



the art and science
of teaching data science
mine çetinkaya-rundel

bit.ly/introds-ecots2020



@minebocek



mine-cetinkaya-rundel



cetinkaya.mine@gmail.com

2016 GAISE

1. Teach statistical thinking.

- ▶ **Teach statistics as an investigative process of problem-solving and decision making.** Students should not leave their introductory statistics course with the mistaken impression that statistics consists of an unrelated collection of formulas and methods. Rather, students should understand that statistics is a problem-solving and decision making process that is fundamental to scientific inquiry and essential for making sound decisions.
- ▶ **Give students experience with multivariable thinking.** We live in a complex world in which the answer to a question often depends on many factors. Students will encounter such situations within their own fields of study and everyday lives. We must prepare our students to answer challenging questions that require them to investigate and explore relationships among many variables. Doing so will help them to appreciate the value of statistical thinking and methods.

2. Focus on conceptual understanding.

3. Integrate real data with a context and purpose.

4. Foster active learning.

5. Use technology to explore concepts and analyse data.

6. Use assessments to improve and evaluate student learning.

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① NOT a commonly used subset of tests and intervals and produce them with hand calculations

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② Multivariate analysis requires the use of computing

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③ NOT use technology that is only applicable in the intro course or that doesn't follow good science principles

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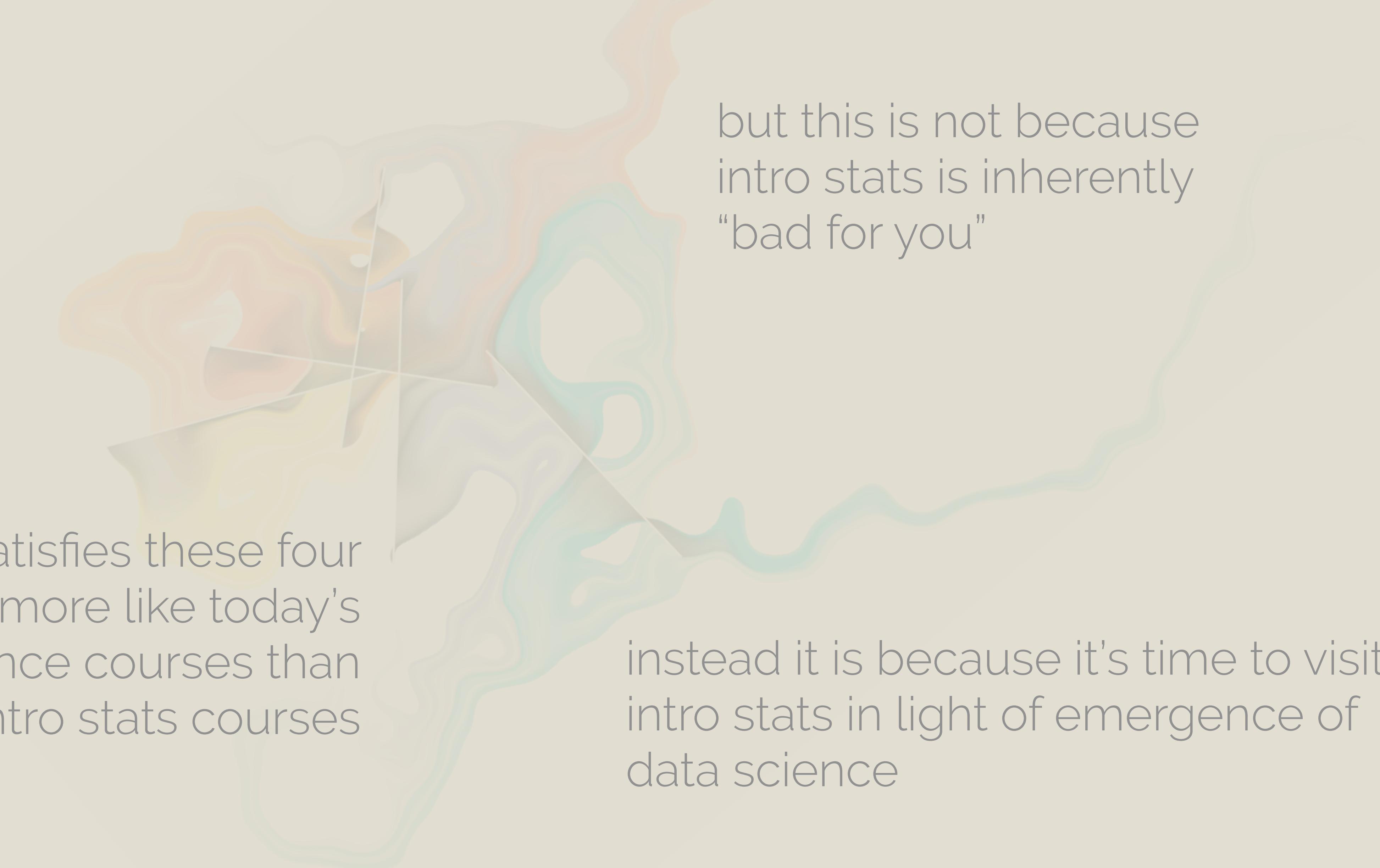
3. Integrate real data with a context and purpose.

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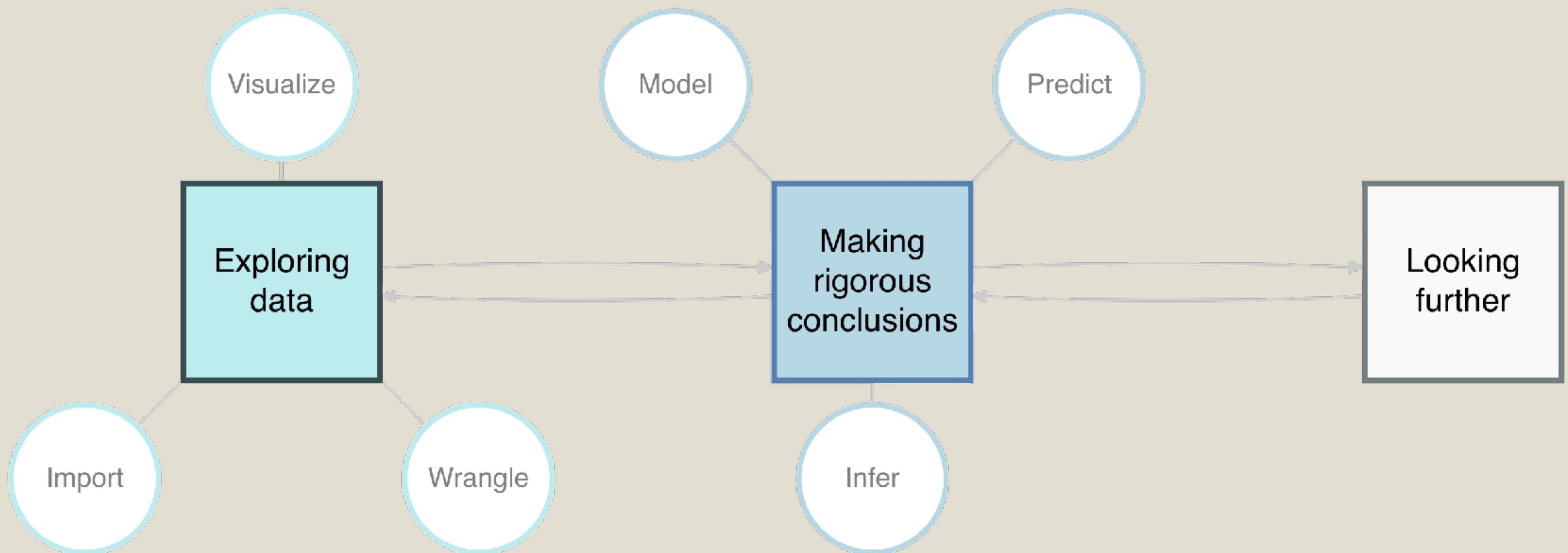
④ Data analysis isn't just inference and modelling, it's also data importing, cleaning, preparation, exploration, and visualisation

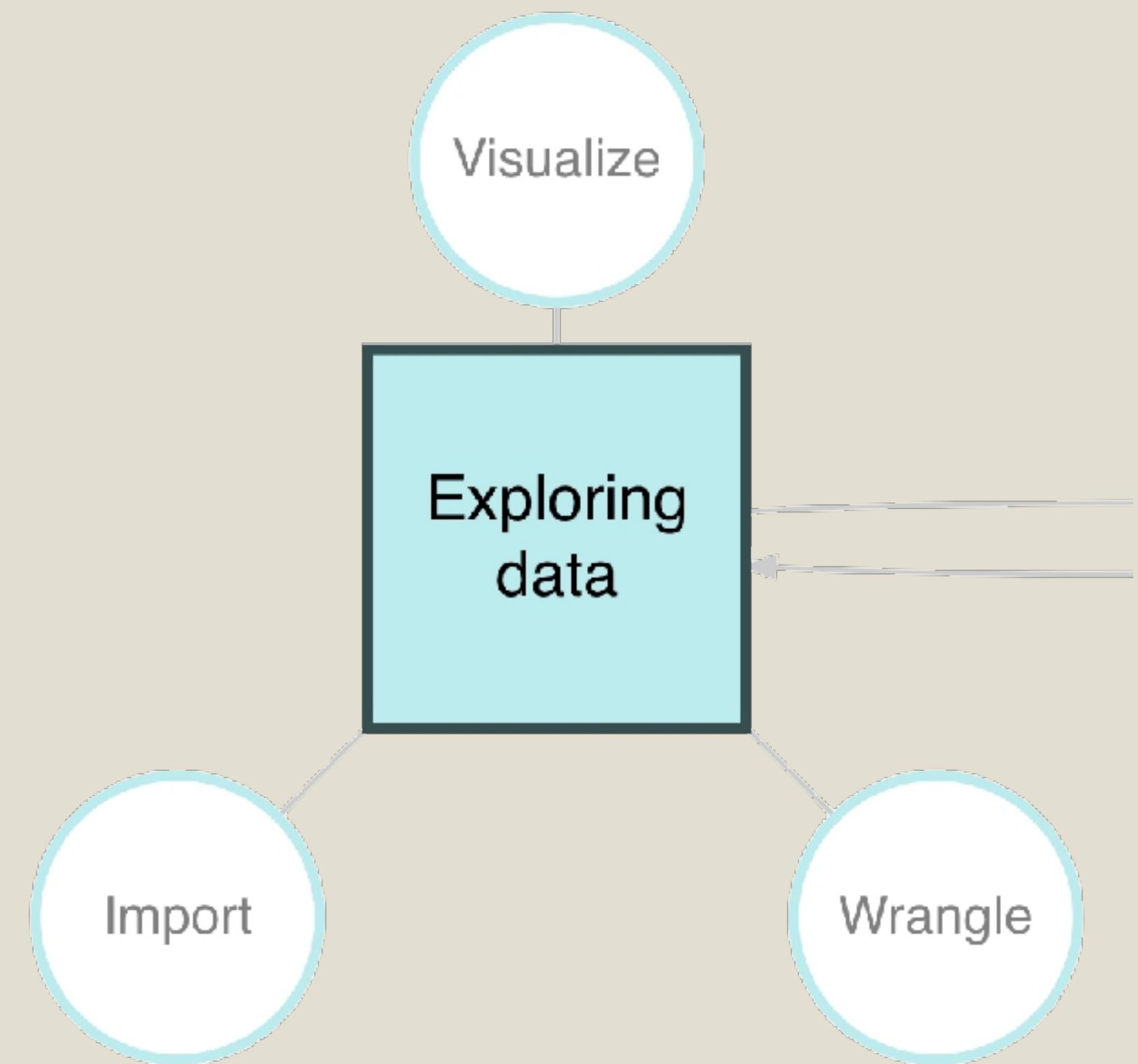


a course that satisfies these four points is looking more like today's intro data science courses than (most) intro stats courses

but this is not because intro stats is inherently "bad for you"

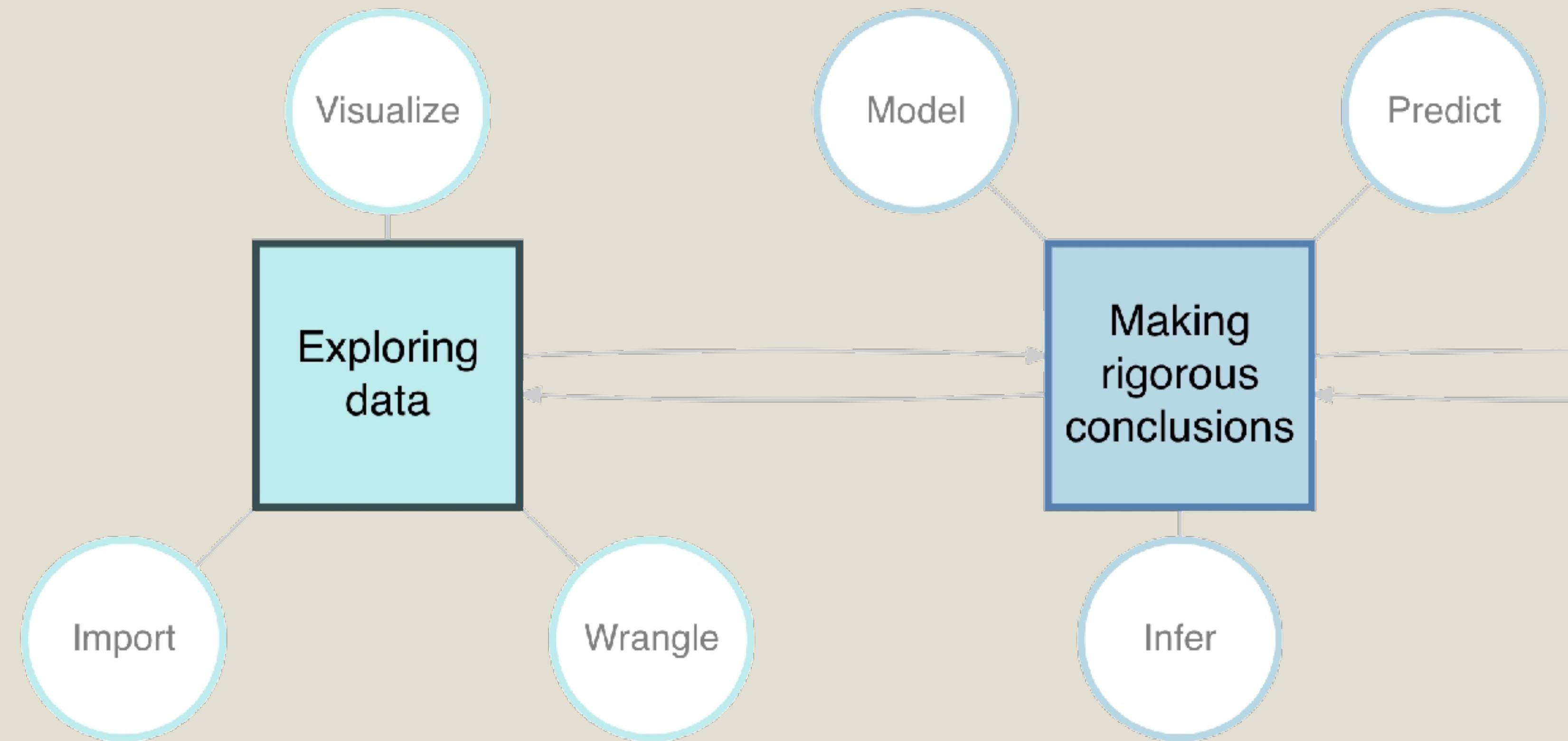
instead it is because it's time to visit intro stats in light of emergence of data science





fundamentals of
data & data viz,
confounding variables,
Simpson's paradox
+
R / RStudio,
R Markdown, simple Git

tidy data, data frames
vs. summary tables,
recoding &
transforming,
web scraping & iteration
+
collaboration on GitHub

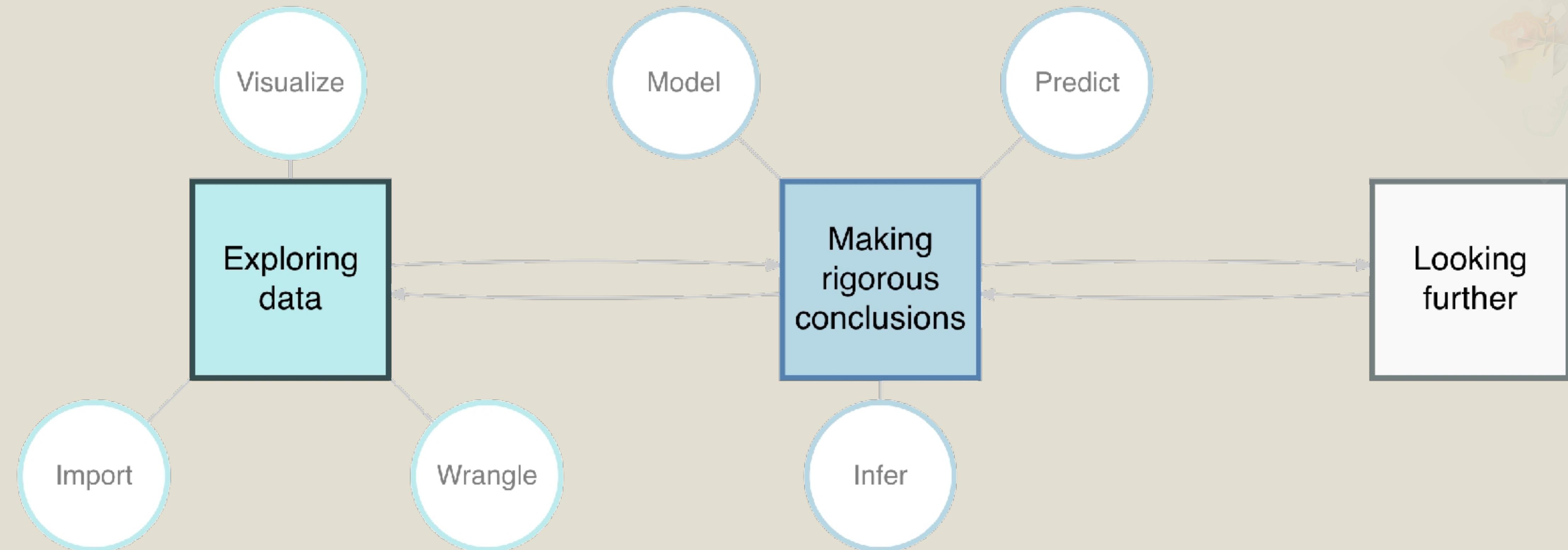


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building & selecting
models,
visualising interactions,
prediction & validation,
inference via simulation





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data science ethics,
text analysis,
Bayesian inference
+
communication &
dissemination





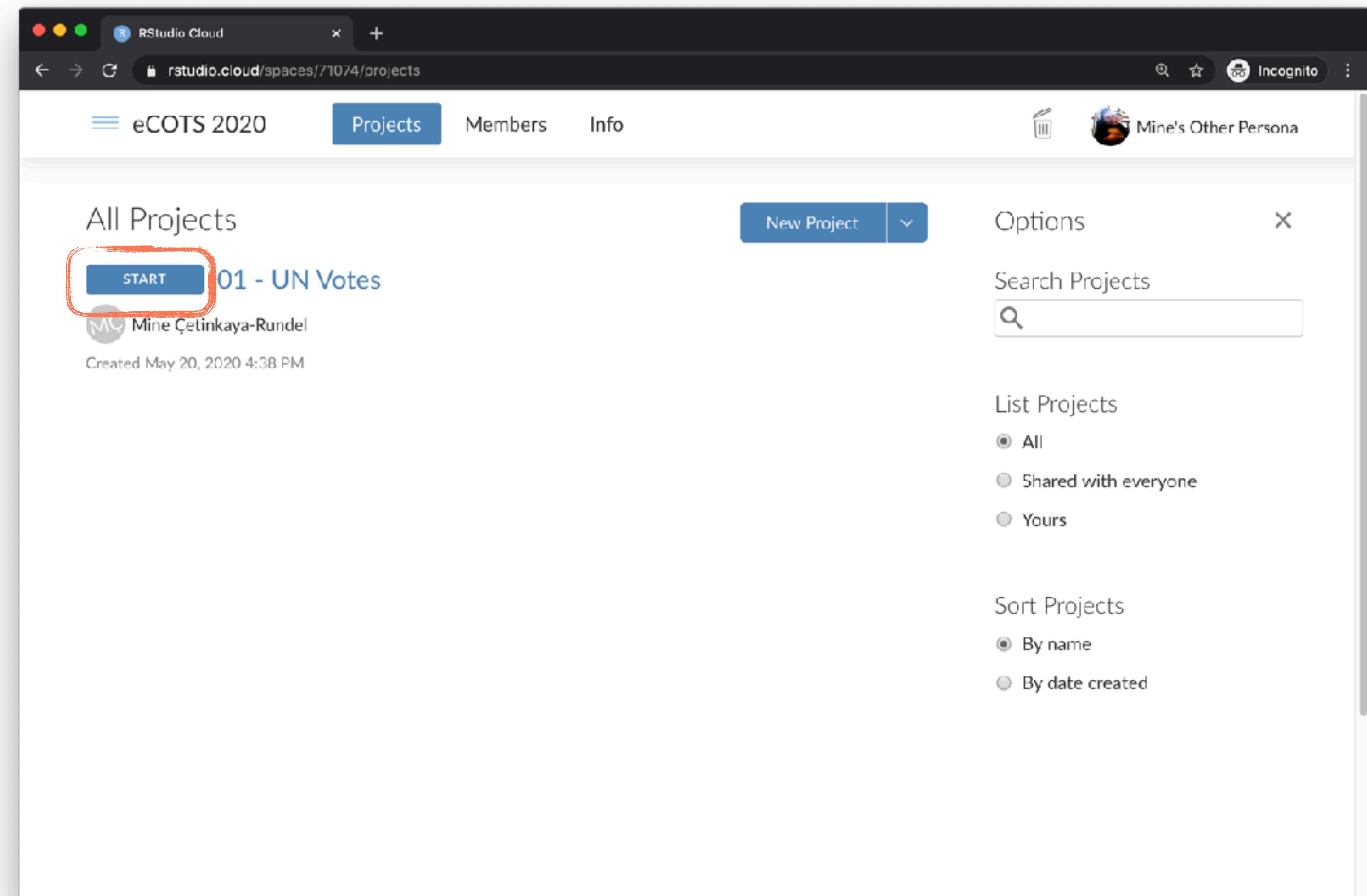
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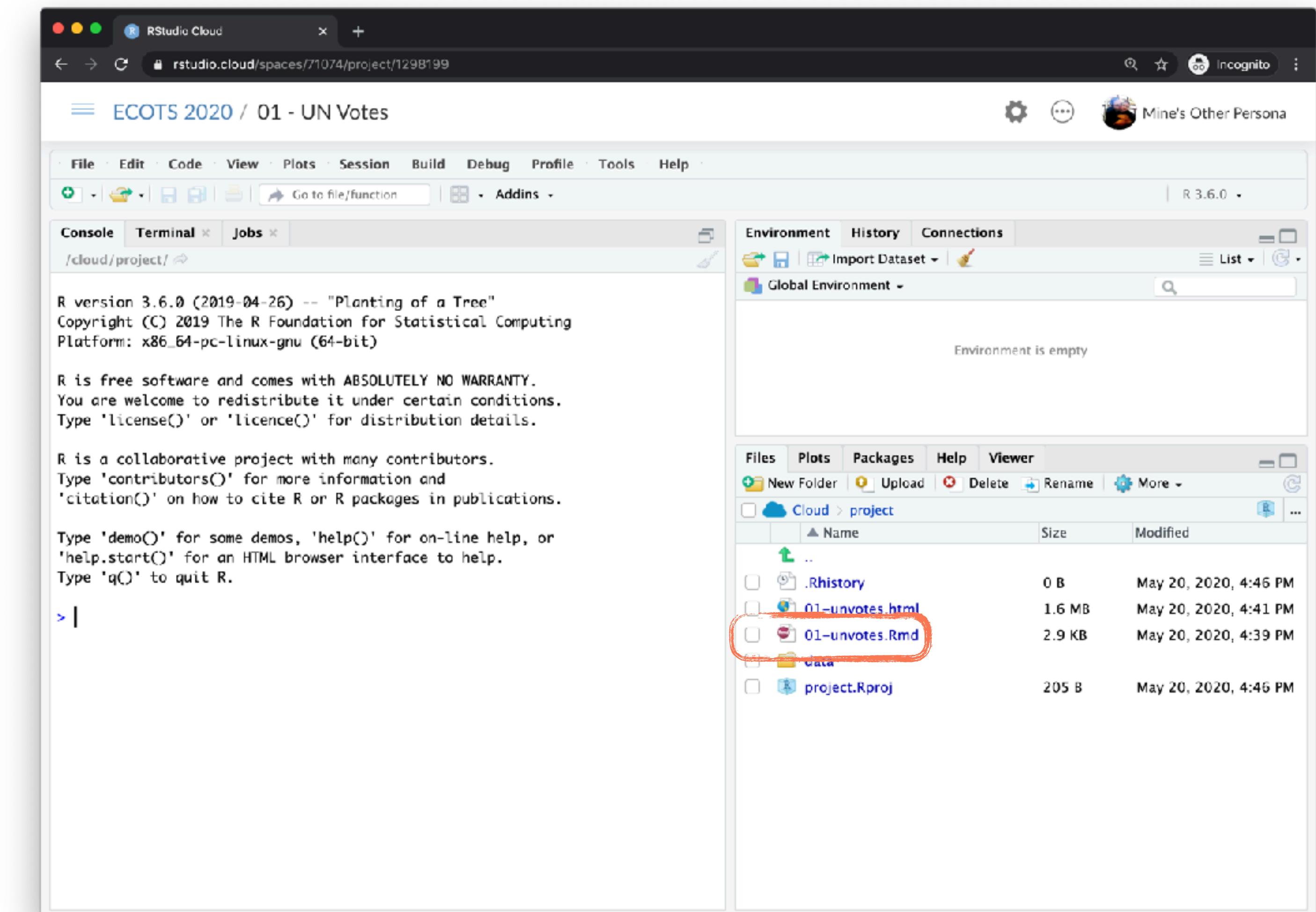
building & selecting
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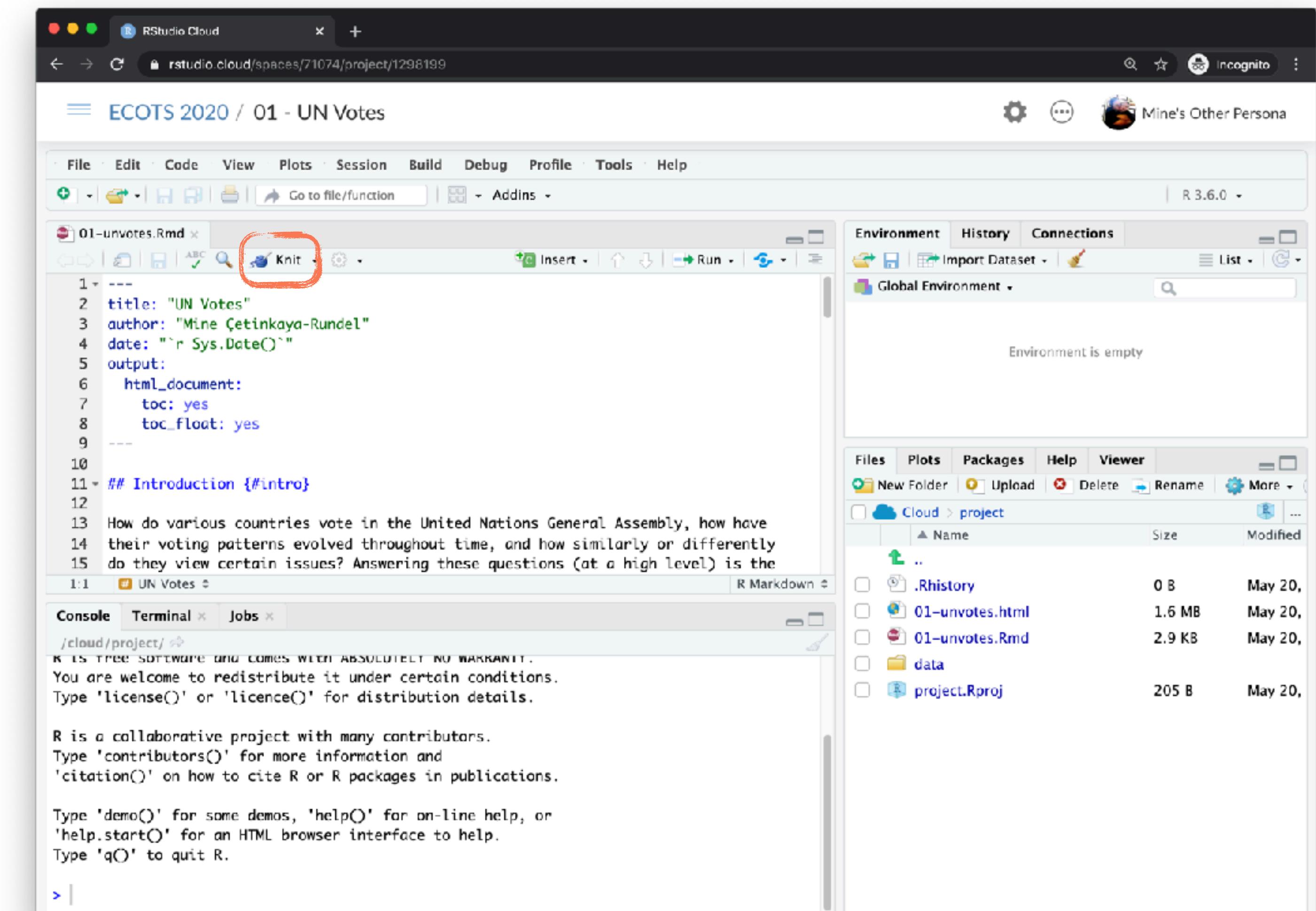
- ▶ Go to bit.ly/rscloud-ecots2020
- ▶ Start the project titled UN Votes



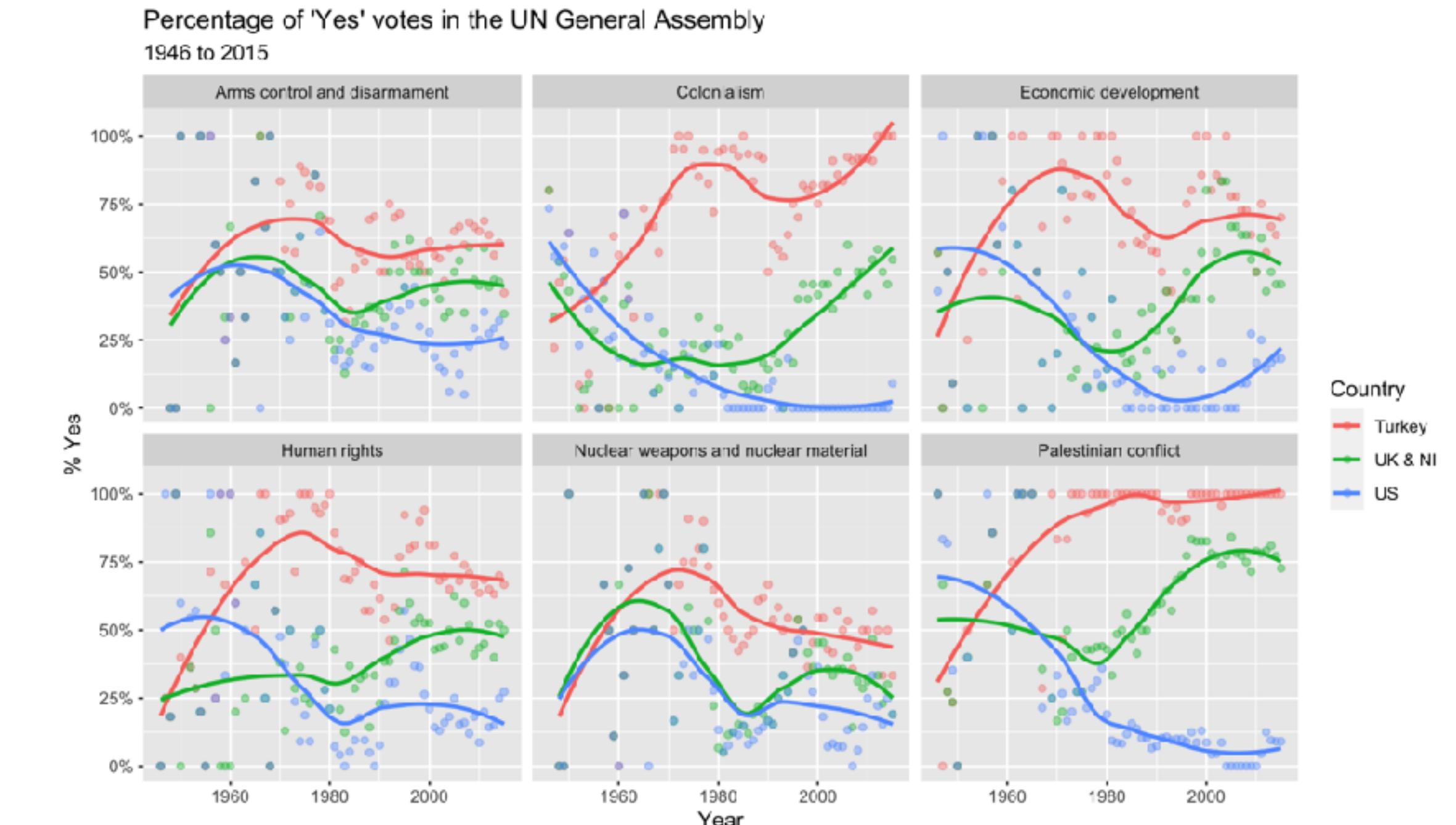
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- ▶ Open the R Markdown document called `unvotes.Rmd`



- ▶ Go to bit.ly/rscloud-ecots2020
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- ▶ Knit the document and review the data visualisation you just produced



- ▶ Go to bit.ly/rscloud-ecots2020
- ▶ Start the project titled UN Votes
- ▶ Open the R Markdown document called `unvotes.Rmd`
- ▶ Knit the document and review the data visualisation you just produced
- ▶ Then, look for the character string “Turkey” in the code and replace it with another country of your choice
- ▶ Knit again, and review how the voting patterns of the country you picked compares to the United States and United Kingdom & Northern Ireland



three questions that keep me up at night...

- 
- 1 what should students learn?
 - 2 how will students learn best?
 - 3 what tools will enhance student learning?

three questions that keep me up at night...

content

1

what should students learn?

pedagogy

2

how will students learn best?

infrastructure

3

what tools will enhance student learning?





content

ex. 1

money in politics



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Foreign-Connected PACs

SELECT A CYCLE

2020

PAC Name (Affiliate)	Country of Origin/Parent Company	Total	Dems	Repubs
ABB Group (ABB Group)	Switzerland/Asea Brown Boveri	\$1,000	\$1,000	\$0
Accenture (Accenture)	Ireland/Accenture plc	\$73,500	\$45,000	\$28,500
Advance America Cash				
Advance Centers (Grupo Salinas)	Mexico/Grupo Salinas	\$3,000	\$1,000	\$2,000

SELECT A CYCLE

2020

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Advance America Cash Advance Centers (Grupo Salinas)	Mexico/Grupo Salinas	\$3,000	\$1,000	\$2,000
Air Liquide America	France/L'Air Liquide SA	\$11,500	\$5,000	\$6,500
Airbus Group	Netherlands/Airbus Group	\$81,500	\$26,500	\$55,000
Alkermes Inc	Ireland/Alkermes Plc	\$40,250	\$11,250	\$29,000
Allergan PLC (Allergan PLC)	Ireland/Allergan PLC	\$111,000	\$6,000	\$105,000
Allianz of America (Allianz)	Germany/Allianz AG Holding	\$35,500	\$17,100	\$18,400

- * web scraping
- * text parsing
- * data types
- * regular expressions

SELECT A CYCLE

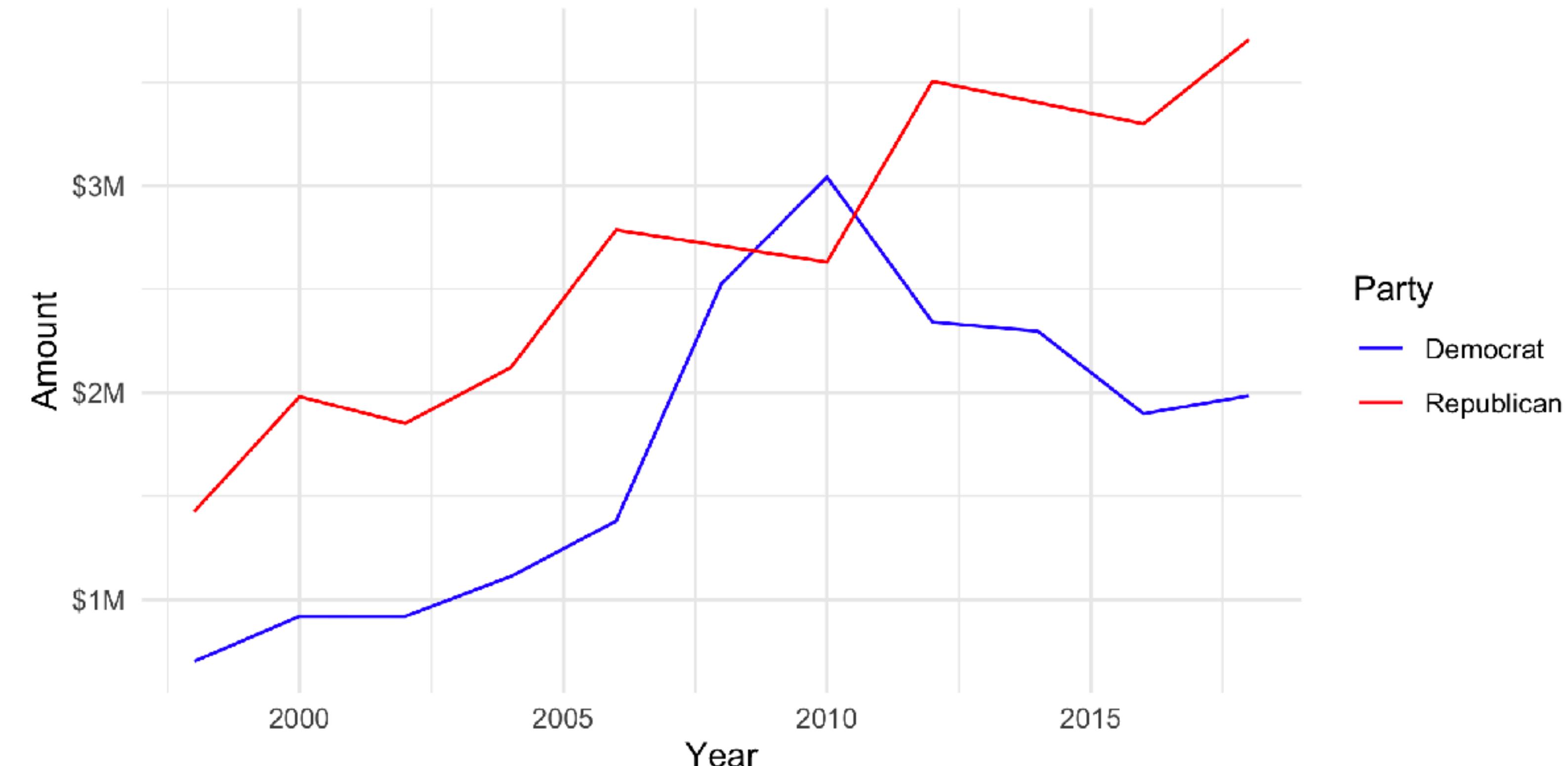
- 2020
- 2018
- 2016
- 2014
- 2012
- 2010
- 2008
- 2006
- 2004
- 2002
- 2000
- 1998

Advance America Case

		Repubs		
Advance Centers (Grupo Salinas)	Mexico/Grupo Salinas	\$3,000	\$1,000	\$2,000
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- ★ web scraping
- ★ text parsing
- ★ data types
- ★ regular expressions
- ★ iteration

Contribution to US politics from UK-Connected PACs By party, over time



- ★ web scraping
- ★ text parsing
- ★ data types
- ★ regular expressions
- ★ iteration
- ★ data visualisation
- ★ interpretation

```
paths_allowed("https://www.opensecrets.org")
```

```
## [1] TRUE
```

- ★ web scraping
- ★ text parsing
- ★ data types
- ★ regular expressions
- ★ iteration
- ★ data visualisation
- ★ interpretation
- ★ data science ethics

Project: The North South Divide: University Edition

Question: Does the geographical location of a UK university affect its university score?

Team: Fried Egg Jelly Fish

University League Tables 2020

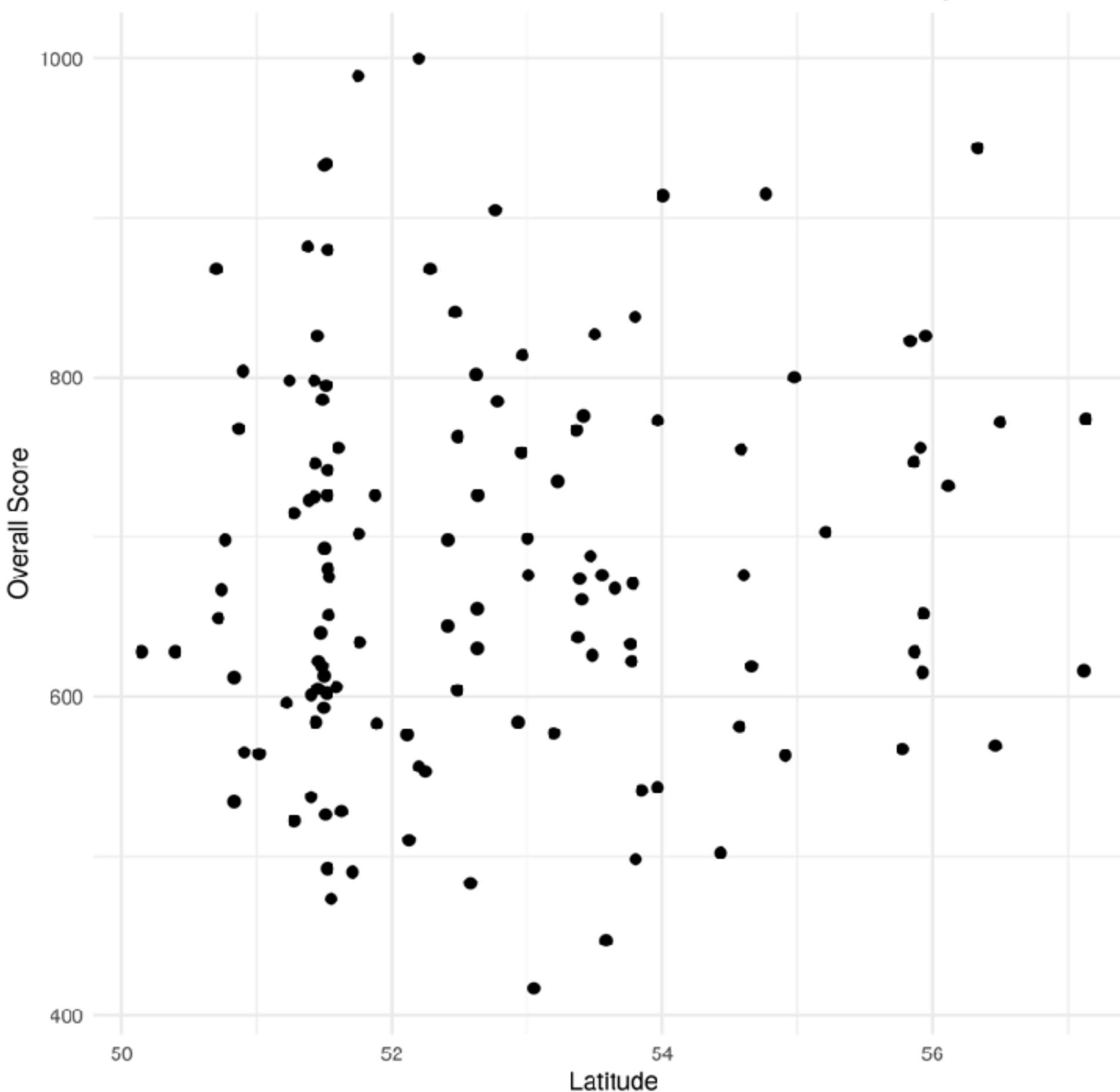
How to use | Methodology | FullTable | Print

Our League Tables rank UK universities both nationally and in 70 subjects. You can sort each table on the measure important to you and compare universities. Read university profiles for more information about the institutions or search for courses. We also rank 12 specialist colleges and conservatoires separately in the Arts, Drama & Music League Table.

Filter by Subjects Year Region Group Order by Overall Score

	Rank	University Name	Entry Standards	Student Satisfaction	Research Quality	Graduate Prospects	Overall Score	Next Steps
▼	1st	► 0 Cambridge	224	4.09	3.55	86.7	1000	PROFILE COURSES
▼	2nd	► 0 Oxford	215	4.10	3.34	83.4	989	PROFILE COURSES
▼	3rd	▲ 2 St Andrews	207	4.26	3.13	79.7	941	PROFILE COURSES
▼	4th	▼ 1 London School of Economics	189	3.67	3.35	86.1	934	PROFILE COURSES
▼	5th	▼ 1 Imperial College London	205	4.02	3.36	90.4	933	PROFILE COURSES
▼	6th	► 0 Durham	191	4.01	3.14	84.8	915	PROFILE COURSES

Association between overall score and the latitude of a university



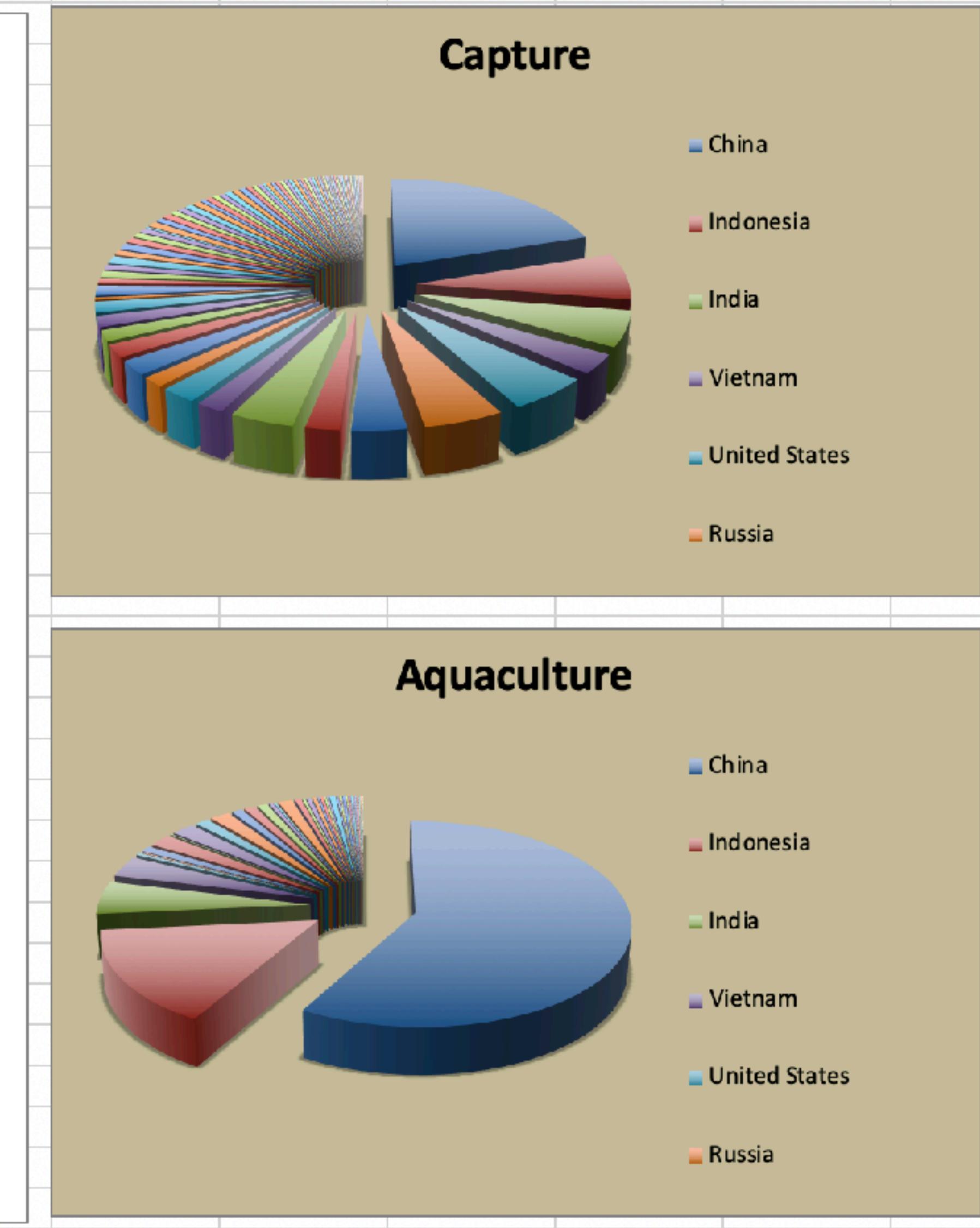
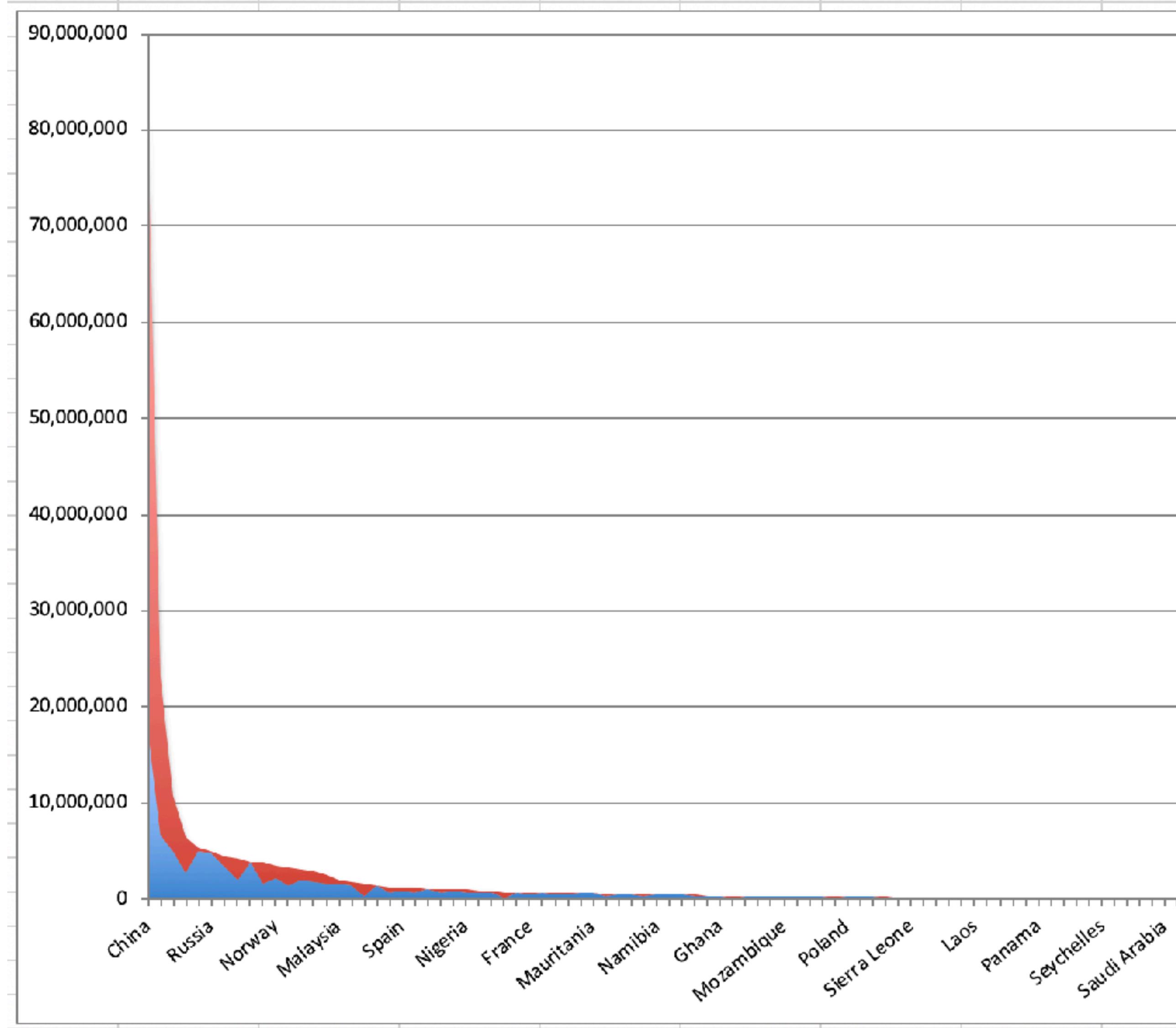
Resources

- ▶ **Sample assignment:** introds.org/hw/hw-06/hw-06-money-in-politics.html
- ▶ **Code:** Go to bit.ly/rscloud-ecots2020, start the project titled **02 - Money in politics**
- ▶ **Paper:** Web Scraping in the Statistics and Data Science Curriculum: Challenges and Opportunities (Dogucu & Çetinkaya-Rundel, 2020)
github.com/mdogucu/web-scrape (conditionally accepted to JSE)

ex. 2

fisheries of the world





```
fisheries %>% select(country)
```

```
## # A tibble: 82 x 1
##   country
##   <chr>
## 1 Angola
## 2 Argentina
## 3 Australia
## 4 Bangladesh
## 5 Brazil
## 6 Cambodia
## 7 Cameroon
## 8 Canada
## 9 Chad
## 10 Chile
```

```
continents
```

```
## # A tibble: 245 x 2
##   country      continent
##   <chr>        <chr>
## 1 Afghanistan Asia
## 2 Åland Islands Europe
## 3 Albania      Europe
## 4 Algeria      Africa
## 5 American Samoa Oceania
## 6 Andorra      Europe
## 7 Angola       Africa
## 8 Anguilla     Americas
## 9 Antigua & Barbuda Americas
## 10 Argentina   Americas
```

* data joins

```
fisheries <- left_join(fisheries, continents)
```

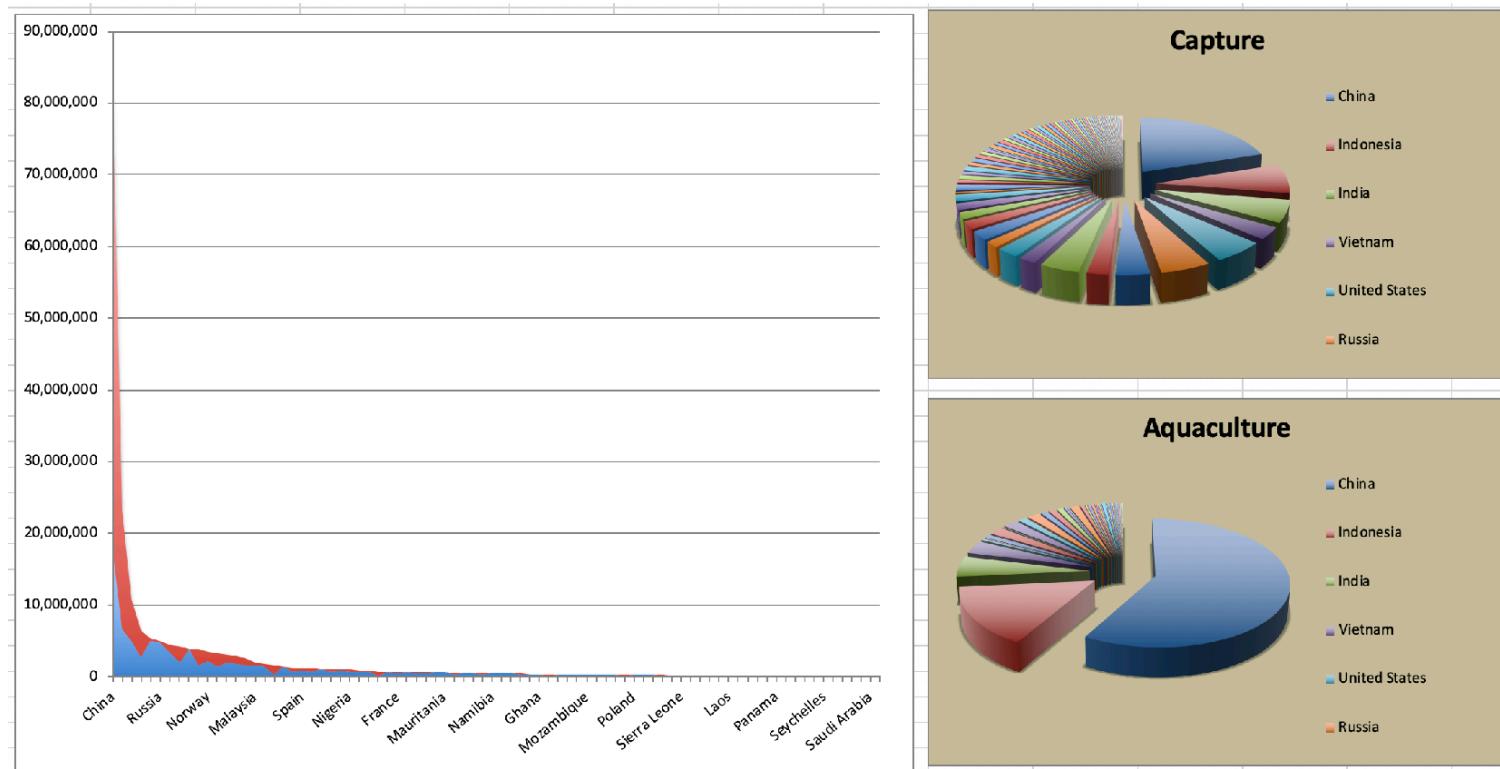
```
## Joining, by = "country"
```

- ★ data joins
- ★ data science ethics

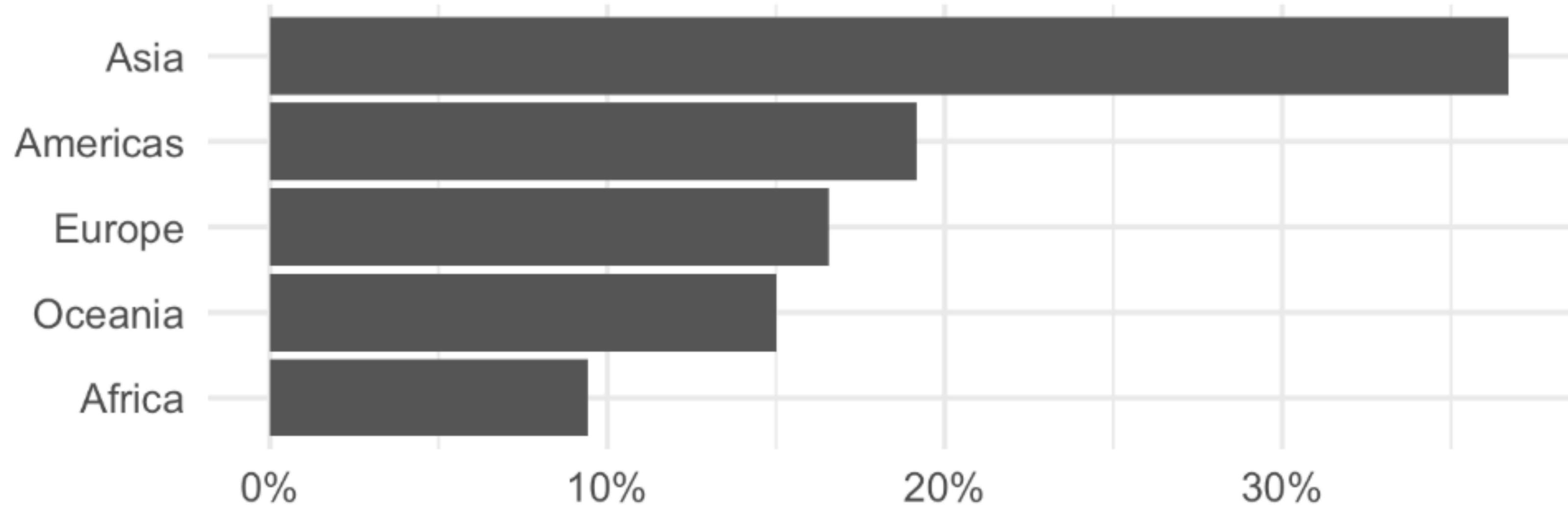
```
fisheries %>%
  filter(is.na(continent))
```

```
## # A tibble: 3 x 5
##   country           capture aquaculture    total continent
##   <chr>            <dbl>      <dbl>     <dbl> <chr>
## 1 Democratic Republic of the Congo 237372       3161  240533 <NA>
## 2 Hong Kong          142775       4258  147033 <NA>
## 3 Myanmar            2072390      1017644 3090034 <NA>
```

```
fisheries <- fisheries %>%
  mutate(continent = case_when(
    country == "Democratic Republic of the Congo" ~ "Africa",
    country == "Hong Kong" ~ "Asia",
    country == "Myanmar" ~ "Asia",
    TRUE ~ continent
  ))
```

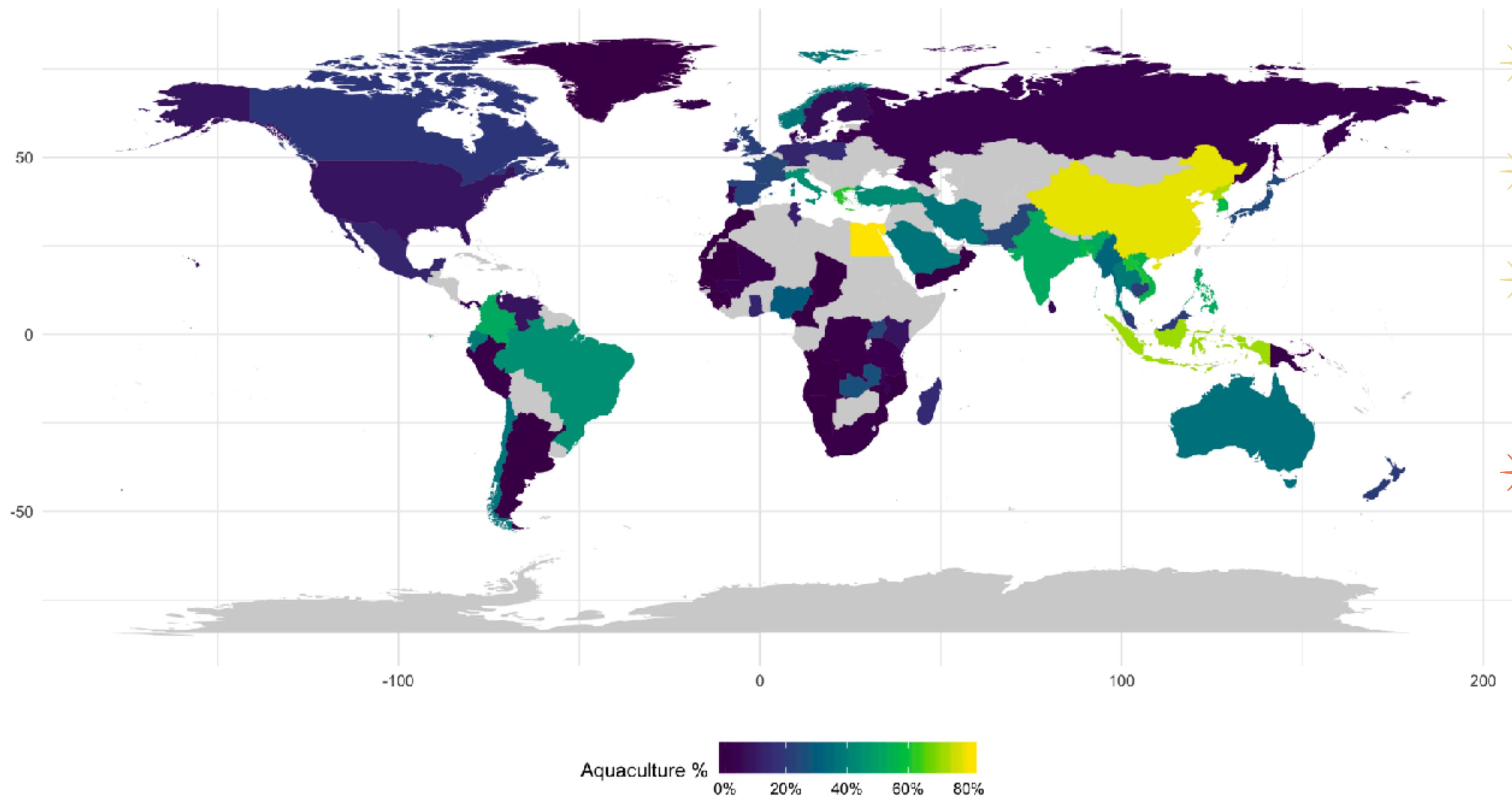


Average share of aquaculture by continent out of total fisheries harvest, 2016



- ★ data joins
- ★ data science ethics
- ★ critique
- ★ improving data visualisations

Average share of aquaculture by country
out of total fisheries harvest, 2016



- ★ data joins
- ★ data science ethics
- ★ critique
- ★ improving data visualisations
- ★ mapping

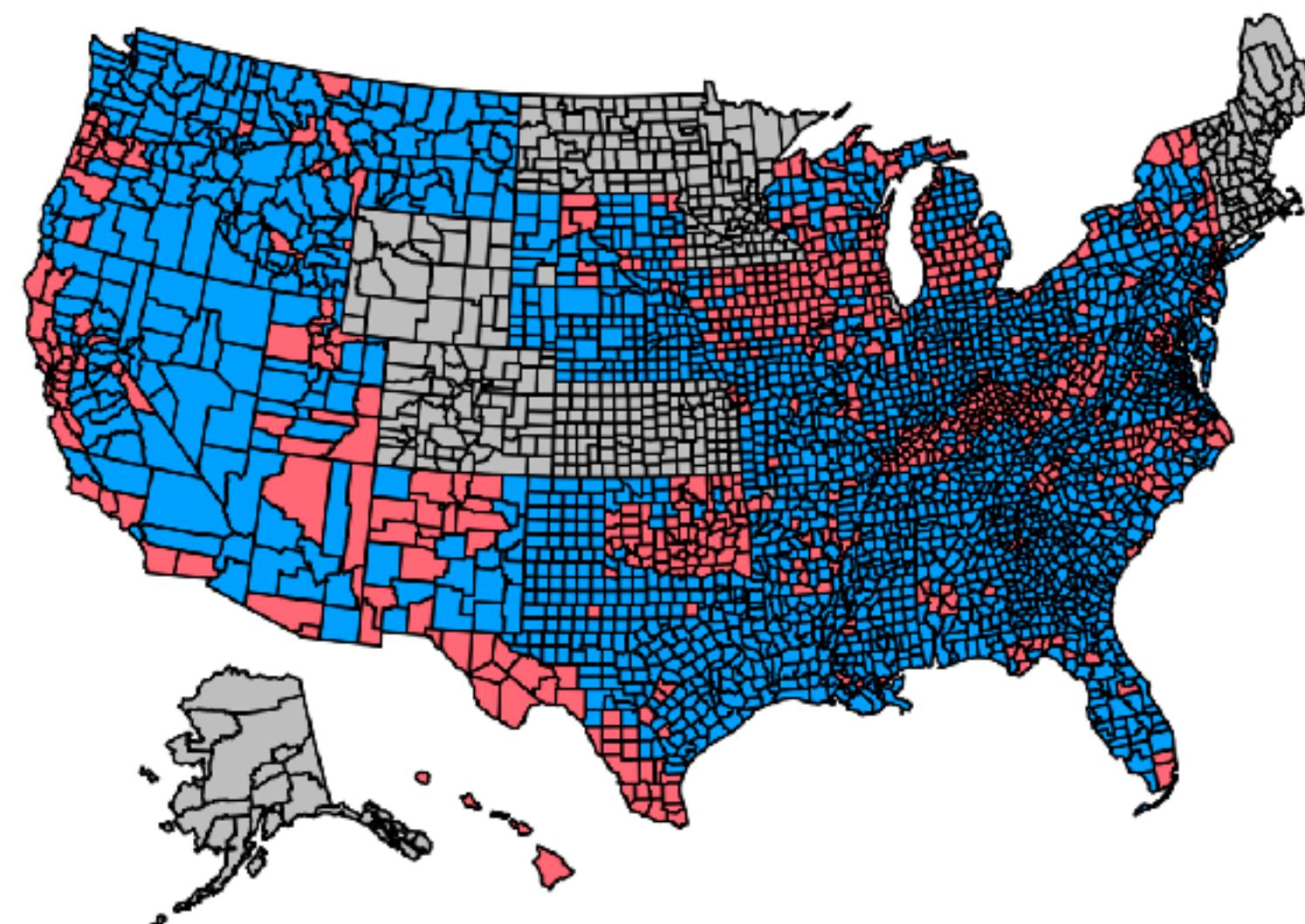
Source: bit.ly/2VrawTt

Project: 2016 US Election Redux

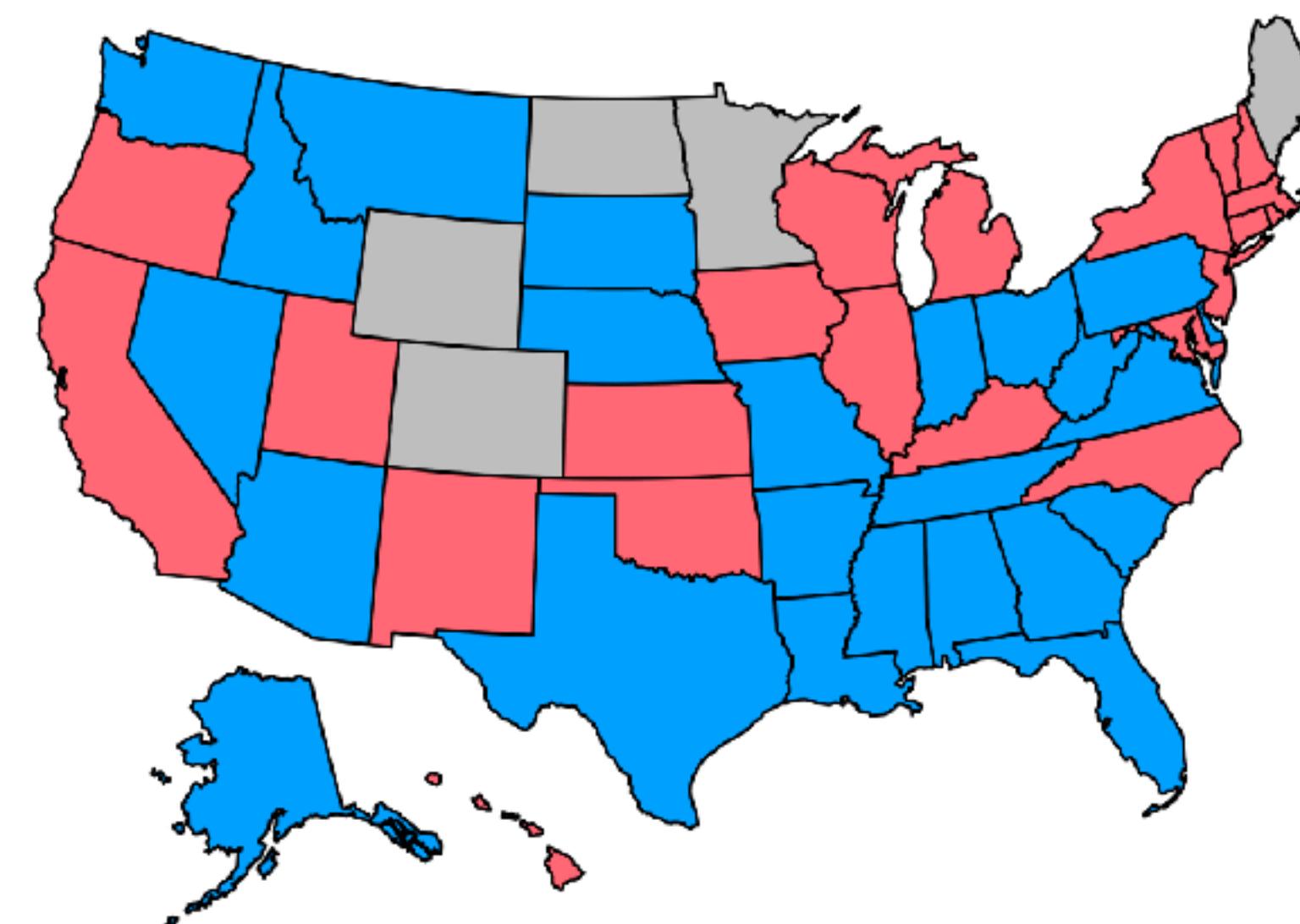
Question: Would the outcome of the 2016 US Presidential Elections been different had Bernie Sanders been the Democrat candidate?

Team: 4 Squared

Predicted Results
By County



Predicted Results
By State



Candidate
Bernie Sanders
Donald Trump
NA

Resources

- ▶ Sample lab: introds.org/labs/lab-04/lab-04-ugly-charts.html
- ▶ Code: Go to bit.ly/rscloud-ecots2020, start the project titled **03 - Fisheries of the world**
- ▶ Sample lecture: introds.org/slides/w4_d1-effective-dataviz/w4_d1-effective-dataviz.html

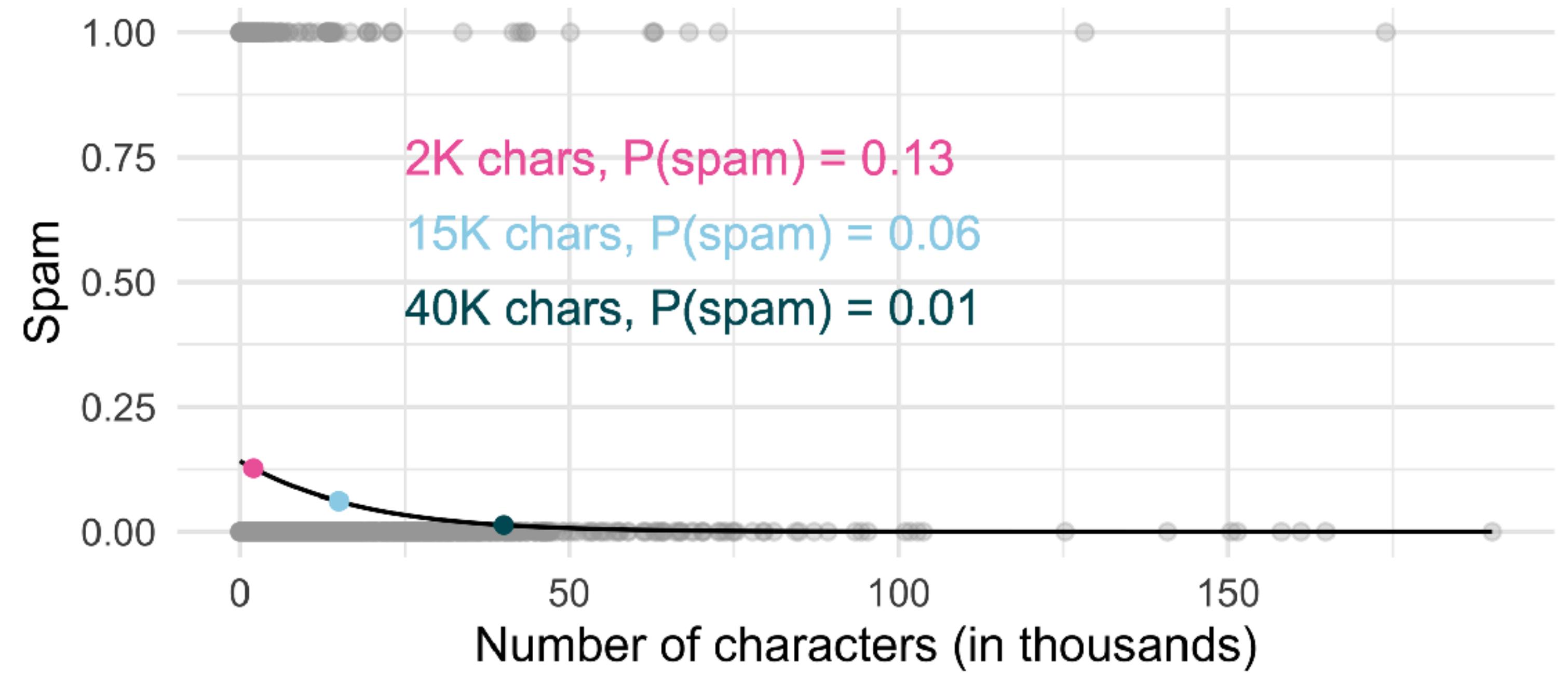
ex. 3

spam filters



Spam vs. number of characters

- * logistic regression
- * prediction



- ★ logistic regression
- ★ prediction
- ★ decision errors
- ★ sensitivity / specificity
- ★ intuition around loss functions

	Email is spam	Email is not spam
Email labelled spam	True positive	False positive (Type 1 error)
Email labelled not spam	False negative (Type 2 error)	True negative

Project: Spotify Top 100 Tracks of 2017/18

Question: Is it possible to predict the year a song made the Top Tracks playlist based on its metadata?

Team: weR20

```
year ~ danceability + energy + key + loudness + mode + speechiness +
      acousticness + instrumentalness + liveness + valence + tempo +
      duration_s
```

2017

	name	artists
I'm the One		DJ Khaled
Redbone		Childish Gambino
Sign of the Times	Harry Styles	

2018

	name	artists
	Everybody Dies In Their Nightmares	XXXTENTACION
	Jocelyn Flores	XXXTENTACION
	Plug Walk	Rich The Kid
	Moonlight	XXXTENTACION
	Nevermind	Dennis Lloyd
	In My Mind	Dynoro
	changes	XXXTENTACION

Resources

- ▶ **Sample lecture:** introds.org/slides/w10_d1-logistic-regression/w10_d1-logistic-regression.html
- ▶ **Code:** Go to bit.ly/rscloud-ecots2020, start the project titled **04 - Spam filter**
- ▶ **Book chapter:** **OpenIntro Statistics**, 4th Edition (Diez, Çetinkaya-Rundel, and Barr, 2019), Chapter 9.5 with randomised controlled trial data on discrimination on job application evaluation openintro.org/book/os



pedagogy



teams: weekly labs in teams +
periodic team evaluations +
term project in teams

peer feedback: used
minimally so far, but
positive experience

“minute paper”: weekly online
quizzes ending with a brief
reflection of the week’s material



Week 07 - Simple linear regression

Teacher salaries

Single numerical predictor

Prediction

Assessing model fit

Working backwards

Single categorical predictor

Finish up

Start Over



Finish up

To finish up the quiz go to the form linked below and answer a few simple questions.

Hi Mine, when you submit this form, the owner will be able to see your name and email address.

* Required

1. What is your name? *

Enter your answer

2. What is your student ID? *

This is the number that starts with s.

Enter your answer

3. Write about one or two questions you didn't get right initially but were able to solve after a few tries. What was difficult about them? What did you ultimately learn?

OR

If you got every single question correct on the first try, write one question you would still like clarified on the topics covered in this quiz. *

Your answers can be brief / in bullet point form. The goal isn't to make you write too much, but instead to make you quickly reflect on your learning.

Enter your answer

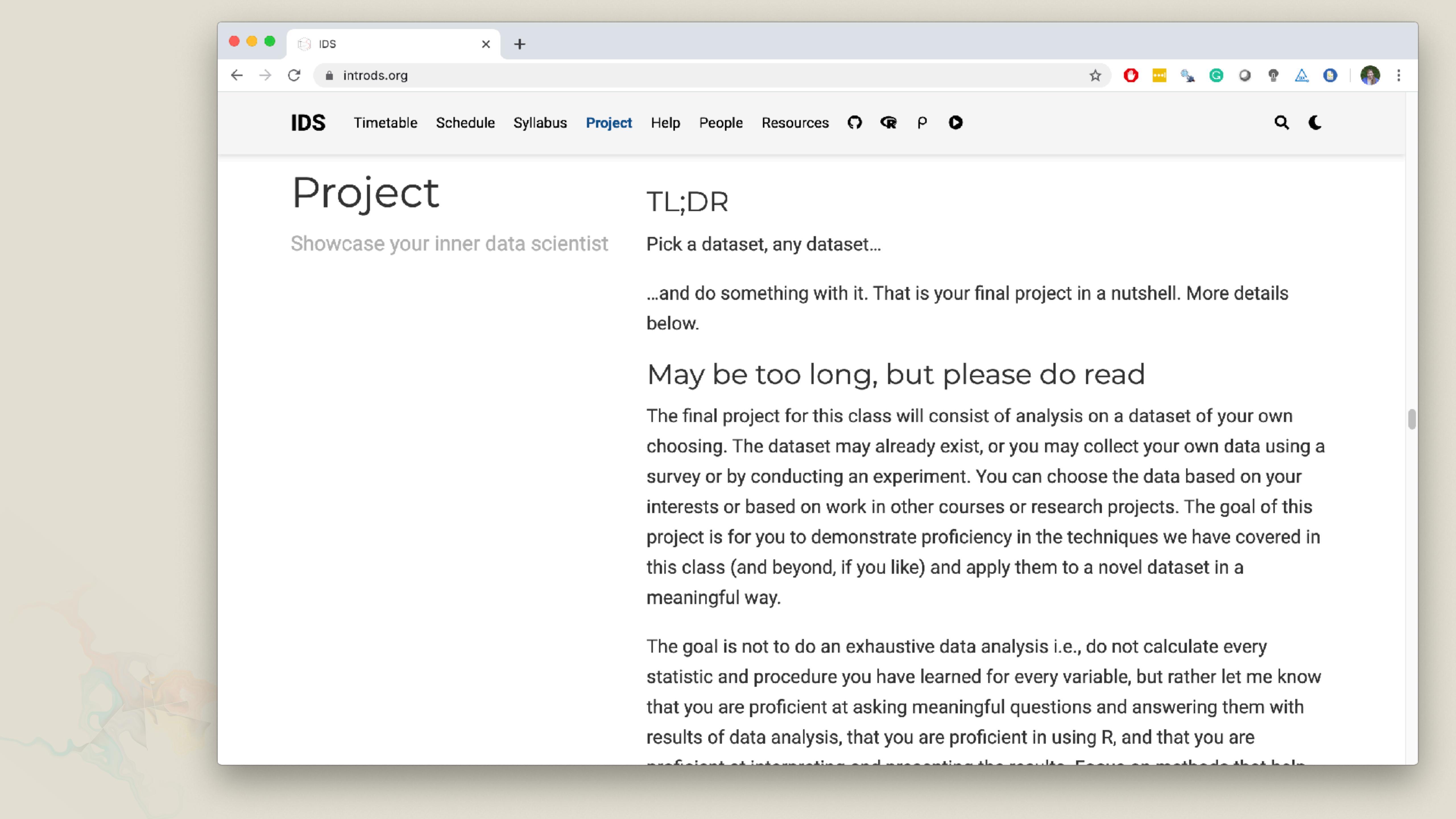


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periodic team evaluations +
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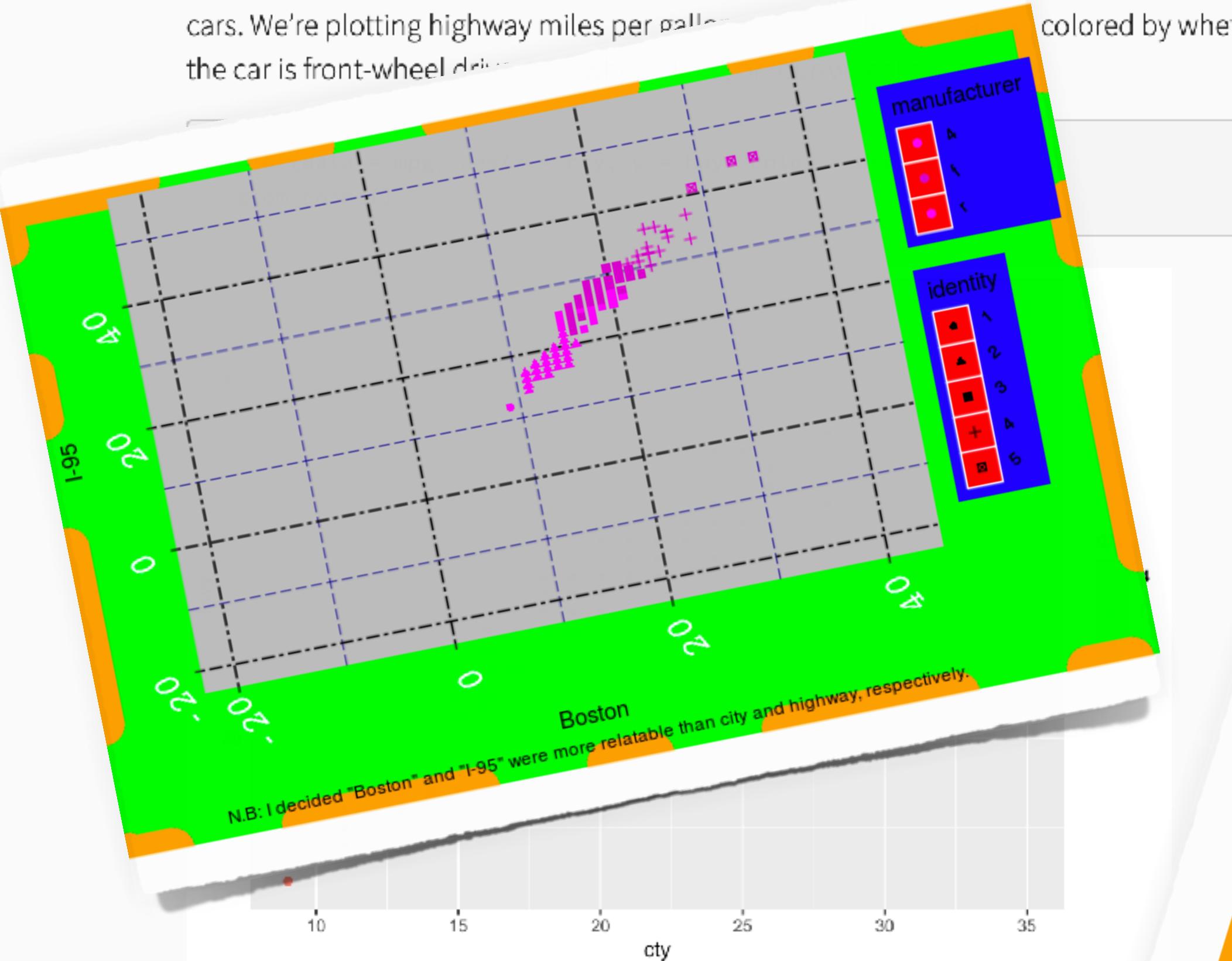
creativity: assignments that
make room for creativity





Part 3 - Mirror, mirror on the wall, who's the ugliest of them all?

Here is a simple plot using the `mpg` dataset, which contains info on fuel economy of cars. We're plotting highway miles per gallon (`hwy`) against city miles per gallon (`cty`). The color of the points indicates whether the car is front-wheel drive (`drv`), with four categories: 4 (red), f (green), and r (blue).

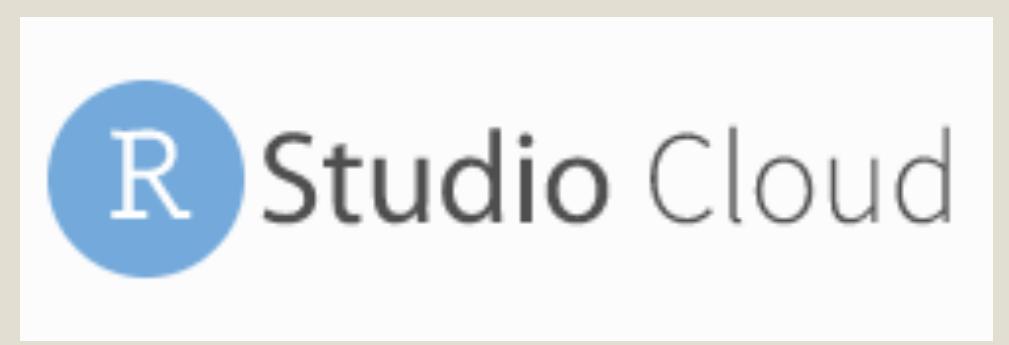


Exercise 11. Make this plot as ugly as possible by changing colors, background color, fonts, or anything else you can think of. You will probably want to play around with [theme options](#), but you can do more. You can also search online for other themes, fonts, etc. that you want to tweak.

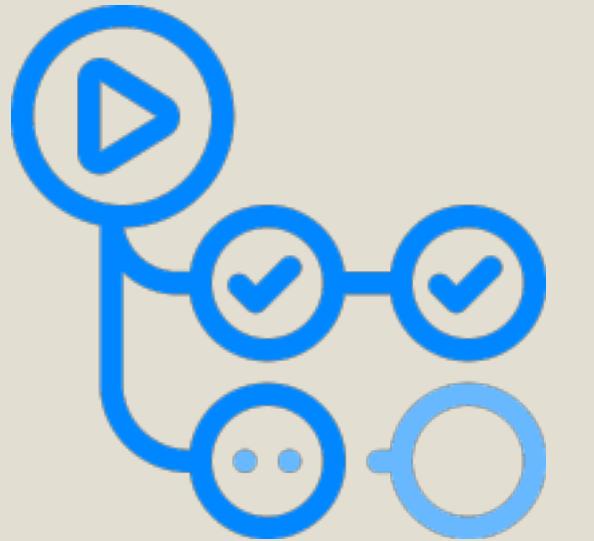




infrastructure



+

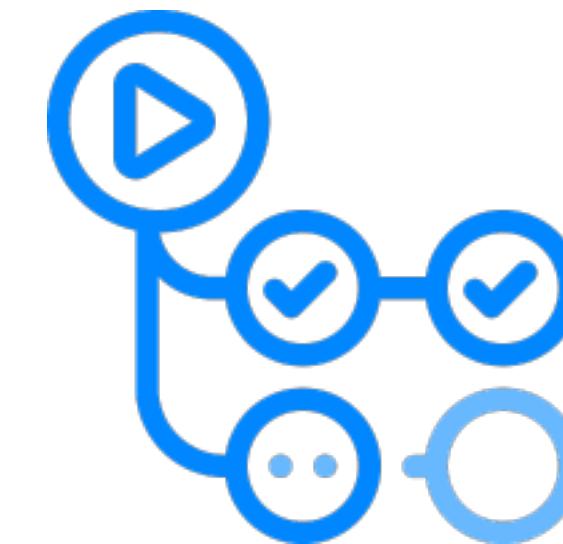
**ghclass**



+



ghclass



ghclass · GitHub

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styler revisions #1

Draft mine-cetinkaya... wants to merge 1 commit into master from styler

Conversation 0 Commits 1 Checks 0 Files changed 1 +16 -18

Changes from all commits ▾ File filter... ▾ Jump to... ▾

Review changes ▾

Results of running styler:

Styling 1 files:
hw-03-ncbikecrash.Rmd ↗

Status	Count	Legend
✓	0	File unchanged.
i	1	File changed.
*	0	Styling threw an error.

Please review the changes carefully!

styler (#1)

mine-cetinkaya-rundel committed 16 minutes ago

commit 721c39cf8b6c0e6b3bc50f2918747415910b980e

34 hw-03-ncbikecrash.Rmd ↗

@@ -7,7 +7,7 @@ output: github_document

```
7
8  ```{r load-packages, message=FALSE}
9  # load packages
10 -library(tidyverse)```
```

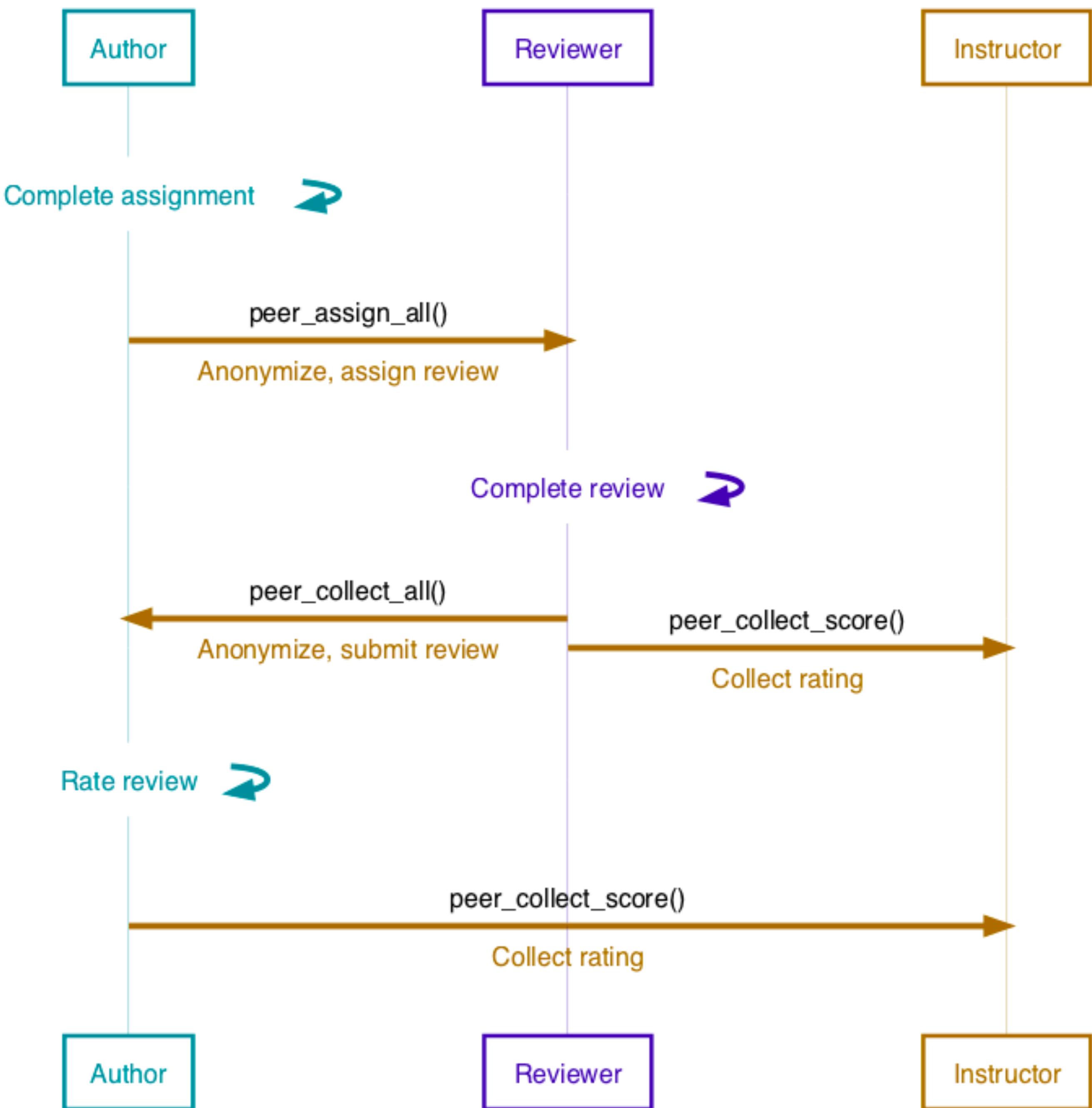
```
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10 +library(tidyverse)```
```

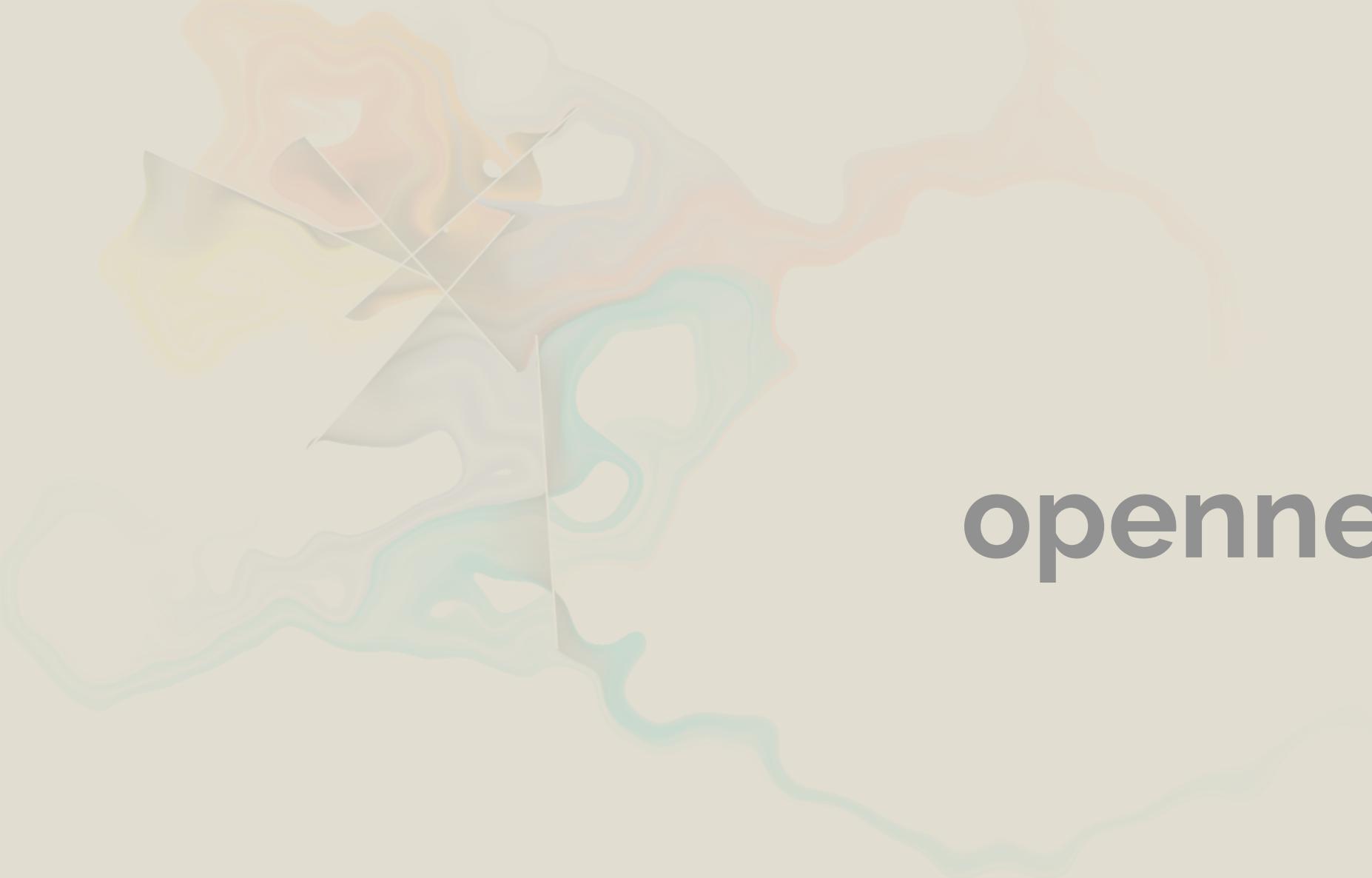


+



ghclass





openness

IDS introds.org Incognito

IDS Timetable Schedule Syllabus Project Help People Resources Q R P ▶

Introduction to Data Science

Learn to explore, visualize, and analyze data to understand natural phenomena, investigate patterns, model outcomes, and make predictions, and do so in a reproducible and shareable manner. Gain experience in data collection, wrangling, and visualization, exploratory data analysis, predictive modeling, and effective communication of results while working on problems and case studies inspired by and based on real-world questions. The course will focus on the R statistical computing language. No statistical or computing background is necessary.

Introduction to Data Science

Fall 2019

University of Edinburgh

Q R P ▶

The screenshot shows a web browser window for the URL datasciencebox.org. The title bar reads "Data Science in a Box :: Data S X". The main content area features a large yellow 3D cube logo with "DATA SCIENCE" on top, "IN A BOX" on the side, and a small "ds" icon on the front. To the right of the logo is a search bar with a magnifying glass icon and the placeholder "Search...". Below the search bar is a sidebar with a dark background containing four links: "Hello #dsbox", "Course content", "Infrastructure", and "Pedagogy". To the right of the sidebar is a large blue arrow pointing right. The main text area starts with a heading "Data Science in a Box" and a paragraph about teaching data science effectively. It then describes the core content of the course, mentioning data acquisition, wrangling, exploratory data analysis, data visualization, inference, modeling, reporting, text analysis, and Bayesian inference. It highlights the use of tools like tidyverse, R Markdown, Git, and GitHub, and interactive tutorials. The goal is to help students work on reproducible projects. The final paragraph states that the materials are freely available and open-source, including course materials and instructor resources. At the bottom left, there is a note: "Built with ❤️ and blogdown, logo by muuuuge."

Data Science in a Box

How can we effectively and efficiently teach data science to students with little to no background in computing and statistical thinking? How can we equip them with the skills and tools for reasoning with various types of data and leave them wanting to learn more? This introductory data science course is our (working) answer to this question.

The core content of the course focuses on data acquisition and wrangling, exploratory data analysis, data visualization, inference, modeling, and effective communication of results. Time permitting, the course also introduces additional concepts and tools like interactive visualization and reporting, text analysis, and Bayesian inference. A heavy emphasis is placed on a consistent syntax (with tools from the [tidyverse](#)), reproducibility (with [R Markdown](#)), and version control and collaboration (with Git and GitHub). In addition, out-of-class learning is supplemented with interactive [tutorials](#). The goal of the course is to bring students from zero to being able to work in a team on a fully reproducible data science project analyzing a dataset of their choice and answering questions they care about.

Data Science in a Box contains the materials required to teach (or learn from) the course described above, all of which are [freely-available and open-source](#). They include course materials such as slide decks, homework assignments, guided labs, sample exams, a final project assignment, as well as materials for instructors such as pedagogical tips, information on computing infrastructure, technology stack, and course logistics.

Built with ❤️ and [blogdown](#), logo by [muuuuge](#).



the art and science of teaching data science

mine çetinkaya-rundel

bit.ly/introds-ecots2020

Code for all case studies: **bit.ly/introds-ecots2020-cases** or **bit.ly/rscloud-ecots2020**



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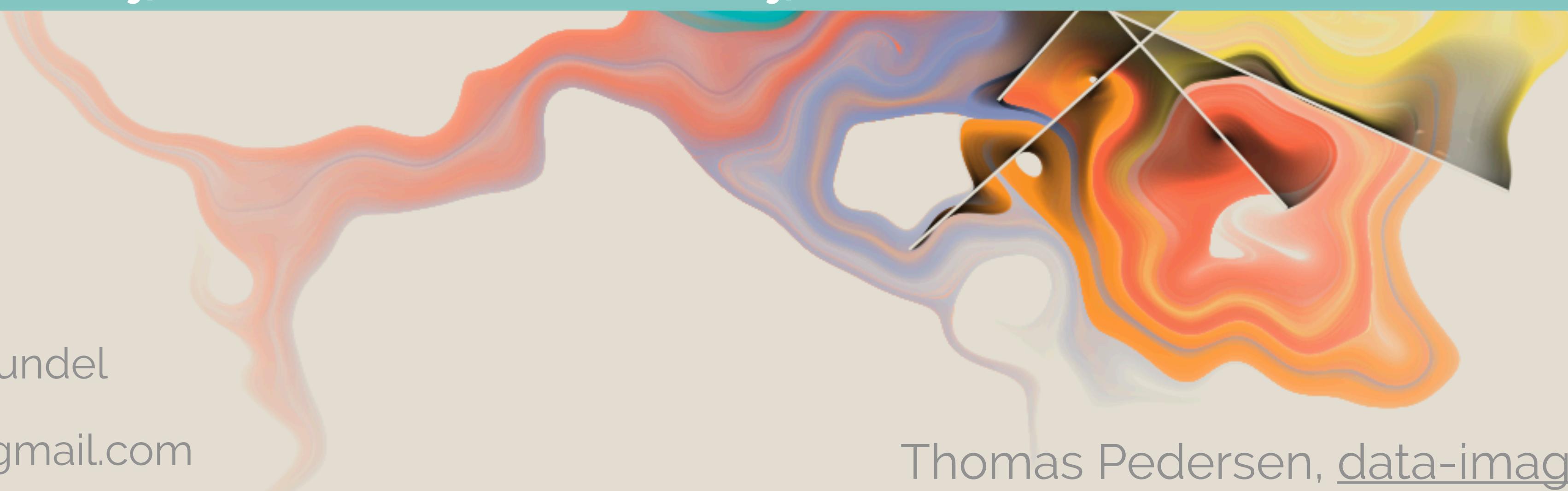


Image credit:
Thomas Pedersen, data-imaginist.com/art

Thomas Pedersen, data-imaginist.com/art

four

~~three~~ questions that keep me up at night...

content

1 what should students learn?

pedagogy

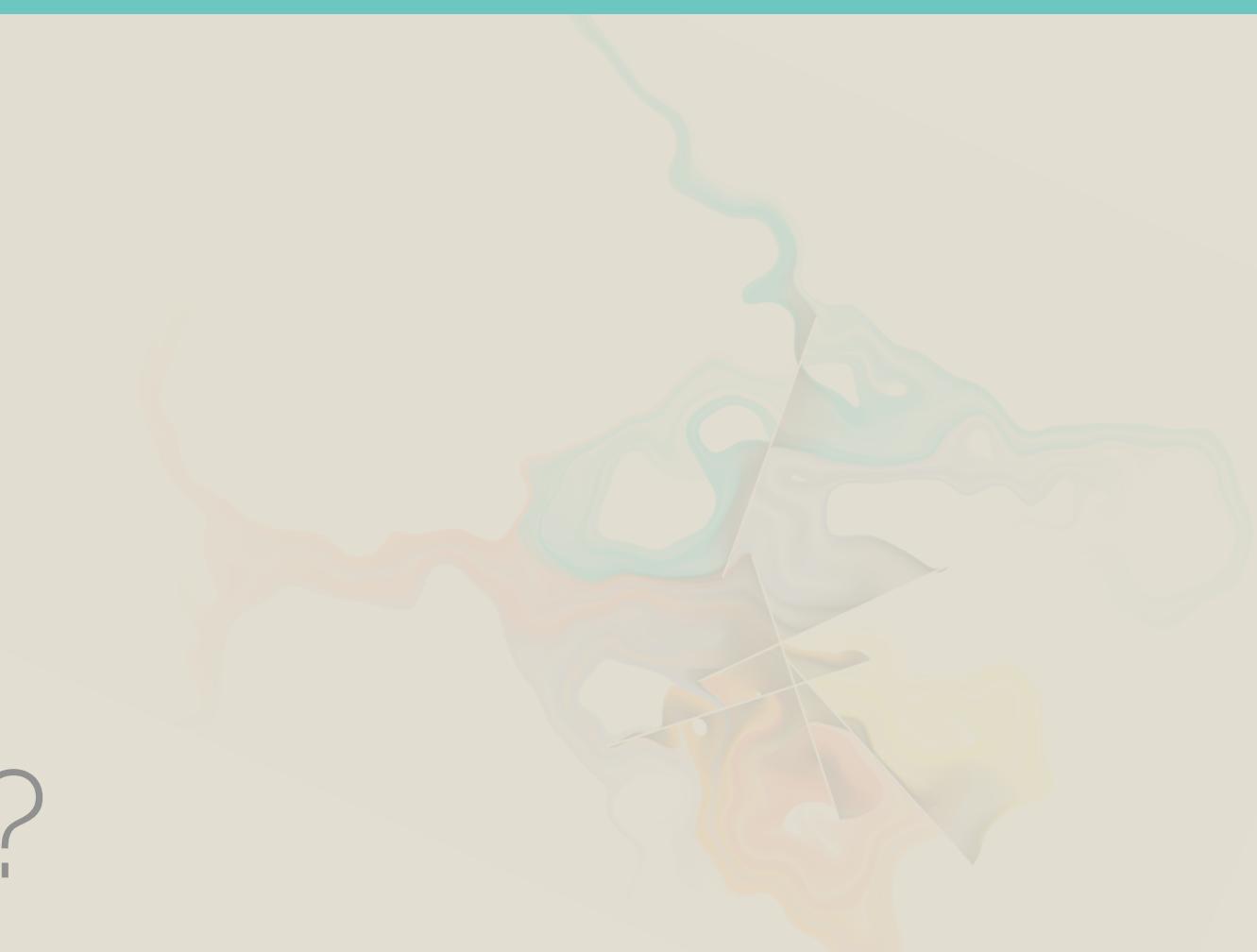
2 how will students learn best?

infrastructure

3 what tools will enhance student learning?

assessment

4 how can we assess any of this?



in progress: retrospective study

data: 205 open-ended student projects
over 4 years

group 1:

learned R & intro
statistics using
base R

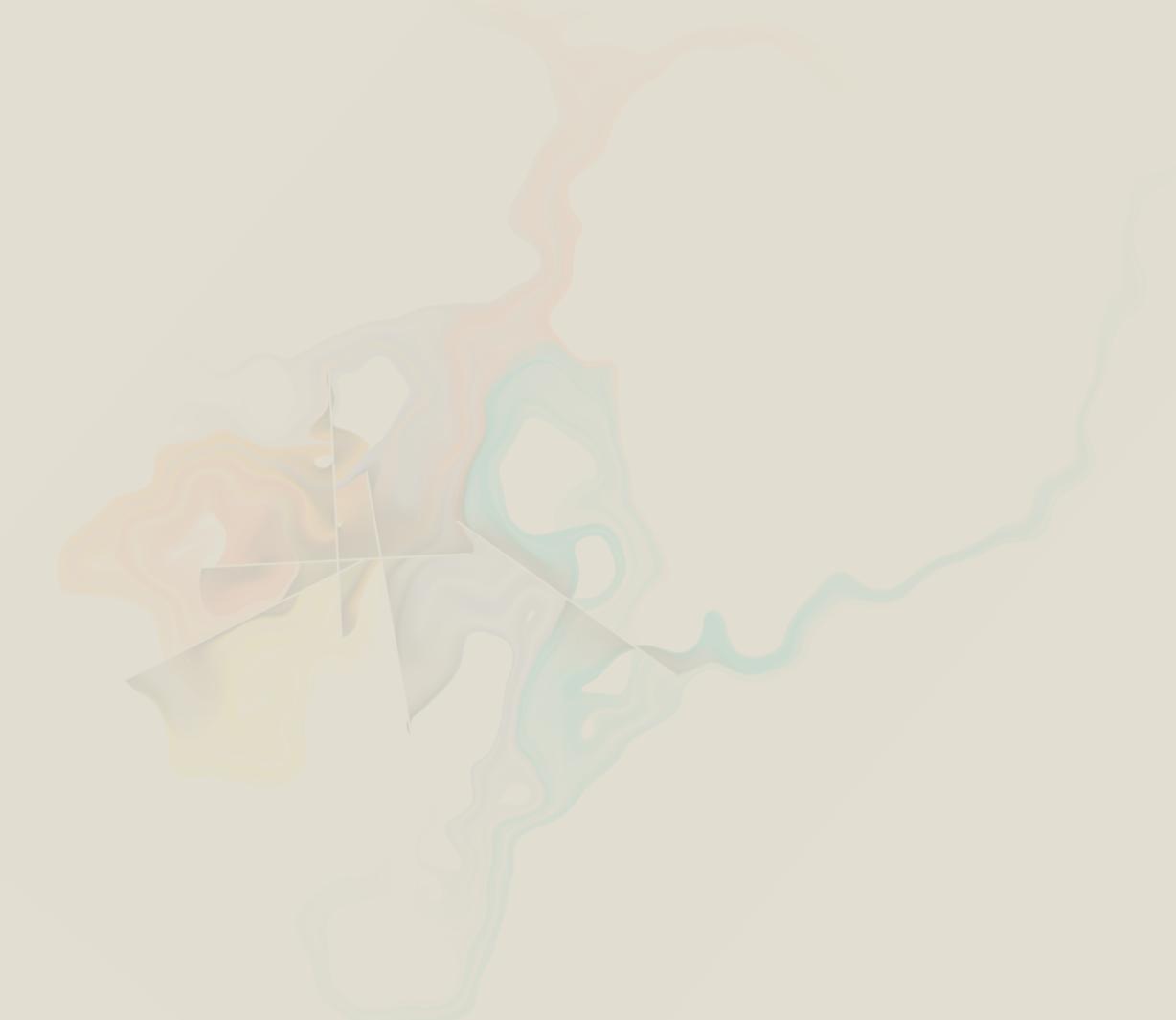
group 2:

learned R & intro
statistics using
tidyverse*

* starting before the term
tidyverse was coined.

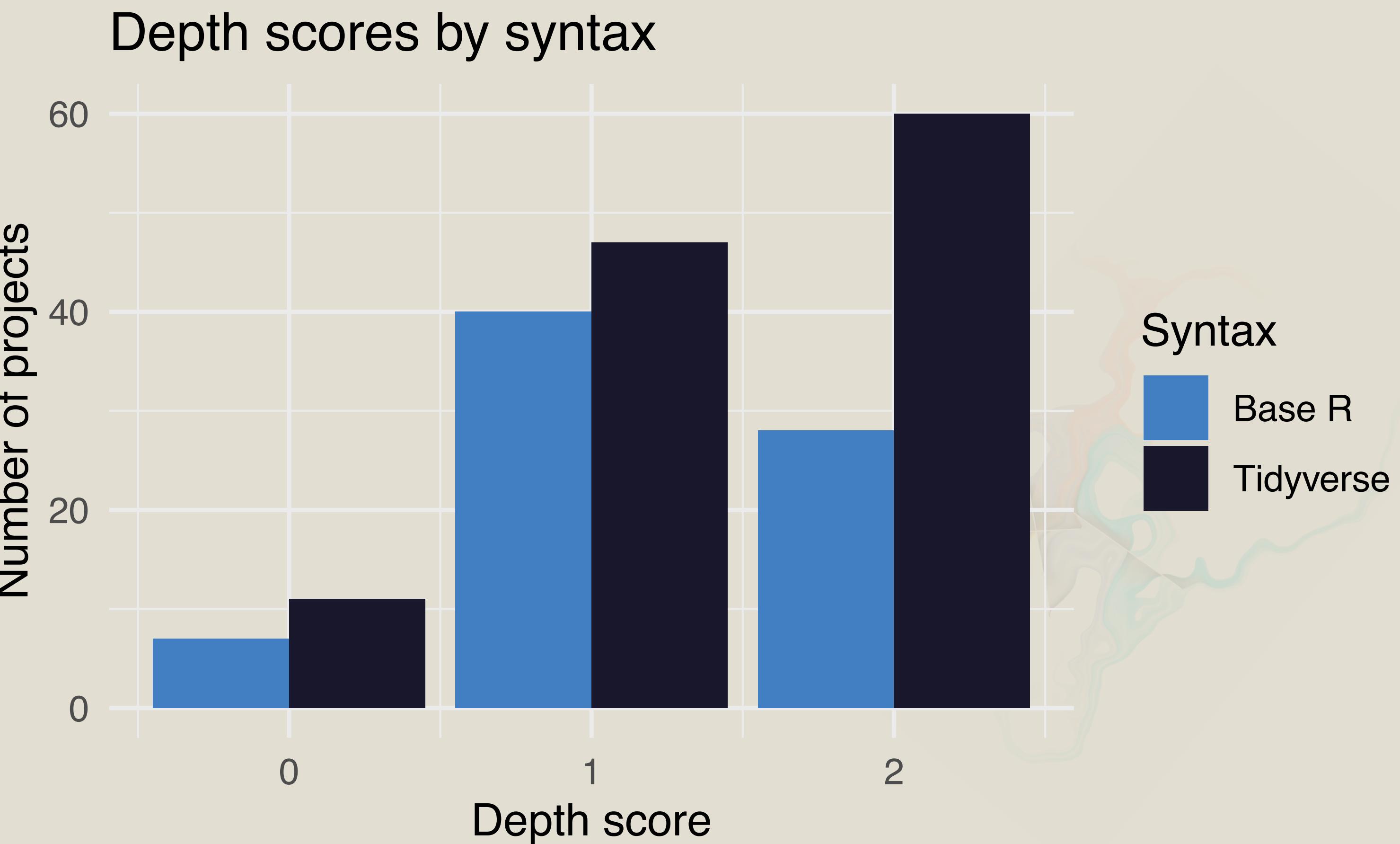
same assignment, same(ish) dataset

measures: *creativity*, *depth* and the
complexity of ***multivariate visualisations***



depth

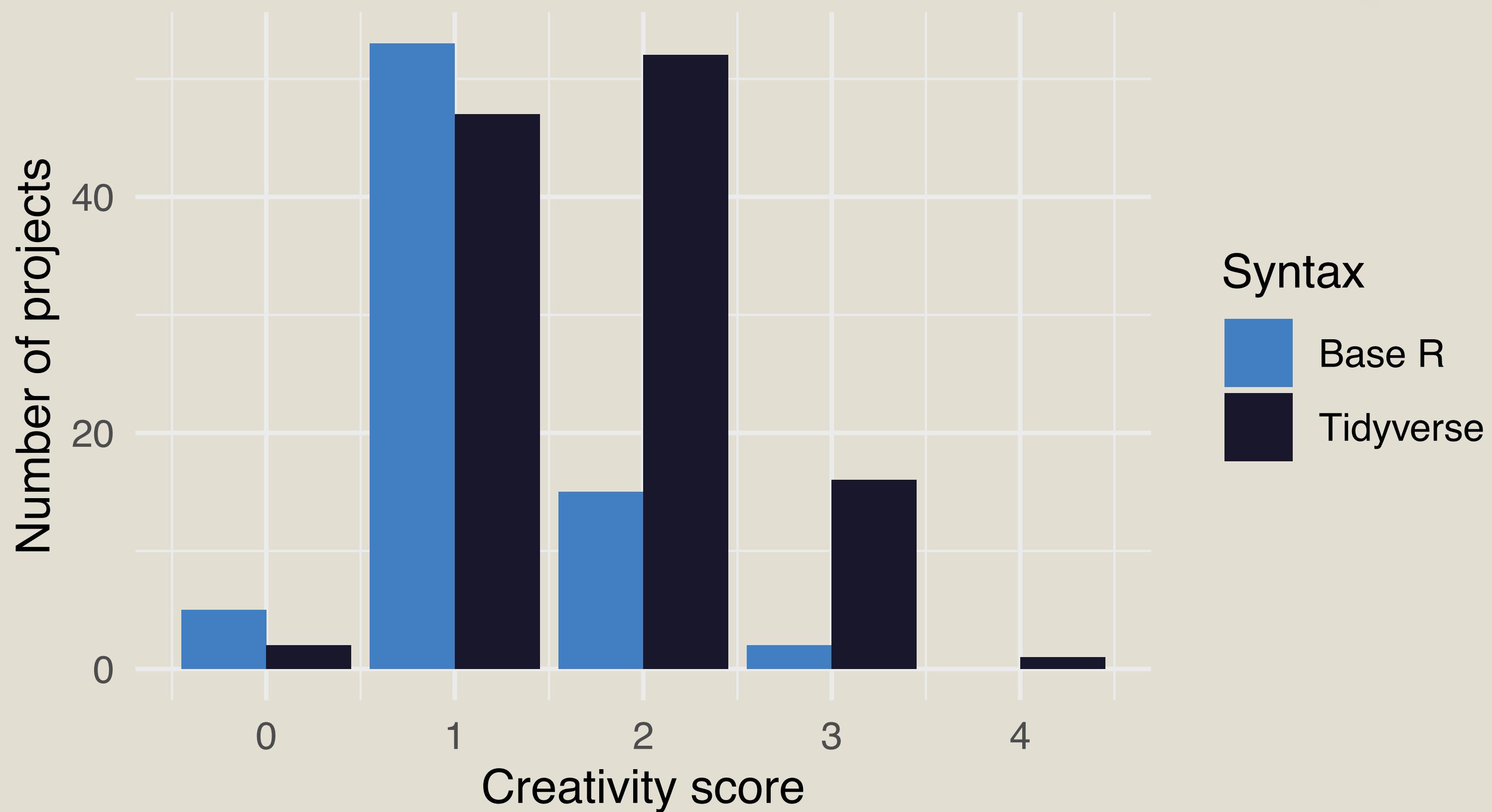
- consistent theme throughout the project
- relevant data for each analysis



creativity

- creation of new variables
- transformation of existing variables
- subgroup analysis
- use of a subset of data for the entire project

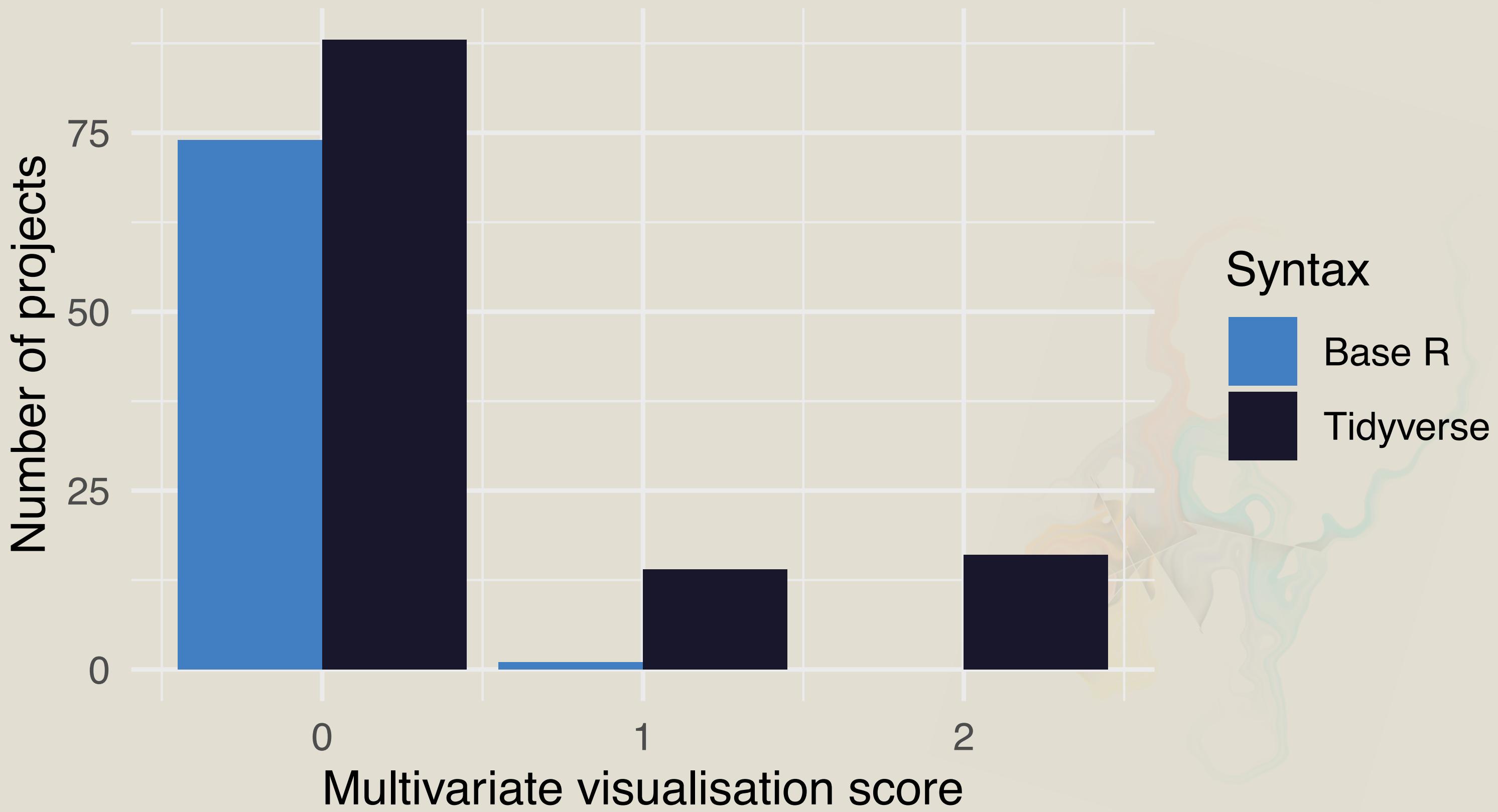
Creativity scores by syntax



multivariate visualisation

- visualisation with 3+ variables
- effective interpretations of visualisations

Multivariate visualisation by syntax



summary

	Estimate	Std. error	Statistic	P-value	95% CI
Creativity (0 - 4)					
Intercept	1.187	0.080	14.876	0.000	(1.029, 1.344)
Tidyverse	0.534	0.102	5.231	0.000	(0.332, 0.735)
Depth (0 - 2)					
Intercept	1.280	0.075	17.153	0.000	(1.133, 1.427)
Tidyverse	0.135	0.095	1.417	0.158	(-0.053, 0.324)
Multivariate visualisation (0 - 2)					
Intercept	0.013	0.065	0.204	0.838	(-0.115, 0.142)
Tidyverse	0.376	0.083	4.509	0.000	(0.212, 0.541)



planned: longitudinal study

motivation: higher conversion rate to stat 2

explorations:

retention, especially of
students from under-
represented
backgrounds

preparation and
confidence for applied
and collaborative
projects