R/exams

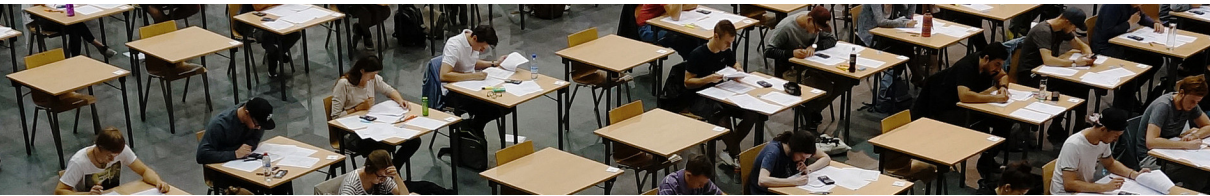
R/exams: A One-for-All Exams Generator

Online Tests, Live Quizzes, and Written Exams with R

Achim Zeileis

`http://www.R-exams.org/`

R/exams



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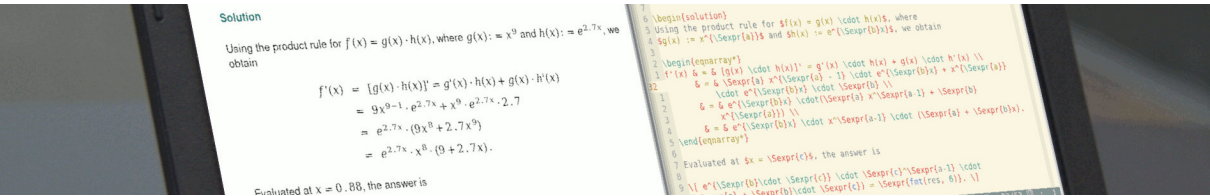

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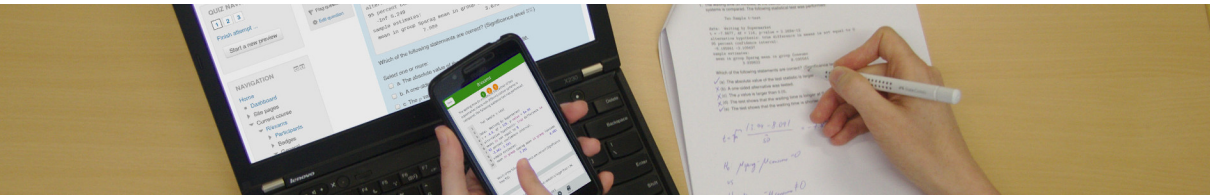

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Motivation and challenges

Motivation:

- Many of us teach large lecture courses, also as support for other fields.
- For example, statistics, probability, or mathematics in curricula such as business and economics, social sciences, psychology, etc.
- At WU Wien and Universität Innsbruck: Some courses are attended by more than 1,000 students per semester.
- Several lecturers teach lectures and tutorials in parallel.

Additionally: In spring 2020.

- Conversion to distance learning.
- Leveraging available e-learning tools and learning management systems.

Motivation and challenges

Strategy:

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

Additionally: In spring 2020.

- Exploit flexibility of the implemented strategy.
- Replace in-class materials by e-learning materials based on the same pool of exercises.

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
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Motivation and challenges

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	Live stream	(+ Tutorial)	
Asynchronous	Textbook	Self test	Online test
	Screencast	(+ Forum)	

Learning:

- *Standard:* Textbook along with presentation slides.
- *Streaming:* Videos streamed simultaneously or (pre-)recorded.

Motivation and challenges

	Learning	Feedback	Assessment
Synchronous	Lecture	Online test	Online exam
	Live stream	(+ Tutorial)	
Asynchronous	Textbook	Self test	Online test
	Screencast	(+ Forum)	

Feedback & assessment:

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

R package *exams*

Exercises:

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

Answer types:

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

R package *exams*

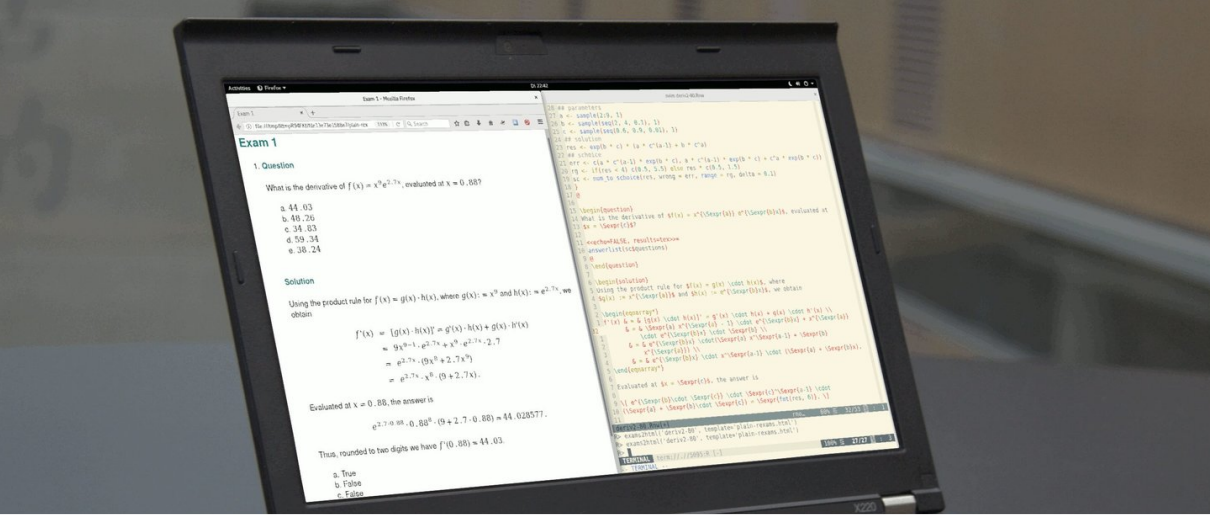
Output:

- PDF – fully customizable vs. standardized with automatic scanning/evaluation.
- HTML – fully customizable vs. embedded into exchange formats below.
- *Moodle* XML.
- QTI XML standard (version 1.2 or 2.1), e.g., for *Canvas* or *OpenOLAT*.
- *Blackboard* (partially based on QTI 1.2)
- *ARSnova*, *TCExam*, *LOPS*, ...

Infrastructure: Standing on the shoulders of lots of open-source software...

R package *exams*

Type	Software	Purpose
Statistical computing	R	Random data generation, computations
Writing/reporting	LaTeX, *Markdown*	Text formatting, mathematical notation
Reproducible research	*knitr*, *rmarkdown*, `Sweave`	Dynamically tie everything together
Document conversion	*TtH*/*TtM*, *pandoc*	Conversion to HTML and beyond
Image manipulation	*ImageMagick*, *magick*, *png*	Embedding graphics
Web technologies	*base64enc*, *RCurl*, …	Embedding supplementary files
Learning management	*Moodle*, *OpenOLAT*, *Canvas*, *ARSnova*, …	E-learning infrastructure



Dynamic Exercises

Dynamic exercises

Text file:

1. Random data generation (optional).
2. Question.
3. Solution (optional).
4. Metainformation.

Examples:

Multiple-choice knowledge quiz with shuffled answer alternatives.
Which of the following cities are the capital of the corresponding country?

Dynamic numeric arithmetic exercise.
What is the derivative of $f(x) = x^a e^{b \cdot x}$, evaluated at $x = c$?

Dynamic exercises: `.Rmd`

Example: Which of the following cities are the capital of the corresponding country?

Dynamic exercises: `.Rmd`

Example: Which of the following cities are the capital of the corresponding country?

```
Question
========
Which of the following cities are the capital of the corresponding country?

Answerlist
----------
* Lagos (Nigeria)
* São Paulo (Brazil)
* Toronto (Canada)
* Auckland (New Zealand)
* Istanbul (Turkey)
* Zürich (Switzerland)
* Tokyo (Japan)
* New Delhi (India)
* Astana (Kazakhstan)
* Warsaw (Poland)
* Riyadh (Saudi Arabia)
```

Dynamic exercises: `.Rmd`

Example: Which of the following cities are the capital of the corresponding country?

```
Solution
========

Answerlist
----------
* False. The capital of Nigeria is Abuja.
* False. The capital of Brazil is Brasilia.
* False. The capital of Canada is Ottawa.
* False. The capital of New Zealand is Wellington.
* False. The capital of Turkey is Ankara.
* False. The de facto capital of Switzerland is Bern.
* True. Tokyo is the capital of Japan.
* True. New Delhi is the capital of India.
* True. Astana is the capital of Kazakhstan.
* True. Warsaw is the capital of Poland.
* True. Riyadh is the capital of Saudi Arabia.
```

Dynamic exercises: `.Rmd`

Example: Which of the following cities are the capital of the corresponding country?

```
Meta-information
================
exname: Capitals
extype: mchoice
exsolution: 00000011111
exshuffle: 5
```

Dynamic exercises: `.Rnw`

Example: What is the derivative of $f(x) = x^a e^{b \cdot x}$, evaluated at $x = c$?

Dynamic exercises: `.Rnw`

Example: What is the derivative of $f(x) = x^a e^{b \cdot x}$, evaluated at $x = c$?

```
<<echo=FALSE, results=hide>>=
## parameters
a <- sample(2:9, 1)
b <- sample(seq(2, 4, 0.1), 1)
c <- sample(seq(0.5, 0.8, 0.01), 1)
## solution
res <- exp(b * c) * (a * c^(a-1) + b * c^a)
@
```

Dynamic exercises: `.Rnw`

Example: What is the derivative of $f(x) = x^a e^{b \cdot x}$, evaluated at $x = c$?

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## solution
res <- exp(b * c) * (a * c^(a-1) + b * c^a)
@

\begin{question}
What is the derivative of $f(x) = x^{\Sexpr{a}} e^{\Sexpr{b}x}$,
evaluated at $x = \Sexpr{c}$?
\end{question}
```

Dynamic exercises: `.Rnw`

Example: What is the derivative of $f(x) = x^a e^{b \cdot x}$, evaluated at $x = c$?

```
\begin{solution}
Using the product rule for $f(x) = g(x) \cdot h(x)$, where
$g(x) := x^{\Sexpr{a}}$ and $h(x) := e^{\Sexpr{b}x}$, we obtain
\begin{eqnarray*}
f'(x) & = & [g(x) \cdot h(x)]' = g'(x) \cdot h(x) + g(x) \cdot h'(x) \\
      & = & \Sexpr{a} x^{\Sexpr{a} - 1} \cdot e^{\Sexpr{b}x} +
            ...
\end{eqnarray*}
Evaluated at $x = \Sexpr{c}$, the answer is
\[ e^{\Sexpr{b}\cdot \Sexpr{c}} \cdot \Sexpr{c}^\Sexpr{a-1} \cdot
   (\Sexpr{a} + \Sexpr{b}\cdot \Sexpr{c}) = \Sexpr{fmt(res, 6)}. \]
Thus, rounded to two digits we have $f'(\Sexpr{c}) = \Sexpr{fmt(res)}$.
\end{solution}
```

Dynamic exercises: `.Rnw`

Example: What is the derivative of $f(x) = x^a e^{b \cdot x}$, evaluated at $x = c$?

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Using the product rule for $f(x) = g(x) \cdot h(x)$, where
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\end{eqnarray*}
Evaluated at $x = \Sexpr{c}$, the answer is
\[ e^{\Sexpr{b}\cdot \Sexpr{c}} \cdot \Sexpr{c}^\Sexpr{a-1} \cdot
   (\Sexpr{a} + \Sexpr{b}\cdot \Sexpr{c}) = \Sexpr{fmt(res, 6)}. \]
Thus, rounded to two digits we have $f'(\Sexpr{c}) = \Sexpr{fmt(res)}$.
\end{solution}

\extype{num}
\exsolution{\Sexpr{fmt(res)}}
\exname{derivative exp}
\extol{0.01}
```
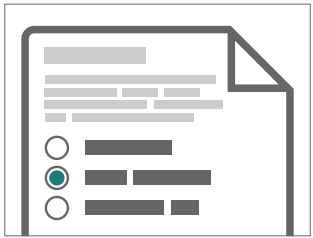
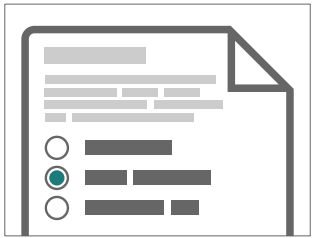

Dynamic exercises: Single choice



```
extype: schoice
exsolution: 010
```

Dynamic exercises: Single choice



```
extype: schoice
exsolution: 010
```

Question
What is the seat of the federal authorities in Switzerland (i.e., the de facto capital)?

(a) Vaduz

(b) Bern

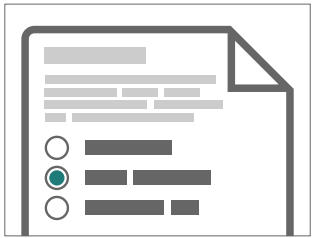
(c) St. Gallen

(d) Basel

(e) Zurich

Knowledge quiz: Shuffled distractors.

Dynamic exercises: Single choice



```
extype: schoice
exsolution: 010
```

Question
What is the derivative of $f(x) = x^7 e^{3.2x}$, evaluated at $x = 0.85$?

(a) 40.08

(b) 55.65

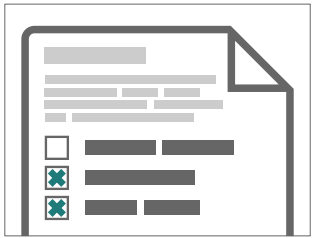
(c) 44.94

(d) 45.32

(e) 31.56

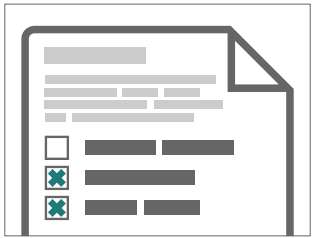
Numeric exercises: Distractors are random numbers and/or typical arithmetic mistakes.

Dynamic exercises: Multiple choice



```
extype: mchoice
exsolution: 011
```

Dynamic exercises: Multiple choice



```
extype: mchoice
exsolution: 011
```

Question
Which of the following cities are the capital of the corresponding country?

(a) Riyadh (Saudi Arabia)

(b) Astana (Kazakhstan)

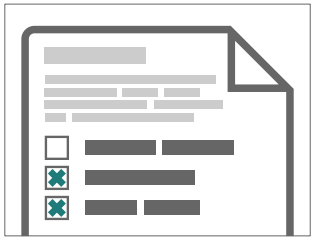
(c) Warsaw (Poland)

(d) Lagos (Nigeria)

(e) Istanbul (Turkey)

Knowledge quiz: Shuffled true/false statements.

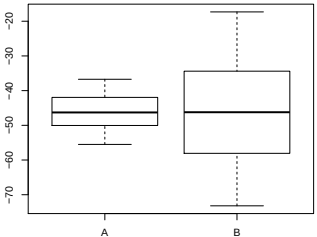
Dynamic exercises: Multiple choice



```
extype: mchoice
exsolution: 011
```

Question

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.)*

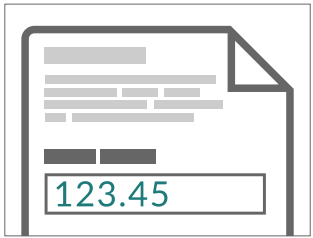


(a) The location of both distributions is about the same.

(b) Both distributions contain no outliers

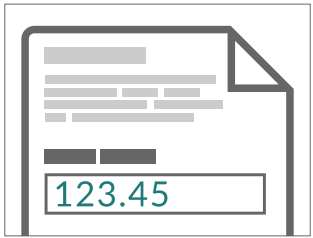
Interpretations: Statements that are approximately correct or clearly wrong.

Dynamic exercises: Numeric

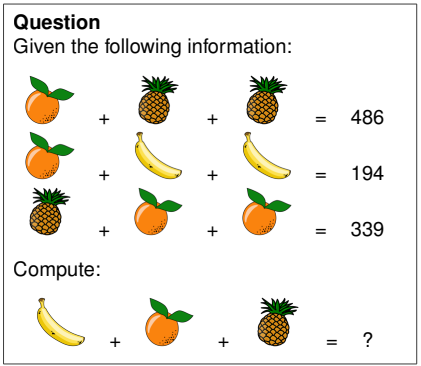



```
extype: num
exsolution: 123.45
```

Dynamic exercises: Numeric




```
extype: num
exsolution: 123.45
```



Numeric exercises: Solving arithmetic problems.

Dynamic exercises: String


```
extype: string
exsolution: ANSWER
```

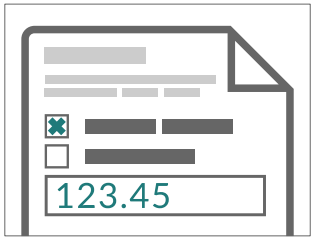
Dynamic exercises: String


```
extype: string
exsolution: ANSWER
```

Question
What is the name of the R function for extracting the estimated coefficients from a fitted (generalized) linear model object?

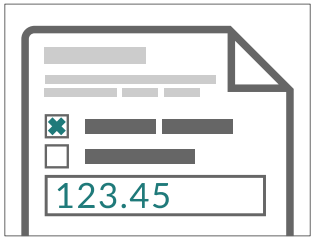
Knowledge quiz: Sample a word/phrase from a given vocabulary or list of question/answer pairs.

Dynamic exercises: Cloze




```
extype: cloze
exclozetype: mchoice|num
exsolution: 10|123.45
```

Dynamic exercises: Cloze



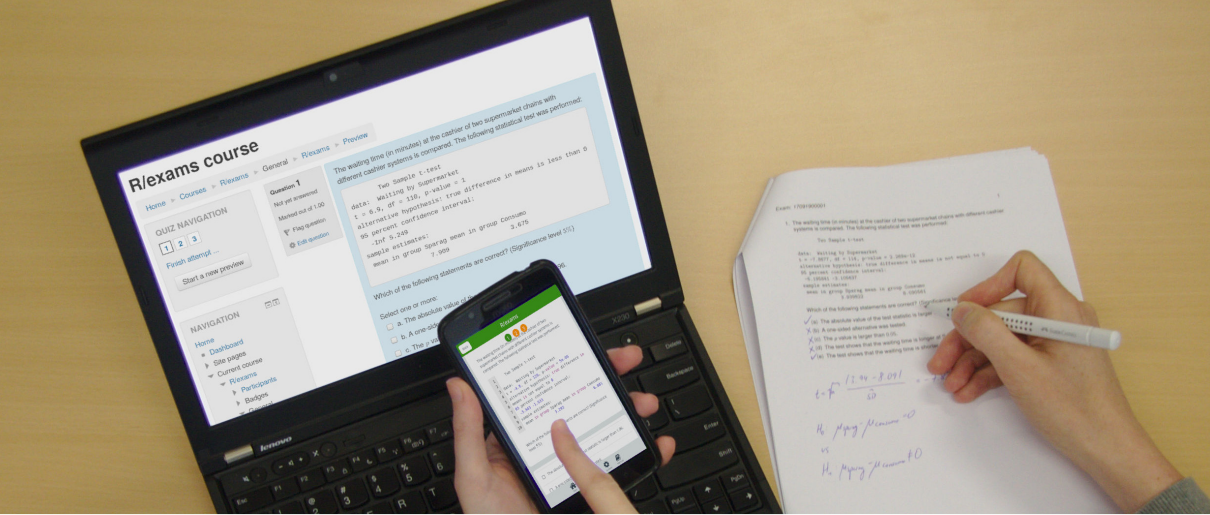

```
extype: cloze
exclozetype: mchoice|num
exsolution: 10|123.45
```

Question
Using the data provided in `regression.csv` estimate a linear regression of `y` on `x` and answer the following questions.

(a) `x` and `y` are not significantly correlated / `y` increases significantly with `x` / `y` decreases significantly with `x`

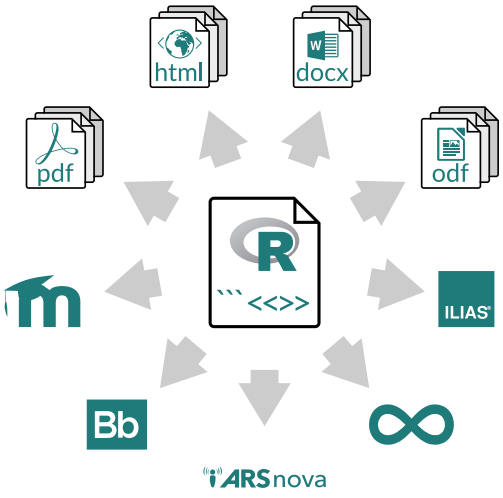
(b) Estimated slope with respect to `x`:

Exercises with sub-tasks: Several questions based on same problem setting.


R/exams course
Home ▸ Courses ▸ R/exams ▸ General ▸ R/exams ▸ Preview
QUIZ NAVIGATION
Finish attempt ...
Start a new preview
NAVIGATION
Home
Dashboard
Site pages
Current course
R/exams
Participants
Badges
Question 1
Not yet answered
Marked out of 1.00
Flag question
Edit question
The waiting time (in minutes) at the cashier of two supermarket chains with different cashier systems is compared. The following statistical test was performed:
Two Sample t-test
data: Waiting by Supermarket
t = 8.4, df = 118, p-value < 1
alternative hypothesis: true difference in means is less than 0
95 percent confidence interval:
-Inf 9.249
sample estimates:
mean in group Sparag mean in group Consuso
7.909 3.675
Which of the following statements are correct? (Significance level 5%)
Select one or more:
a. The absolute value of the test statistic is larger than 1.64.
b. A one-sided alternative was tested.
c. The p-value is larger than 0.05.
d. The test shows that the waiting time is shorter at Consuso than at Sparag.
e. The test shows that the waiting time is shorter at Sparag than at Consuso.
Exam: 17091900001
1. The waiting time (in minutes) at the cashier of two supermarket chains with different cashier systems is compared. The following statistical test was performed:
Two Sample t-test
data: Waiting by Supermarket
t = -7.4877, df = 118, p-value = 2.365e-12
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-3.182661 -1.836437
sample estimates:
mean in group Sparag mean in group Consuso
5.909032 7.409091
Which of the following statements are correct? (Significance level 5%)
(a) The absolute value of the test statistic is larger than 1.64.
X (b) A one-sided alternative was tested.
X (c) The p-value is larger than 0.05.
X (d) The test shows that the waiting time is shorter at Consuso than at Sparag.
✓(e) The test shows that the waiting time is shorter at Sparag than at Consuso.
H0: μSparag − μConsuso = 0
vs
H1: μSparag − μConsuso ≠ 0

One-for-All

One-for-all



- The *same* exercise can be exported into different formats.
- Multiple standalone documents vs. combined exercise pool.
- Multiple-choice and single-choice supported in all output formats.

One-for-All

Idea: An exam is simply a list of exercise templates.

```
R> myexam <- list(
+    "capitals.Rmd",
+    "deriv2.Rmd",
+    c("ttest.Rnw", "boxplots.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, …).

One-for-All

Online test:

```
R> exams2moodle(myexam, n = 10, dir = odir)
```

Live quiz:

```
R> exams2arsnova(myexam, n = 1, dir = odir)
```

Written exam:

```
R> exams2nops(myexam, n = 3, dir = odir,
+    language = "hu", institution = "WhyR?")
```

Other: `exams2pdf()`, `exams2html()`, `exams2canvas()`, `exams2openolat()`, ...

E-Learning

E-Learning

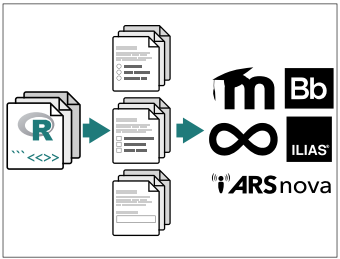
1. Goal

- Online tests with flexible exercise types.
- Possibly: Dynamic supplements and/or complete correct solution.
- Random variations of similar exercises to reduce the risk of cheating.
- Use university's learning management system, e.g., Moodle, …

Scenarios:

- Short quizzes conducted in-class.
- Online tests conducted over several days.
- E-exams conducted in-class or remotely.

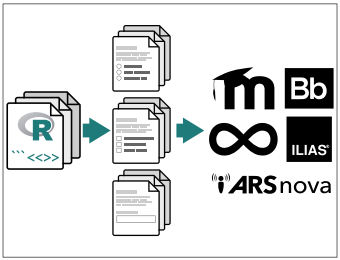
E-Learning



2. Create

- Draw random replications from exercise templates, e.g., via `exams2moodle()`, ...
- Automatically embed these into exchange file format (typically via HTML/XML).

E-Learning



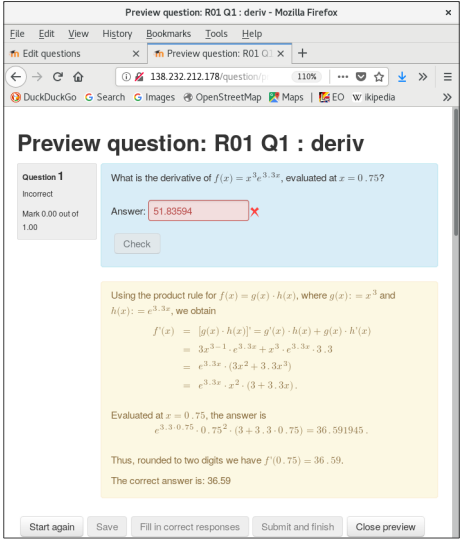
2. Create

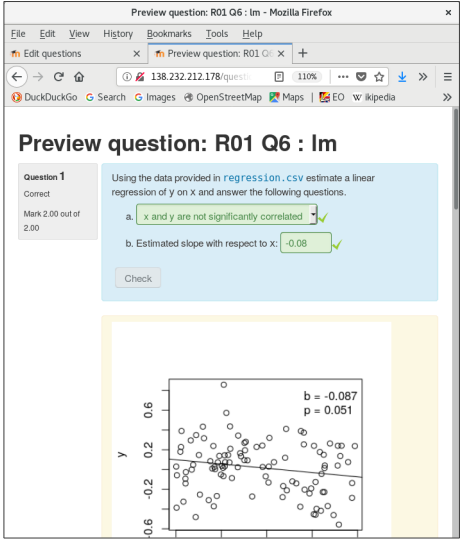
- Draw random replications from exercise templates, e.g., via `exams2moodle()`, ...
- Automatically embed these into exchange file format (typically via HTML/XML).

3. Import

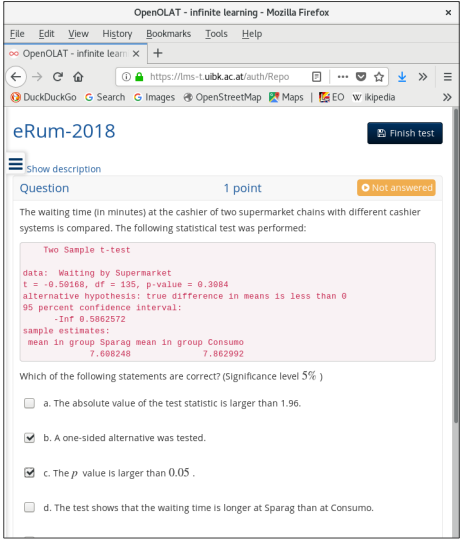
- Import in learning management system.
- From there handling “as usual” in the system.

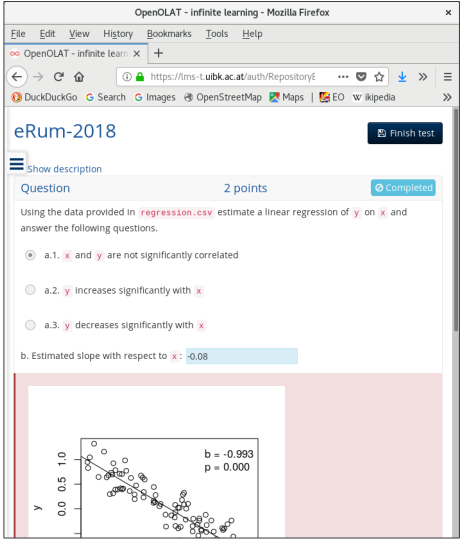
E-Learning: Online test



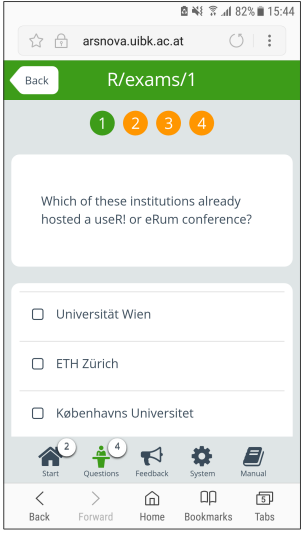


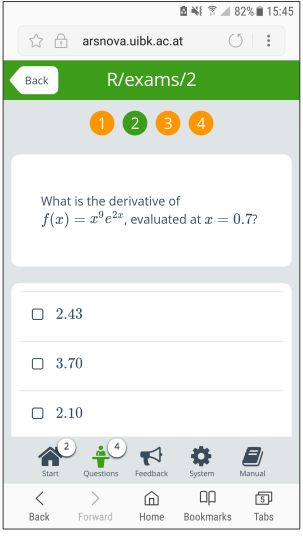
E-Learning: Online test

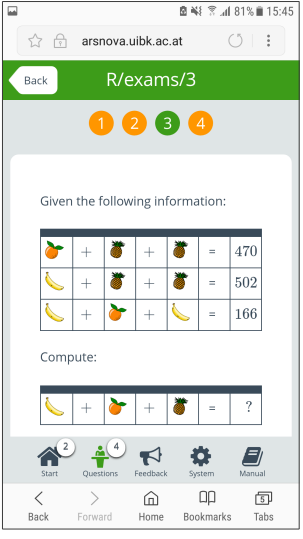


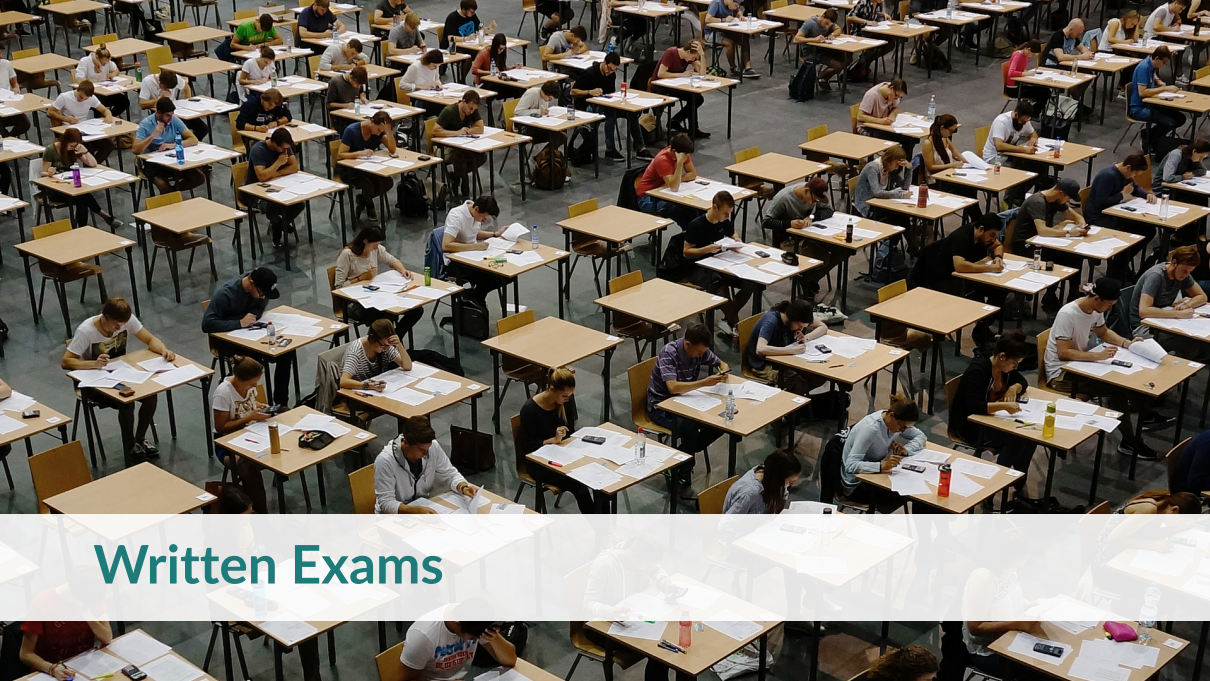


E-Learning: Live quiz









Written Exams

Written Exams

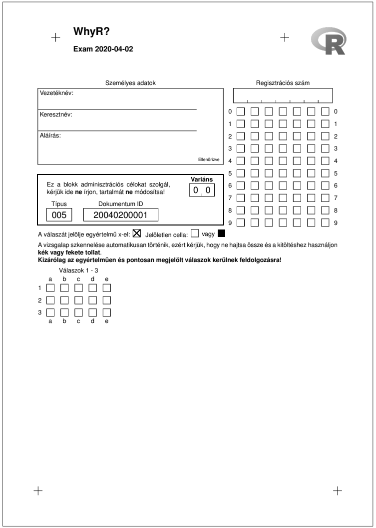
Flexible: Roll your own.

- Combination with user-specified template in `exams2pdf()` and `exams2pandoc()`.
- Customizable but typically has to be evaluated “by hand”.

Standardized: “NOPS” format.

- `exams2nops()` intended for single- and multiple-choice questions.
- Can be scanned and evaluated automatically within R.
- Limited support for open-ended questions that have to be marked by a person.

Written exams



WhyR?

Exam 2020-04-02

Személyes adatok

Vezetéknév:

Keresztnév:

Aláírás:

Ellenőrizve

Regisztrációs szám

0 1 2 3 4 5 6 7 8 9

Ez a blokk adminisztrációs célokat szolgál, kérjük ide **ne** írjon, tartalmát **ne** módosítsa!

Variáns

0 0

Típus: 005

Dokumentum ID: 20040200001

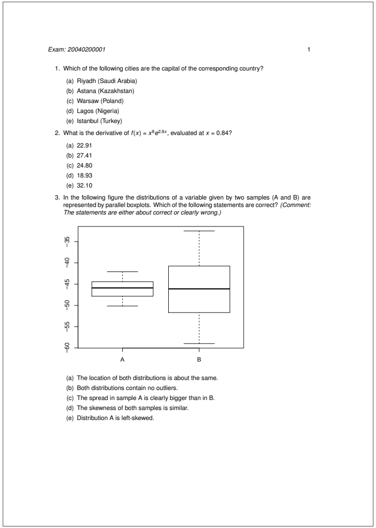
A válaszát jelölje egyértelmű x-el: ☒ Jelöletlen cella: ☐ vagy ■

A vizsgalap szkennelése automatikusan történik, ezért kérjük, hogy ne hajtsa össze és a kitöltéshez használjon **kék vagy fekete tollat**.

Kizárólag az egyértelműen és pontosan megjelölt válaszok kerülnek feldolgozásra!

Válaszok 1 - 3

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

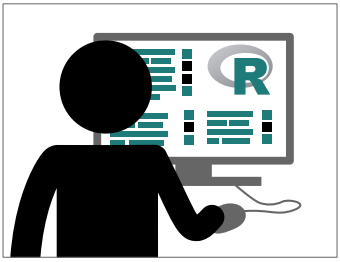


Exam: 20040200001 1

1. Which of the following cities are the capital of the corresponding country?
   (a) Riyadh (Saudi Arabia)
   (b) Astana (Kazakhstan)
   (c) Warsaw (Poland)
   (d) Lagos (Nigeria)
   (e) Istanbul (Turkey)
2. What is the derivative of $f(x) = x^8 e^{2.8x}$, evaluated at $x = 0.84$?
   (a) 22.91
   (b) 27.41
   (c) 24.80
   (d) 18.93
   (e) 32.10
3. 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.)*

   (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 left-skewed.

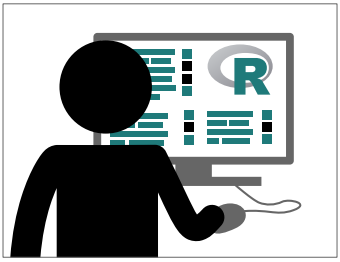
Written exams

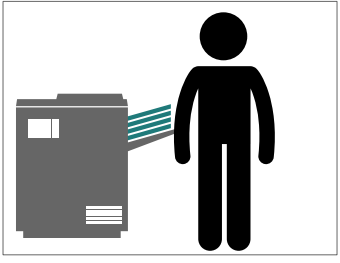


1. Create

- As illustrated above.
- Using `exams2nops()`, create (individual) PDF files for each examinee.

Written exams





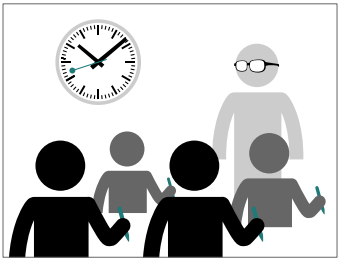
1. Create

- As illustrated above.
- Using `exams2nops()`, create (individual) PDF files for each examinee.

2. Print

- Print the PDF exams, e.g., on a standard printer.
- …or for large exams at a print shop.

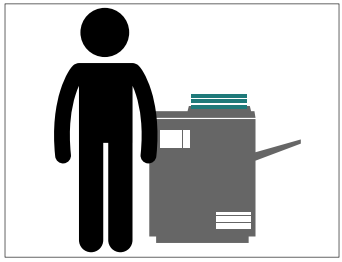
Written exams



3. Exam

- Conduct the exam as usual.
- Collect the completed exams sheets.

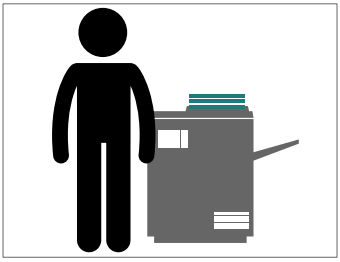
Written exams

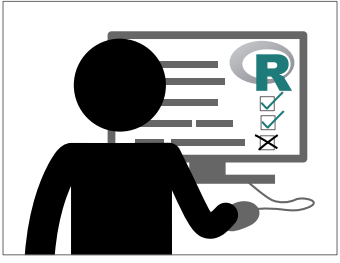


4. Scan

- Scan exam sheets, e.g., on a photocopier.
- Using `nops_scan()`, process the scanned exam sheets to machine-readable content.

Written exams





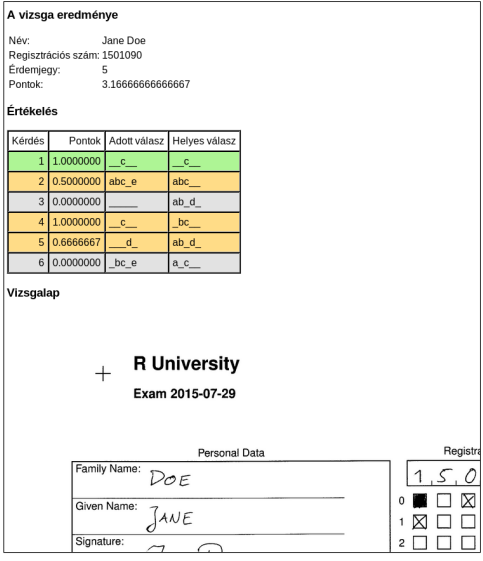
4. Scan

- Scan exam sheets, e.g., on a photocopier.
- Using `nops_scan()`, process the scanned exam sheets to machine-readable content.

5. Evaluate

- Using `nops_eval()`, evaluate the exam to obtain marks, points, etc. and individual HTML reports for each examinee.
- Required files: Correct answers (1.), scans (4.), and a participant list in CSV format.

Written exams



A vizsga eredménye

Név: Jane Doe
Regisztrációs szám: 1501090
Érdemjegy: 5
Pontok: 3.16666666666667

Értékelés

Kérdés	Pontok	Adott válasz	Helyes válasz
1	1.0000000	__c__	__c__
2	0.5000000	abc_e	abc__
3	0.0000000	_____	ab_d_
4	1.0000000	__c__	_bc__
5	0.6666667	___d_	ab_d_
6	0.0000000	_bc_e	a_c__

Vizsgalap

R University

Exam 2015-07-29

Personal Data

Family Name: DOE

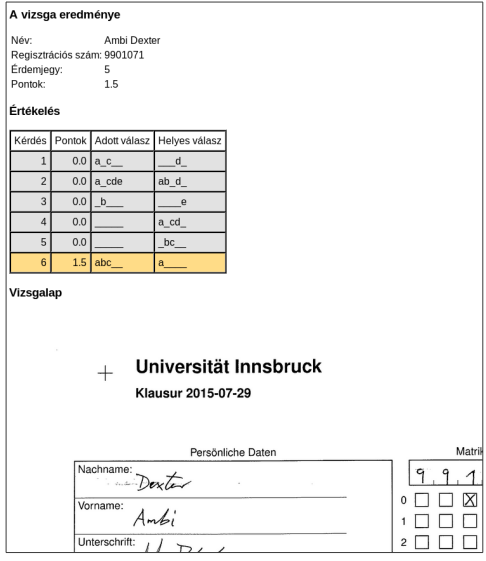
Given Name: JANE

Signature:

Registra

1,5,0

0 1 2



A vizsga eredménye

Név: Ambi Dexter
Regisztrációs szám: 9901071
Érdemjegy: 5
Pontok: 1.5

Értékelés

Kérdés	Pontok	Adott válasz	Helyes válasz
1	0.0	a_c__	___d_
2	0.0	a_cde	ab_d_
3	0.0	_b___	___e
4	0.0	_____	a_cd_
5	0.0	_____	_bc__
6	1.5	abc__	a____

Vizsgalap

Universität Innsbruck

Klausur 2015-07-29

Persönliche Daten

Nachname: Dexter

Vorname: Ambi

Unterschrift:

Matrik

9,9,1

0 1 2

Getting Started

Getting started

If you want to try  R/exams:

- Start with simple exercises before moving to more complex tasks.
- Focus on content of exercises.
- Don’t worry about layout/formatting too much.
- Try to build a team (with lecturers, assistants, etc.).
- Use exercise types creatively.
- Don’t be afraid to try stuff, especially in formative assessments.
- Thorough quality control for dynamic exercises before summative assessments.

Getting started

Installation:

1. R (including Rtools on Windows and OS X).
   RStudio recommended for beginners.
2. R package *exams* (including dependencies).
   `install.packages("exams", dependencies = TRUE)`
3. LaTeX for producing PDF output.
   New: *tinytex* integration.
   `install.packages("tinytex")`
   `tinytex::install_tinytex()`
4. Pandoc (e.g., provided along with RStudio).

More details: http://www.R-exams.org/tutorials/installation/

Getting started

First steps: Create exams skeleton.

- `demo-*.R` scripts.
- `exercises/` folder with all `.Rmd`/`.Rnw` exercises.
- `templates/` folder with various customizable templates.
- `nops/` folder (empty) for `exams2nops()` output.

```
R> exams_skeleton()
```

More details: `http://www.R-exams.org/tutorials/first_steps/`

Getting started

First steps: Compile built-in exercises to both HTML and PDF.

Single-choice question: Knowledge quiz about the Swiss capital (`http://www.R-exams.org/templates/swisscapital/`).

```
R> exams2html("swisscapital.Rmd")
R> exams2pdf("swisscapital.Rmd")
```

Numeric question with mathematical notation: Product rule for derivatives (`http://www.R-exams.org/templates/deriv/`).

```
R> exams2html("deriv.Rmd")
R> exams2html("deriv.Rmd", converter = "pandoc-mathjax")
R> exams2pdf("deriv.Rmd")
```

Getting started

First steps: Extract the meta-information to check whether it is processed correctly.

```
R> exm <- exams2html(c("swisscapital.Rmd", "tstat.Rmd"))
R> exams_metainfo(exm)
```

```
exam1
    1. Swiss Capital: 2
    2. t statistic: 27.783 (27.773--27.793)
```

Getting started

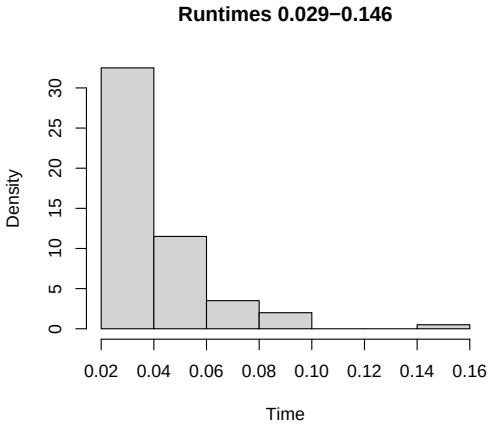
Quality control: Stress testing.

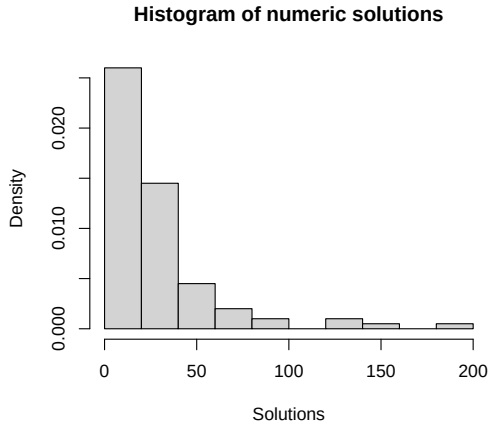
- Generate a large number of random versions of an exercise.
- Check for errors, warnings, long computation times, ...
- Especially for numeric exercises: Check solution distribution, outliers, dependency on randomized parameters.
- Especially for multiple-choice exercises: Check shuffling of correct answers.

More details: `http://www.R-exams.org/tutorials/stresstest/`

Getting started

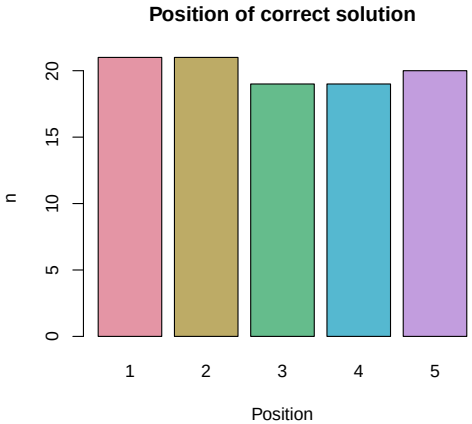
```
R> s <- stresstest_exercise("deriv2.Rnw")
R> plot(s)
```

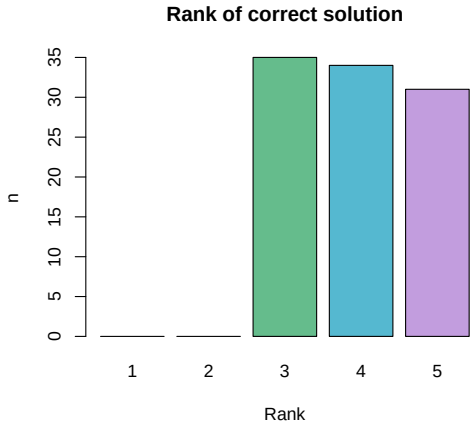




Getting started

```
R> s <- stresstest_exercise("deriv2.Rnw")
R> plot(s)
```





Resources

Contributors:
Zeileis, Grün, Leisch, Umlauf, Smits, Birbaumer, Ernst, Keller, Krimm, Stauffer, Sato.

Links:

Web	`http://www.R-exams.org/`
CRAN	`https://CRAN.R-project.org/package=exams`
Forum	`http://R-Forge.R-project.org/forum/?group_id=1337`
StackOverflow	`https://stackoverflow.com/questions/tagged/r-exams`
Twitter	@AchimZeileis

References:

- 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`