the art and science of teaching data science

mine çetinkaya-rundel

bit.ly/introds-ecots2020

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

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.

amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf

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

amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf

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(2) Multivariate analysis requires the use of computing

amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf

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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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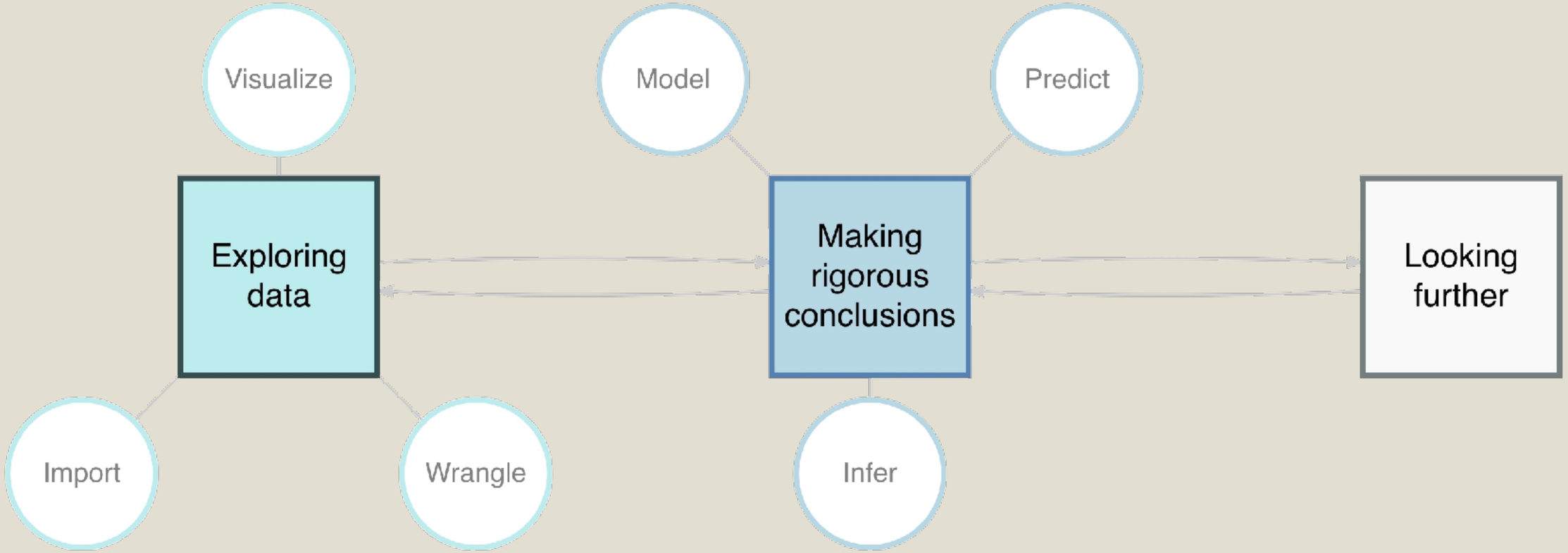
amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf

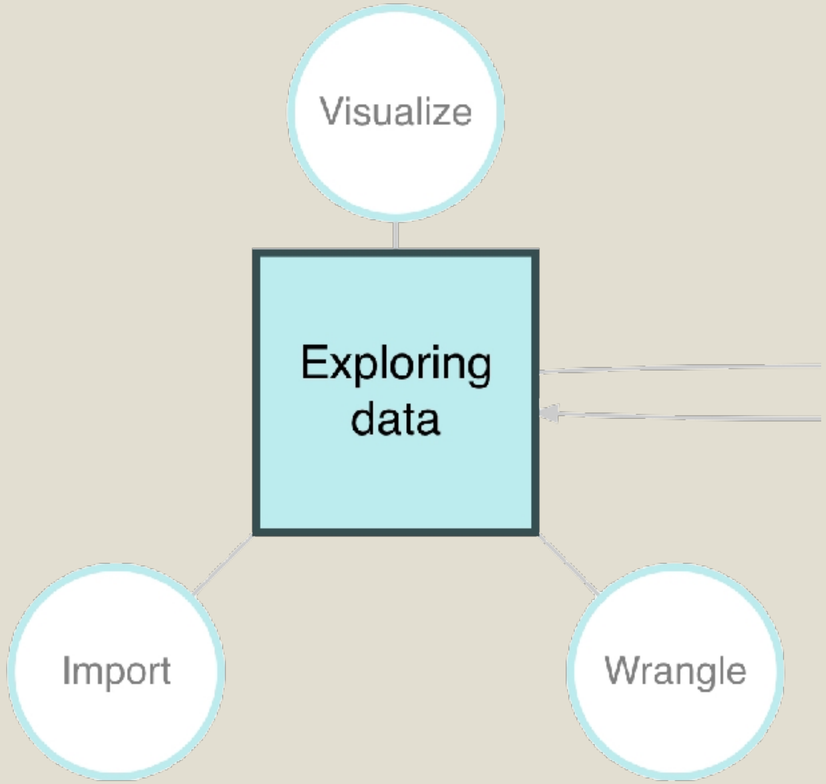
④ Data analysis isn't just inference and modelling, it's also data importing, cleaning, preparation, exploration, and visualisation

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

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

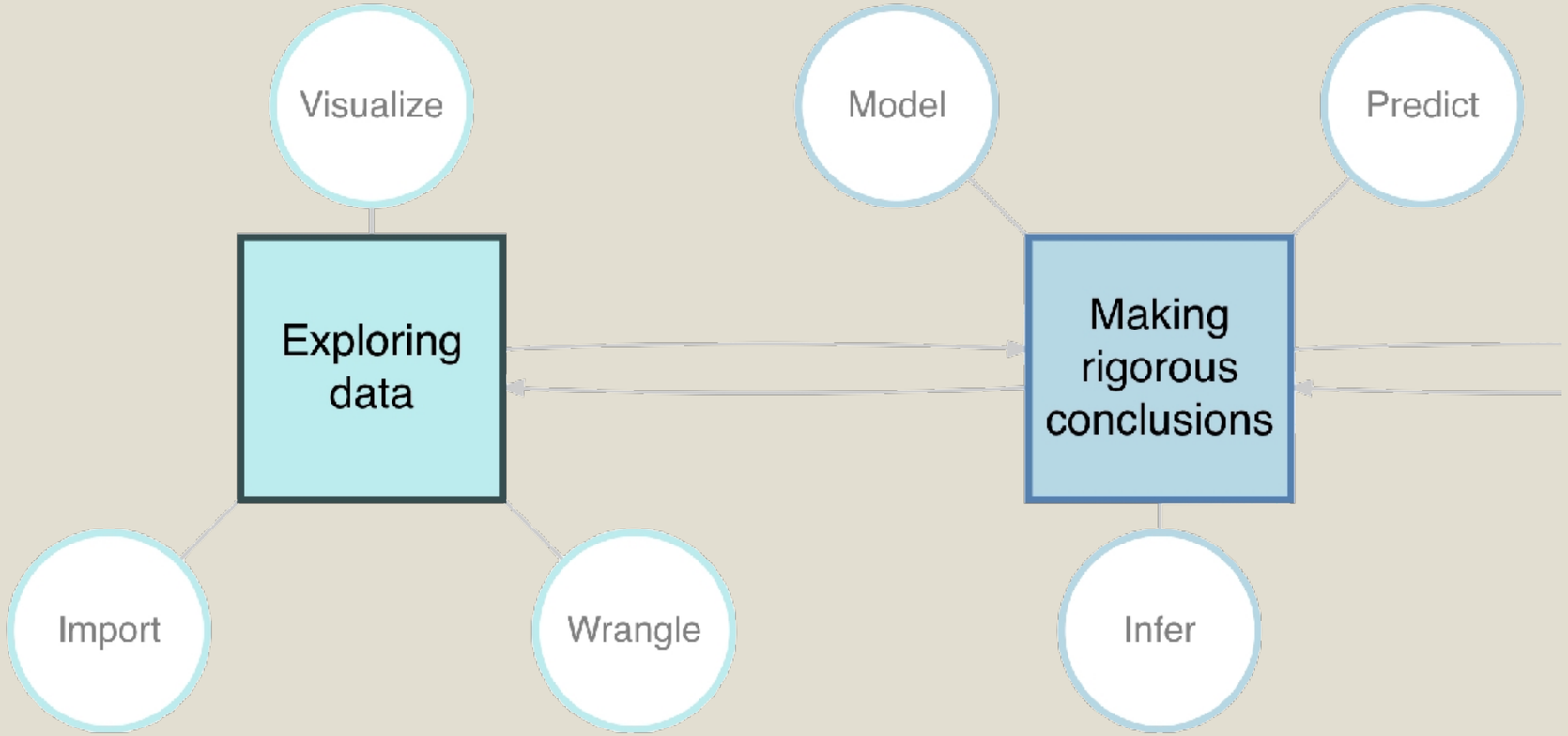
instead it is because it's time to visit intro stats in light of emergence of data science


Visualize
Model
Predict
Exploring data
Making rigorous conclusions
Looking further
Import
Wrangle
Infer



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



fundamentals of data & data viz, confounding variables, Simpson's paradox

+

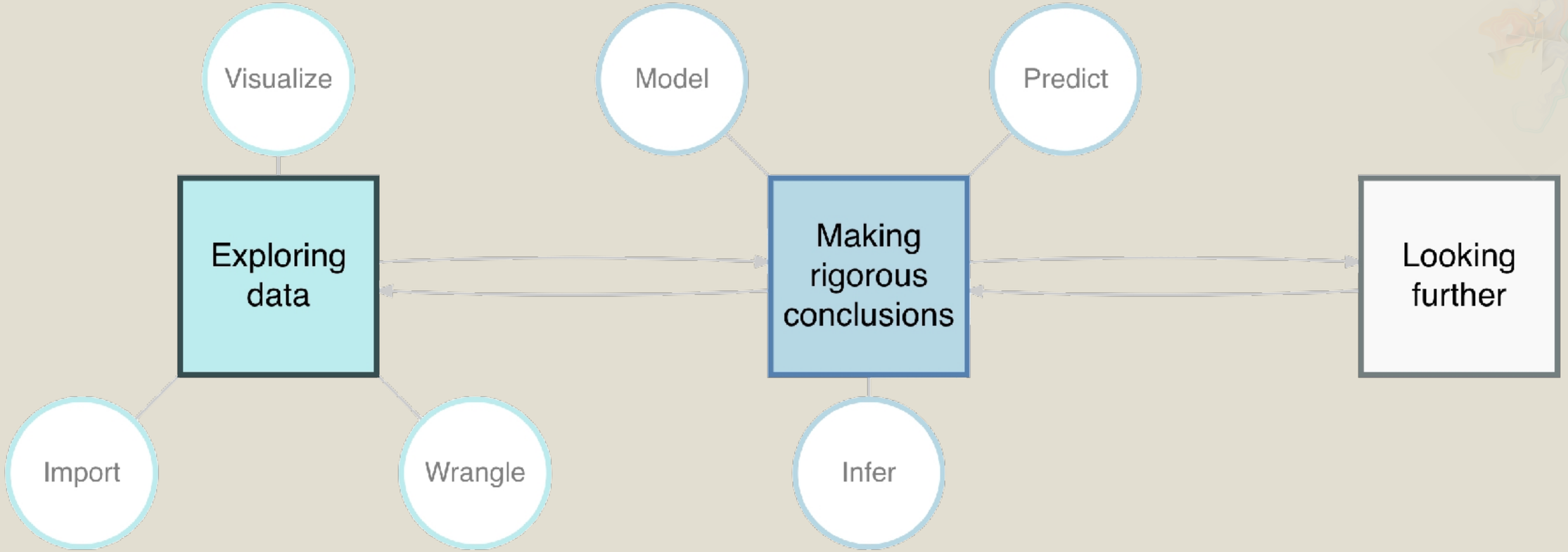
R / RStudio, R Markdown, simple Git

tidy data, data frames vs. summary tables, recoding & transforming, web scraping & iteration

+

collaboration on GitHub

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



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

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

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

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

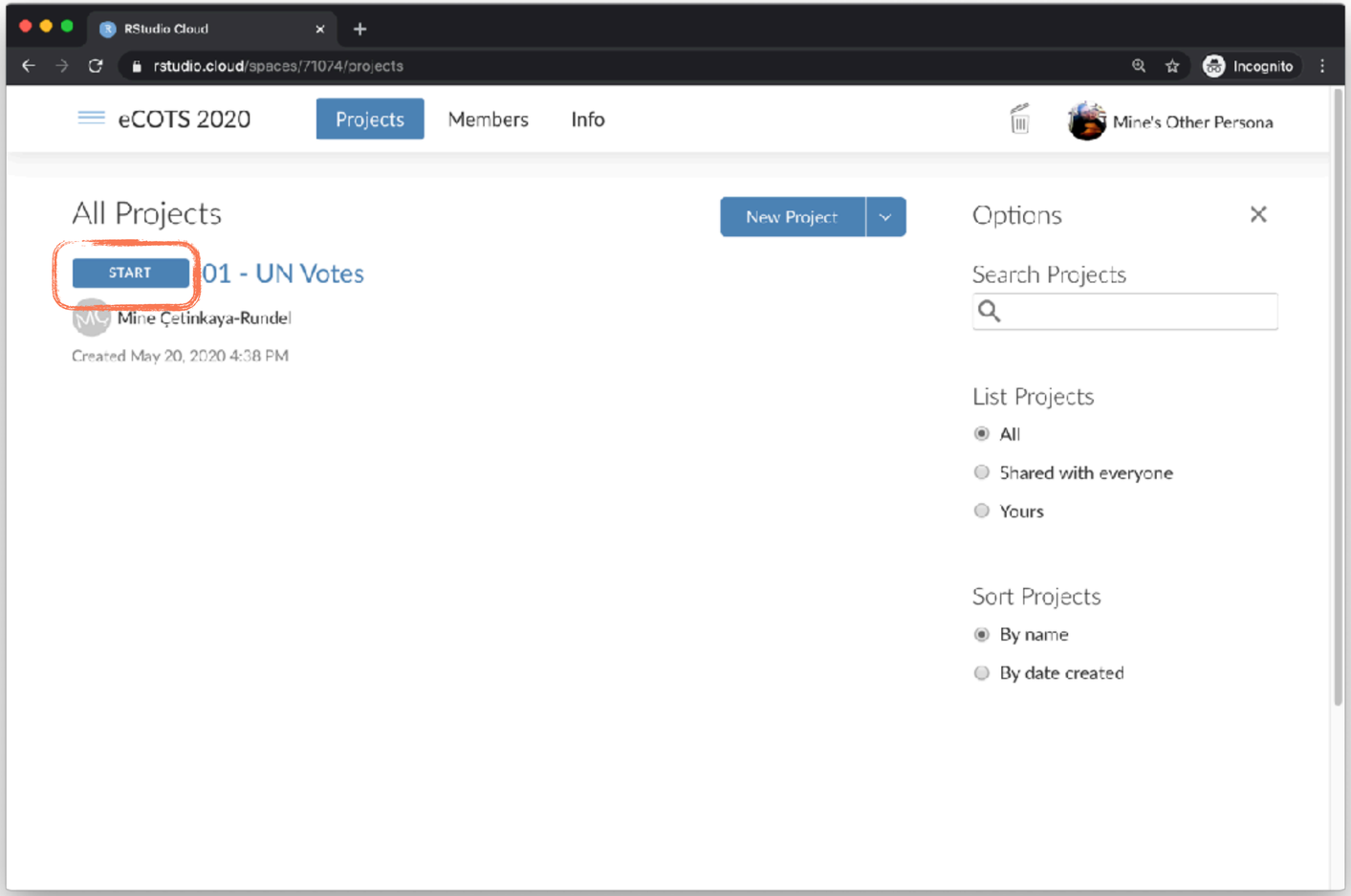
fundamentals of data & data viz, confounding variables, Simpson's paradox + R / RStudio, R Markdown, simple Git

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

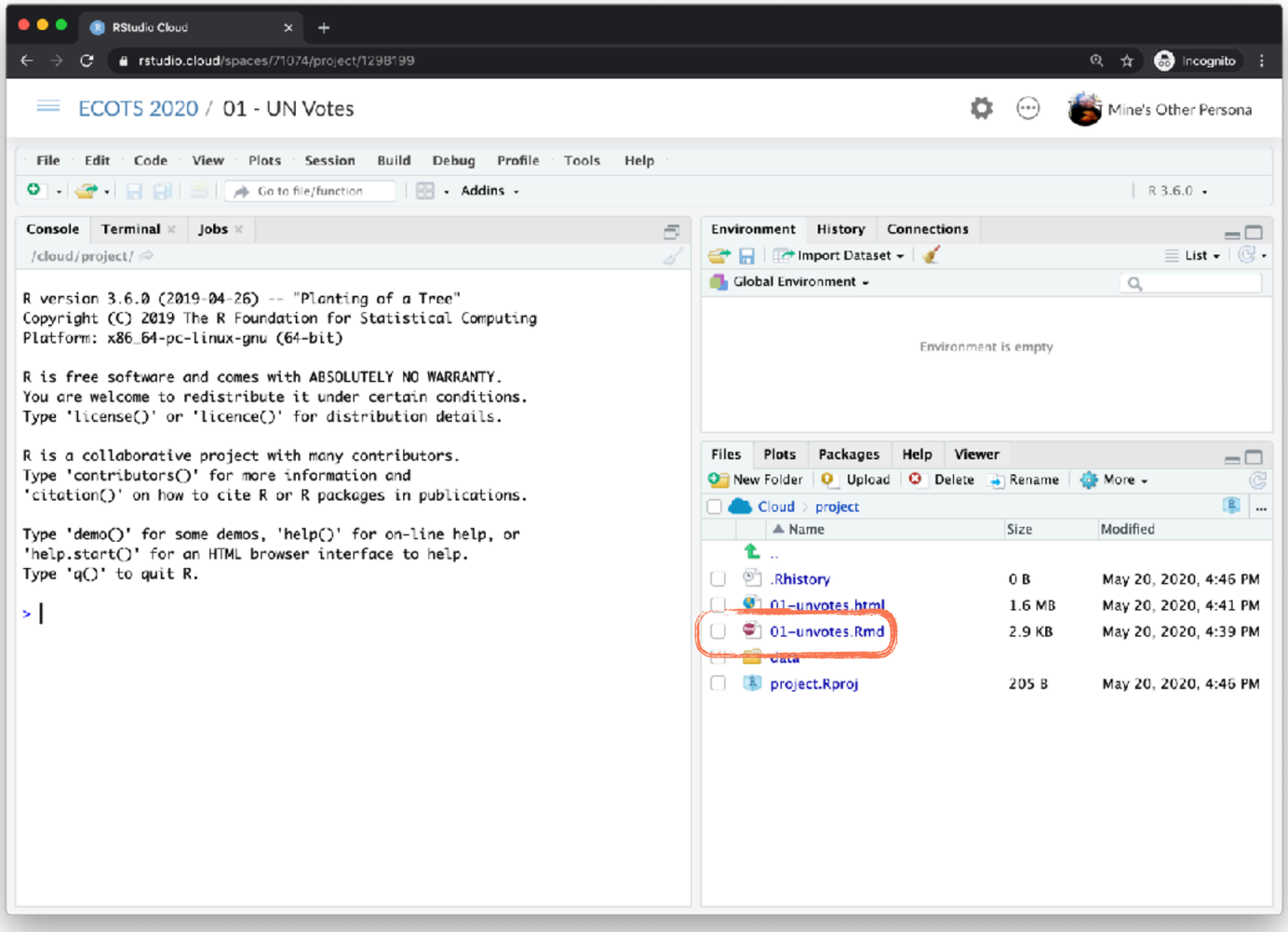
building & selecting models, visualising interactions, prediction & validation, inference via simulation

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

- Go to **bit.ly/rscloud-ecots2020**
- Start the project titled UN Votes



- Go to **bit.ly/rscloud-ecots2020**
- Start the project titled UN Votes
- Open the R Markdown document called `unvotes.Rmd`



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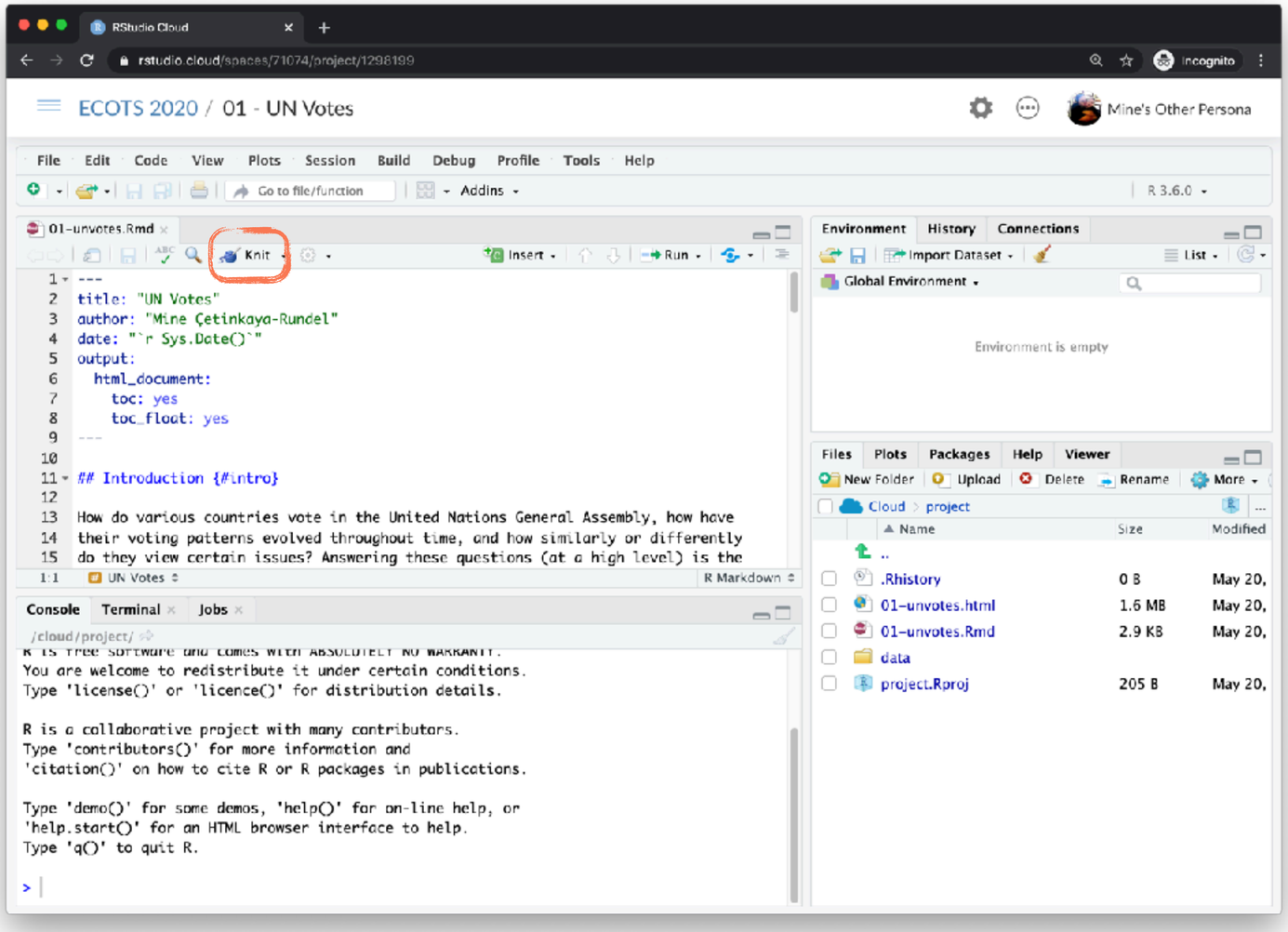
- Knit the document and review the data visualisation you just produced



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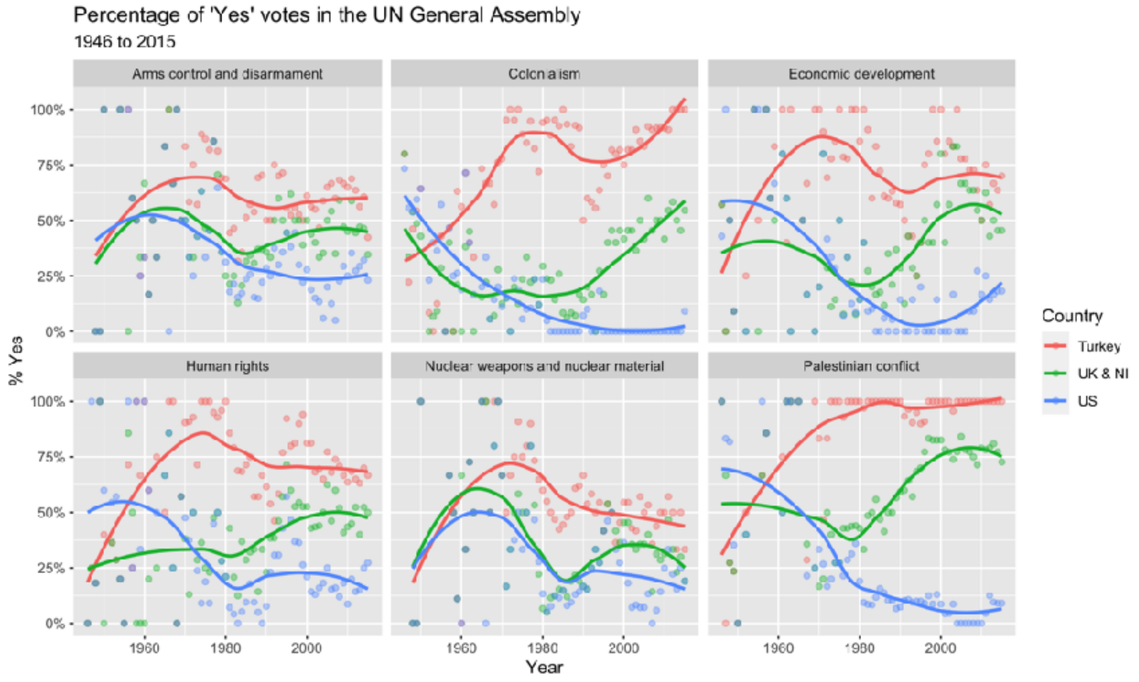
- Start the project titled UN Votes
- Open the R Markdown document called `unvotes.Rmd`
- Knit the document and review the data visualisation you just produced
- Then, look for the character string "Turkey" in the code and replace it with another country of your choice
- Knit again, and review how the 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

OpenSecrets.org
Center for Responsive Politics

SECTIONS
Top PACs ›
Top Recipients of PAC Money ›
Industry Breakdown ›
Leadership PACs ›
Super PACs ›
Search ›
Foreign-connected PACs ›
What is a PAC? ›

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

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
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

				Repubs
				$0
				$28,500
Advance Centers (Grupo Salinas)	Mexico/Grupo Salinas	$3,000	$1,000	$2,000
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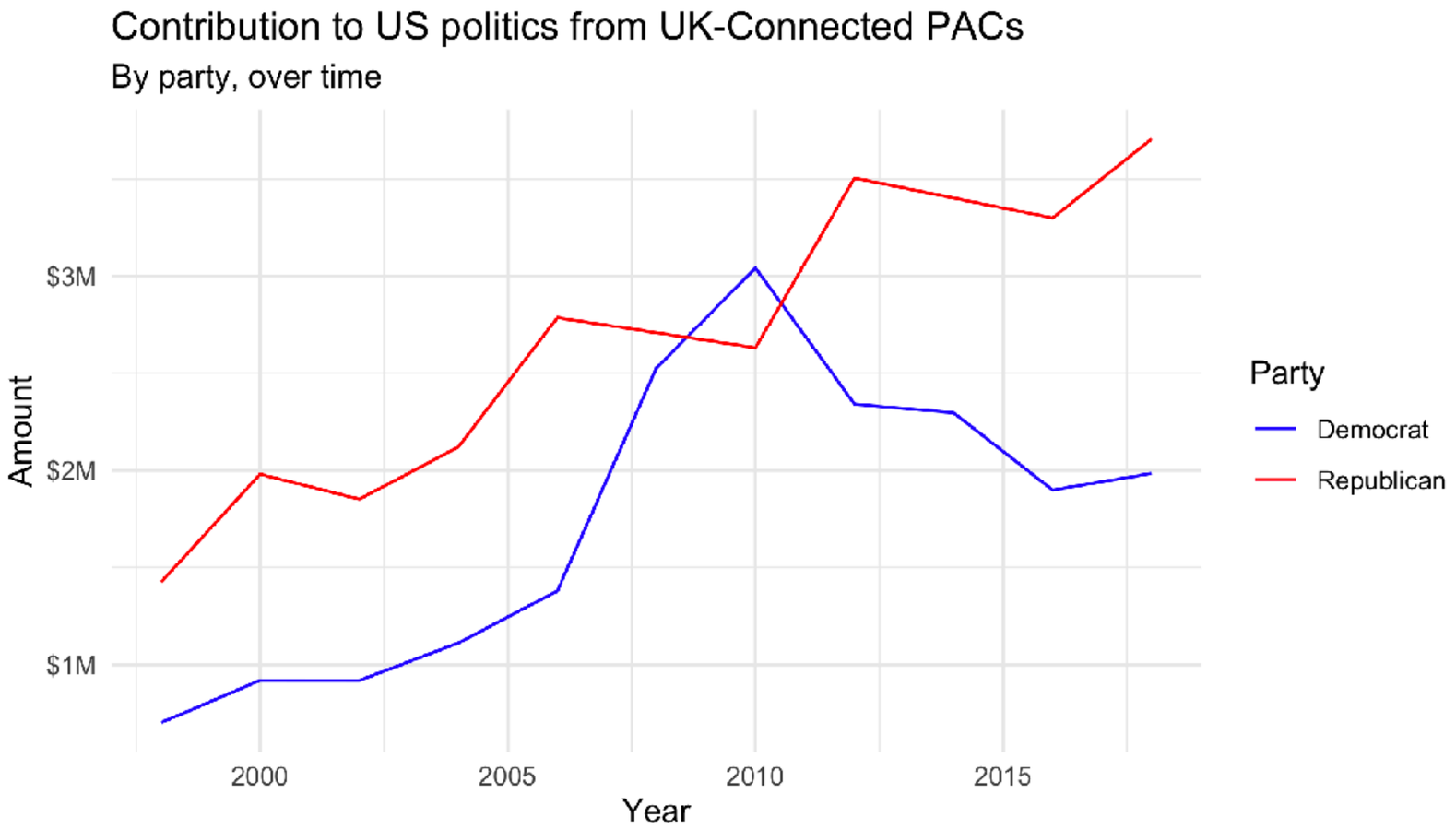
- ✳ web scraping
- ✳ text parsing
- ✳ data types
- ✳ regular expressions
- ✳ iteration



- 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

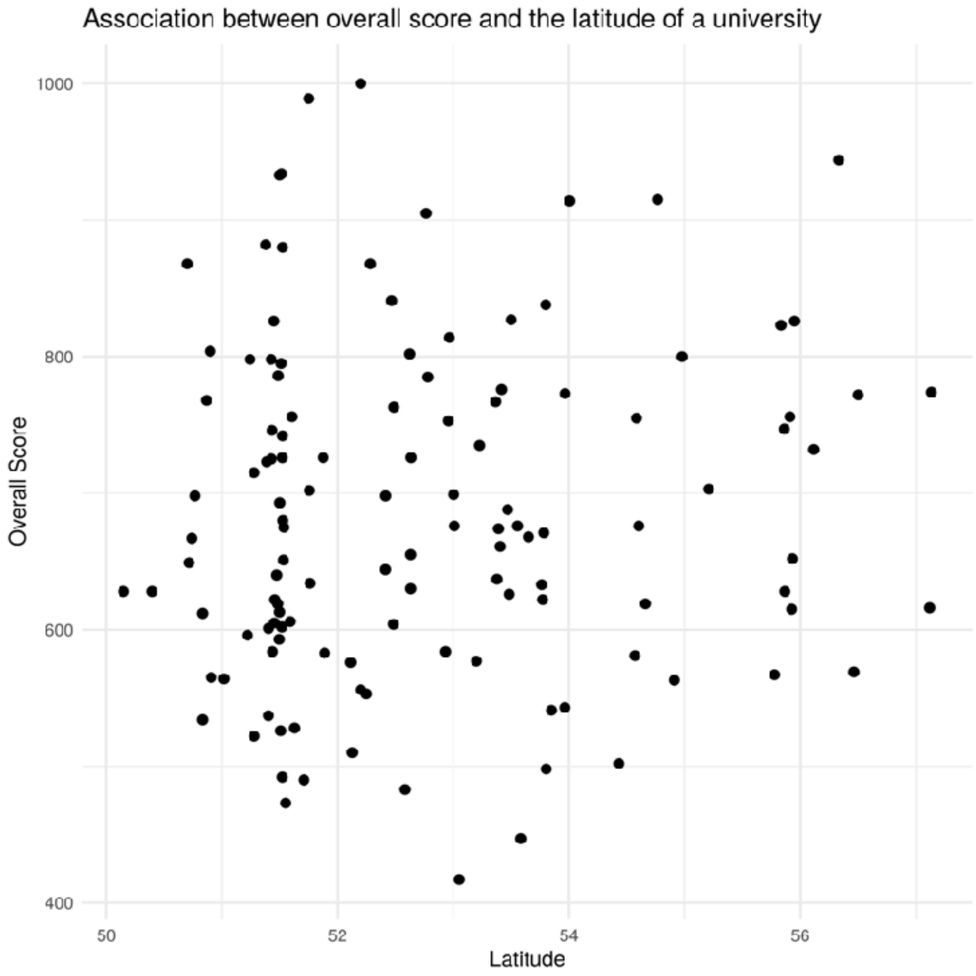
How to use | Methodology | Full Table | Print

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	944	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	194	4.01	3.14	84.8	915	PROFILE	COURSES

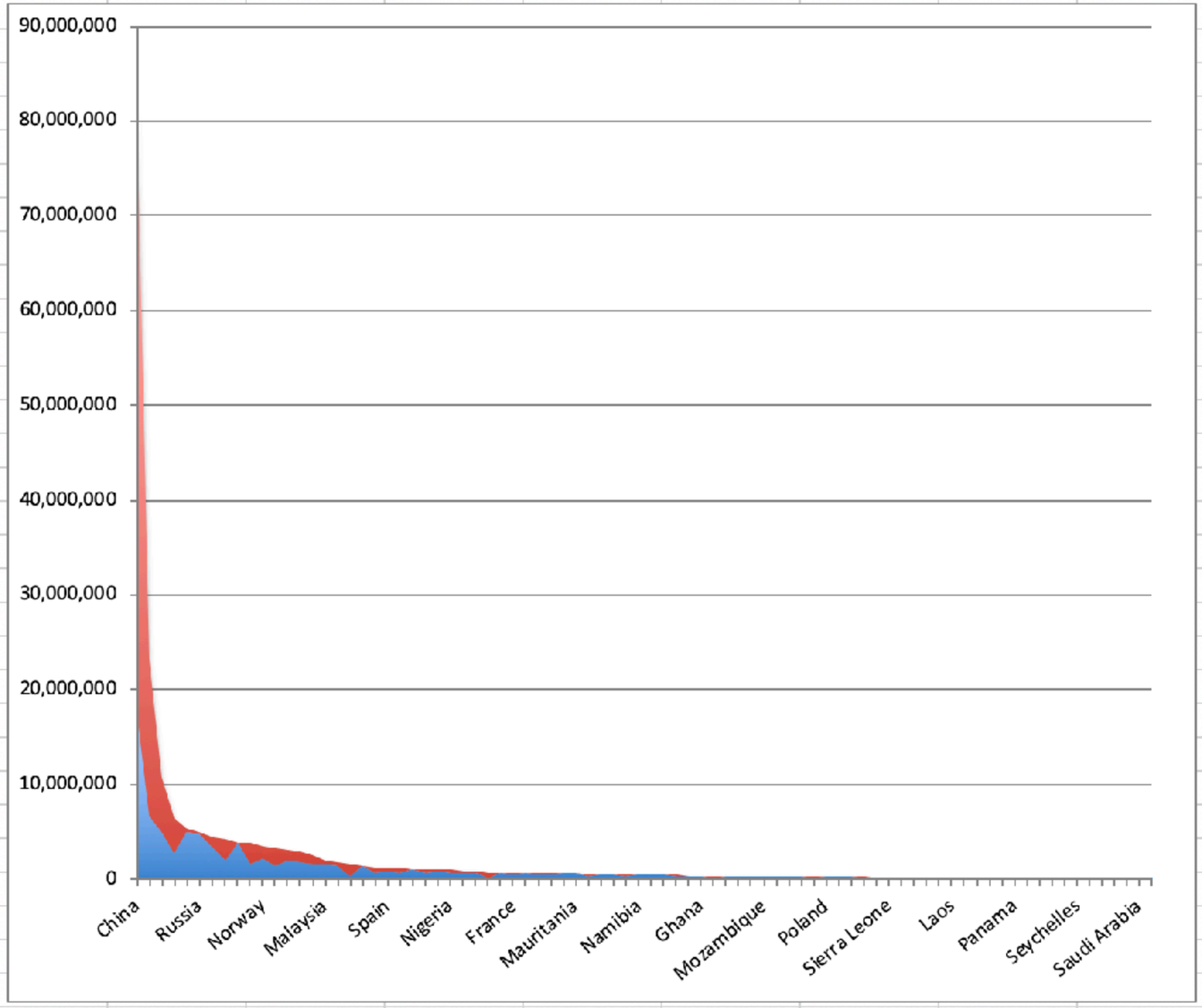


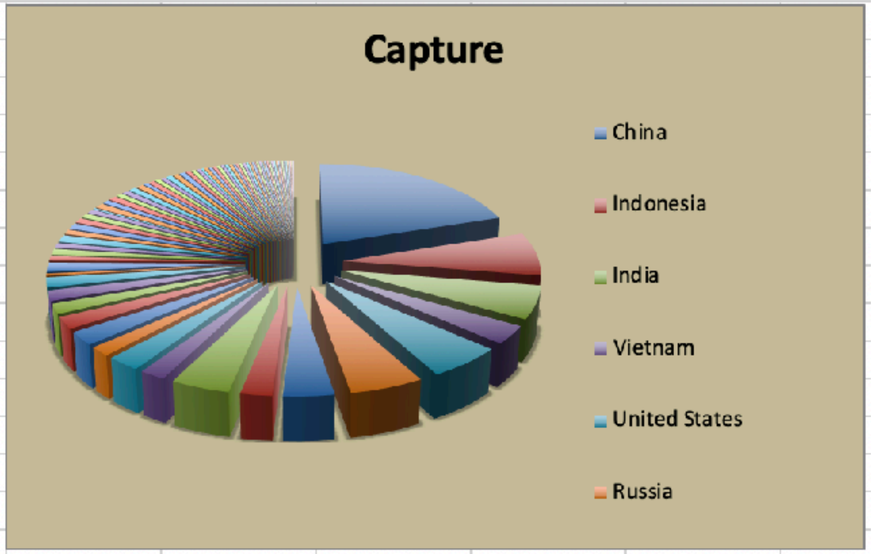
Resources

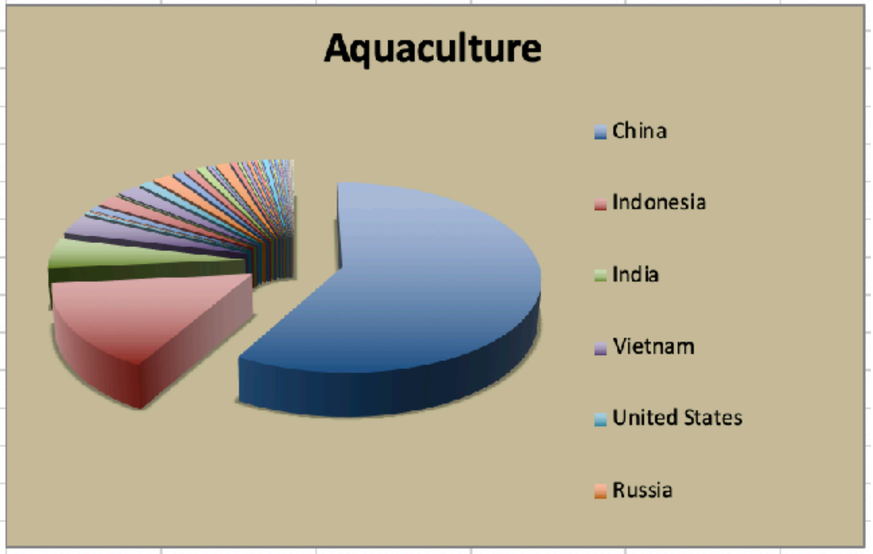
- **Sample assignment:** **introds.org/hw/hw-06/hw-06-money-in-politics.html**
- **Code:** Go to **bit.ly/rscloud-ecots2020**, start the project titled **02 - Money in politics**
- **Paper:** Web Scraping in the Statistics and Data Science Curriculum: Challenges and Opportunities (Dogucu & Çetinkaya-Rundel,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

ex. 2

fisheries of the world


90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
China
Russia
Norway
Malaysia
Spain
Nigeria
France
Mauritania
Namibia
Ghana
Mozambique
Poland
Sierra Leone
Laos
Panama
Seychelles
Saudi Arabia


Capture
China
Indonesia
India
Vietnam
United States
Russia


Aquaculture
China
Indonesia
India
Vietnam
United States
Russia

✳ data joins

```
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
```

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

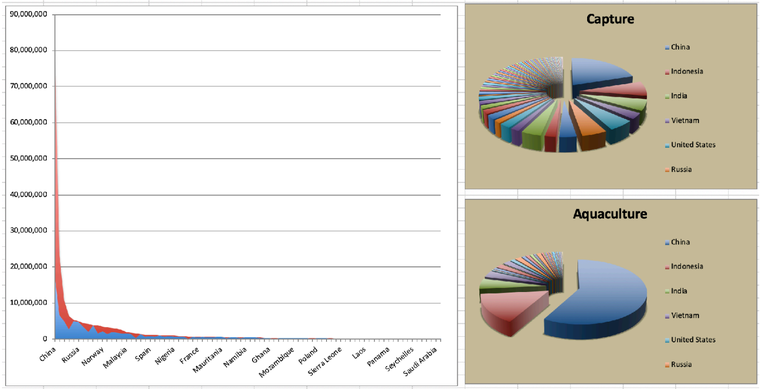
```
## Joining, by = "country"
```

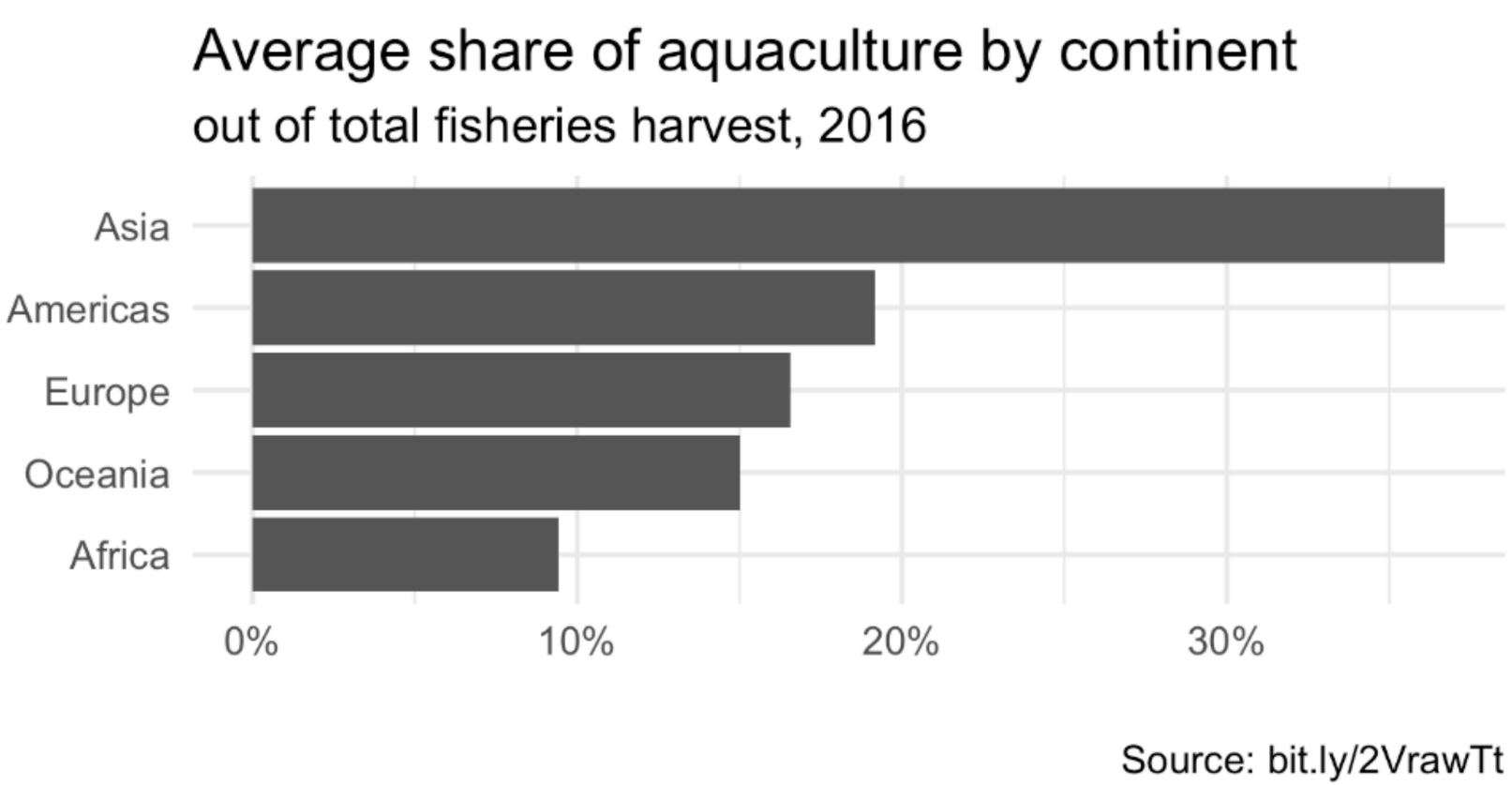
- data joins
- data science ethics

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

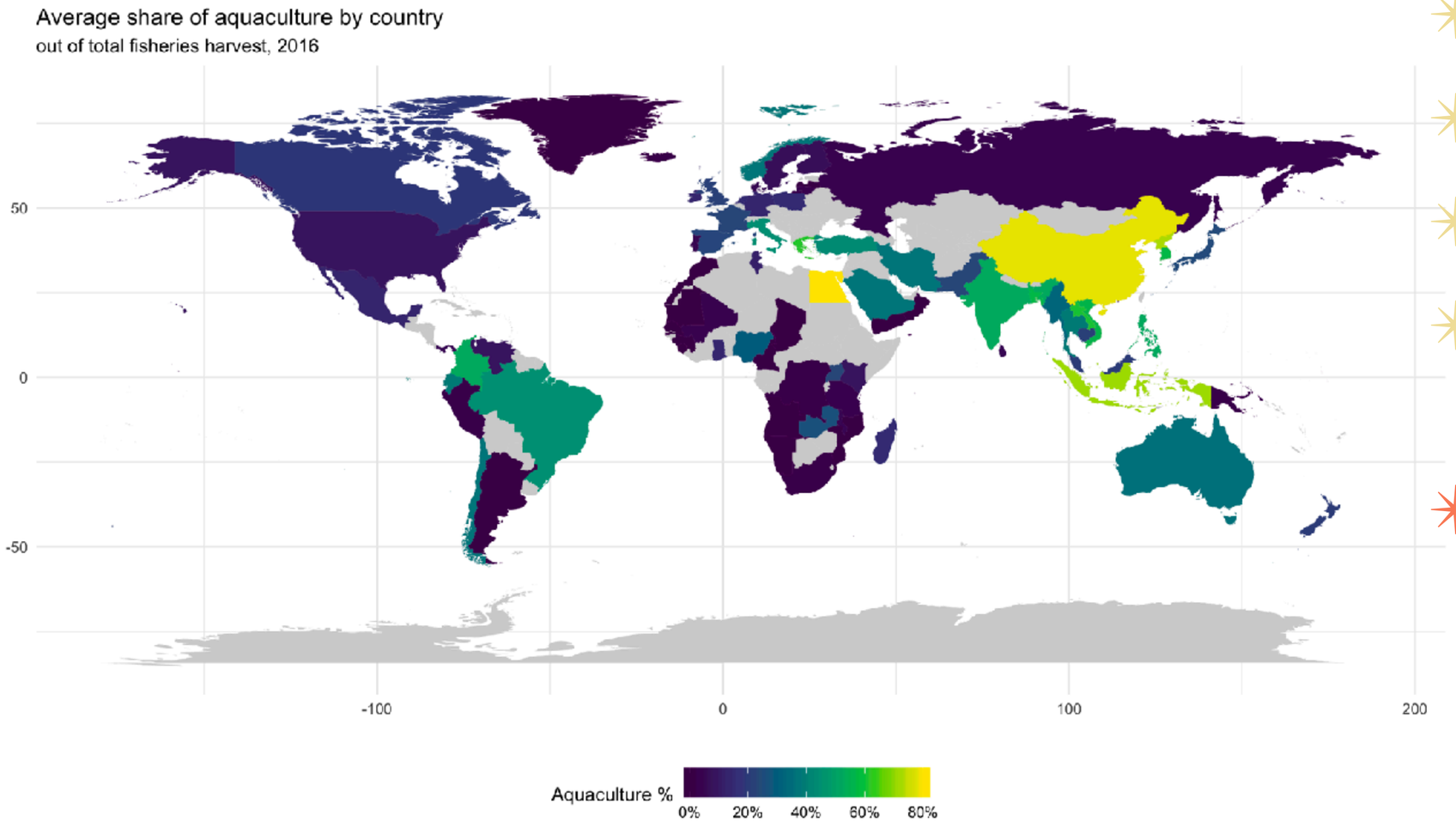
```
## # A tibble: 3 x 5
##   country                          capture aquaculture   total continent
##   <chr>                              <dbl>       <dbl>   <dbl> <chr>
## 1 Democratic Republic of the Congo  237372        3161  240533 <NA>
## 2 Hong Kong                         142775        4258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





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



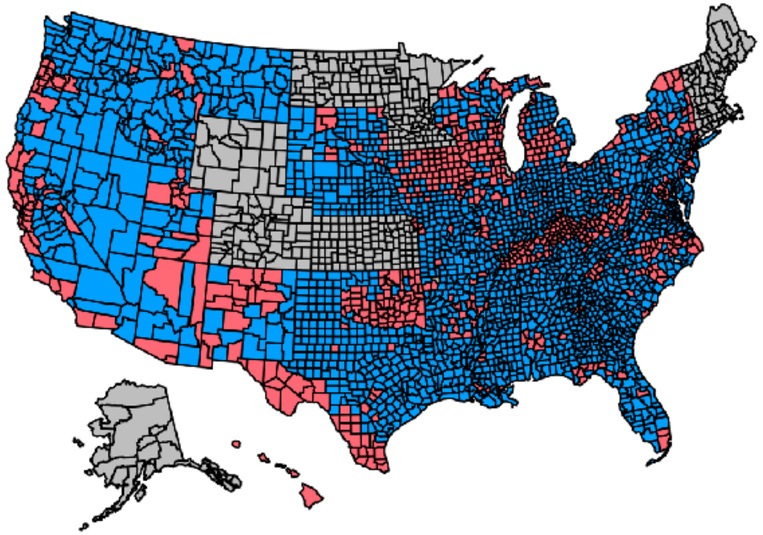
- data joins
- data science ethics
- critique
- improving data visualisations
- mapping

Project: 2016 US Election Redux

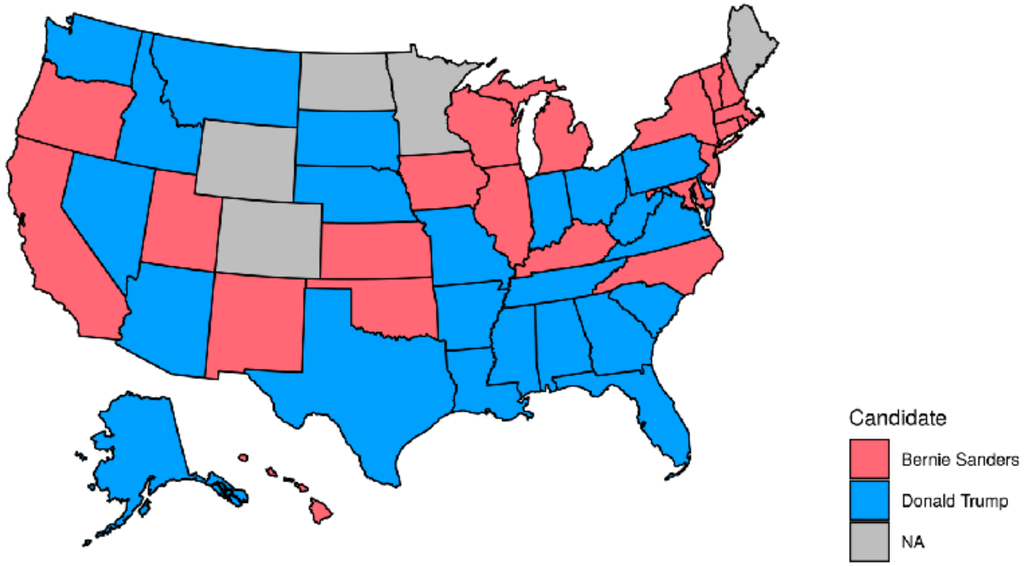
Question: Would the outcome of the 2016 US Presidential Elections been different had Bernie Sanders been the Democrat candidate?

Team: 4 Squared

Predicted Results
By County



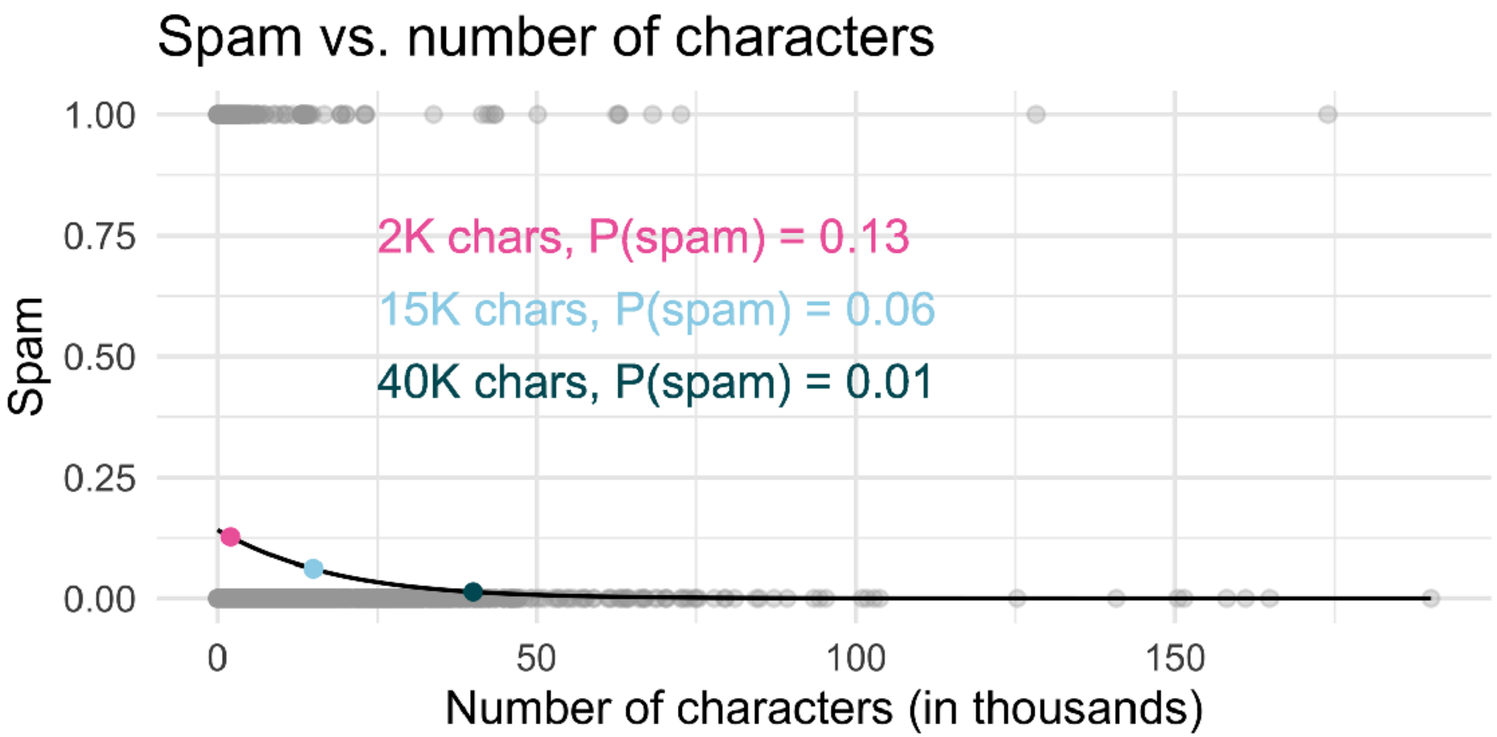
Predicted Results
By State



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



- logistic regression
- prediction

	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

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

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 regres

minecr.shinyapps.io/07-modeling-simple/#section-finish-up

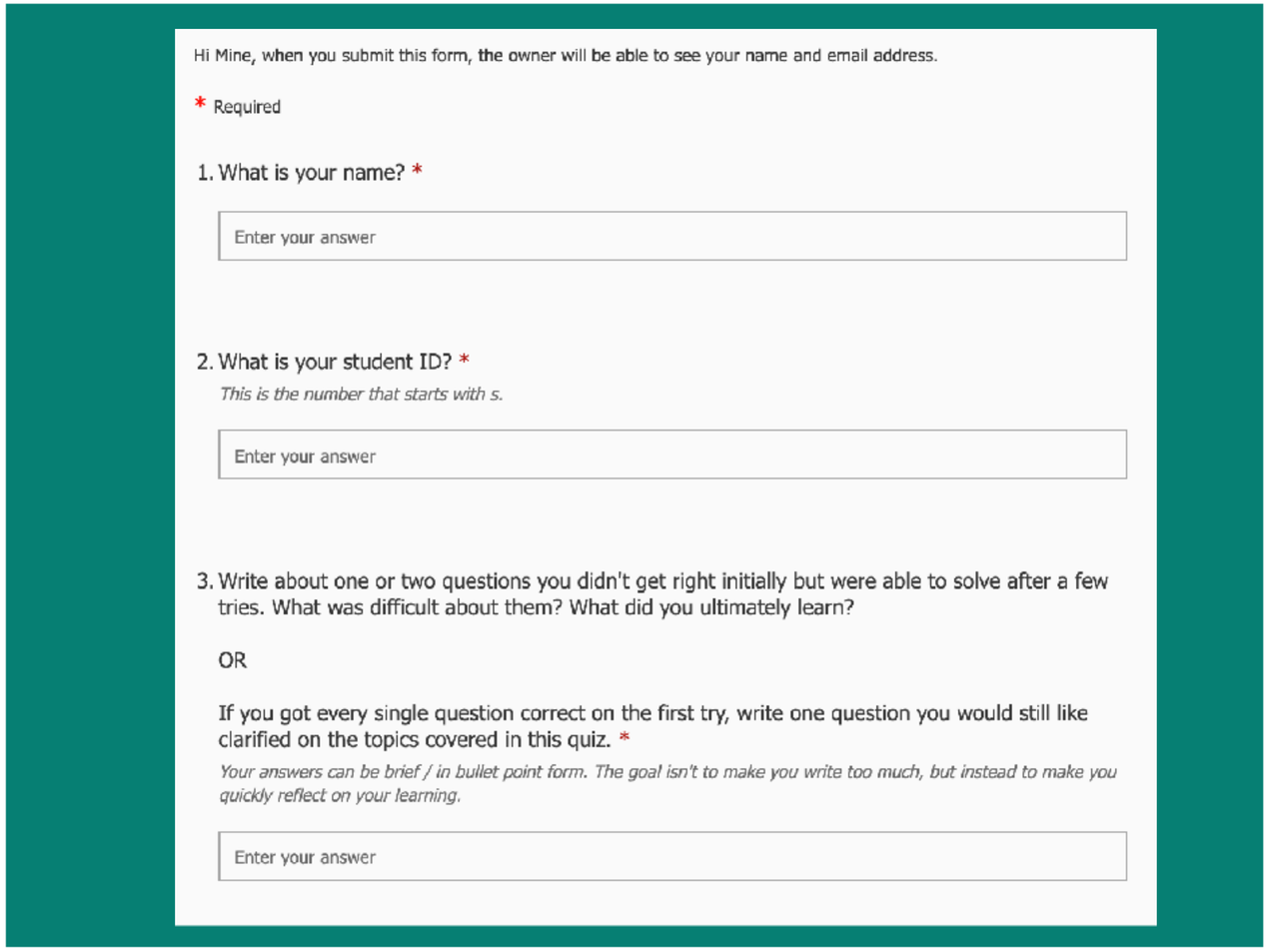
Week 07 - Simple linear regression

- 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.

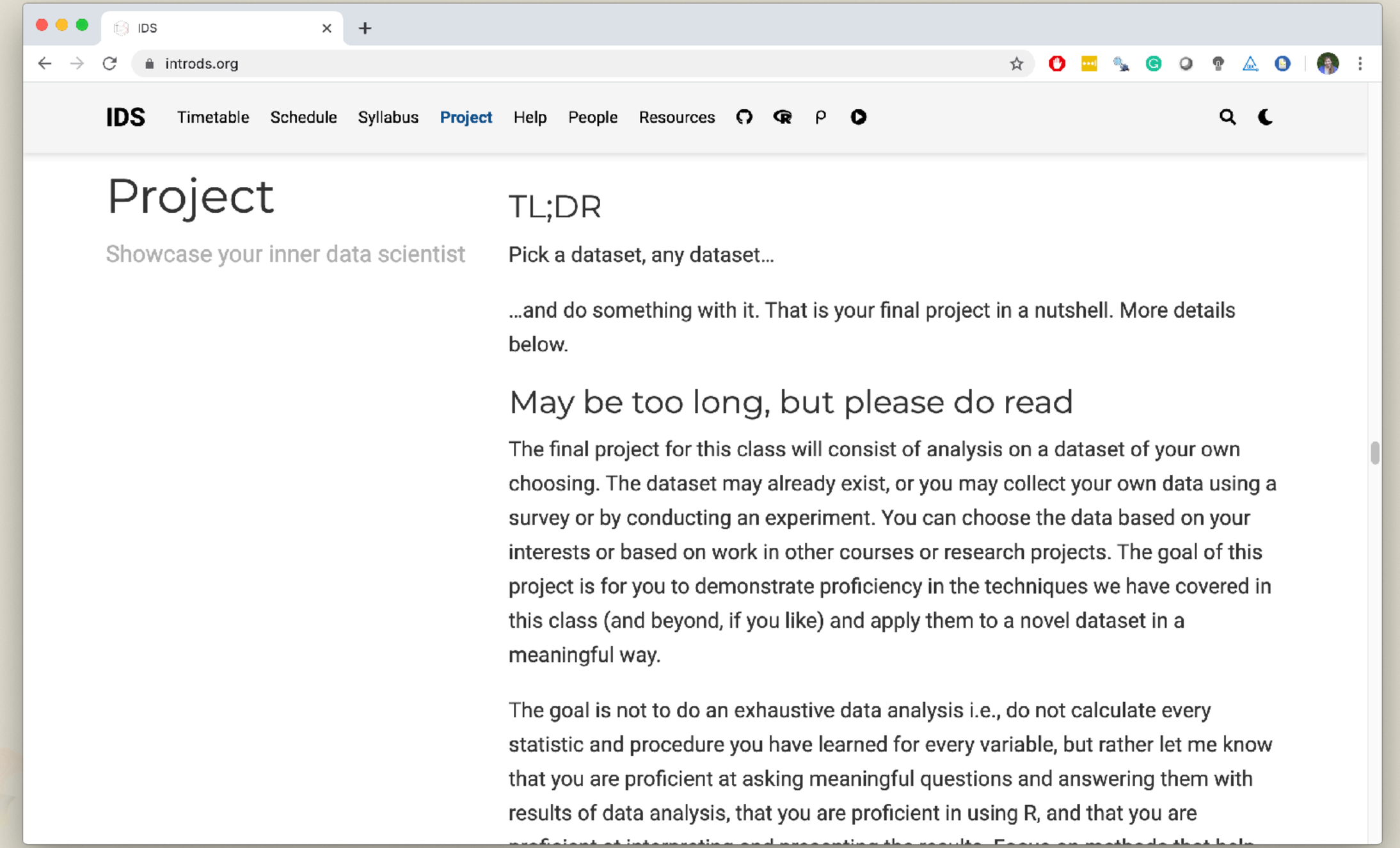
Enter your answer

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

peer feedback: used minimally so far, but positive experience

creativity: assignments that make room for creativity

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

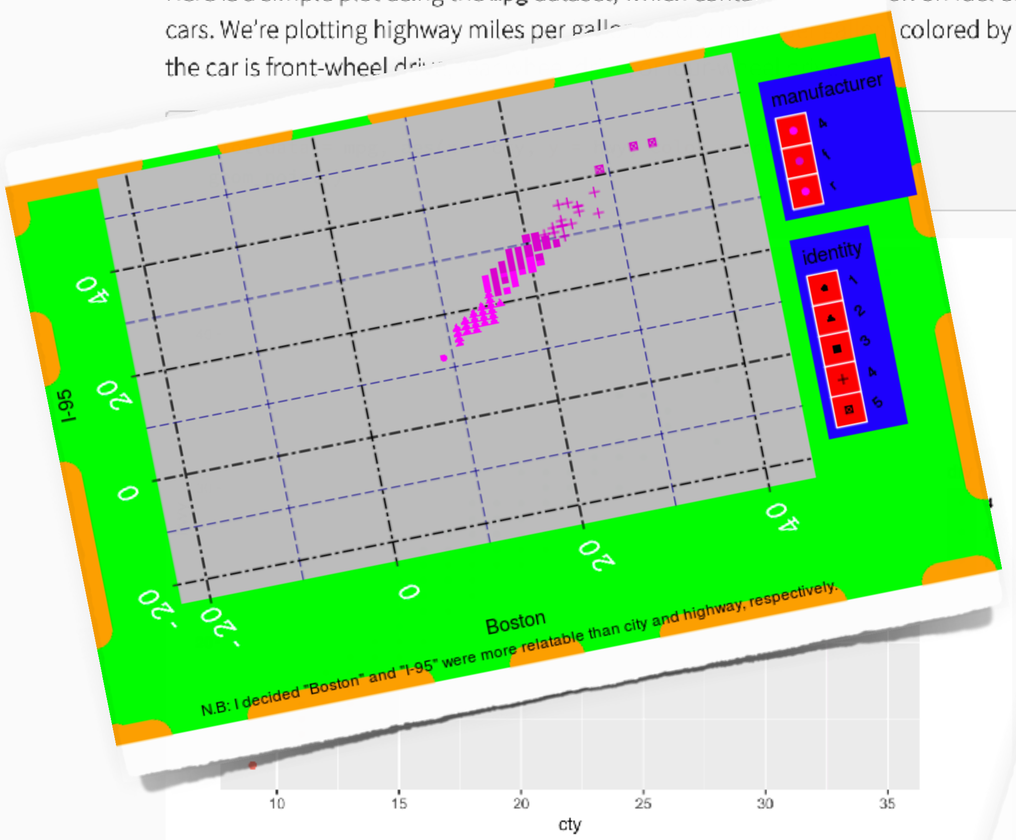

IDS
introds.org
IDS
Timetable
Schedule
Syllabus
Project
Help
People
Resources
Project
Showcase your inner data scientist
TL;DR
Pick a dataset, any dataset...
...and do something with it. That is your final project in a nutshell. More details below.
May be too long, but please do read
The final project for this class will consist of analysis on a dataset of your own choosing. The dataset may already exist, or you may collect your own data using a survey or by conducting an experiment. You can choose the data based on your interests or based on work in other courses or research projects. The goal of this project is for you to demonstrate proficiency in the techniques we have covered in this class (and beyond, if you like) and apply them to a novel dataset in a meaningful way.
The goal is not to do an exhaustive data analysis i.e., do not calculate every statistic and procedure you have learned for every variable, but rather let me know that you are proficient at asking meaningful questions and answering them with results of data analysis, that you are proficient in using R, and that you are

HW 10 - Wrap up!

introds.org/hw/hw-10/hw-10-wrap-up.html

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 inf on on fuel economy of cars. We're plotting highway miles per gall colored by whether the car is front-wheel dri



Exercise 11. Make this plot as ugly as possible by changing colors, backgr color, fonts, or anything else you can think of. You will probab 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.

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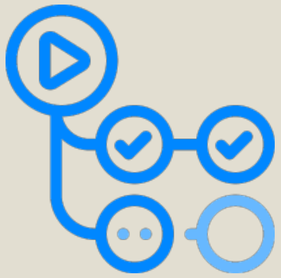
infrastructure

RStudio Cloud

+

ghclass +



Code | Issues 0 | Pull requests 1 | Projects 0 | Wiki | Security | Insights | Settings

styler revisions #1

Edit

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 ℹ
──────────────────────────────────────
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

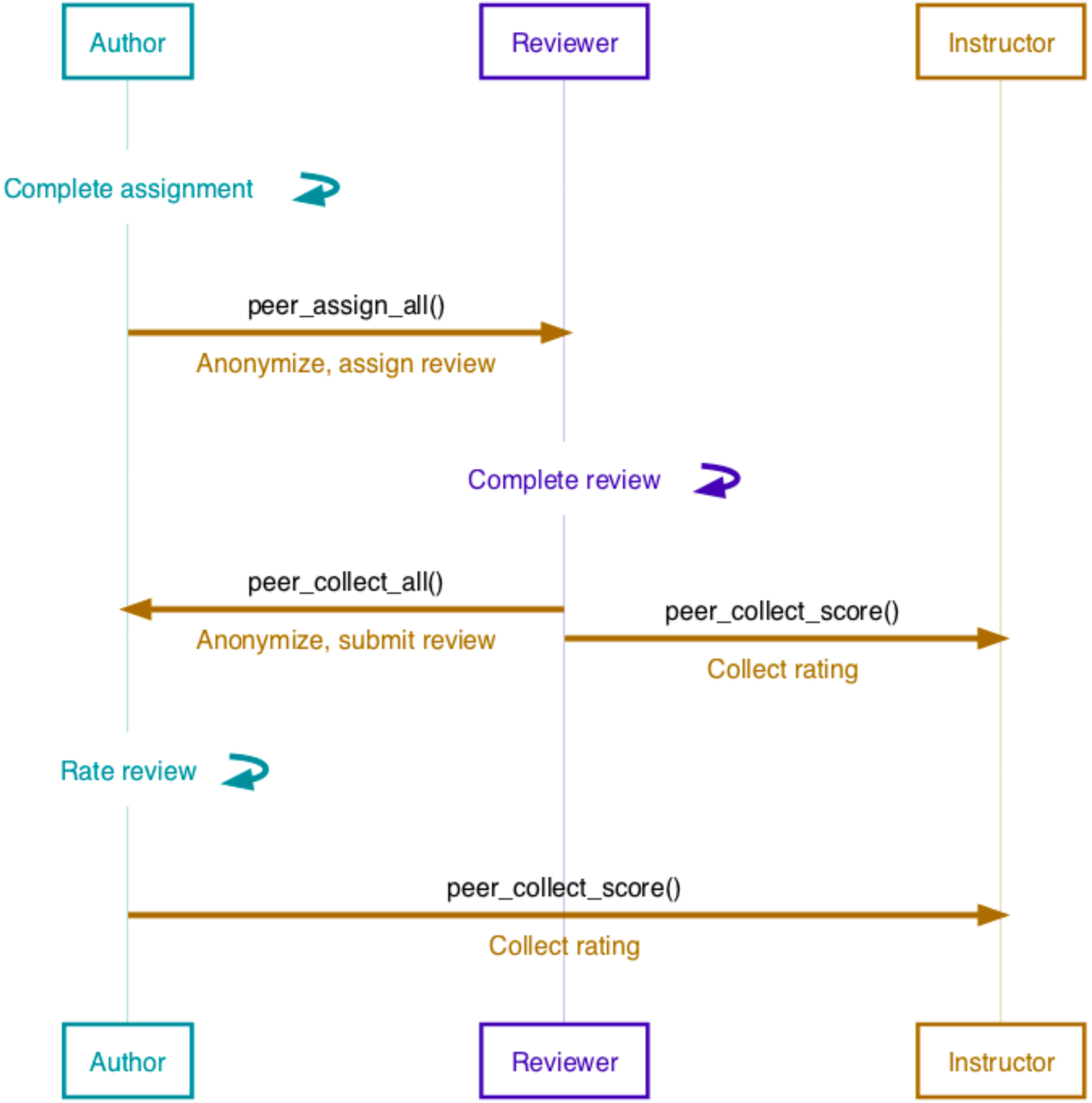
```
@@ -7,7 +7,7 @@ output: github_document
```

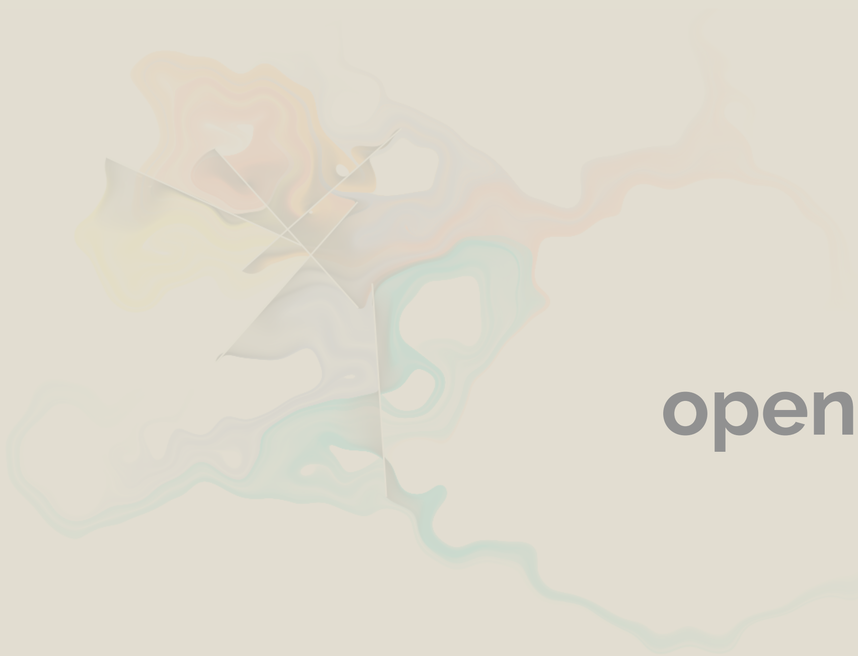
```
-```{r load-packages, message=FALSE}
-# load packages
-library(tidyverse)
```

```
+```{r load-packages, message=FALSE}
+# load packages
+library(tidyverse)
```

+

ghclass


Author
Reviewer
Instructor
Complete assignment
peer_assign_all()
Anonymize, assign review
Complete review
peer_collect_all()
Anonymize, submit review
peer_collect_score()
Collect rating
Rate review
peer_collect_score()
Collect rating
Author
Reviewer
Instructor



openness

IDS

introds.org

Incognito

IDS Timetable Schedule Syllabus Project Help People Resources

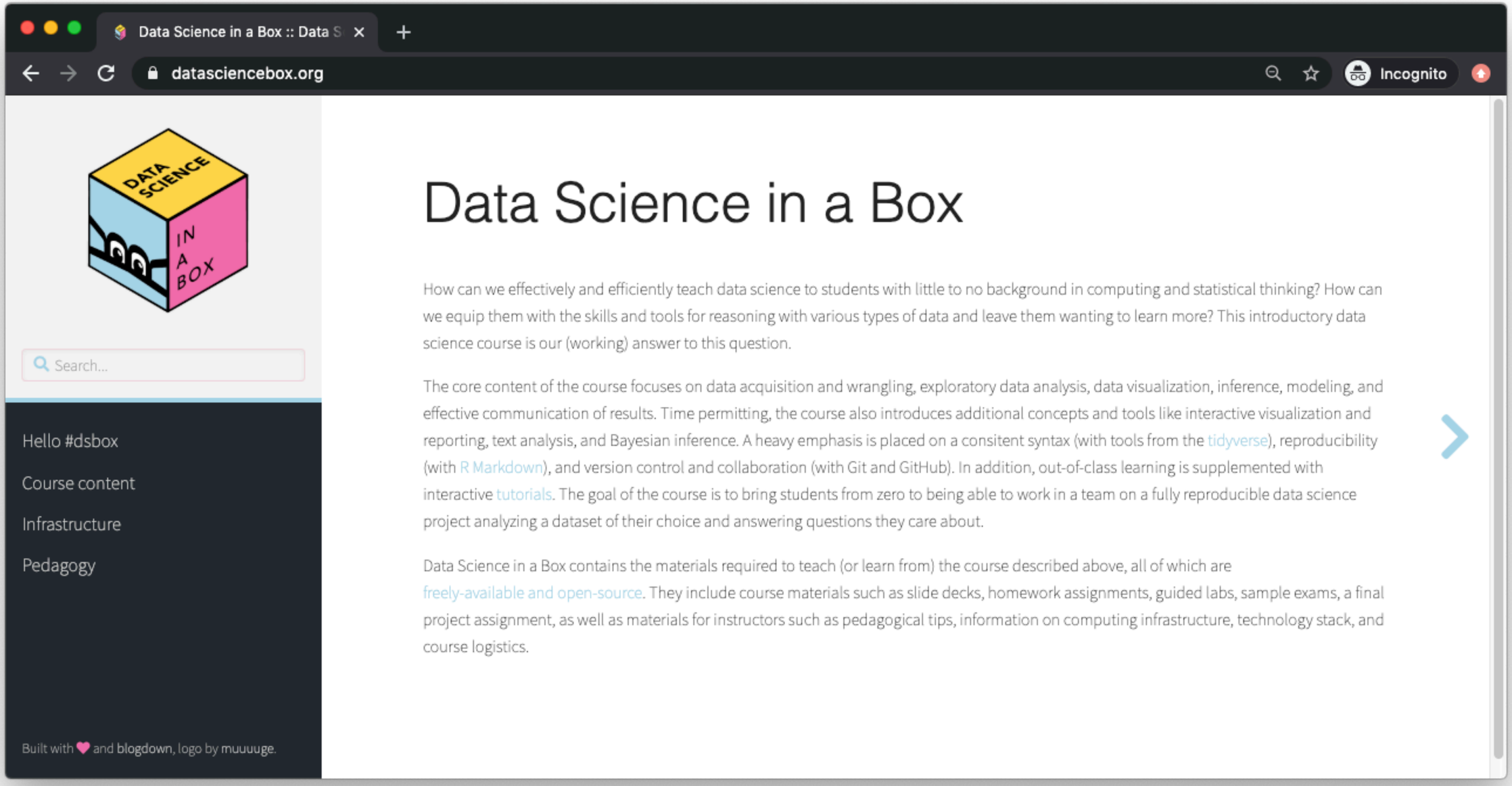
Introduction to Data Science

Fall 2019

University of Edinburgh

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.


Data Science in a Box :: Data S
datasciencebox.org
Incognito
DATA SCIENCE
IN A BOX
Search...
Hello #dsbox
Course content
Infrastructure
Pedagogy
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 consitent 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.

the art and science of teaching data science

mine çetinkaya-rundel

bit.ly/introds-ecots2020


@minebocek


mine-cetinkaya-rundel


mcetinka@ed.ac.uk


university of edinburgh

Image credit:
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?

i**n 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.

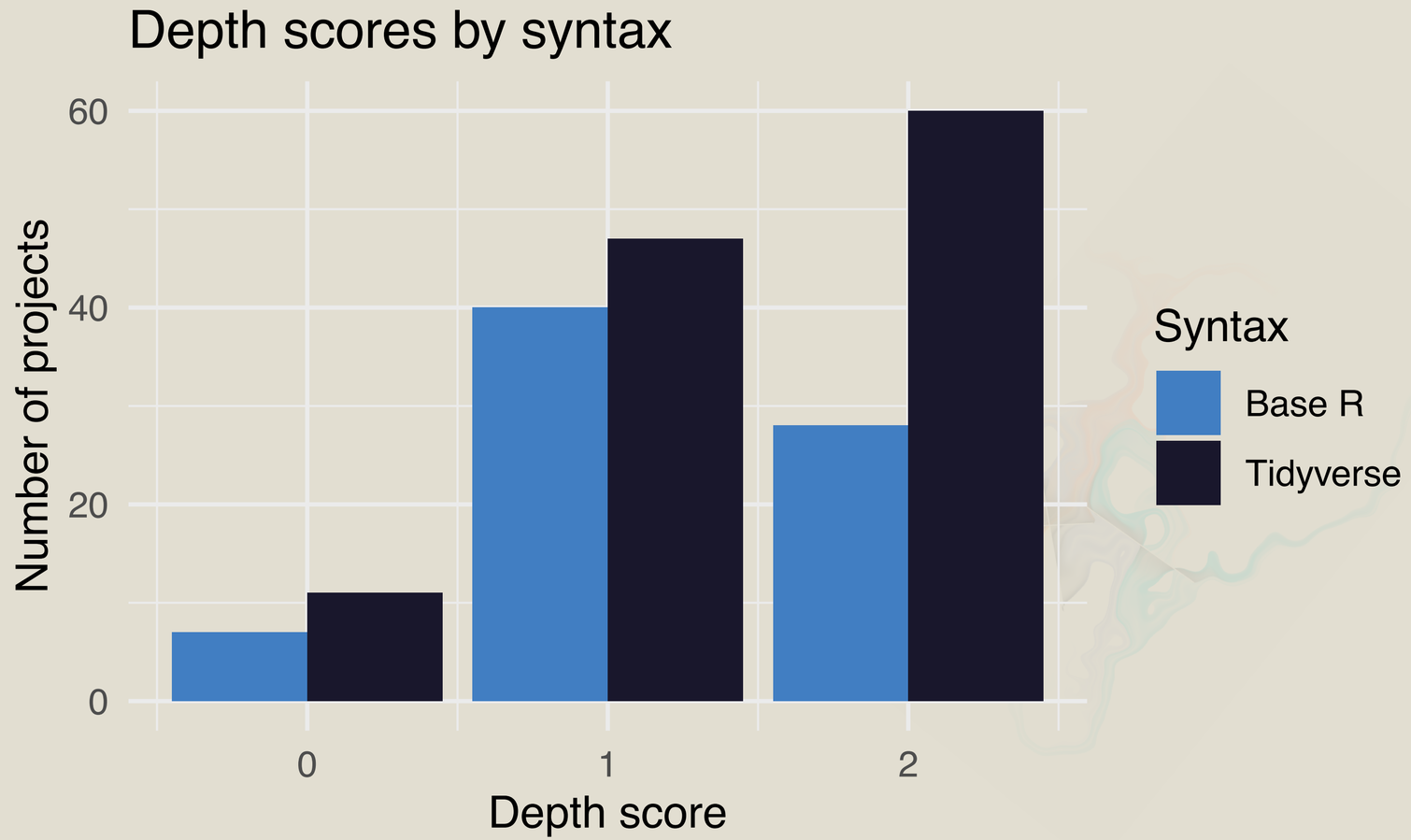
same assignment, same(ish) dataset

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

depth

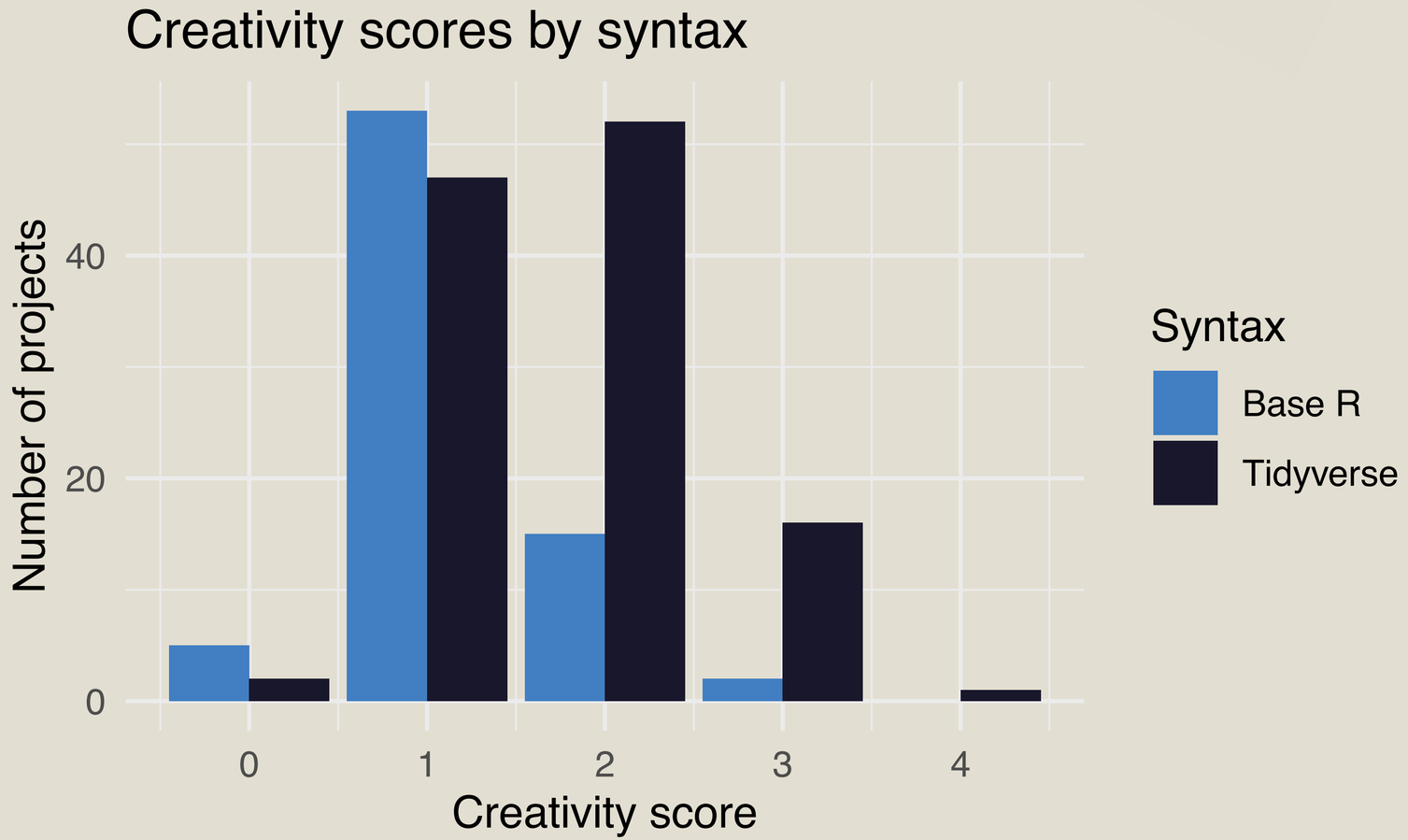
- consistent theme throughout the project

- relevant data for each analysis



creativity

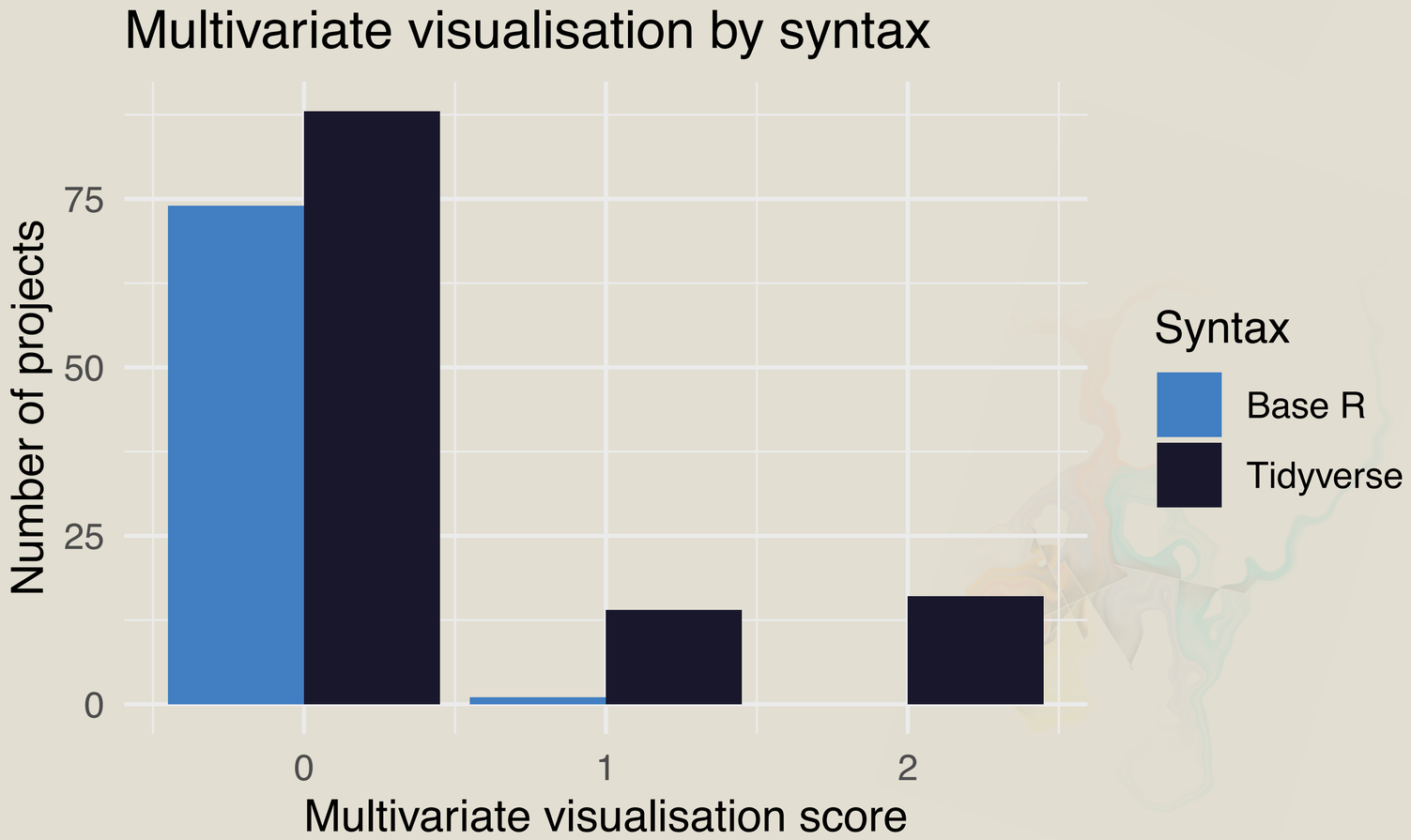
- creation of new variables
- transformation of existing variables
- subgroup analysis
- use of a subset of data for the entire project



multivariate visualisation

- visualisation with 3+ variables

- effective interpretations of visualisations



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