01
curriculum design

teaching data science

rstd.io/teach-ds-jsm19

Let them eat cake (first)!

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rstd.io/teach-ds-jsm19

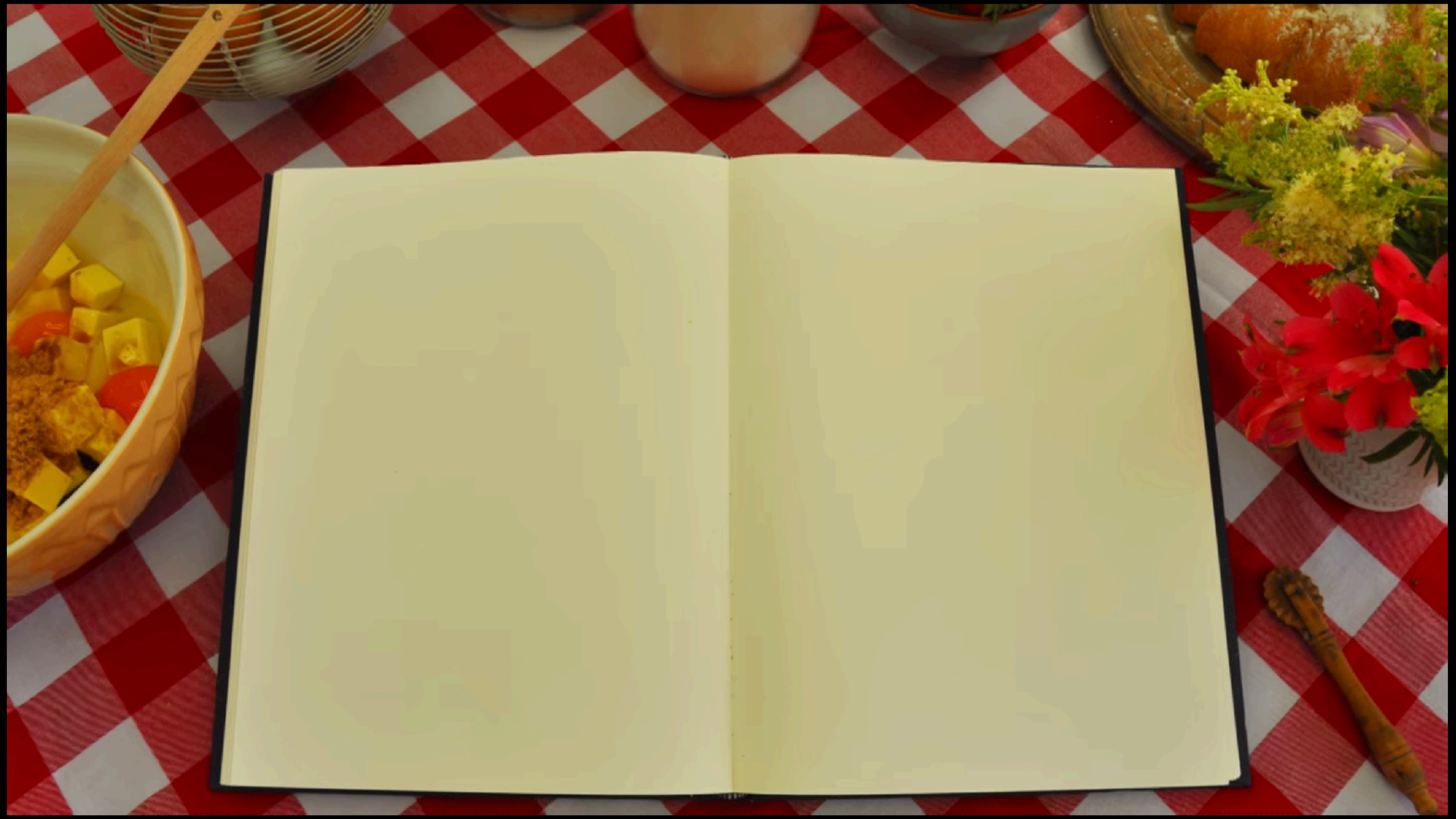
Which of the following gives you a **better sense** of the final product?

Pineapple and Coconut Sandwich Cake

Pineapple and Coconut Sandwich Cake

Pineapple and Coconut Sandwich Cake

rstd.io/teach-ds-jsm19



(a) Pineapple and Coconut Sandwich Cake

(b)

(c) <with audio>

(d)

start with cake

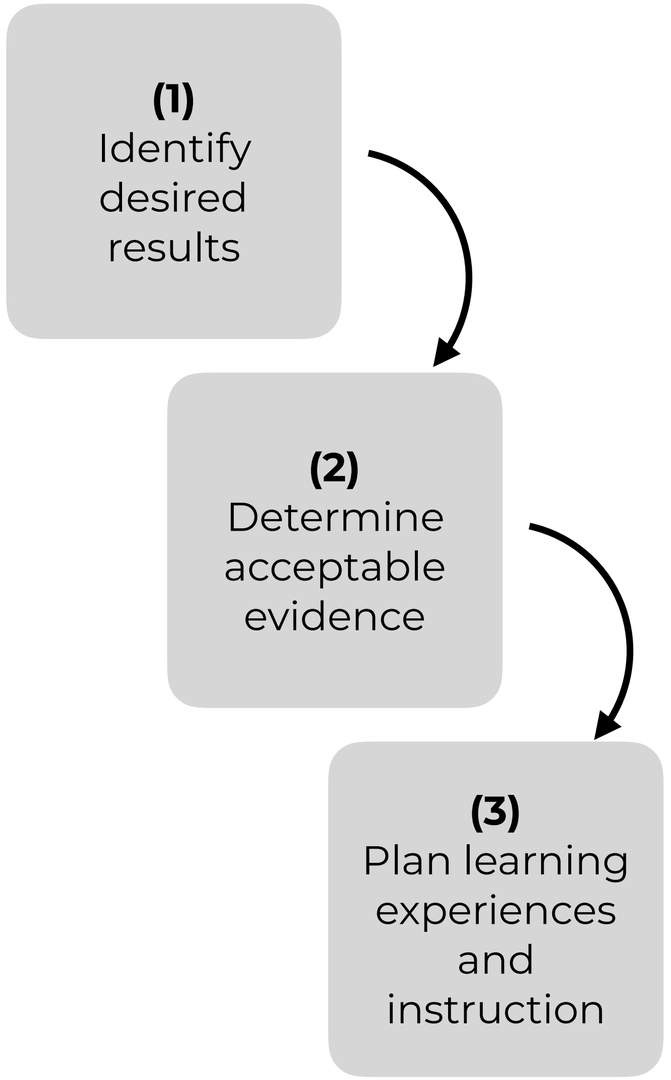
Backward design

set goals for educational curriculum before choosing instructional methods + forms of assessment

🎯

analogous to travel planning - itinerary deliberately designed to meet cultural goals, not purposeless tour of all major sites in a foreign country

🗺️



Wiggins, Grant P., Grant Wiggins, and Jay McTighe. *Understanding by design*. Ascd, 2005.

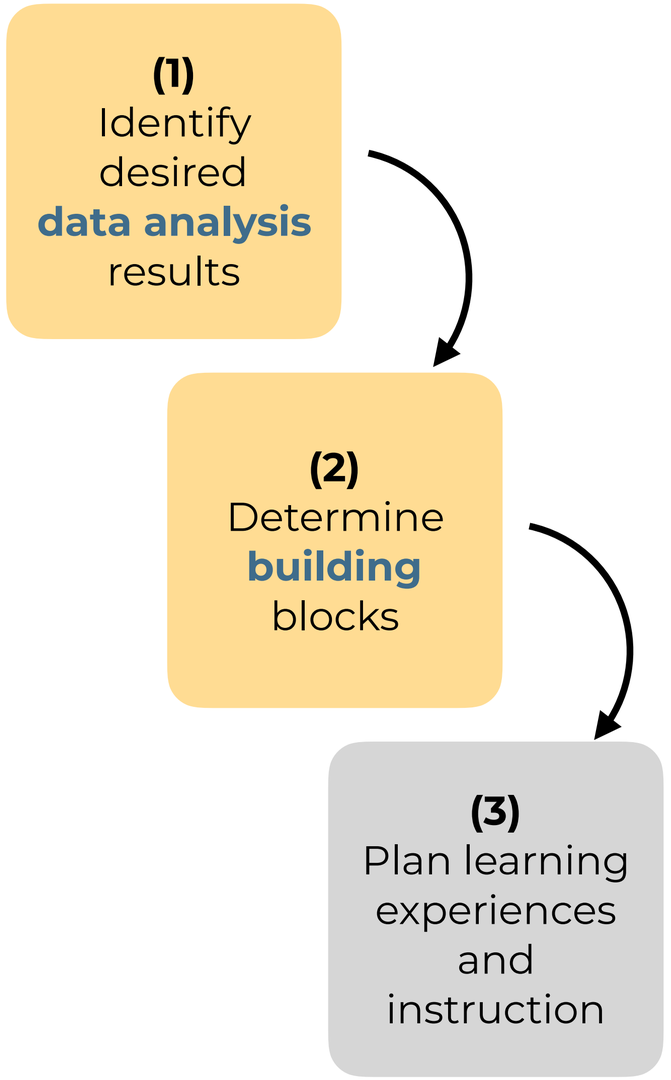
Designing backwards

students are first exposed to results and findings of a data analysis

👀

and then learn the building blocks of the methods and techniques used along the way

✍️



Context

assumes no background

focuses on EDA + modeling & inference + modern computing

uses R as the statistical programming language

requires reproducibility

emphasizes collaboration + effective communi-cation

GAISE 2016

1. Teach statistical thinking.

   a. **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.

   b. **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 a purpose.
4. Foster active learning.
5. Use technology to explore concepts and analyze data.
6. Use assessments to improve and evaluate student learning.

GAISE 2016, http://www.amstat.org/asa/files/pdfs/GAISE/GaiseCollege_Full.pdf.

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

(2) Multivariate analysis requires the use of computing

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

(4) Data analysis isn't just inference and modeling, it's also data importing, cleaning, preparation, exploration, and visualization

ex 1.

visualization

Which of the following is more likely to be **motivating** for a wide range of students?

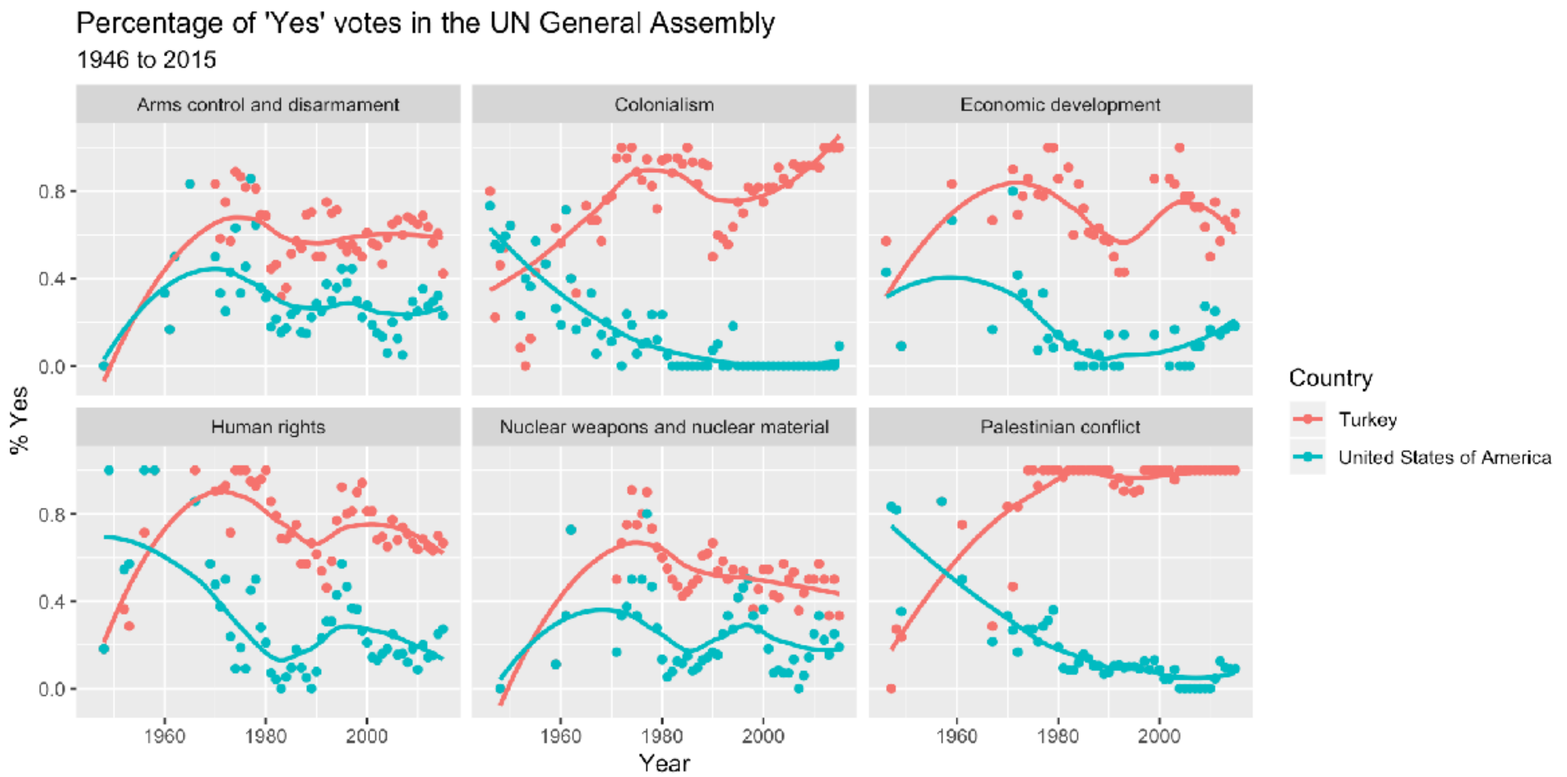
(a)

- Declare the following variables
- Then, determine the class of each variable

```
# Declare variables
x ← 8
y ← "monkey"
z ← FALSE

# Check class of x
class(x)
#> [1] "numeric"

# Check class of y
class(y)
#> [1] "character"

# Check class of z
class(z)
#> [1] "logical"
```

(b)

- Open today's demo project
- Knit the document and discuss the results with your neighbor



- Then, change `Turkey` to a different country, and plot again

with great examples,

comes a great amount of code...

but let's focus on the task at hand...

- Open today's demo project
- Knit the document and discuss the results with your neighbor
- Then, change `Turkey` to a different country, and plot again

```r
un_votes %>%
  filter(country %in% c("United States of America", "Turkey")) %>%
  inner_join(un_roll_calls, by = "rcid") %>%
  inner_join(un_roll_call_issues, by = "rcid") %>%
  group_by(country, year = year(date), issue) %>%
  summarize(
    votes = n(),
    percent_yes = mean(vote == "yes")
    ) %>%
  filter(votes > 5) %>%  # only use records where there are more than 5 votes
  ggplot(mapping = aes(x = year, y = percent_yes, color = country)) +
    geom_point() +
    geom_smooth(method = "loess", se = FALSE) +
    facet_wrap(~ issue) +
    labs(
      title = "Percentage of 'Yes' votes in the UN General Assembly",
      subtitle = "1946 to 2015",
      y = "% Yes",
      x = "Year",
      color = "Country"
    )
```

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      title = "Percentage of 'Yes' votes in the UN General Assembly",
      subtitle = "1946 to 2015",
      y = "% Yes",
      x = "Year",
      color = "Country"
    )
```

```r
un_votes %>%
  filter(country %in% c("United States of America", "Canada")) %>%
  inner_join(un_roll_calls, by = "rcid") %>%
  inner_join(un_roll_call_issues, by = "rcid") %>%
  group_by(country, year = year(date), issue) %>%
  summarize(
    votes = n(),
    percent_yes = mean(vote == "yes")
    ) %>%
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      subtitle = "1946 to 2015",
      y = "% Yes",
      x = "Year",
      color = "Country"
    )
```
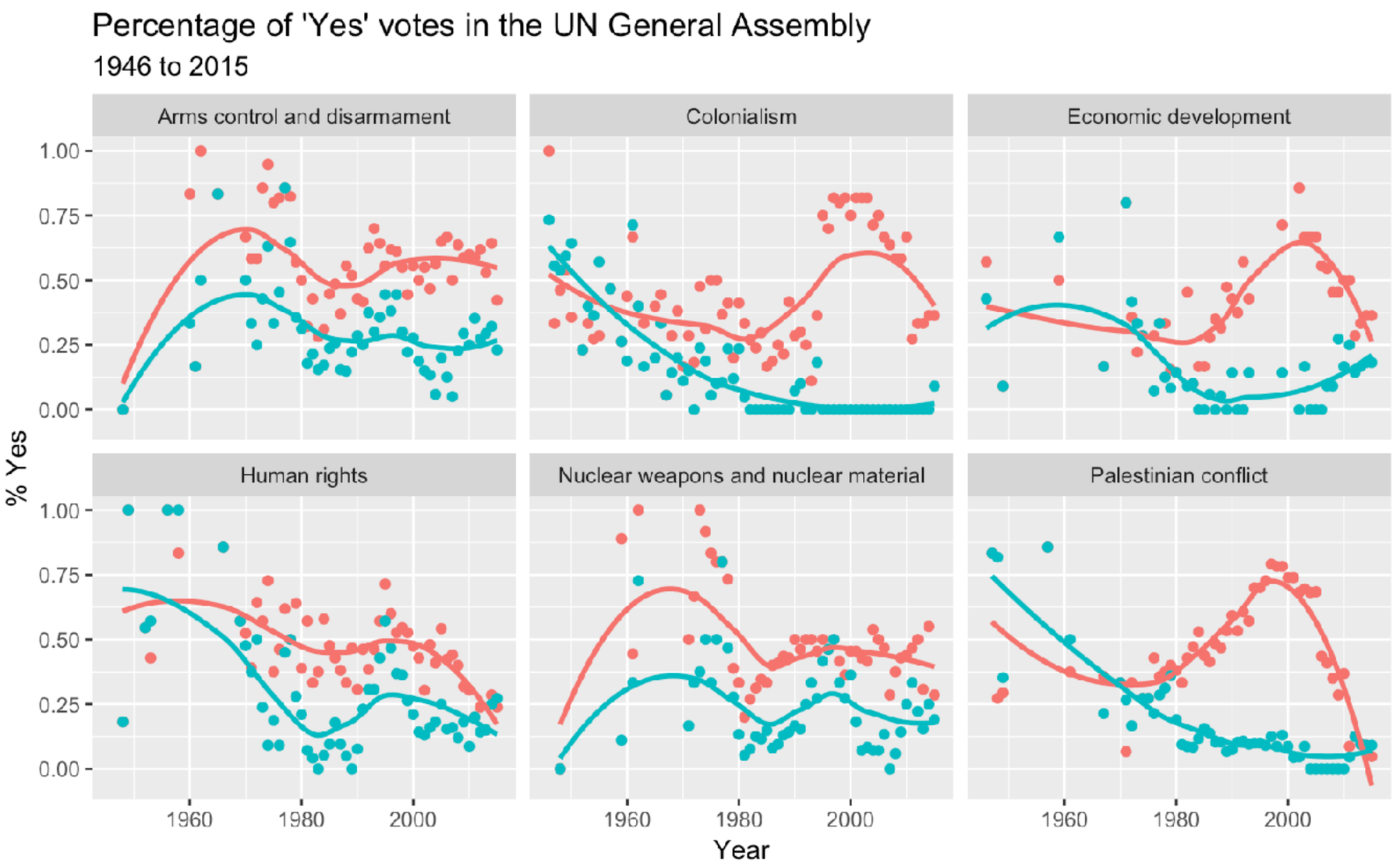
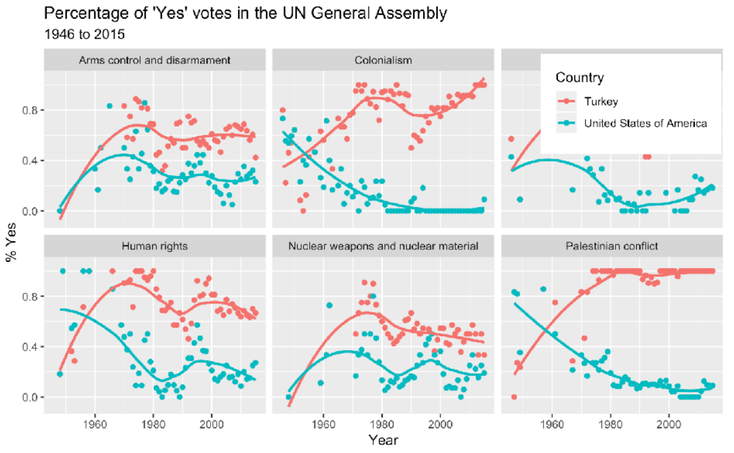


Percentage of 'Yes' votes in the UN General Assembly
1946 to 2015
Arms control and disarmament
Colonialism
Economic development
Human rights
Nuclear weapons and nuclear material
Palestinian conflict
% Yes
1.00
0.75
0.50
0.25
0.00
1960
1980
2000
Year
Country
Canada
United States of America


Percentage of 'Yes' votes in the UN General Assembly
1946 to 2015
Arms control and disarmament
Colonialism
Human rights
Nuclear weapons and nuclear material
Palestinian conflict
Country
Turkey
United States of America
% Yes
Year

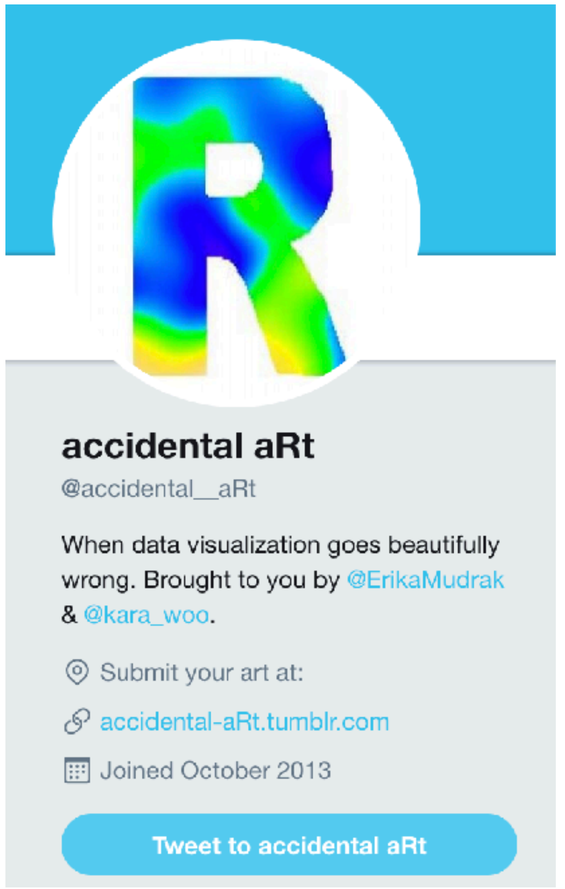
Why 🍰 = 📊?

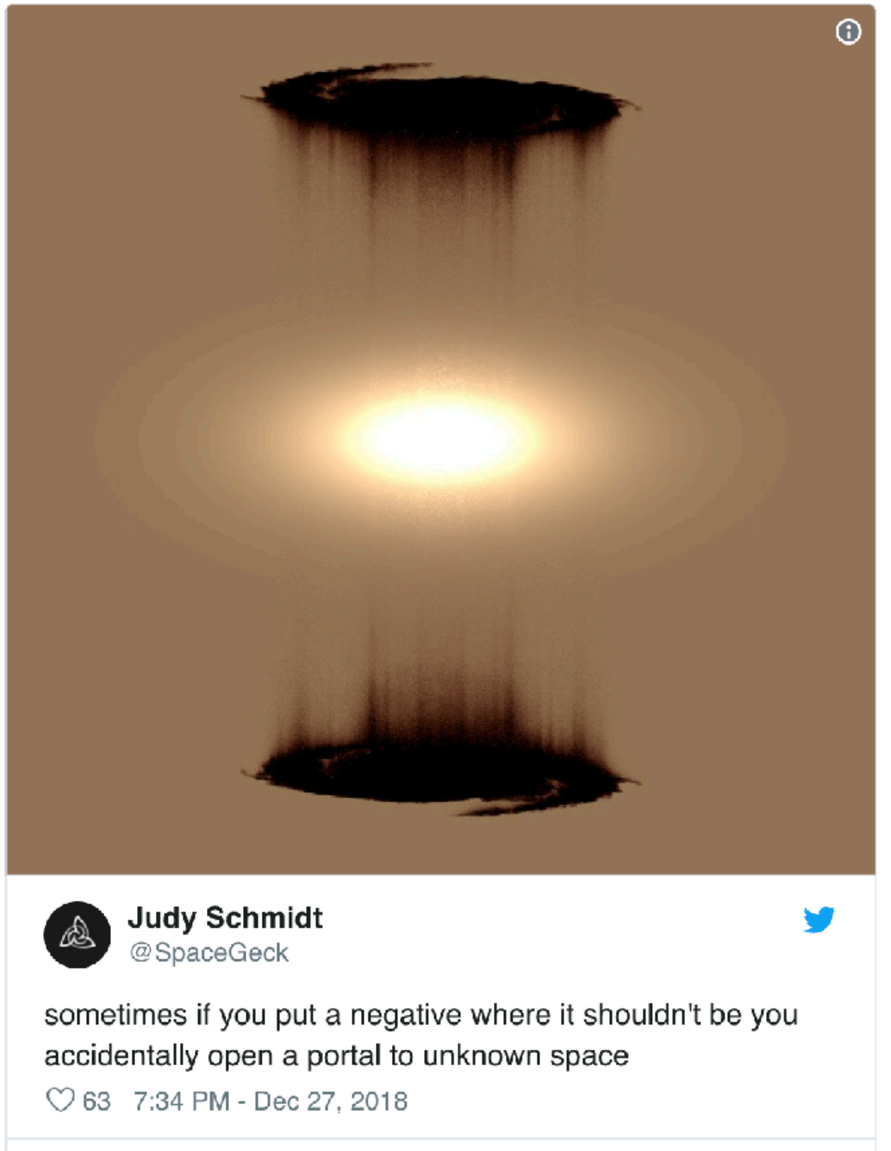
more likely for students to have intuition coming in

💡

easier for students to catch their own mistakes

👓


accidental aRt
@accidental__aRt
When data visualization goes beautifully wrong. Brought to you by @ErikaMudrak & @kara_woo.
Submit your art at:
accidental-aRt.tumblr.com
Joined October 2013
Tweet to accidental aRt


Judy Schmidt
@SpaceGeck
sometimes if you put a negative where it shouldn't be you accidentally open a portal to unknown space
63 7:34 PM - Dec 27, 2018


My niece just found the color markers.
tmblr.co/Z7M53q2eUJdrx
5 12:40 PM - Dec 7, 2018
accidental-art
My niece just found the color markers.
accidental-art.tumblr.com

Why 🍰 = 📊?

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💡

easier for students to catch their own mistakes

👓

who doesn't like a good piece of ~~cake~~ visualization?

😋

ex: Introduction to R for Data Science

Microsoft Professional Program Certificate in Data Science

Course Syllabus

Section 1: Introduction to Basics
Take your first steps with R. Discover the basic data types in R and assign your first variable.

Section 2: Vectors
Analyze gambling behaviour using vectors. Create, name and select elements from vectors.

Section 3: Matrices
Learn how to work with matrices in R. Do basic computations with them and demonstrate your knowledge by analyzing the Star Wars box office figures.

Section 4: Factors
R stores categorical data in factors. Learn how to create, subset and compare categorical data.

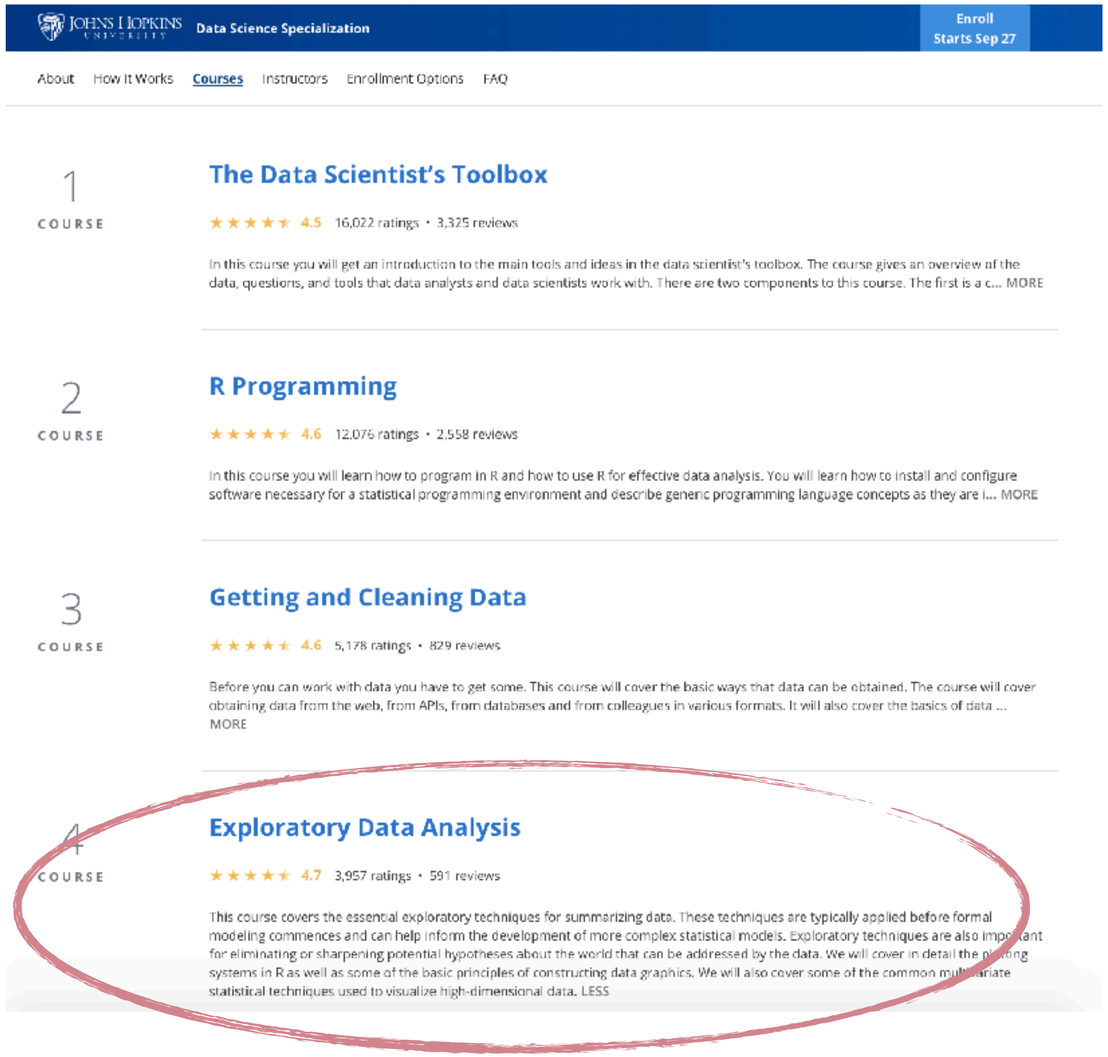
Section 5: Data Frames
When working R, you'll probably deal with Data Frames all the time. Therefore, you need to know how to create one, select the most interesting parts of it, and order them.

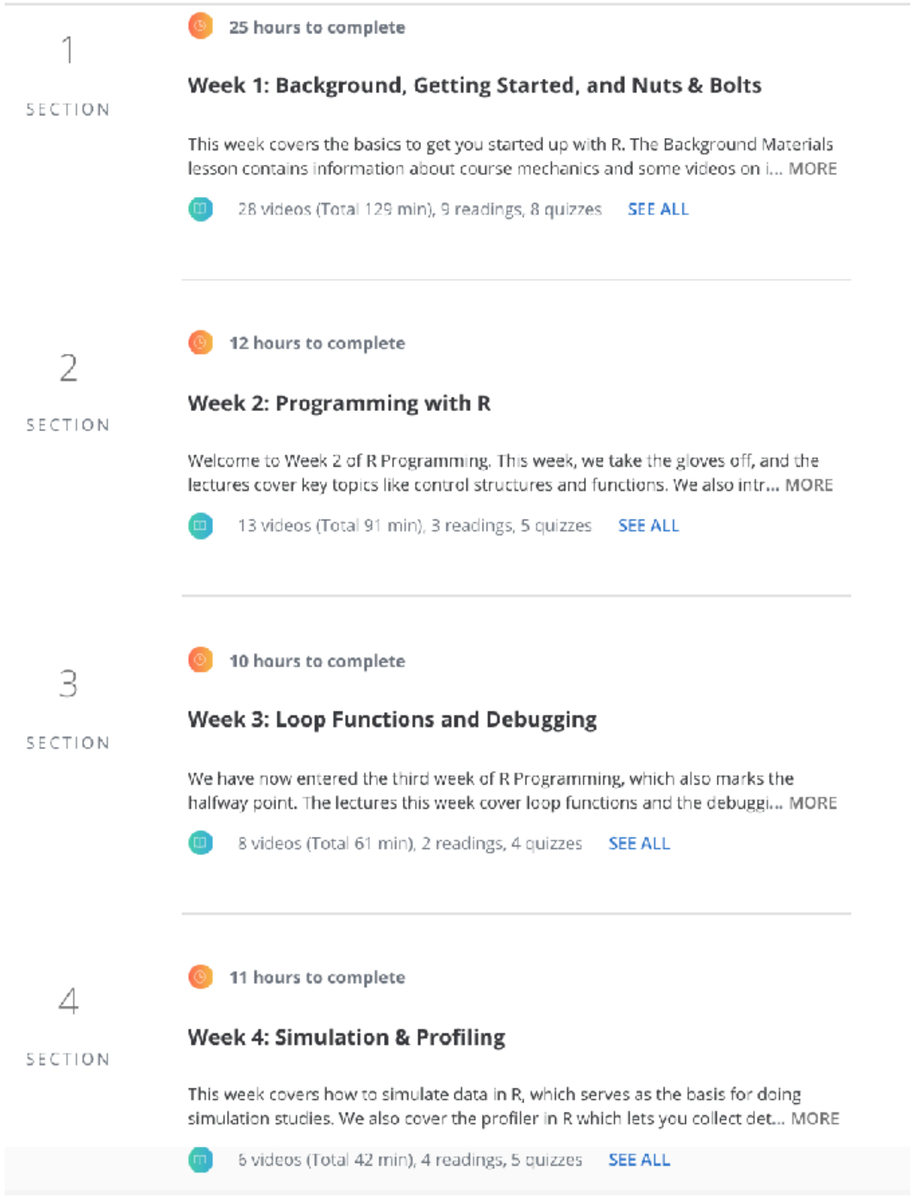
Section 6: Lists
Lists allow you to store components of different types. Section 6 will show you how to deal with lists.

Section 7: Basic Graphics
Discover R's packages to do graphics and create your own data visualizations.

ex: Data Science Specialization

Johns Hopkins University

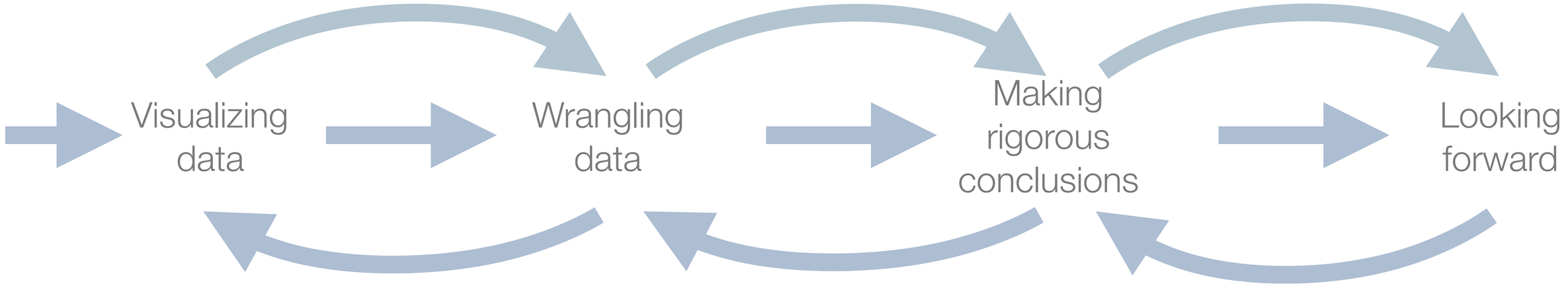




coursera.org/specializations/jhu-data-science#courses

ex: Intro to Data Science

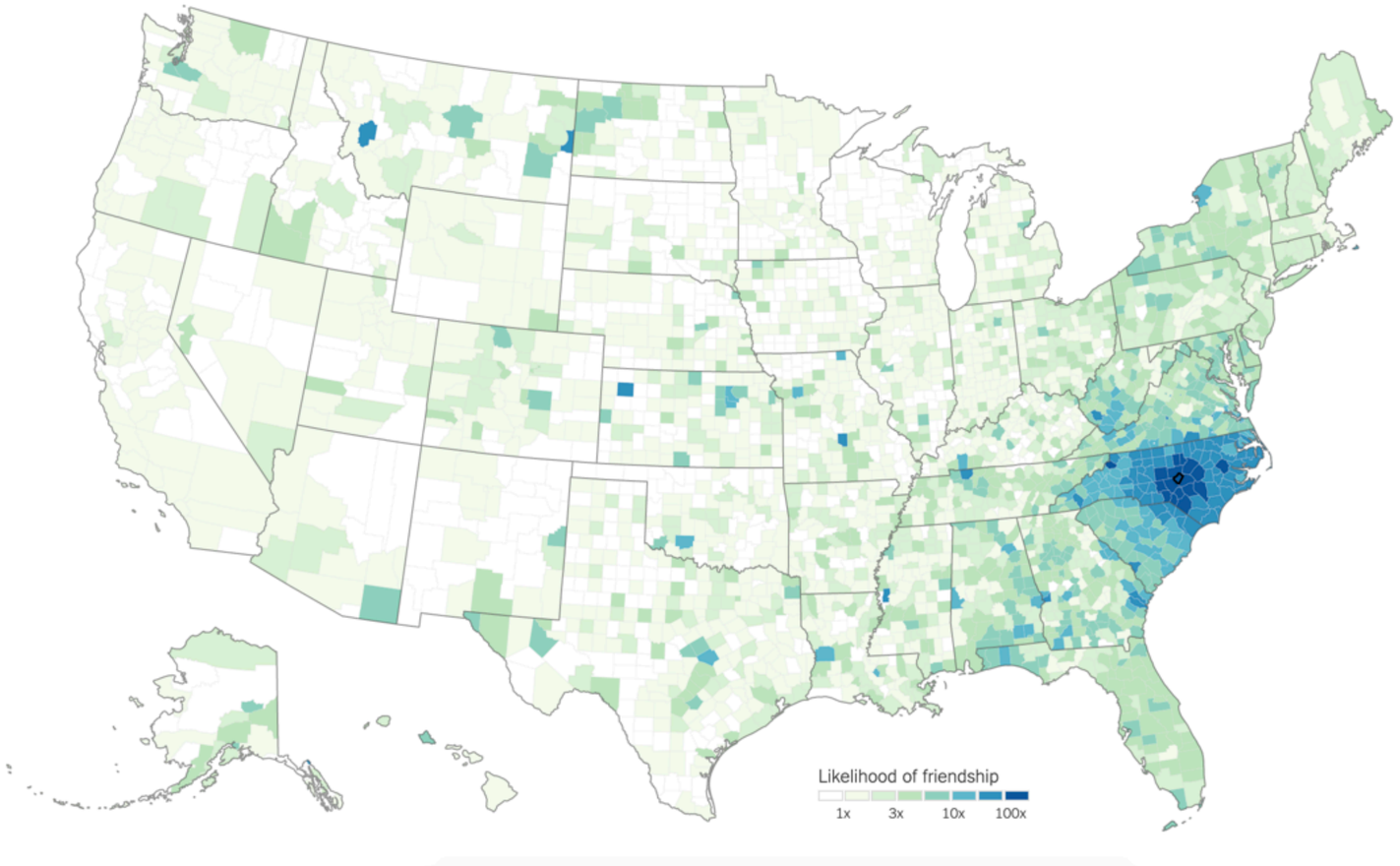
Duke University , soon University of Edinburgh



Fundamentals of data & data viz, confounding variables, Simpson's paradox + R / RStudio, R Markdown, simple git	Tidy data, data frames vs. summary tables, recoding and transforming, web scraping and iteration + collaboration on GitHub	Building & selecting models, visualizing interactions, prediction & validation, inference via simulation	Data science ethics, interactive viz & reporting, text analysis, Bayesian inference + communication, dissemination

> Your turn!

Go to nytimes.com/2019/01/03/learning/whats-going-on-in-this-graph-jan-9-2019.html and answer what might be going on in this graph? Write a catchy headline that captures the graph's main idea. If your headline makes a claim, tell us what you noticed that supports your claim.

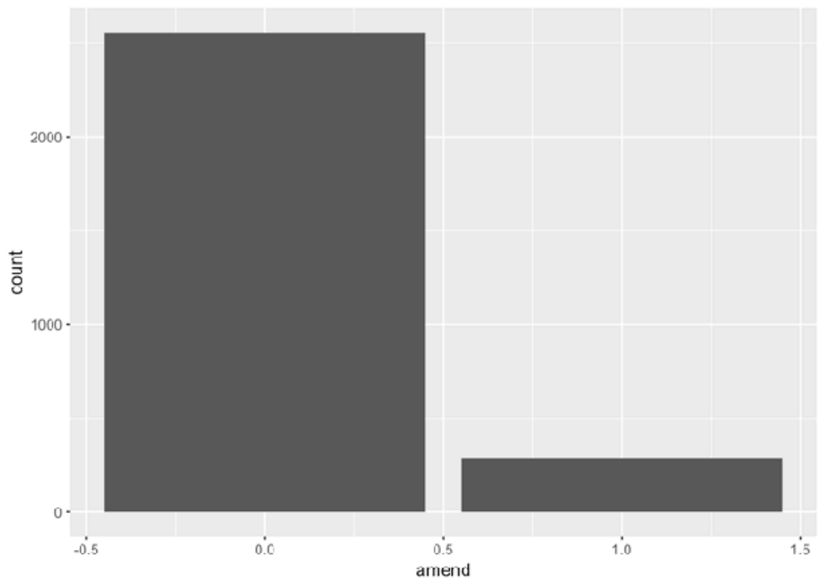


skip baby steps

Which of the following is more likely to **inspire** students to want to learn more?

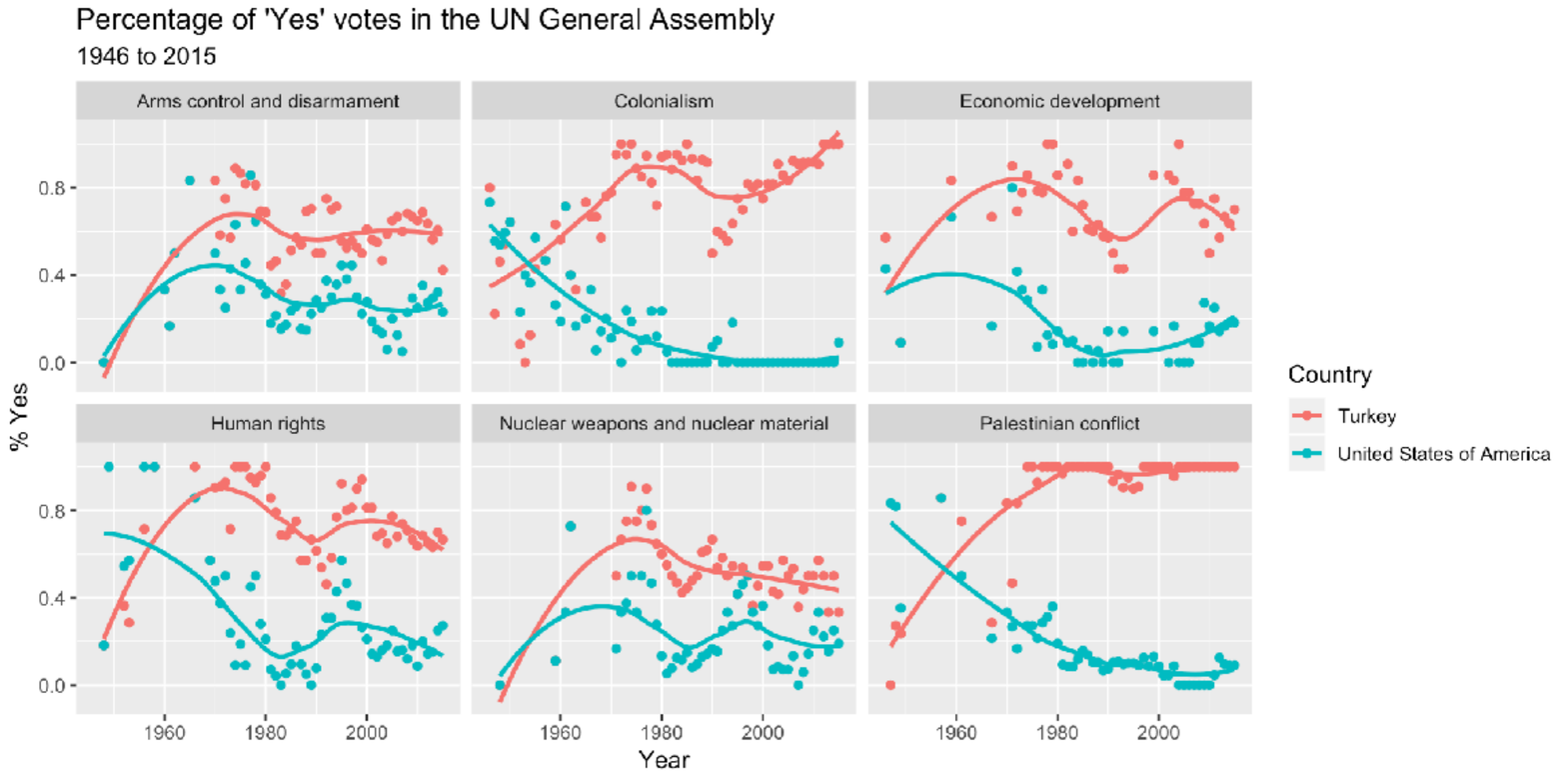
(a)

Create a visualization displaying whether the vote was on an amendment.

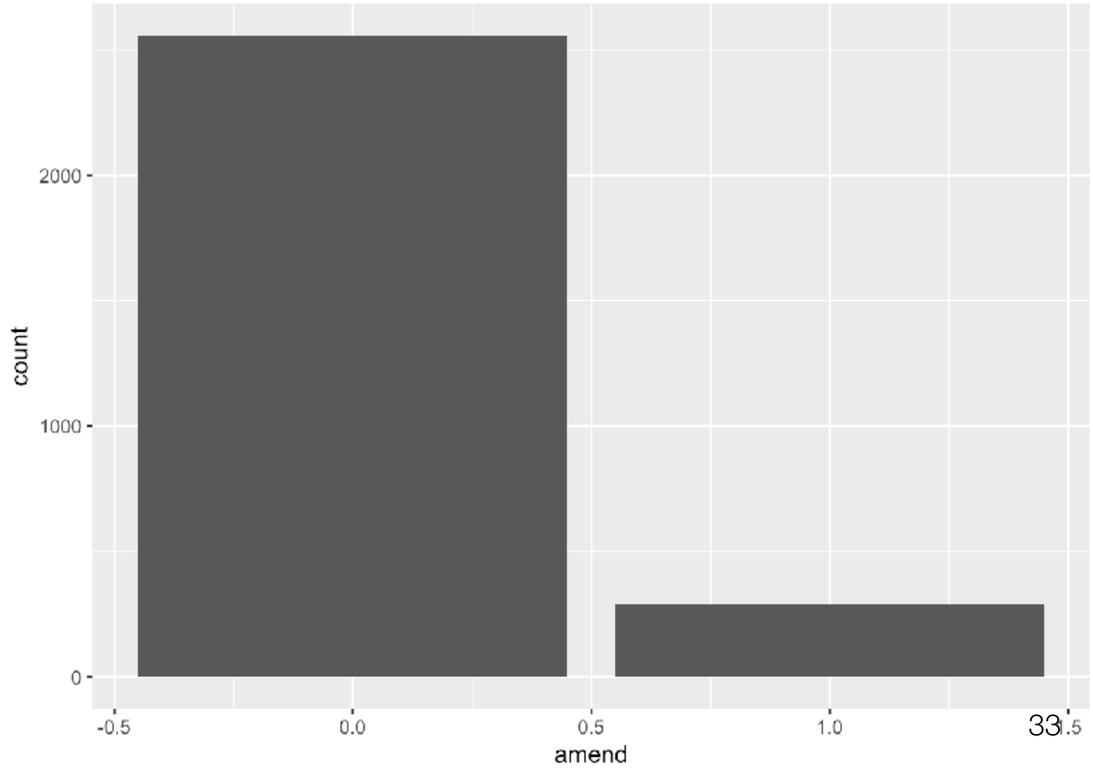


(b)

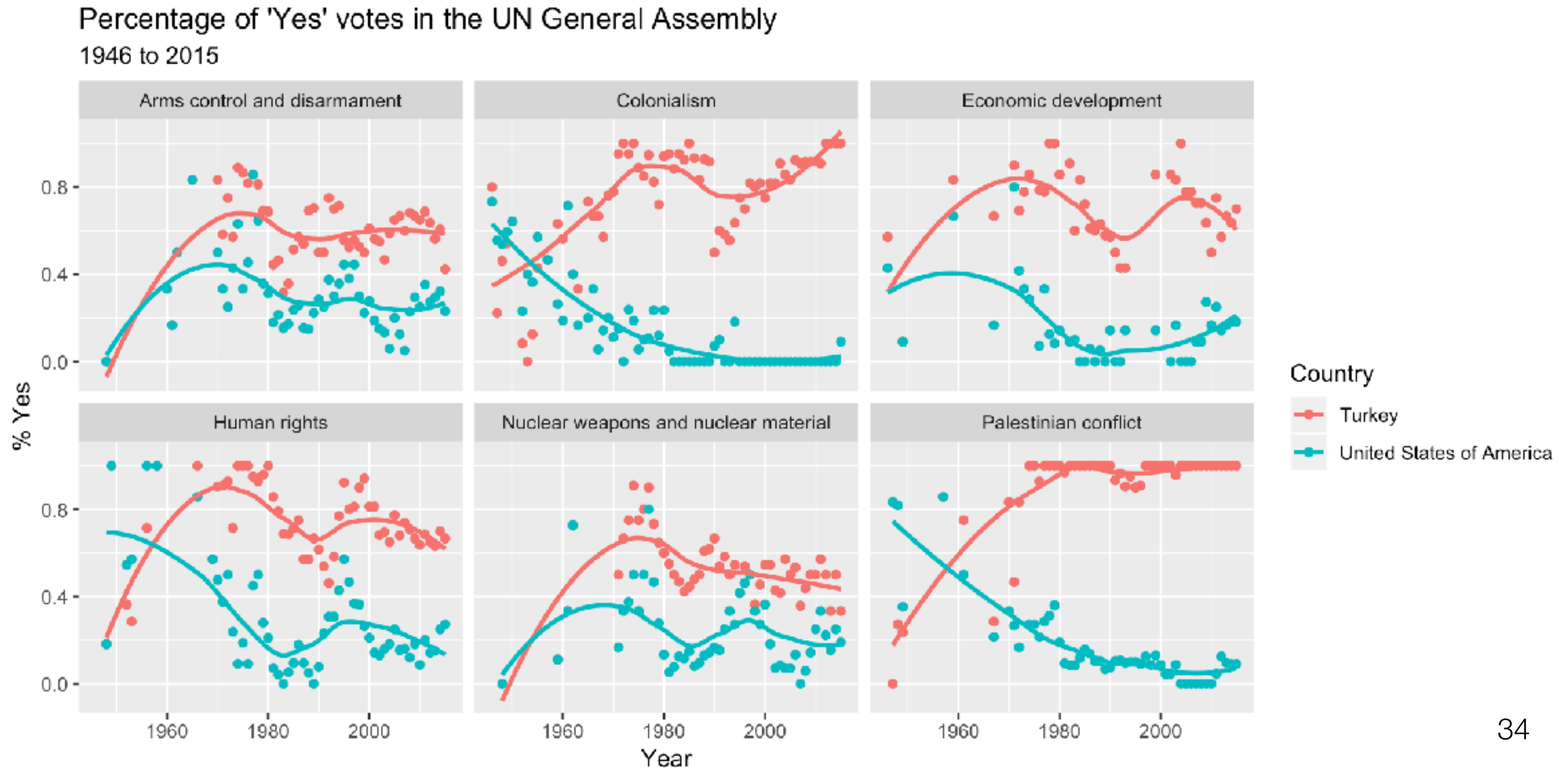
Create a visualization displaying how US and Turkey voted over the years on issues of arms control and disarmament, colonialism, economic development, human rights, nuclear weapons, and Palestinian conflict.



```
ggplot(data = un_roll_calls, mapping = aes(x = amend)) +
  geom_bar()
```

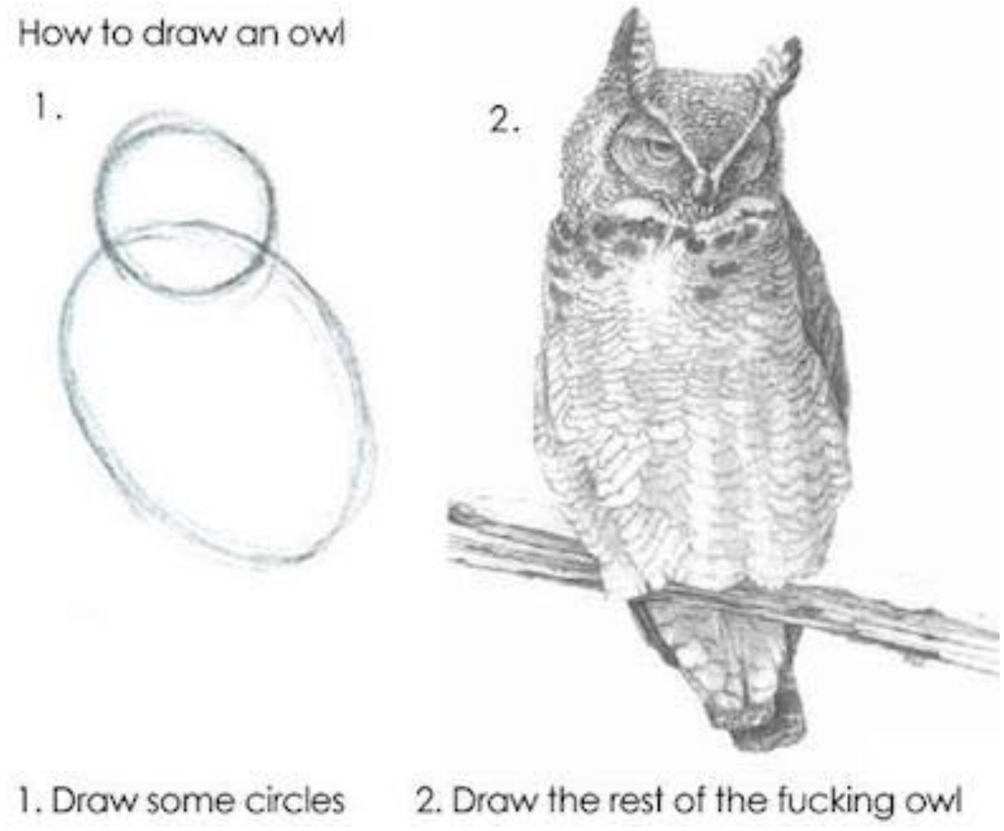


```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes, color = country)) +
  geom_point() +
  geom_smooth(method = "loess", se = FALSE) +
  facet_wrap(~ issue) +
  labs(
    title = "Percentage of 'Yes' votes in the UN General Assembly",
    subtitle = "1946 to 2015",
    y = "% Yes",
    x = "Year",
    color = "Country"
  )
```



non-trivial examples can be motivating,

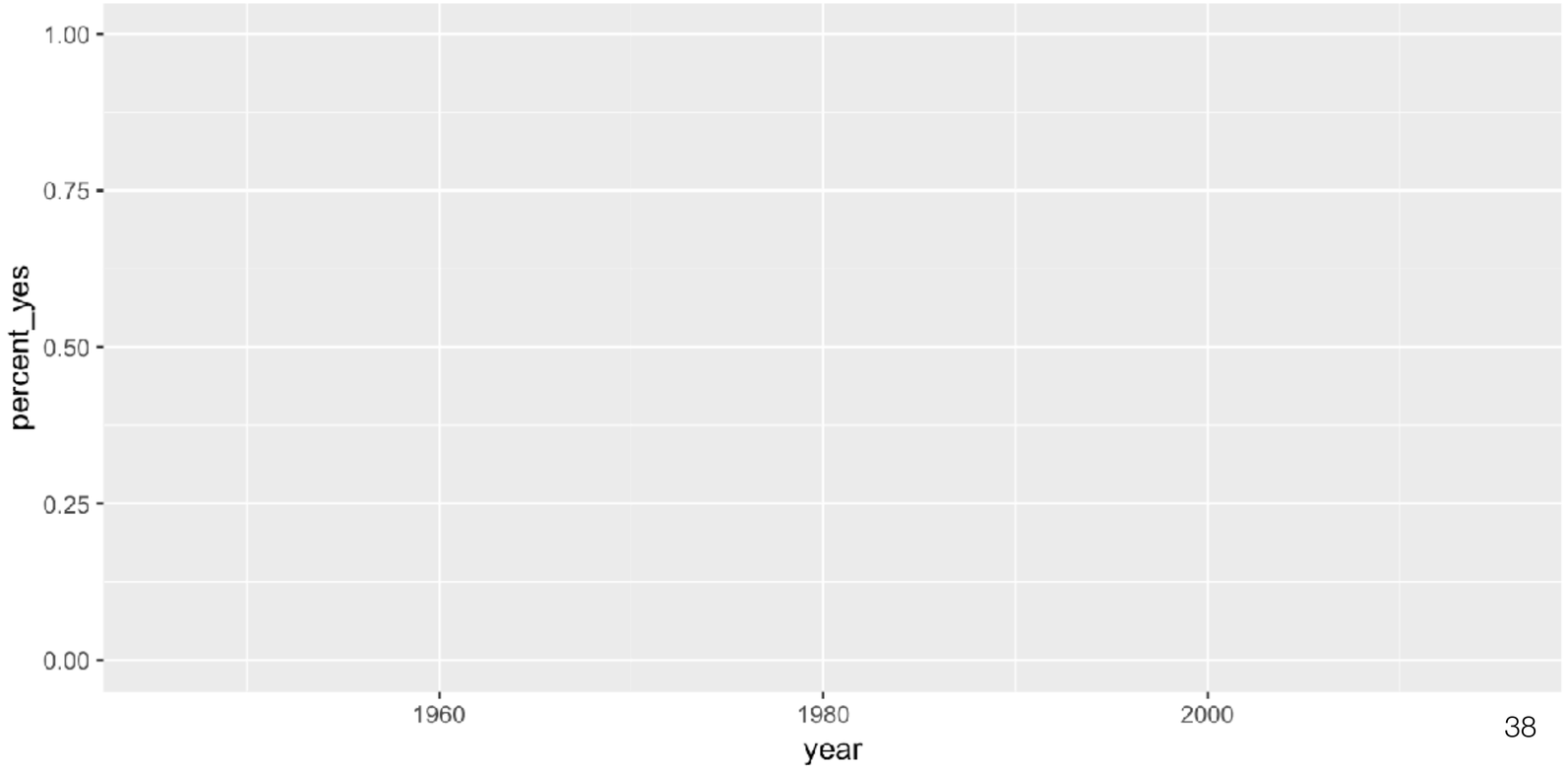
but need to avoid 👇!



→ introduce + scaffold + layer →

```
ggplot(data = un_votes_joined)
```

```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes))
```



```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes))
```

function(arguments)

often a verb

what to apply that verb to

```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes))
```

rows = observations

un_votes_joined

Filter

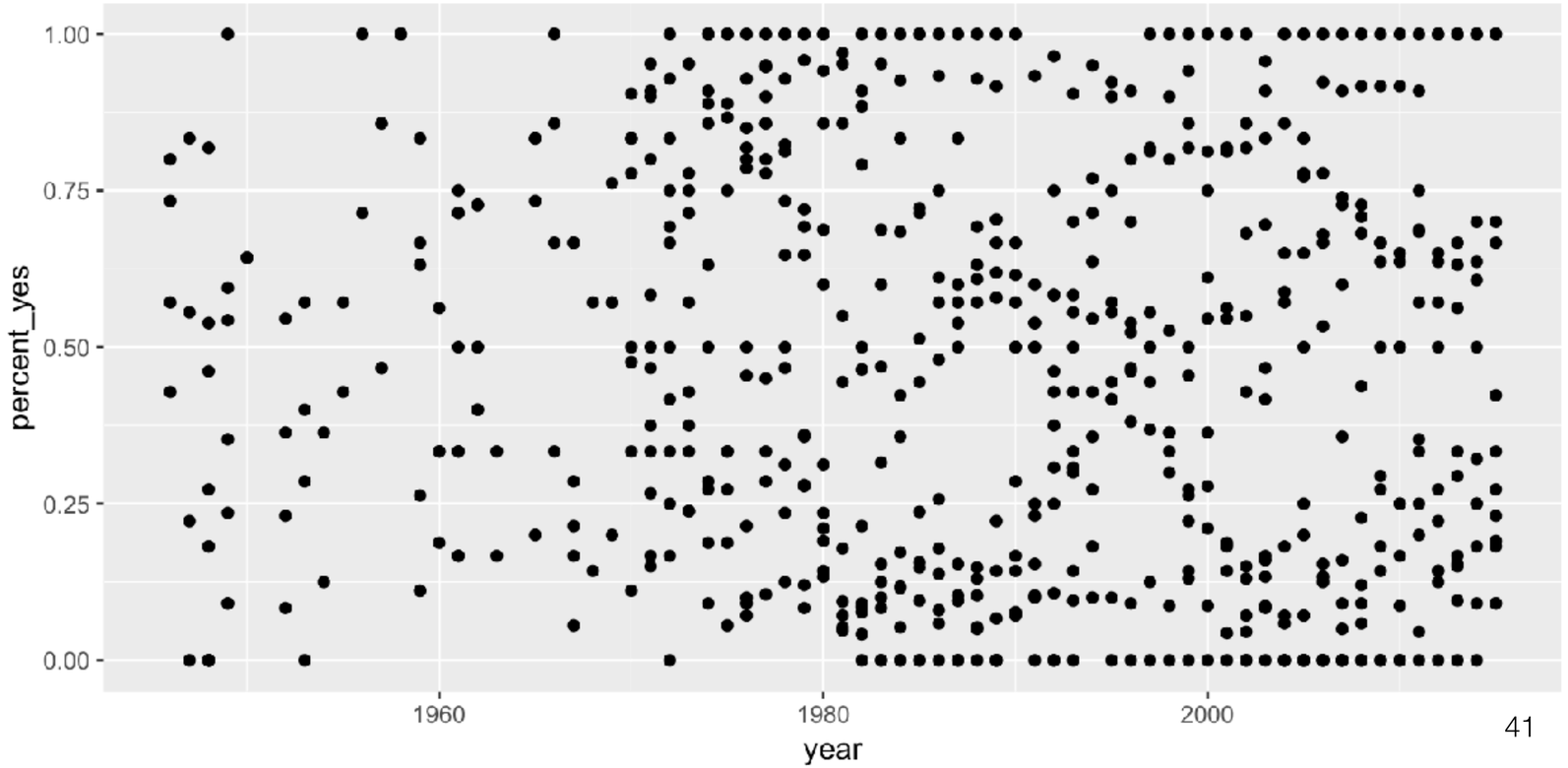
	country	year	issue	votes	percent_yes
1	Turkey	1946	Colonialism	15	0.80000000
2	Turkey	1946	Economic development	7	0.57142857
3	Turkey	1947	Colonialism	9	0.22222222
4	Turkey	1947	Palestinian conflict	6	0.00000000
5	Turkey	1948	Arms control and disarmament	8	0.00000000
6	Turkey	1948	Colonialism	13	0.46153846
7	Turkey	1948	Human rights	11	0.18181818
8	Turkey	1948	Nuclear weapons and nuclear material	7	0.00000000
9	Turkey	1948	Palestinian conflict	11	0.27272727
10	Turkey	1949	Colonialism	35	0.54285714
11	Turkey	1949	Economic development	11	0.09090909
12	Turkey	1949	Palestinian conflict	17	0.23529412
13	Turkey	1950	Colonialism	14	0.64285714
14	Turkey	1952	Colonialism	12	0.08333333
15	Turkey	1952	Human rights	11	0.36363636
16	Turkey	1953	Colonialism	9	0.00000000
17	Turkey	1953	Human rights	7	0.28571429
18	Turkey	1954	Colonialism	8	0.12500000

Showing 1 to 19 of 621 entries

"tidy" data frame

columns = variables

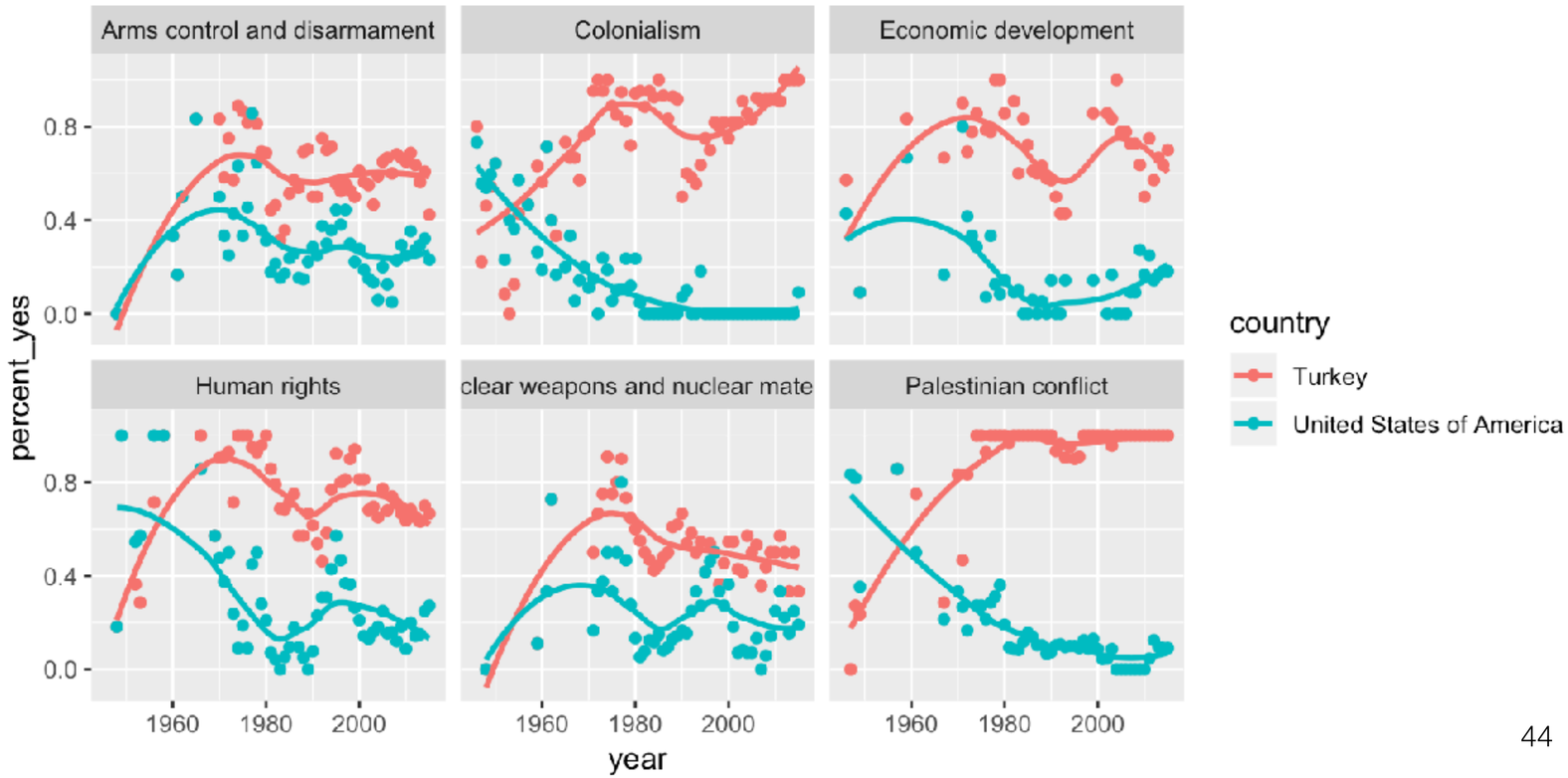
```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes)) +
  geom_point()
```



```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes, color = country)) +
  geom_point()
```

```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes, color = country)) +
  geom_point() +
  geom_smooth(method = "loess", se = FALSE)
```

```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes, color = country)) +
  geom_point() +
  geom_smooth(method = "loess", se = FALSE) +
  facet_wrap(~ issue)
```



```
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    title = "Percentage of 'Yes' votes in the UN General Assembly",
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    color = "Country"
  )
```
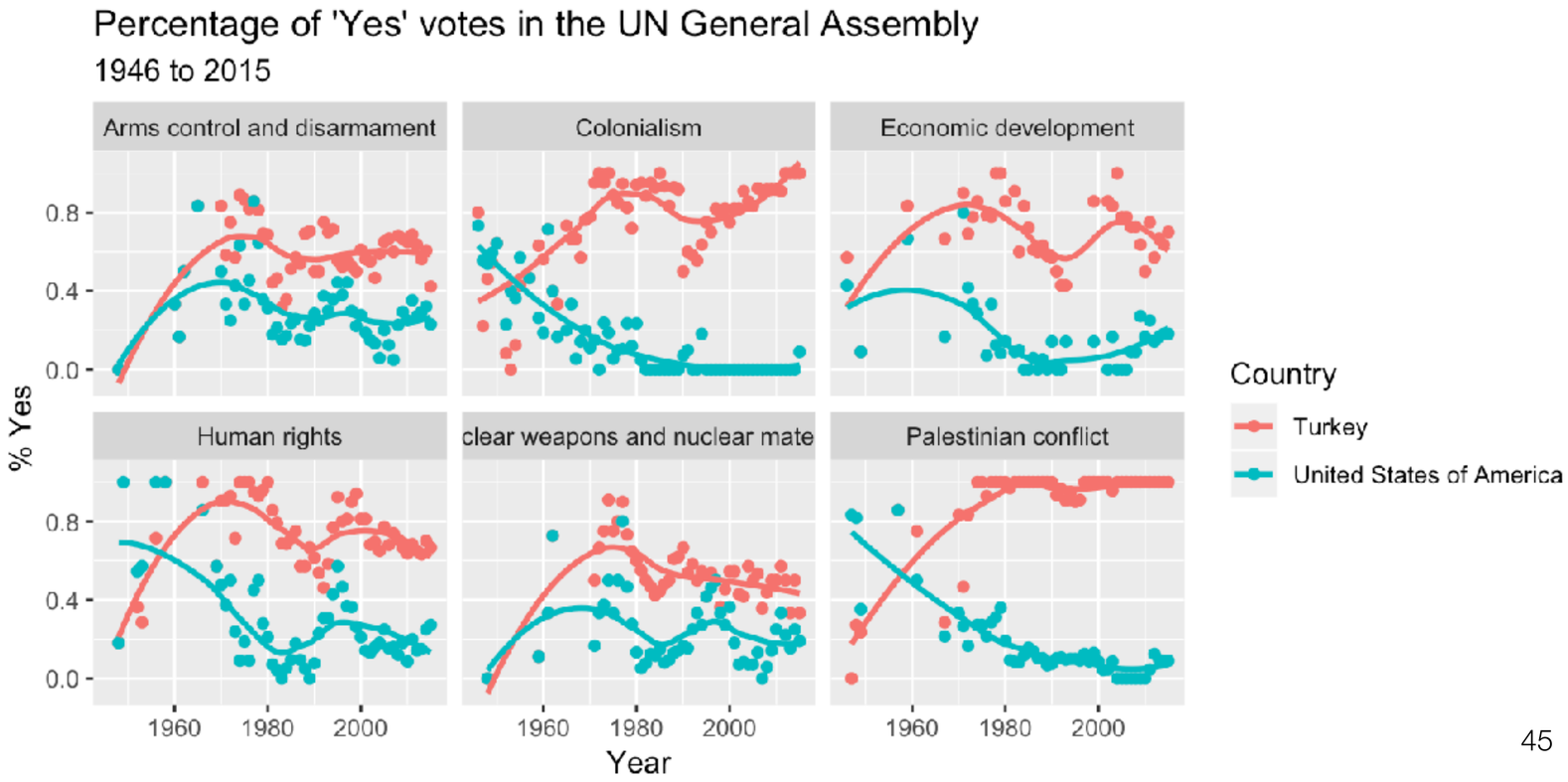



cherish

day

one

Which of the following is more likely to be **welcoming** for a wide range of students?

(a)

- Install R
- Install RStudio
- Install the following packages:
  - tidyverse
  - rmarkdown
  - ...
- Load these packages
- Install git

(b)

- Go to rstudio.cloud (or some other server based solution)
- Log in with your ID & pass

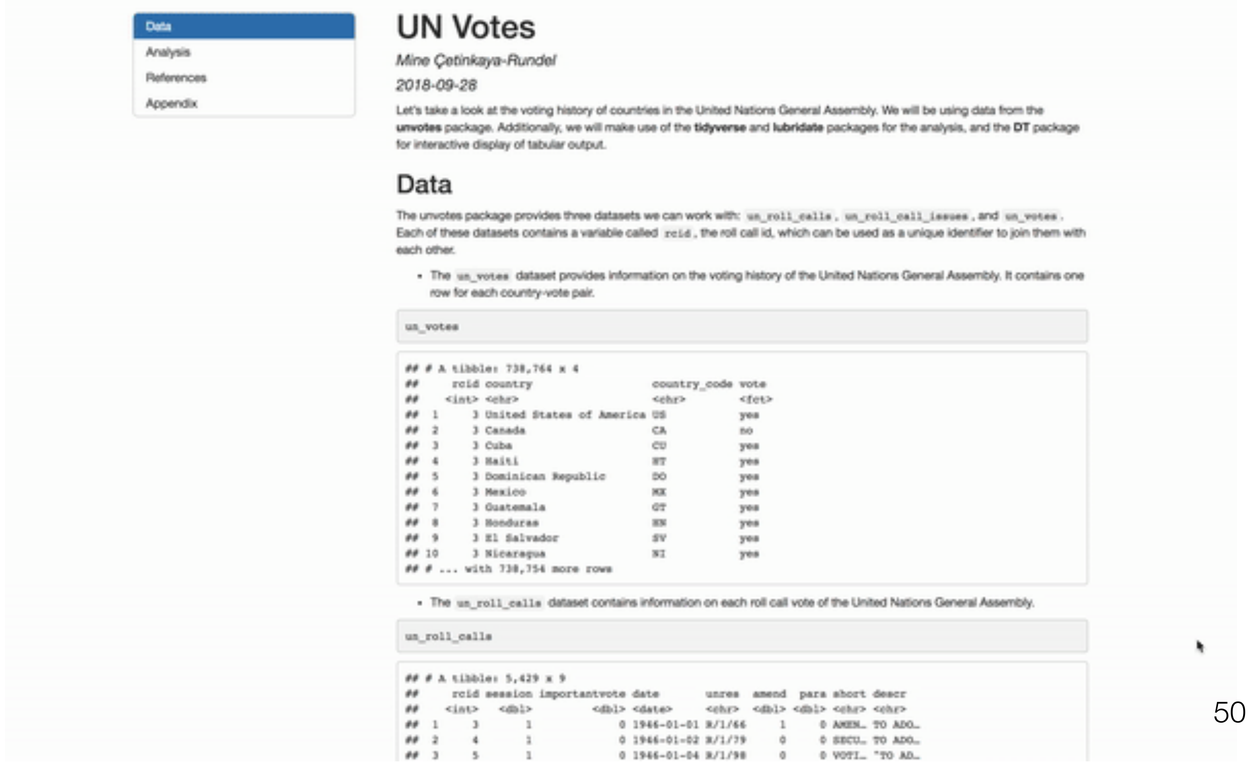
```
> hello R!
```

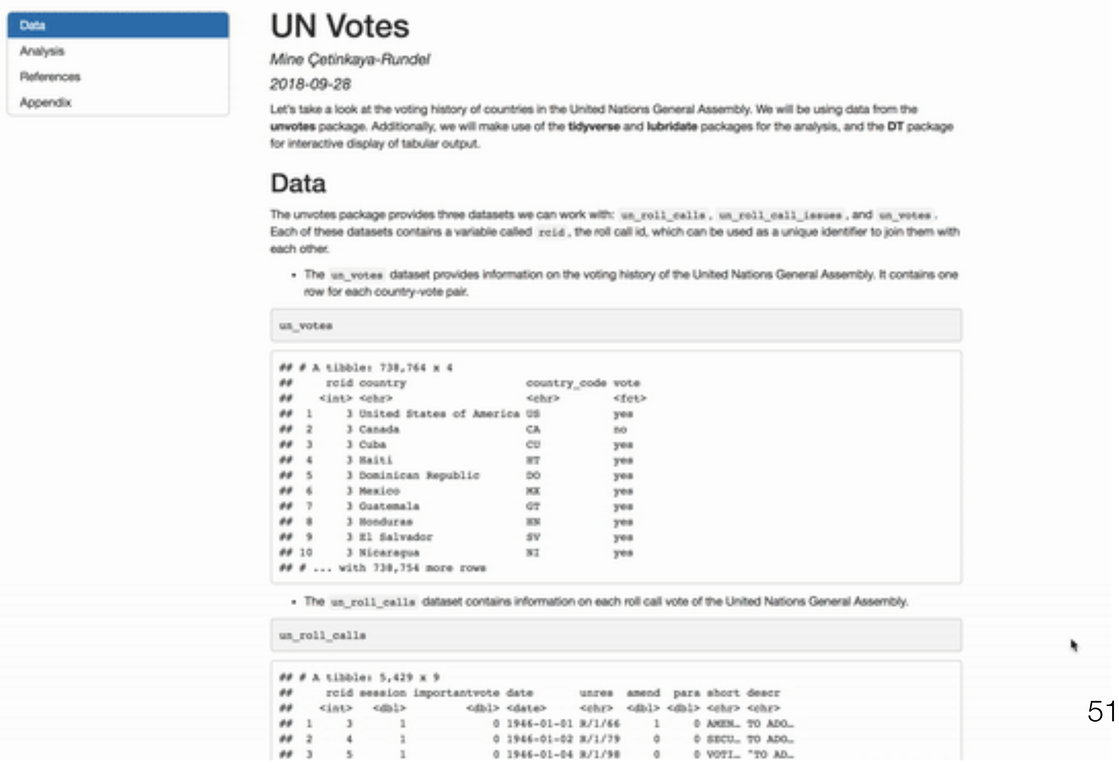
method of delivery,

and medium of interaction matters


R Studio


rmarkdown


Data
Analysis
References
Appendix
UN Votes
Mine Çetinkaya-Rundel
2018-09-28
Let's take a look at the voting history of countries in the United Nations General Assembly. We will be using data from the unvotes package. Additionally, we will make use of the tidyverse and lubridate packages for the analysis, and the DT package for interactive display of tabular output.
Data
The unvotes package provides three datasets we can work with: un_roll_calls, un_roll_call_issues, and un_votes. Each of these datasets contains a variable called rcid, the roll call id, which can be used as a unique identifier to join them with each other.
The un_votes dataset provides information on the voting history of the United Nations General Assembly. It contains one row for each country-vote pair.
un_votes
A tibble: 738,764 x 4
rcid country country_code vote
<int> <chr> <chr> <fct>
1 3 United States of America US yes
2 3 Canada CA no
3 3 Cuba CU yes
4 3 Haiti HT yes
5 3 Dominican Republic DO yes
6 3 Mexico MX yes
7 3 Guatemala GT yes
8 3 Honduras HN yes
9 3 El Salvador SV yes
10 3 Nicaragua NI yes
... with 738,754 more rows
The un_roll_calls dataset contains information on each roll call vote of the United Nations General Assembly.
un_roll_calls
A tibble: 5,429 x 9
rcid session importantvote date unres amend para short descr
<int> <dbl> <dbl> <date> <chr> <dbl> <dbl> <chr> <chr>
1 3 1 0 1946-01-01 R/1/66 1 0 AMEN… TO ADO…
2 4 1 0 1946-01-02 R/1/79 0 0 SECU… TO ADO…
3 5 1 0 1946-01-04 R/1/98 0 0 VOTI… "TO AD…



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UN Votes

Mine Çetinkaya-Rundel

2018-09-28

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Data

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- The `un_votes` dataset provides information on the voting history of the United Nations General Assembly. It contains one row for each country-vote pair.

```
un_votes
```

```
## # A tibble: 738,764 x 4
##     rcid country                  country_code vote
##    <int> <chr>                    <chr>        <fct>
##  1     3 United States of America US           yes
##  2     3 Canada                   CA           no
##  3     3 Cuba                     CU           yes
##  4     3 Haiti                    HT           yes
##  5     3 Dominican Republic       DO           yes
##  6     3 Mexico                   MX           yes
##  7     3 Guatemala                GT           yes
##  8     3 Honduras                 HN           yes
##  9     3 El Salvador              SV           yes
## 10     3 Nicaragua                NI           yes
## # ... with 738,754 more rows
```

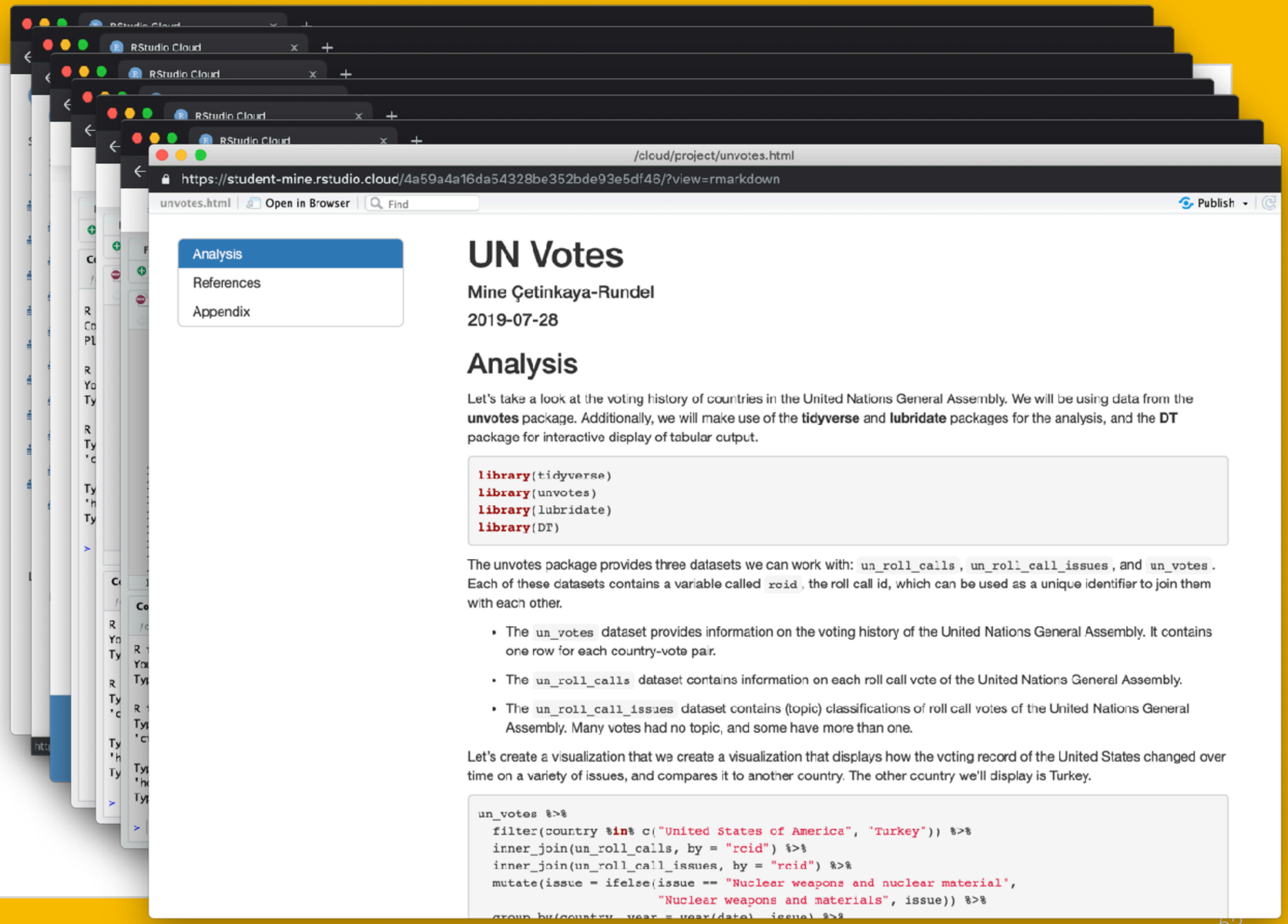
- The `un_roll_calls` dataset contains information on each roll call vote of the United Nations General Assembly.

```
un_roll_calls
```

```
## # A tibble: 5,429 x 9
##     rcid session importantvote date       unres  amend  para short descr
##    <int>   <dbl>         <dbl> <date>     <chr>  <dbl> <dbl> <chr> <chr>
##  1     3       1             0 1946-01-01 R/1/66     1     0 AMEN… TO ADO…
##  2     4       1             0 1946-01-02 R/1/79     0     0 SECU… TO ADO…
##  3     5       1             0 1946-01-04 R/1/98     0     0 VOTI… "TO AD…
```

> Your turn!

- Go to **rstd.io/teach-ds-cloud** to join the RStudio Cloud workspace for this workshop.
- Start the assignment called **01 - UN Votes**.
- Open the R Markdown document called `un-votes.Rmd`, knit the document, view the result.
- Then, change `"Turkey"` to another country, and knit again.



hide the veggies

ex 2.

data acquisition

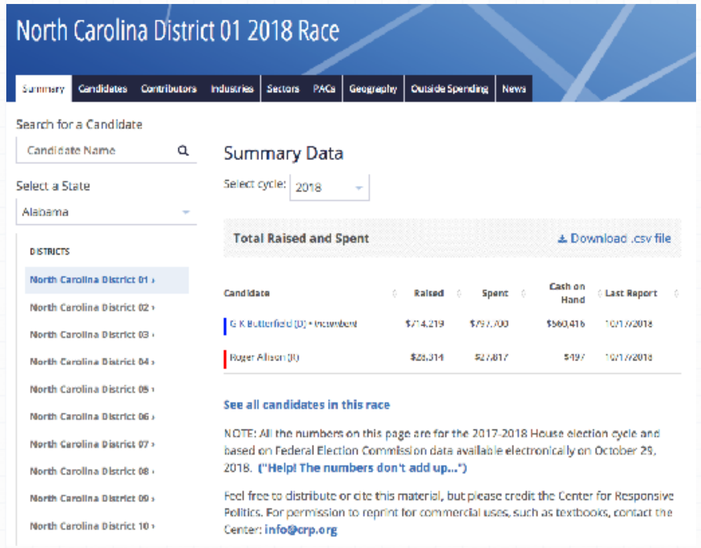
Which of the following is more likely to be **interesting** for a wide range of students?

(a)

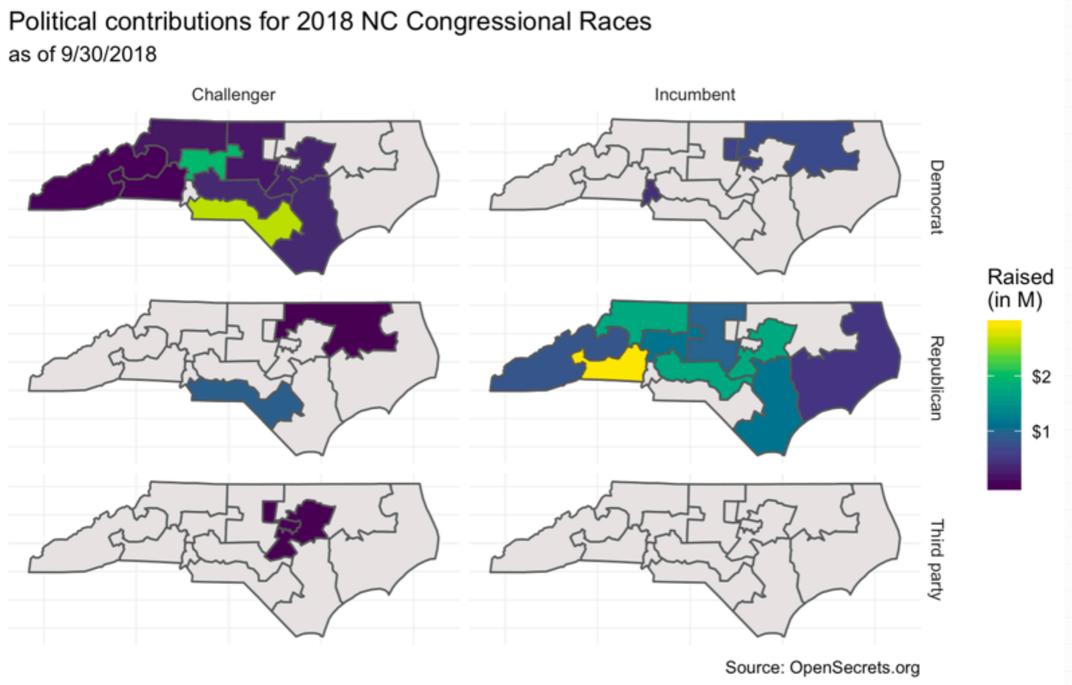
- Topic: Web scraping
- Tools:
  - `rvest`
  - regular expressions

(b)

- Today we start with this:



- and end with this:



- and do so in a way that is easy to replicate for another state

students will encounter lots of new

challenges along the way —

let that happen,

and then provide a solution

- **Lesson:** Web scraping essentials for turning a structured table into a data frame in R.

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- **Ex 1:** Scrape the table off the web and save as a data frame.

Candidate	Raised	Spent	Cash on Hand	Last Report
G K Butterfield (D) • *Incumbent*	$714,219	$797,700	$560,416	10/17/2018
Roger Allison (R)	$28,314	$27,817	$497	10/17/2018

	candidate_info	raised	spent	cash_on_hand	last_report	race
1	G K Butterfield (D) • Incumbent	714219	797700	560416	2018-10-17	North Carolina District 01
2	Roger Allison (R)	28314	27817	497	2018-10-17	North Carolina District 01

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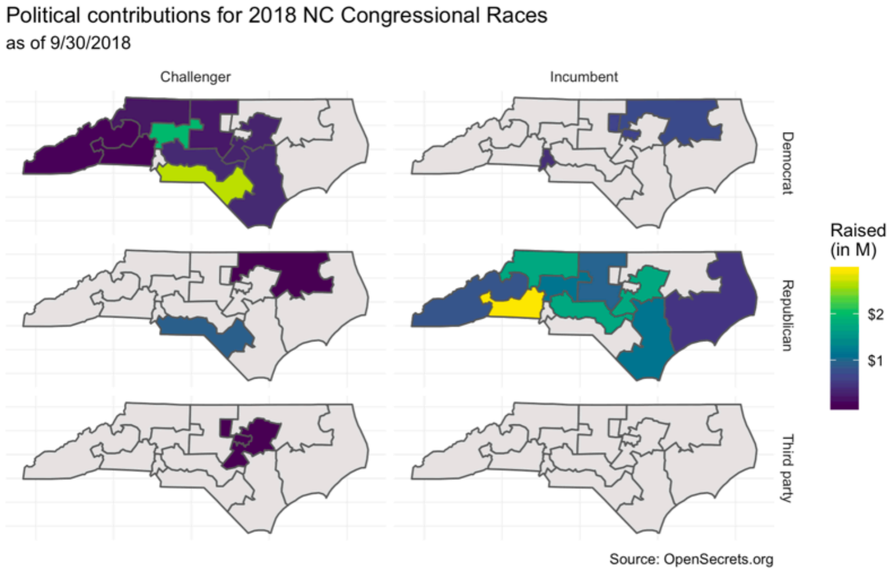
- **Ex 2:** What other information do we need represented as variables in the data to obtain the desired facets?



- **Lesson:** Web scraping essentials for turning a structured table into a data frame in R.

- **Lesson:** "Just enough" string parsing and regular expressions to go from

	candidate_info
1	G K Butterfield (D) • Incumbent
2	Roger Allison (R)

to

	candidate_name	party	status
1	G K Butterfield	Democrat	Incumbent
2	Roger Allison	Republican	Challenger

- **Ex 1:** Scrape the table off the web and save as a data frame.

Candidate	Raised	Spent	Cash on Hand	Last Report
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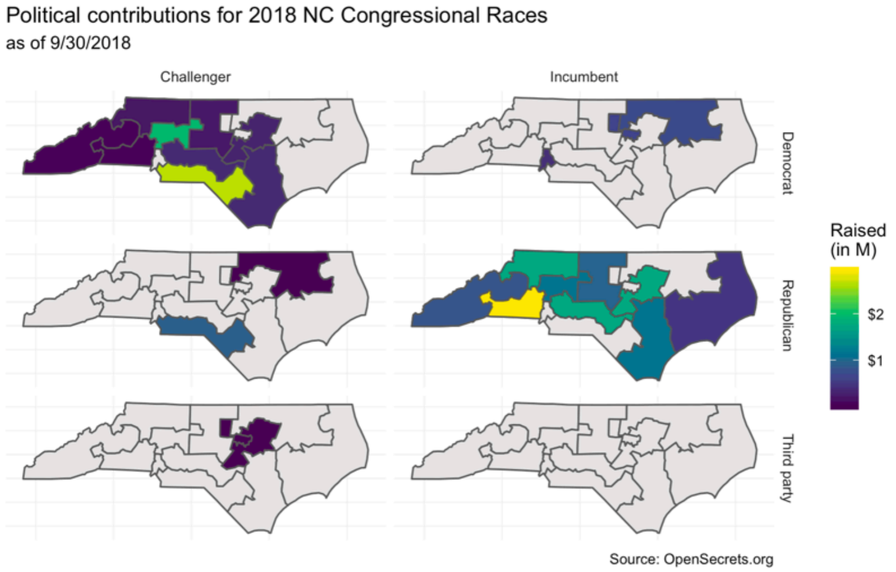


leverage the ecosystem

ex 3.

inference

- Estimate the difference between the average evaluation score of male and female faculty.

	score	rank	ethnicity	gender	bty_avg
	<dbl>	<chr>	<chr>	<chr>	<dbl>
1	4.7	tenure track	minority	female	5
2	4.1	tenure track	minority	female	5
3	3.9	tenure track	minority	female	5
4	4.8	tenure track	minority	female	5
5	4.6	tenured	not minority	male	3
6	4.3	tenured	not minority	male	3
7	2.8	tenured	not minority	male	3
8	4.1	tenured	not minority	male	3.33
9	3.4	tenured	not minority	male	3.33
10	4.5	tenured	not minority	female	3.17
…	…	…	…	…	…
463	4.1	tenure track	minority	female	5.33

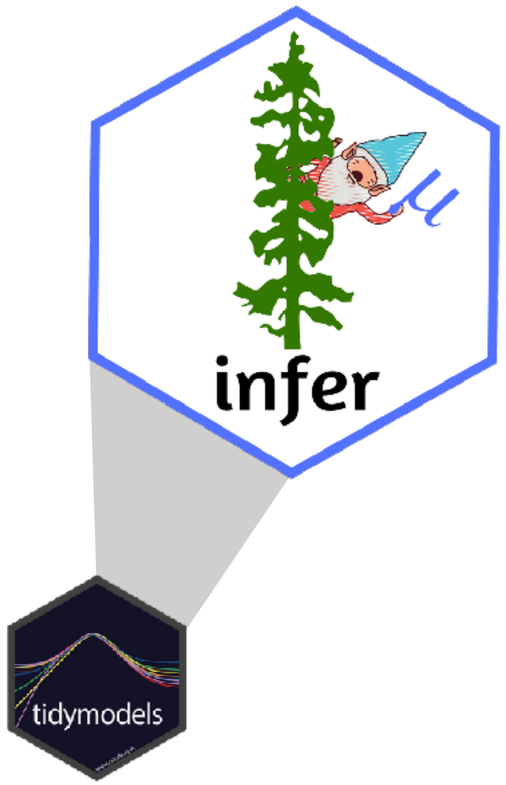
Hamermesh, Parker.
"Beauty in the classroom: instructors pulchritude and putative pedagogical productivity",
Econ of Ed Review, Vol 24-4.

(a)

```
t.test(evals$score ~ evals$gender)


# Welch Two Sample t-test

# data:  evals$score by evals$gender
# t = -2.7507, df = 398.7, p-value = 0.006218
# alternative hypothesis: true difference in
# means is not equal to 0
# 95 percent confidence interval:
# -0.24264375 -0.04037194
# sample estimates:
# mean in group female   mean in group male
#             4.092821             4.234328
```

(b)

```
library(tidyverse)
library(infer)

evals %>%
  specify(score ~ gender) %>%
  generate(reps = 15000,
    type = "bootstrap") %>%
  calculate(stat = "diff in means",
    order = c("male", "female")) %>%
  summarise(
    l = quantile(stat, 0.025),
    u = quantile(stat, 0.975)
    )


#      l     u
# 0.0410 0.243
```



`infer`

The objective of this package is to perform statistical inference using an expressive statistical grammar that coheres with the `tidyverse` design framework.

Now part of the `tidymodels` suite of modeling packages.

```
library(tidyverse)
library(infer)

evals %>%
```

start with data

```
library(tidyverse)
library(infer)

evals %>%
  specify(score ~ gender)
```

specify the model

```
library(tidyverse)
library(infer)

evals %>%
  specify(score ~ gender) %>%
  generate(reps = 15000, type = "bootstrap")
```

generate bootstrap samples

`calculate` sample statistics

```
library(tidyverse)
library(infer)

evals %>%
  specify(score ~ gender) %>%
  generate(reps = 15000, type = "bootstrap") %>%
  calculate(stat = "diff in means", order = c("male", "female"))
```

`summarise` CI bounds

```
library(tidyverse)
library(infer)

evals %>%
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  summarise(l = quantile(stat, 0.025), u = quantile(stat, 0.975))
```
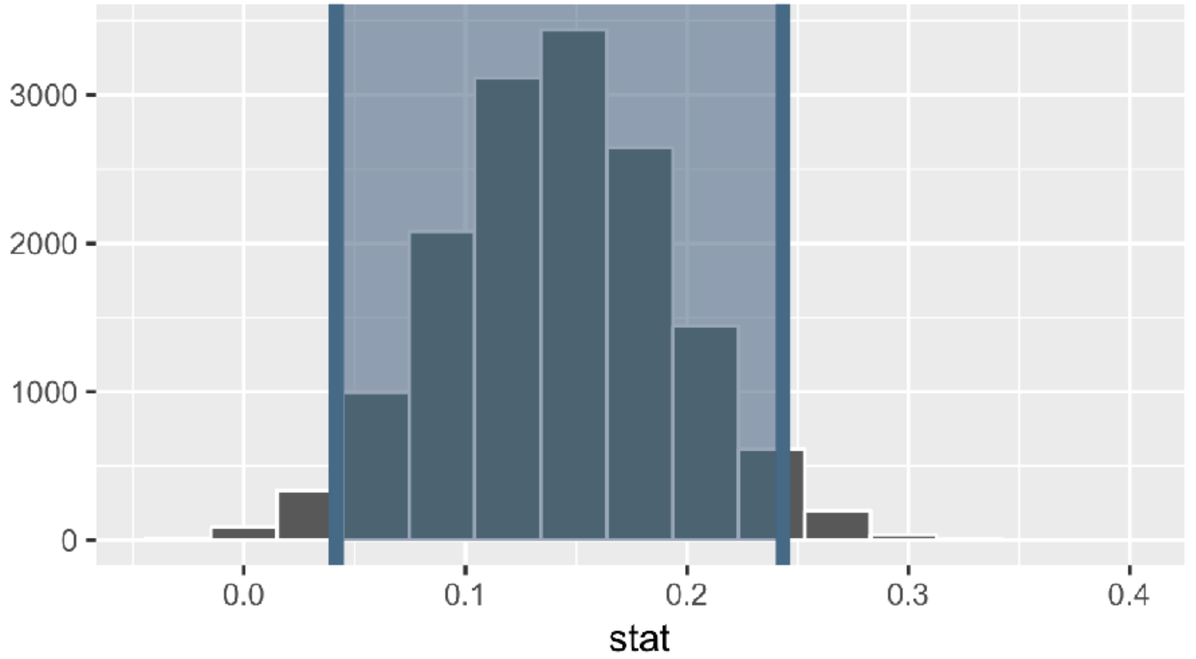

```
#       l     u
# 0.0410 0.243
```



> Your turn!

- How much do you think a typical one bedroom apartment in Manhattan rents for?
- In RStudio Cloud, start the assignment called **02 - Manhattan rents**.
  - If you haven't yet joined the RStudio Cloud workspace, go to **rstd.io/teach-ds-cloud**.
- Open the R Markdown document called `manhattan-rents.Rmd`, knit the document, inspect the result of each code chunk and discuss it with your neighbor.
- Then, complete the task to calculate a 90% confidence interval for the mean.

tl;dr

1 start with cake

2 skip baby steps

3 cherish day one

4 hide the veggies

5 leverage the ecosystem

Fine,
I'm intrigued,
but I need to see
the big picture

Topics :: Data Science in a Box

datasciencebox.org

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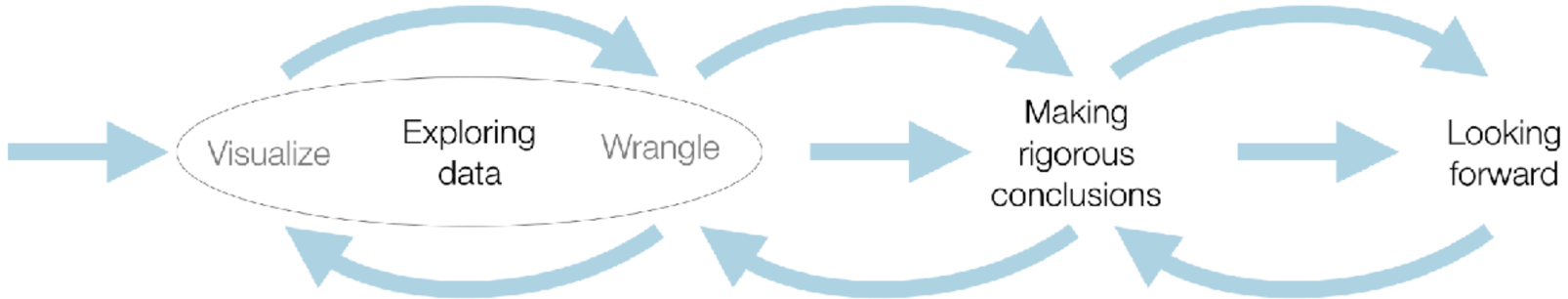
  - Topics
  - Tech stack
  - Community
- Course content
- Infrastructure
- Pedagogy

Data Science in a Box > Hello #dsbox > Topics

Topics

The course content is organized in three units:



Unit 1 - Exploring data: This unit focuses on data visualiation and data wranling. Specifically we cover fundamentals of data and data visualization, confounding variables, and Simpson's paradox as well as the concept of tidy data, data import, data cleaning, and data curation. We end the unit with web scraping and introduce the idea of iteration in preparation for the next unit. Also in this unit students are introduced to the toolkit: R, RStudio, R Markdown, Git, GitHub, etc.

Unit 2 - Making rigorous conclusions: In this part we introduce modeling and statistical inference for making data based conclusions. We discuss building, interpreting, and selecting models, visualizing interaction effects, and prediction and model validity. Statistical inference is introduced from a simulation based perspective, and the Central Limit Theorem is discussed very briefly to lay the foundation for future coursework in statistics.

Unit 3 - Looking forward: In the last unit we present a series of modules such as interactive reporting and visualizaiton with Shiny, text analysis, and Bayesian inference. These are independent modules that instructors can choose to include in their introductory data science curriculum depending on how much time they have left in the semester.

rstd.io/teach-ds-jsm19

> Your turn!

Think - pair - share: What are your first reactions to the curriculum design principles you have heard so far? What aspects of it seem natural to adopt and what aspects not so much?

Let them eat cake (first)!*

🔗 rstd.io/teach-ds-jsm19

* You can tell them all about the ingredients later!

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