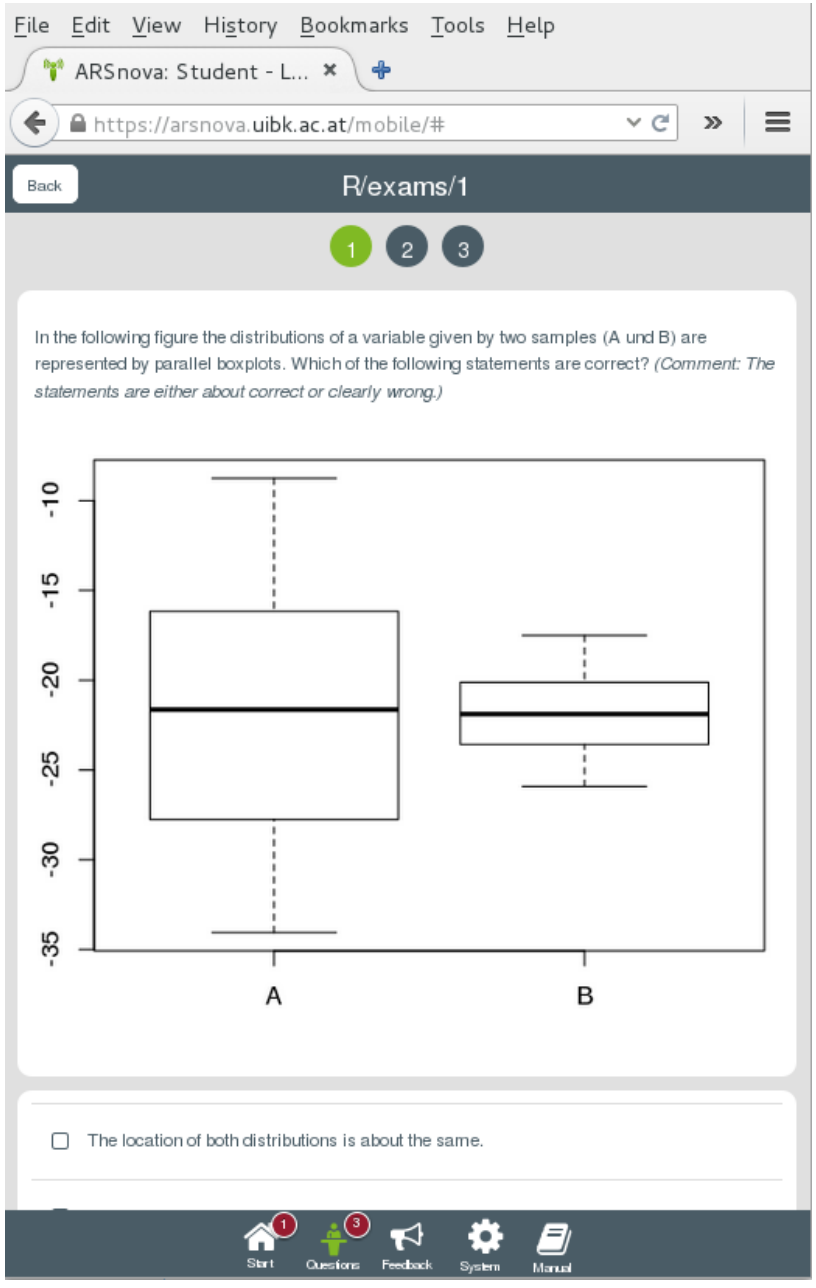


Figure 1: Parallel boxplots.

- [ ] a. The location of both distributions is about the same.
- [ ] b. Both distributions contain no outliers.
- [ ] c. The spread in sample A is clearly bigger than in B.
- [ ] d. The skewness of both samples is similar.
- [ ] e. Distribution A is about symmetric.

Save answer

Exams: ARSnova



Exams: Transformers

Transformer functions:

- For LaTeX to HTML: Ian H. Hutchinson's **TtH** (TeX to HTML) package (**tth** in R). Mathematical notation is either represented using MathML (`ttm`), requiring a suitable browser (e.g., Firefox or Safari), or plain HTML (`tth`).
- Alternatively: John MacFarlane's **pandoc** package (**rmarkdown** in R) with various options for rendering mathematical notation (including MathML).
- For Markdown to HTML or LaTeX: **pandoc** only.
- In either case: No LaTeX installation needed, but also limited to LaTeX commands supported by **TtH** or **pandoc**, respectively.
- Links to dynamically generated data can be easily included, e.g., `\url{mydata.rda}` or `[mydata.rda](mydata.rda)`, respectively.

Discussion

Package exams:

- Framework for automatic generation of simple (mathematical or statistical) exams and associated self-study materials.
- Based on independent exercises in `.Rnw`/`.Rmd` format which can be compiled into exams (or other collections of exercises).
- Version 1 (Grün and Zeileis 2009) only supported PDF output, version 2 (Zeileis *et al.* 2014) added a toolbox for various output formats, recent versions add support for Markdown and **pandoc**.
- Contributing to the pool of exercises only requires knowledge of `Sweave`/**knitr** and minimal markup for metainformation.
- For a first session employ `exams_skeleton()` which copies demo scripts, exercises, and templates into a working directory.
- Hosted on R-Forge, providing a support forum: `http://R-Forge.R-project.org/projects/exams/`

Discussion

At Universität Innsbruck:

- Large-scale introductory mathematics course.
- Team of about 5–10 persons (professors, lecturers, student assistants) contributes to the pool of exercises.
- During the semester: Online tests (and self tests) in **OpenOLAT** (`exams2qti12`) using numerical and multiple-choice exercises.
- Tutorial sessions: Live quizzes based on single-choice exam exercises in **ARSnova**.
- Written exams (`exams2nops`) with single-choice exercises. Results are scanned (`nops_scan`) and automatically evaluated (`nops_eval`). HTML report for each student in **OpenOLAT**.
- E-exams in dedicated computer pool with **TCExam** might be used as an alternative to written exams.

Discussion

Under development:

- *Nikolaus Umlauf:* Graphical exams manager based on **shiny** that can be used on a local machine or on a server.
- *Niels Smits:* **Blackboard** interface based on QTI 1.2.
- *Mirko Birbaumer, Achim Zeileis:* **Ilias** interface based on QTI 1.2.
- *Achim Zeileis:* Evaluation reports for lecturers/examiners based on IRT models.

References

Zeileis A, Grün B, Leisch F, Umlauf N (2015). ***exams**: Automatic Generation of Exams in R.* R package version 2.1-0.
URL `http://CRAN.R-project.org/package=exams`

Zeileis A, Umlauf N, Leisch F (2014). "Flexible Generation of E-Learning Exams in R: Moodle Quizzes, OLAT Assessments, and Beyond." *Journal of Statistical Software*, **58**(1), 1–36. `doi:10.18637/jss.v058.i01`

Grün B, Zeileis A (2009). "Automatic Generation of Exams in R." *Journal of Statistical Software*, **29**(10), 1–14. `doi:10.18637/jss.v029.i10`