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

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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 (∼500 participants) and tutorials (∼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

<table>
<thead>
<tr>
<th>Learning</th>
<th>Feedback</th>
<th>Assessment</th>
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<td>Live quiz</td>
<td>Written exam</td>
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<tr>
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<td>(+ tutorial)</td>
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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
- \texttt{Sweave} or \texttt{knitr/rmarkdown} for tying everything together.

**HTML conversion**: Required for some output formats.
- Via \texttt{tth} or \texttt{pandoc}.
- Default: MathML for mathematical notation.
- Default: Base64 encoding for images and other supplements.
R package *exams*

**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.

**Answer types:**
- Single choice and multiple choice.
- Numeric values.
- Text strings (typically short).
- Combinations of the above (cloze).
R package *exams*

**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, . . .*
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 \( s^2 \) 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:

<table>
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<tr>
<th>Variable</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>58</td>
<td>124</td>
</tr>
<tr>
<td>B</td>
<td>232</td>
<td>1606</td>
</tr>
</tbody>
</table>

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

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(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.
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.)

![Parallel Boxplots](image.png)

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.
R package **exams**: Moodle XML

![R exams course](image)

**R exams course**

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

- 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.
In Figure 3, the distributions of a variable given by two samples (A and B) are represented by parallel boxplots. Which of the following statements are correct? (Comment: The statements are either 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.
R package exams: ARSnova
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, ...).

Interfaces: exams2pdf(), exams2html(), exams2moodle(), exams2qti12(), exams2nops(), exams2arsnova(),...
Exams: Combination of exercises

Usage:

- A single exam popped up in a PDF viewer:
  \[
  \text{R}\geq \text{exams2pdf}(\text{myexam, template = "exam"})
  \]

- Multiple PDF/NOPS exams written to an output directory:
  \[
  \text{R}\geq \text{odir} \leftarrow \text{tempfile()}
  \text{R}\geq \text{exams2nops}(\text{myexam[-(2:3)]}, n = 3, \text{dir} = \text{odir})
  \]

- Multiple replications in a single Moodle XML file in output directory:
  \[
  \text{R}\geq \text{exams2moodle}(\text{myexam, n = 3, dir = odir})
  \]
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 (Grünstich 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: https://R-Forge.R-project.org/projects/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

