01 curriculum design

teaching data science

rstd.io/teach-ds-latinR

Imagine you're new to baking, and you're in a baking class. I'm going to present two options for starting the class. Which one gives you **better sense** of the final product?

Pineapple and Coconut Sandwich Cake

bit.ly/eat-cake-cetl-msor

Pineapple and Coconut Sandwich Cake

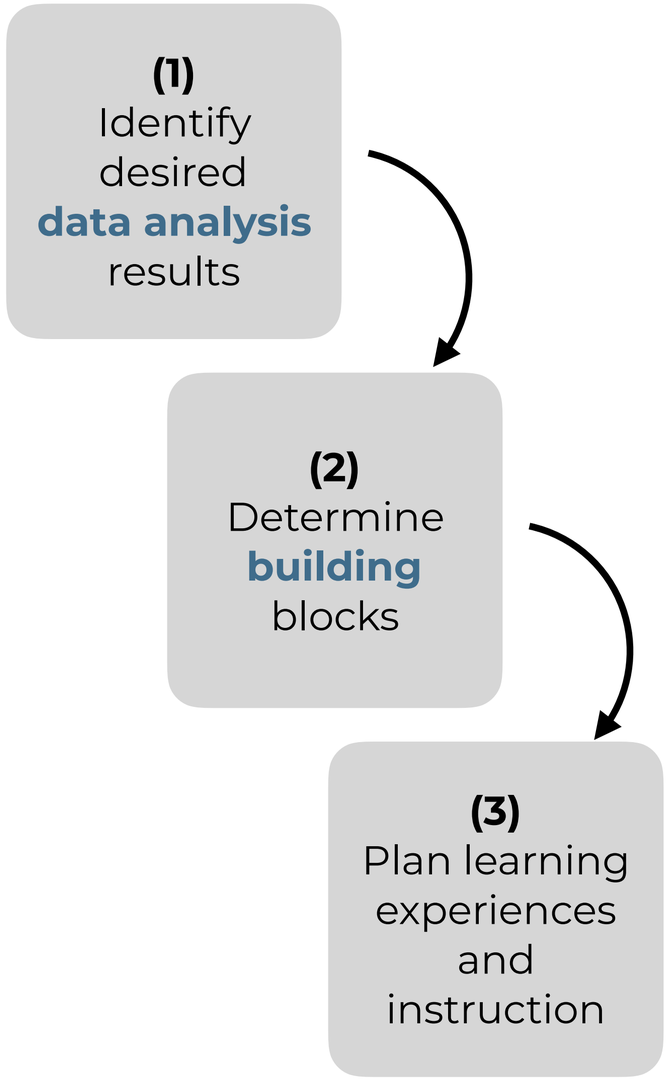
bit.ly/eat-cake-cetl-msor

design foundations

2

bit.ly/teach-ds-latinR

1 backwards design



2 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.

(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) Not just inference & modeling, also data importing, cleaning, preparation, exploration, & visualization

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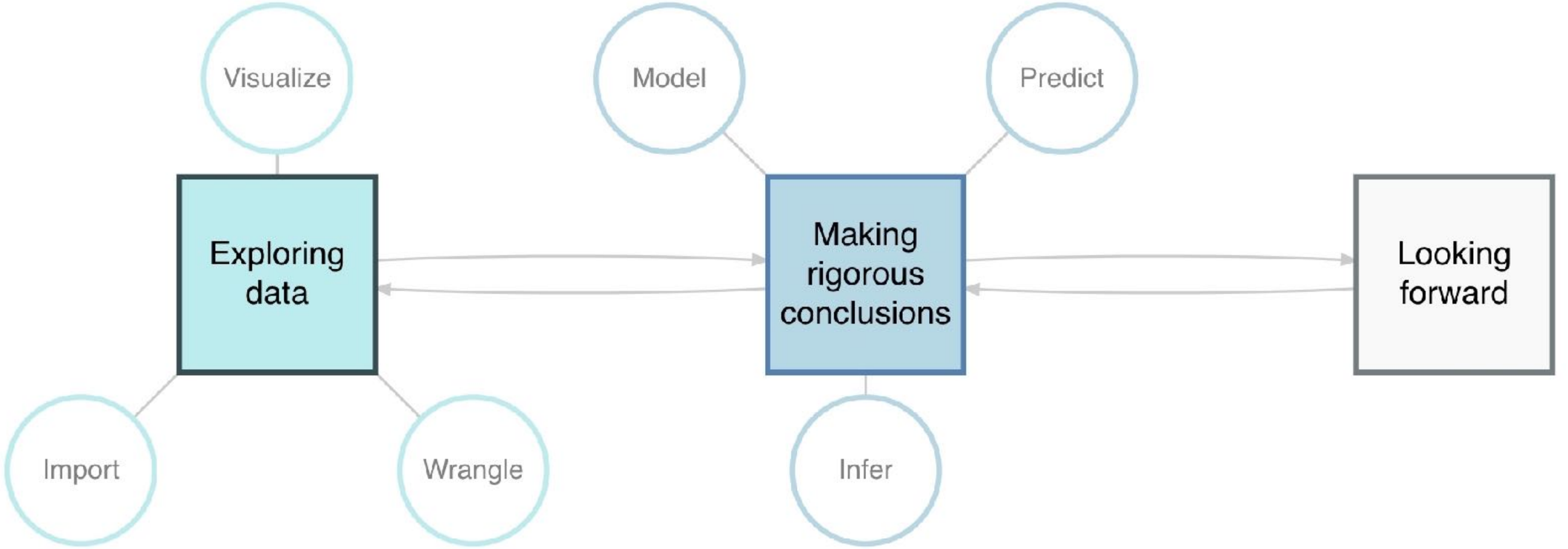

Fundamentals of data & data viz, confounding variables, Simpson's paradox + R / RStudio, R Markdown, simple git

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

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design principles

5

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Q

Which kitchen would you rather bake a cake?

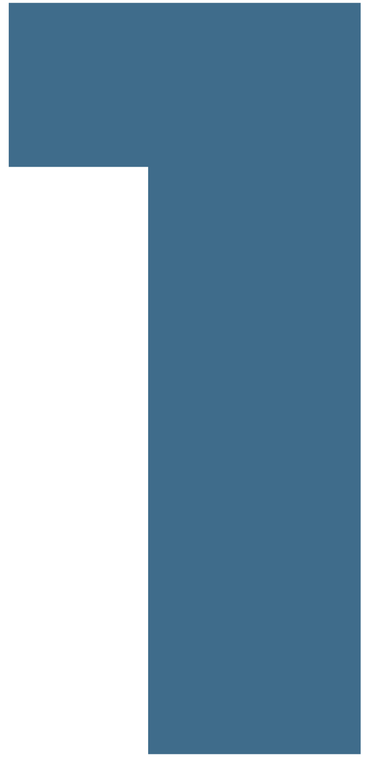
Q

Which kitchen would you rather bake a cake?

cherish

day

one



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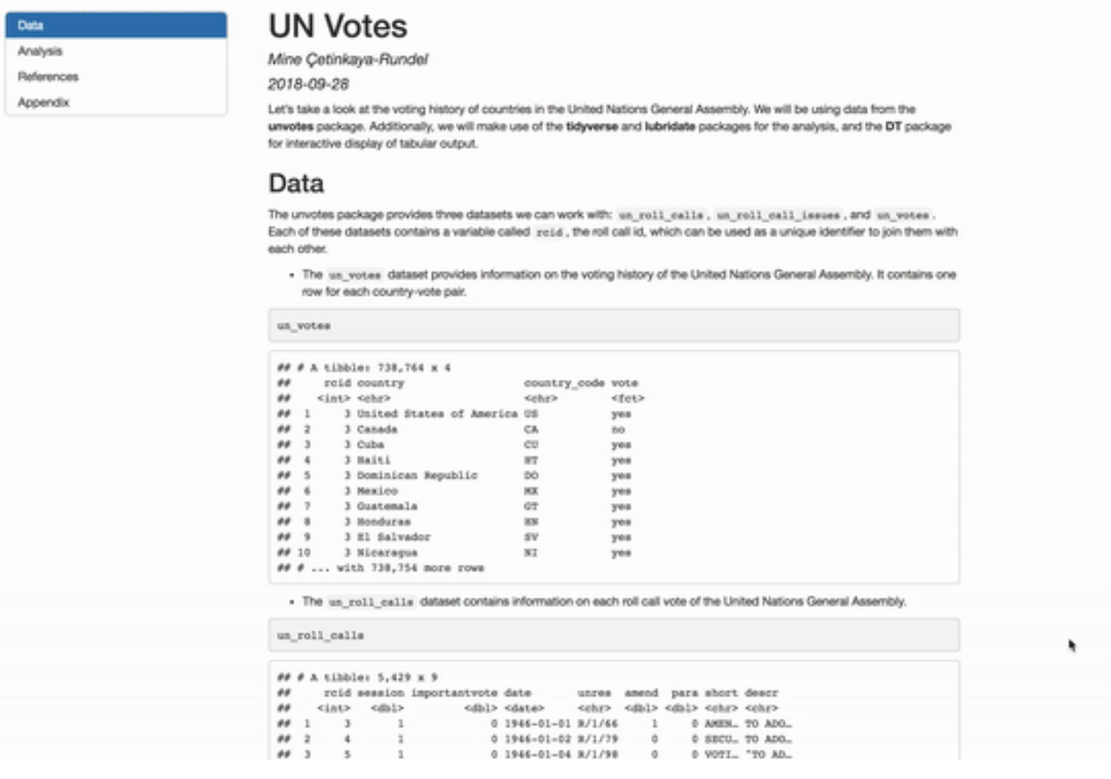
- Install R
- Install RStudio
- Install the following packages:
  - tidyverse
  - rmarkdown
  - ...
- Load these packages
- Install git

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

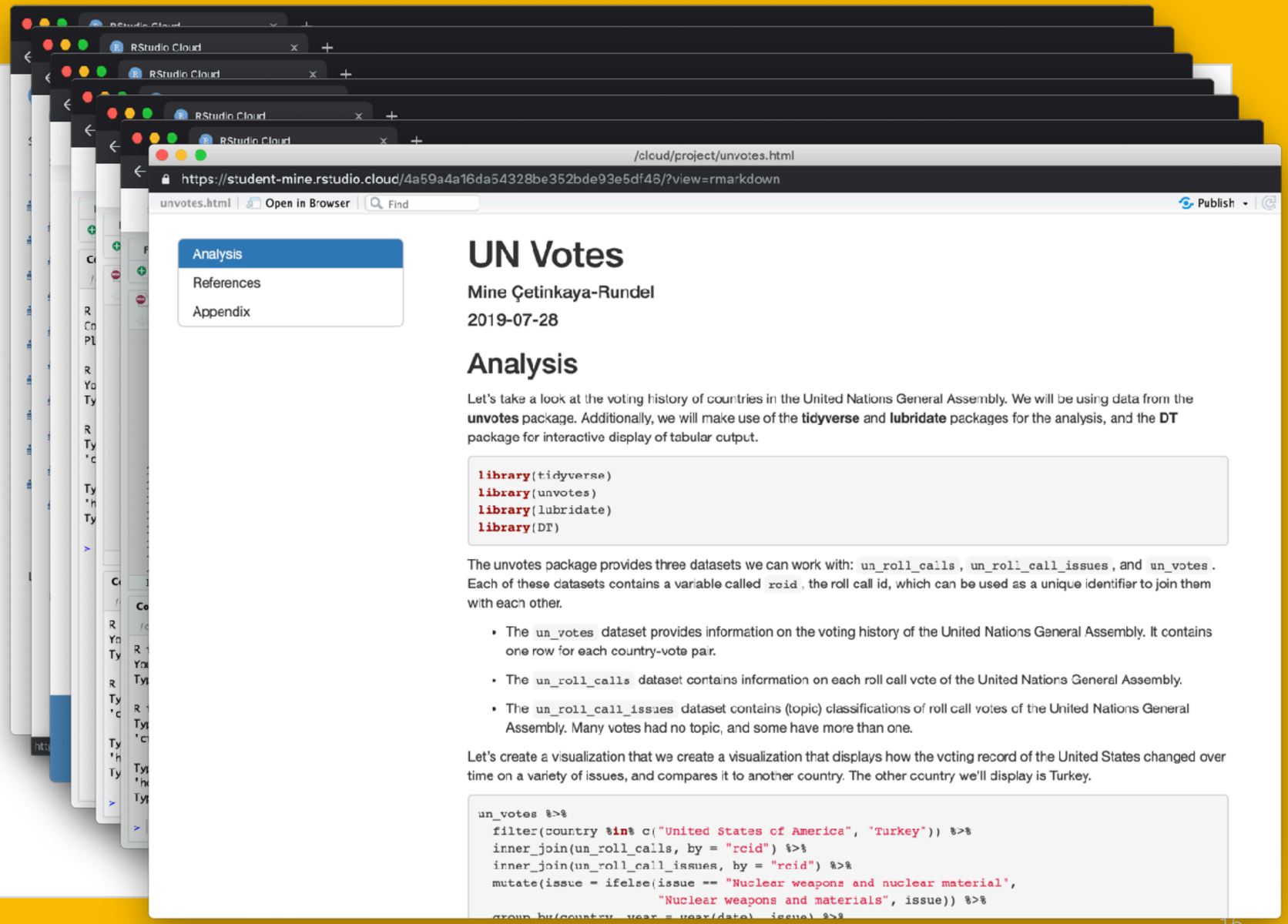
```
> hello R!
```



bit.ly/teach-ds-latinR

> 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.



Q

How do you prefer your cake recipes? Words only, or words & pictures?

Ingredients

For the Cake:

16 ounces plain or toasted sugar (about 2 1/4 cups; 455g)

4 1/2 teaspoons baking powder

2 teaspoons (8g) Diamond Crystal kosher salt; for table salt, use about half as much by volume or the same weight

8 ounces unsalted butter (16 tablespoons; 225g), soft but cool, about 60°F (16°C)

3 large eggs, brought to about 65°F (18°C)

1/2 ounce vanilla extract (about 1 tablespoon; 15g)

16 ounces whole milk (about 2 cups; 455g), brought to about 65°F (18°C)

16 ounces all-purpose flour (about 3 1/2 cups, spooned; 455g)

Directions

1. **For the Cake:** Adjust oven rack to lower-middle position and preheat to 350°F (180°C). Lightly grease three 8-inch anodized aluminum cake pans and line with parchment (explanation and tutorial here). If you don't have three pans, it's okay to bake the cakes in stages, the batter will keep at room temperature until needed.

2. In the bowl of a stand mixer fitted with the paddle attachment, combine sugar, baking powder, salt, and butter. Mix on low speed to roughly incorporate, then increase to medium and beat until fluffy and light, about 5 minutes. About halfway through, pause to scrape the bowl and beater with a flexible spatula.

3. With the mixer still running, add the eggs one at a time, letting each fully incorporate before adding the next, then dribble in the vanilla. Reduce speed to low and sprinkle in about 1/3 of the flour, then drizzle in 1/3 of the milk. Repeat with remaining flour and milk, working in thirds as before.

4. Scrape the bowl and beater with a flexible spatula, and resume mixing on medium speed for about 3 seconds to ensure everything is well combined. The batter should look creamy and thick, registering between 65 and 68°F (18 and 20°C) on a digital thermometer. (Significant

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start with cake

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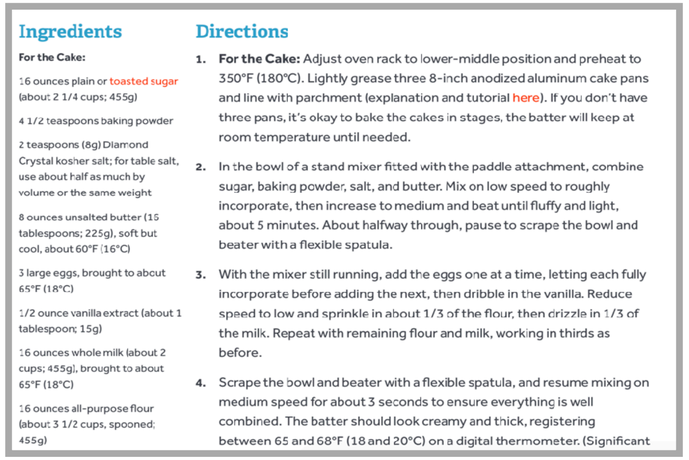

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- Declare the following variables
- Then, determine the class of each variable

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

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

class(y)
#> [1] “character"

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

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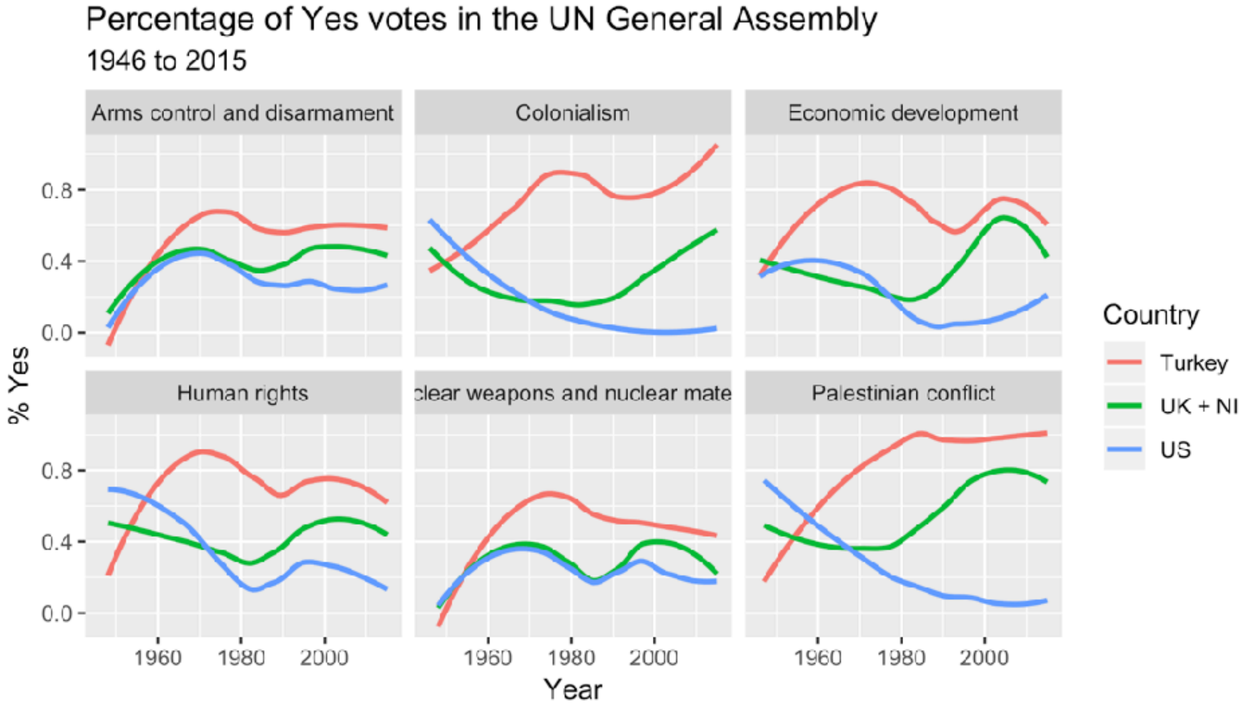
- Open today's demo project
- Knit the document and discuss the results with your neighbor



- 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("UK & NI", “US”, "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_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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    y = "% Yes",
    x = "Year",
    color = "Country"
  )
```

"Turkey"

```r
un_votes %>%
  filter(country %in% c("UK & NI", “US”, “France")) %>%
  inner_join(un_roll_calls, by = "rcid") %>%
  inner_join(un_roll_call_issues, by = "rcid") %>%
  group_by(country, year = year(date), issue) %>%
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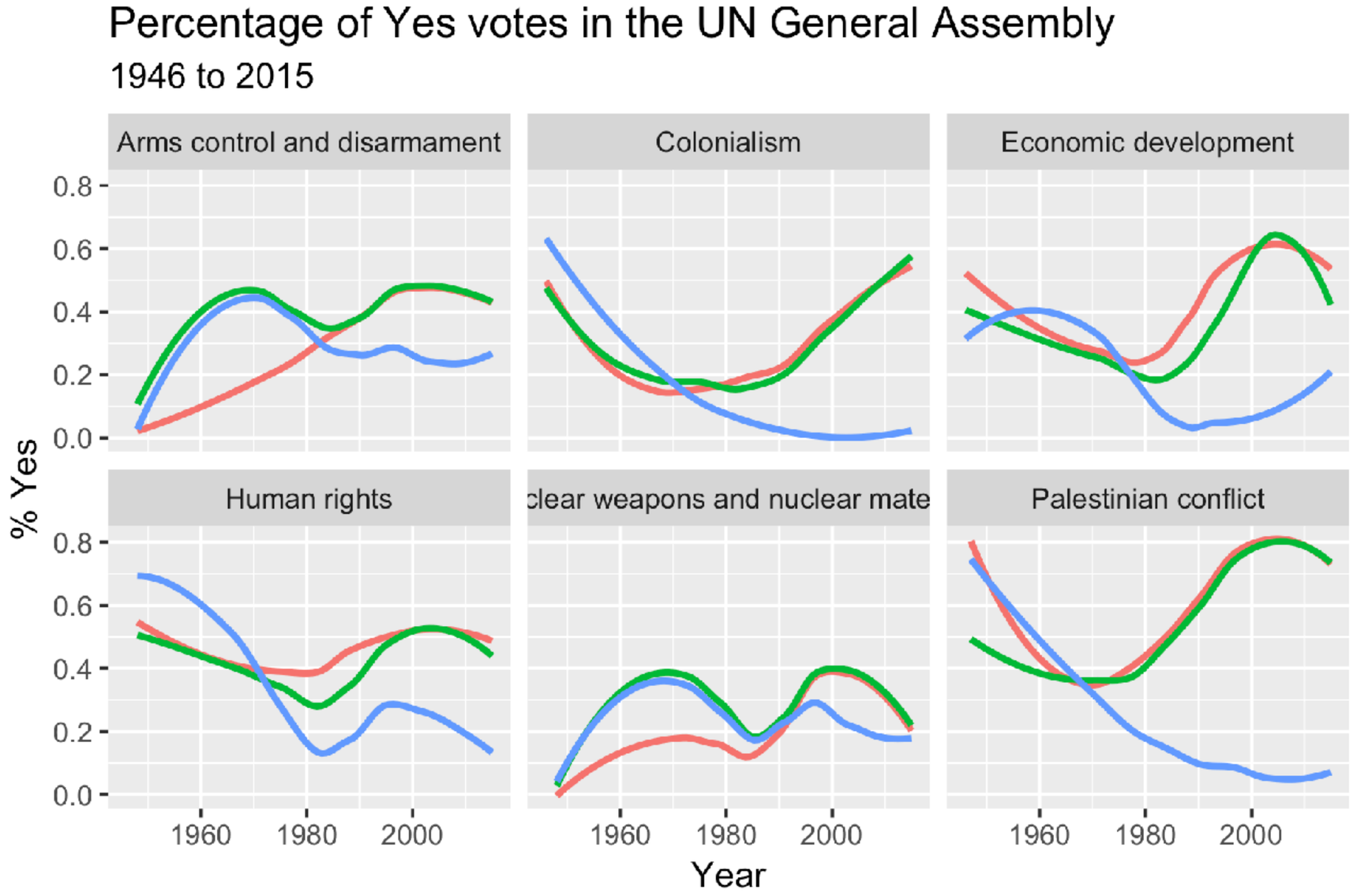
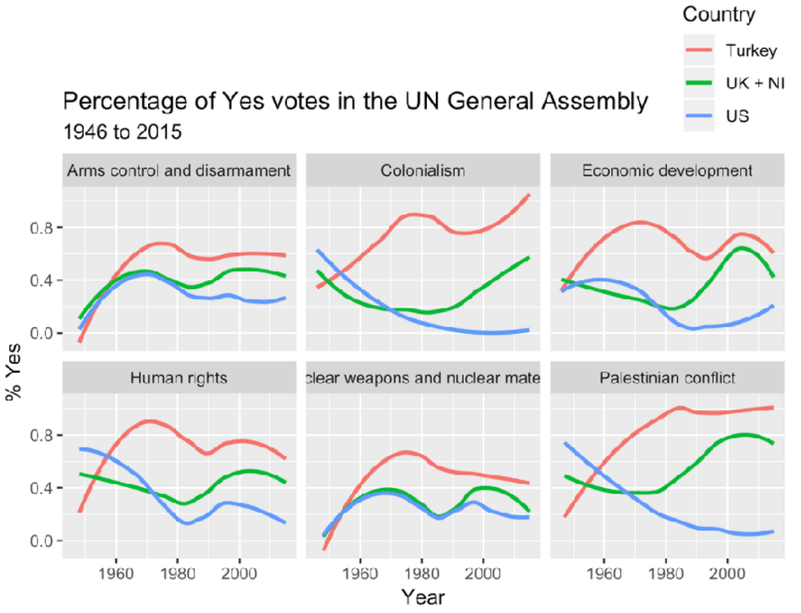
    y = "% Yes",
    x = "Year",
    color = "Country"
  )
```

“France"





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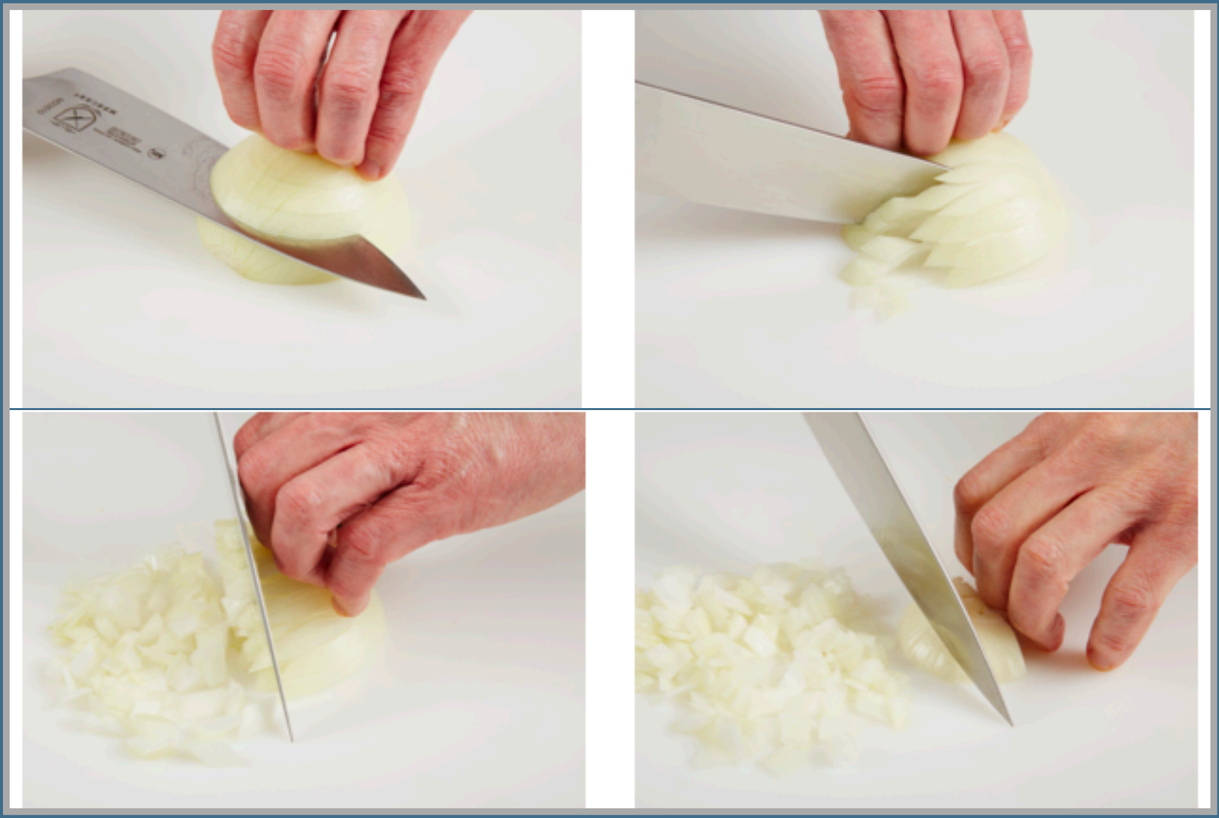
Q

Which motivates you more to learn how to cook: perfectly chopped onions or ratatouille?

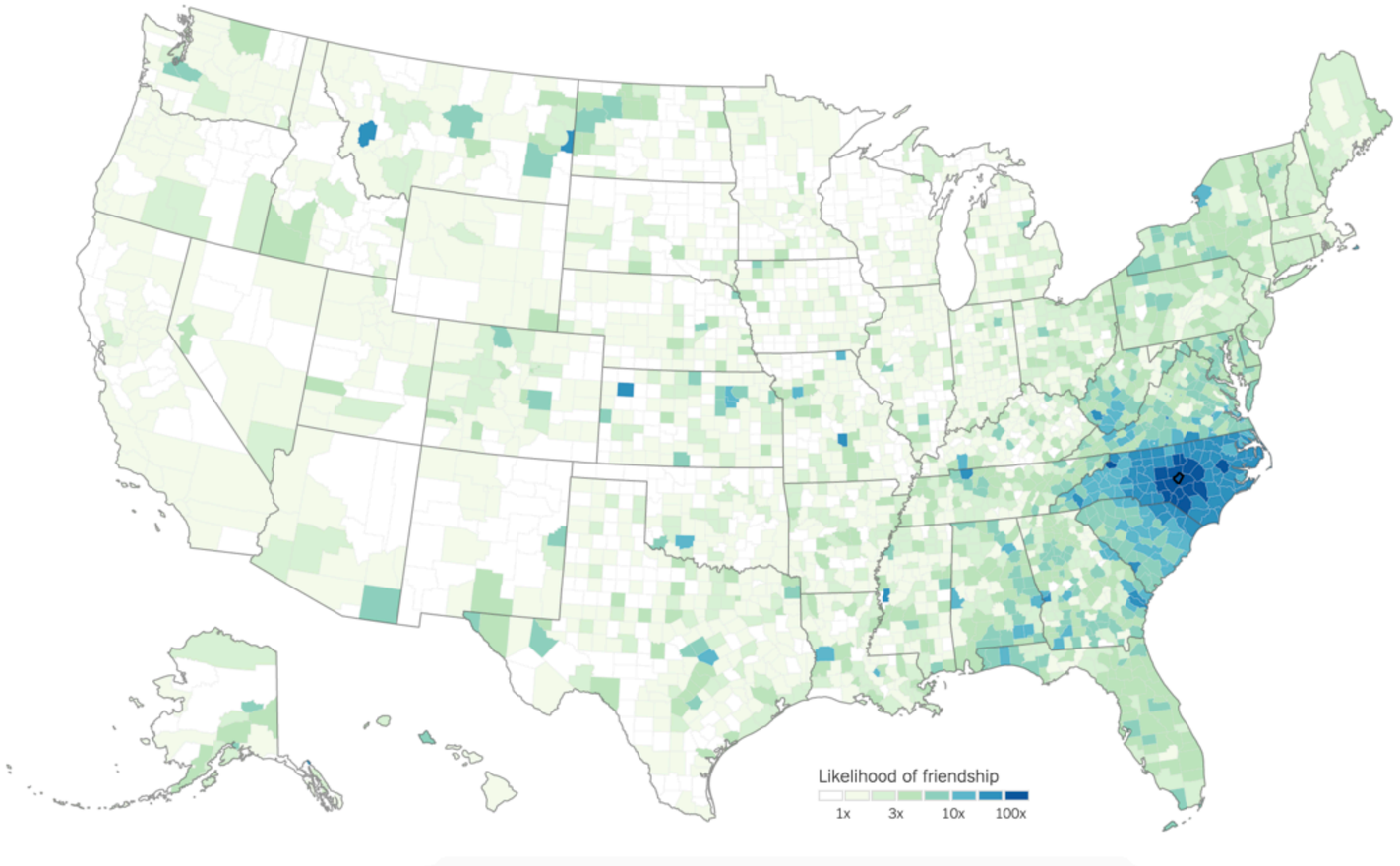


Q

Which motivates you more to learn how to cook: perfectly chopped onions or ratatouille?

> 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

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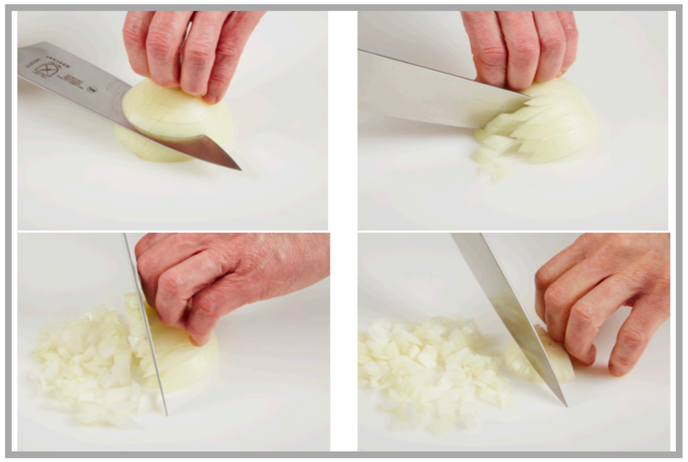
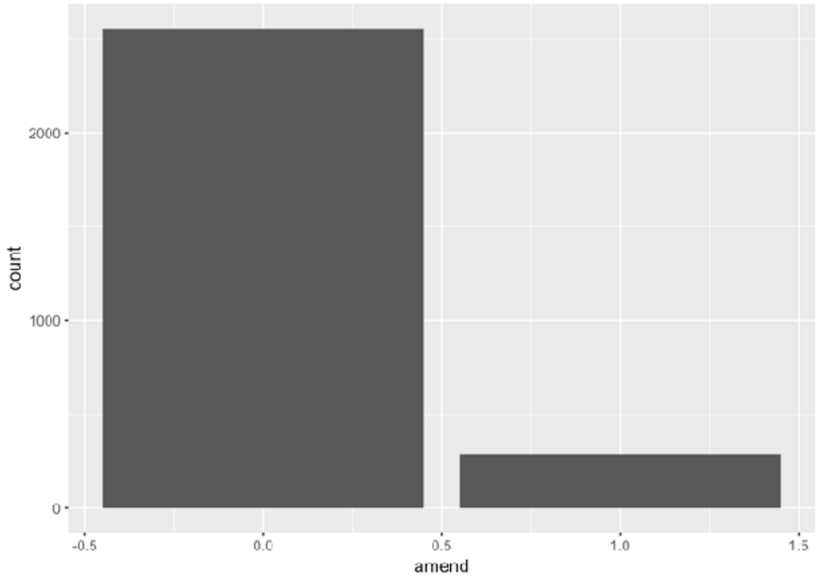
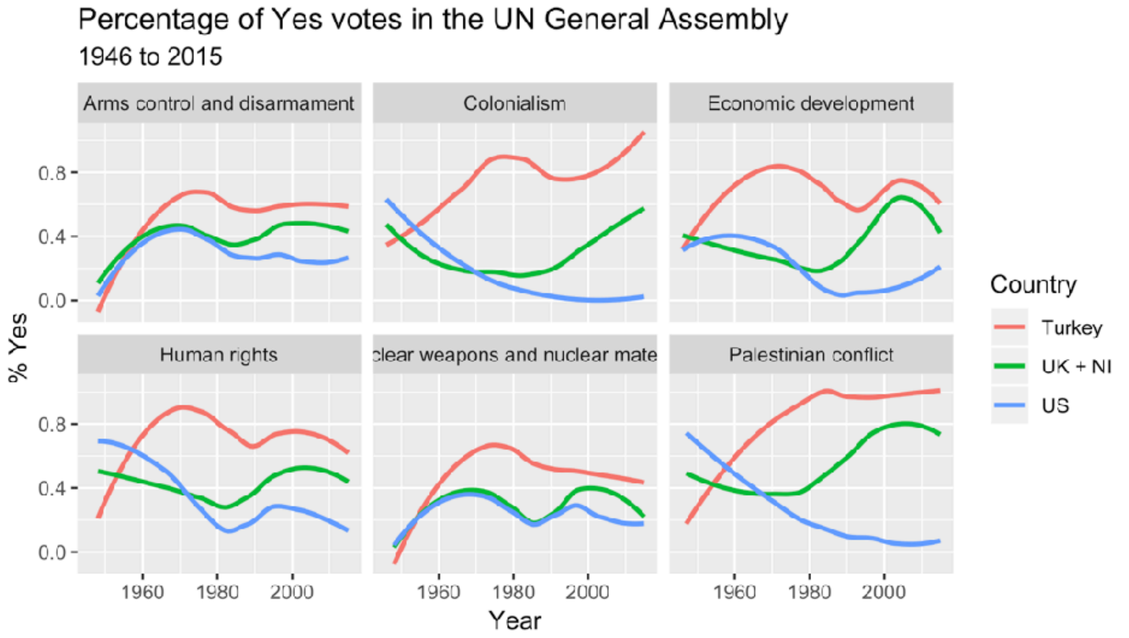


Create a visualization displaying whether the vote was on an amendment.



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



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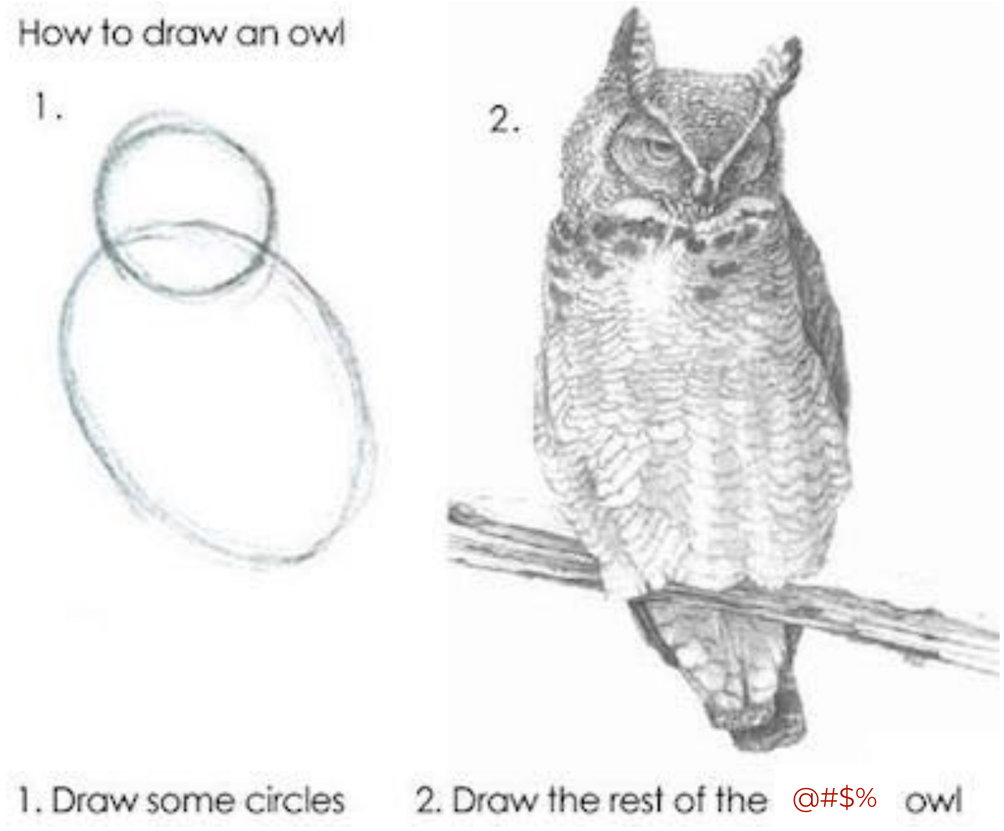
non-trivial examples can be motivating,

but need to avoid 👇!



How to draw an owl

1.

1. Draw some circles

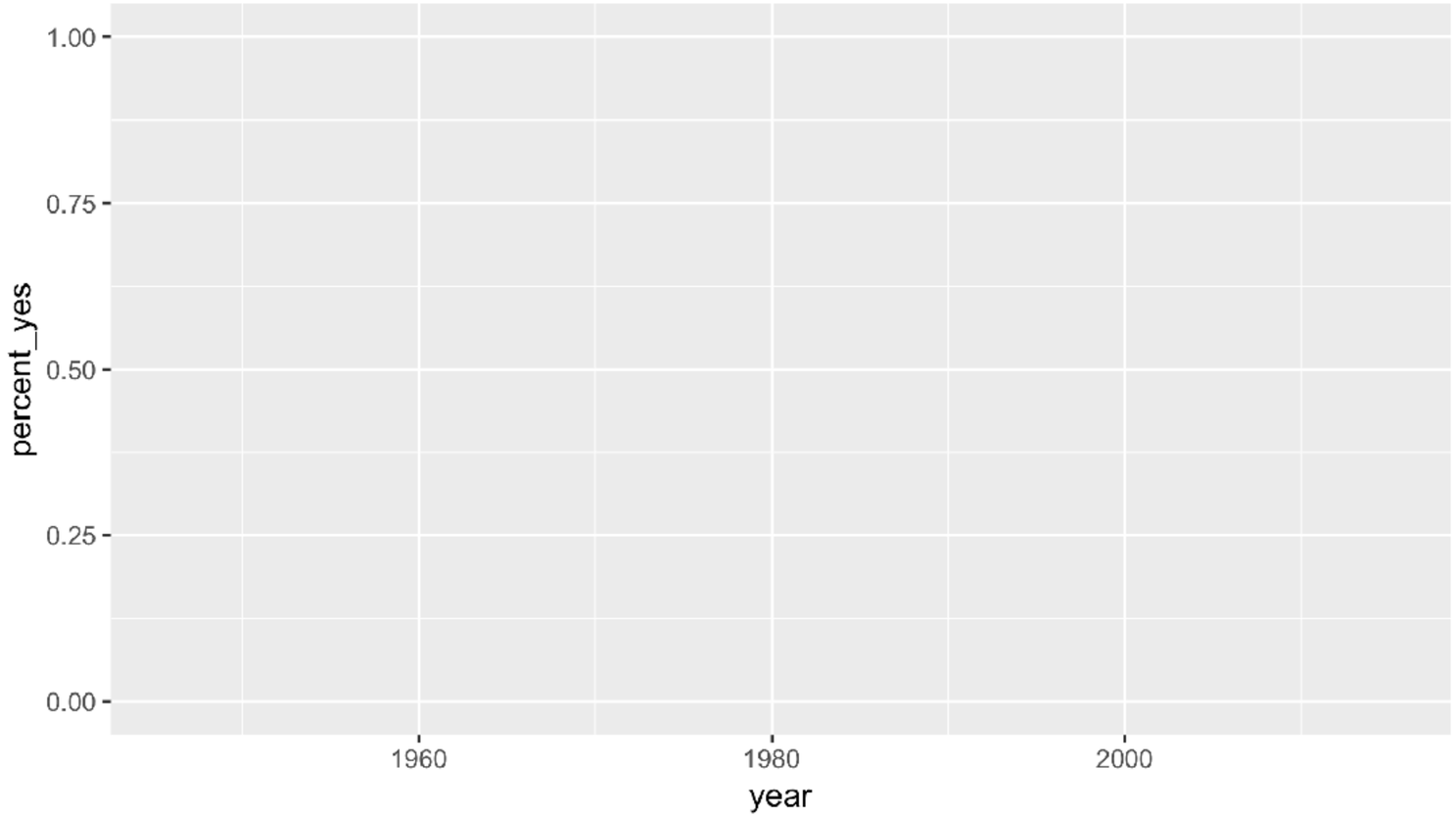
2.

2. Draw the rest of the @#$% owl

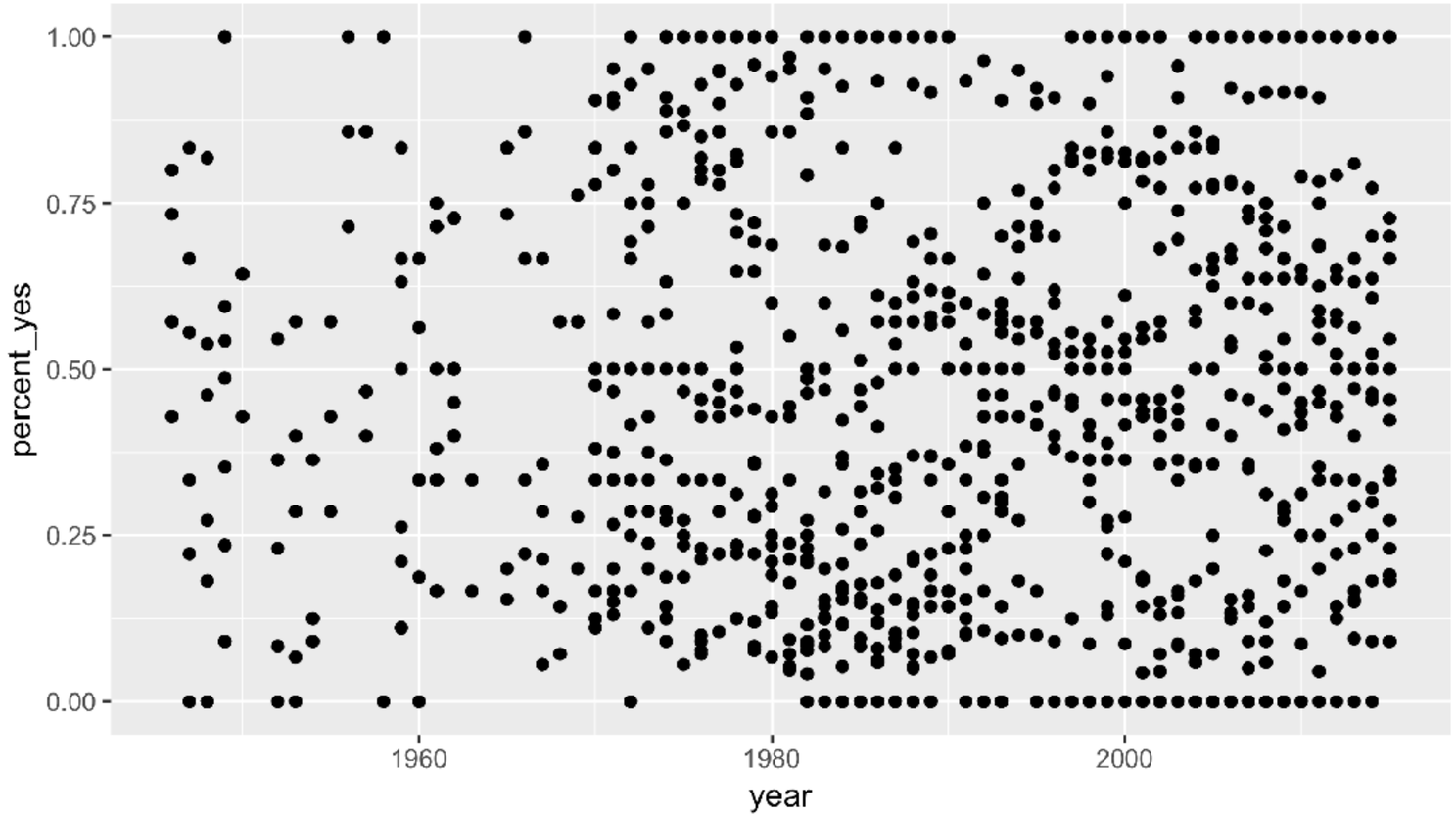
scaffold + layer

```
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)) +
  geom_point()
```



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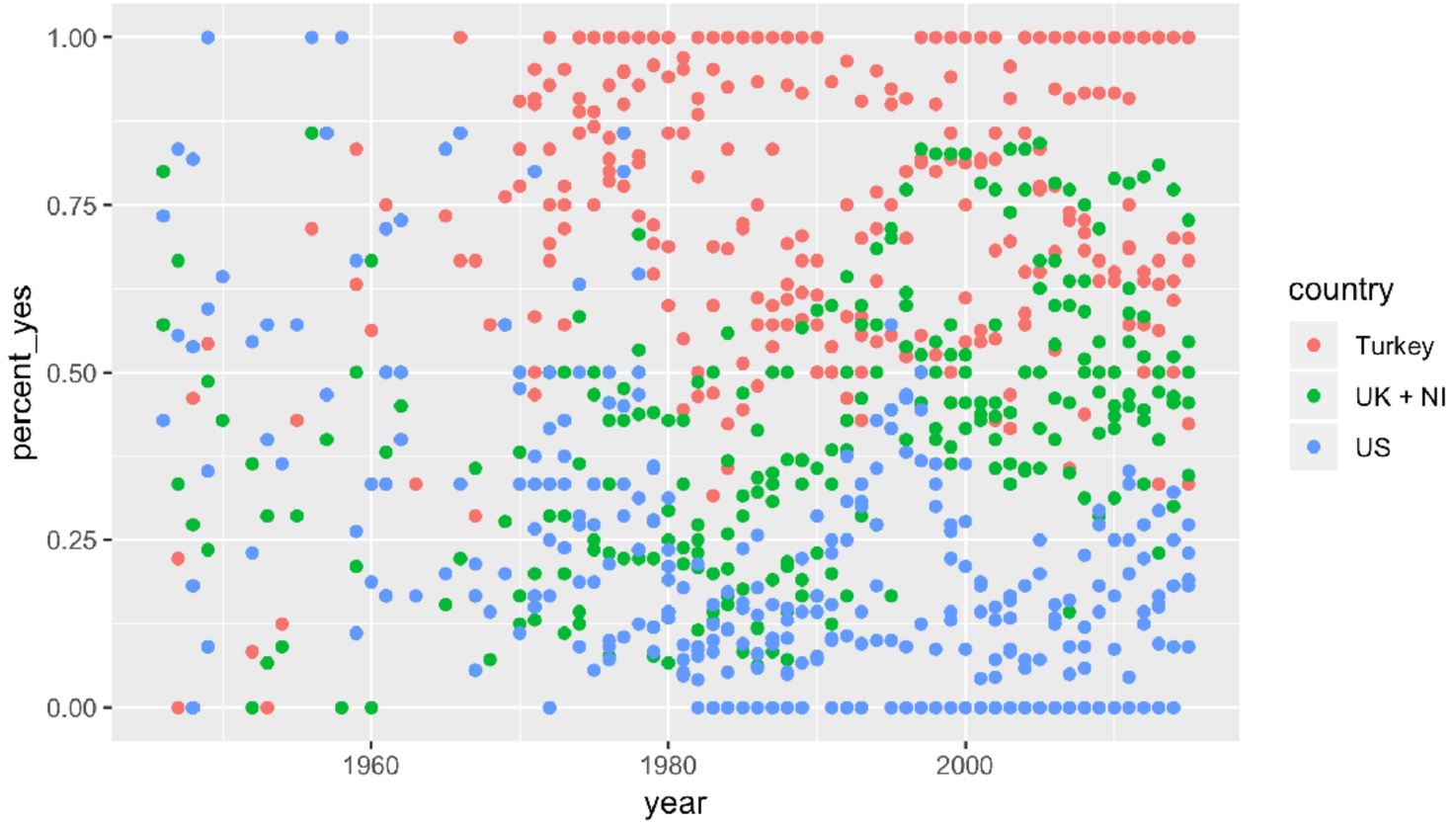
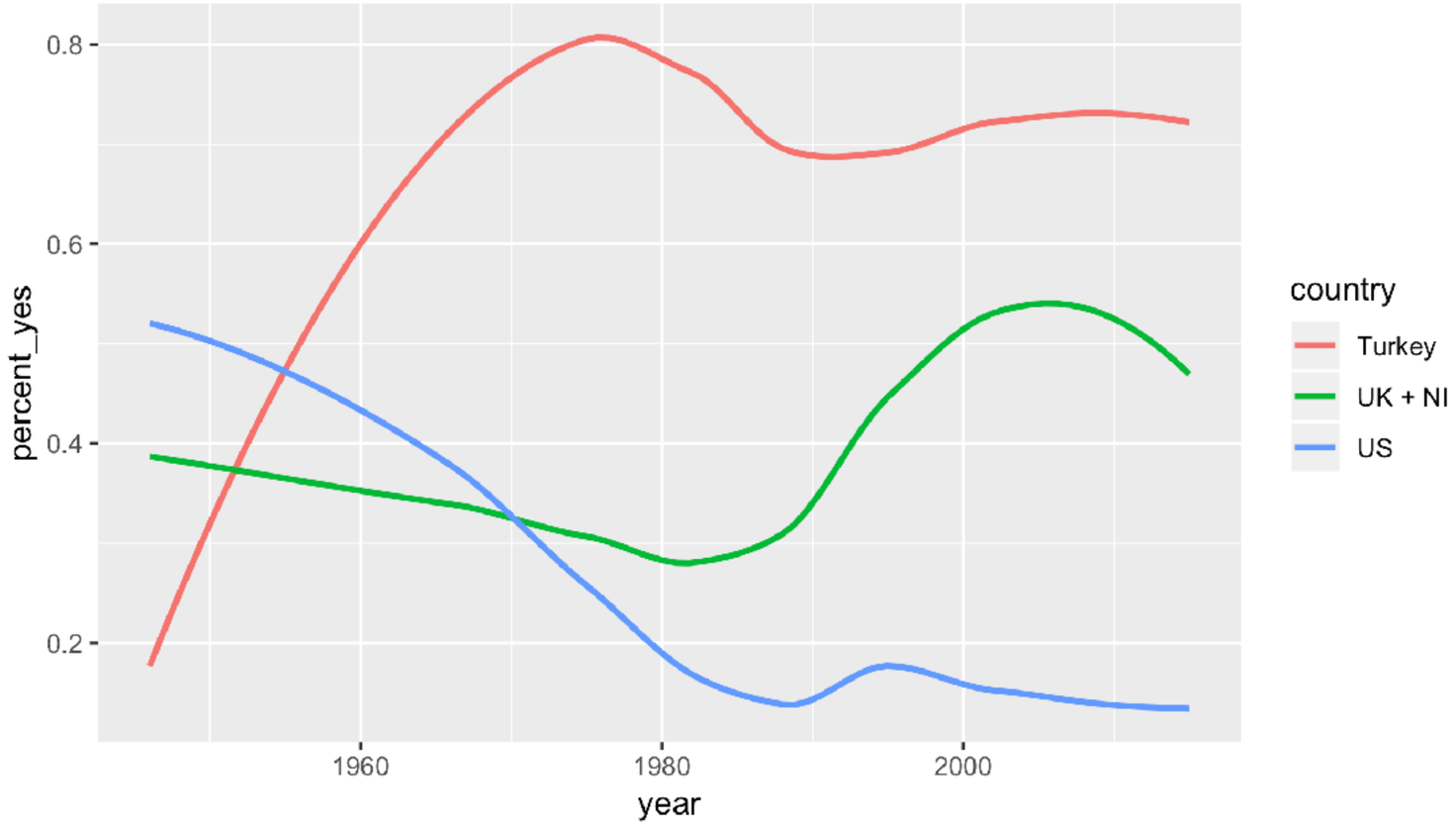


```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes, color = country)) +
  geom_smooth(method = "loess", se = FALSE)
```



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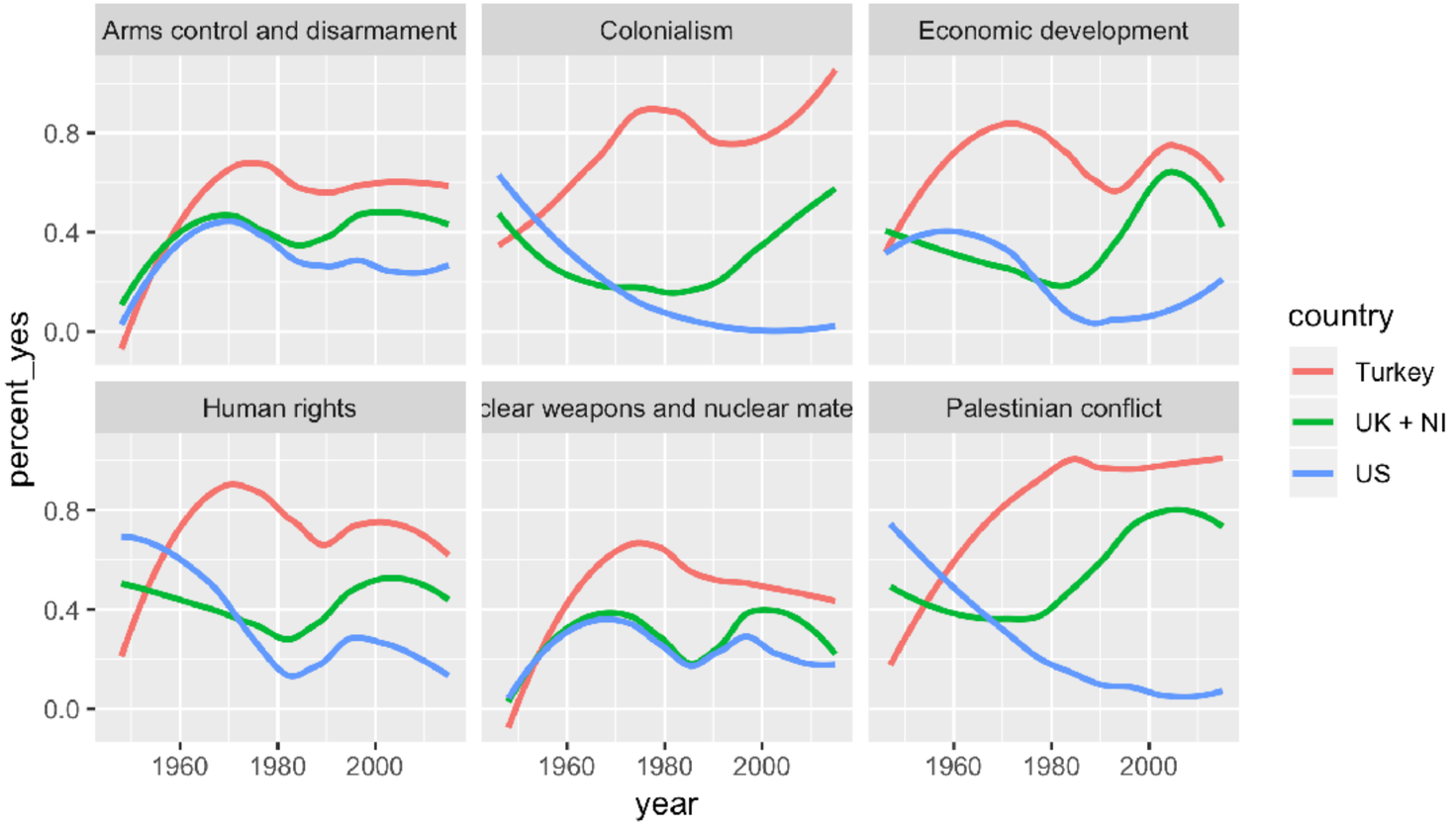

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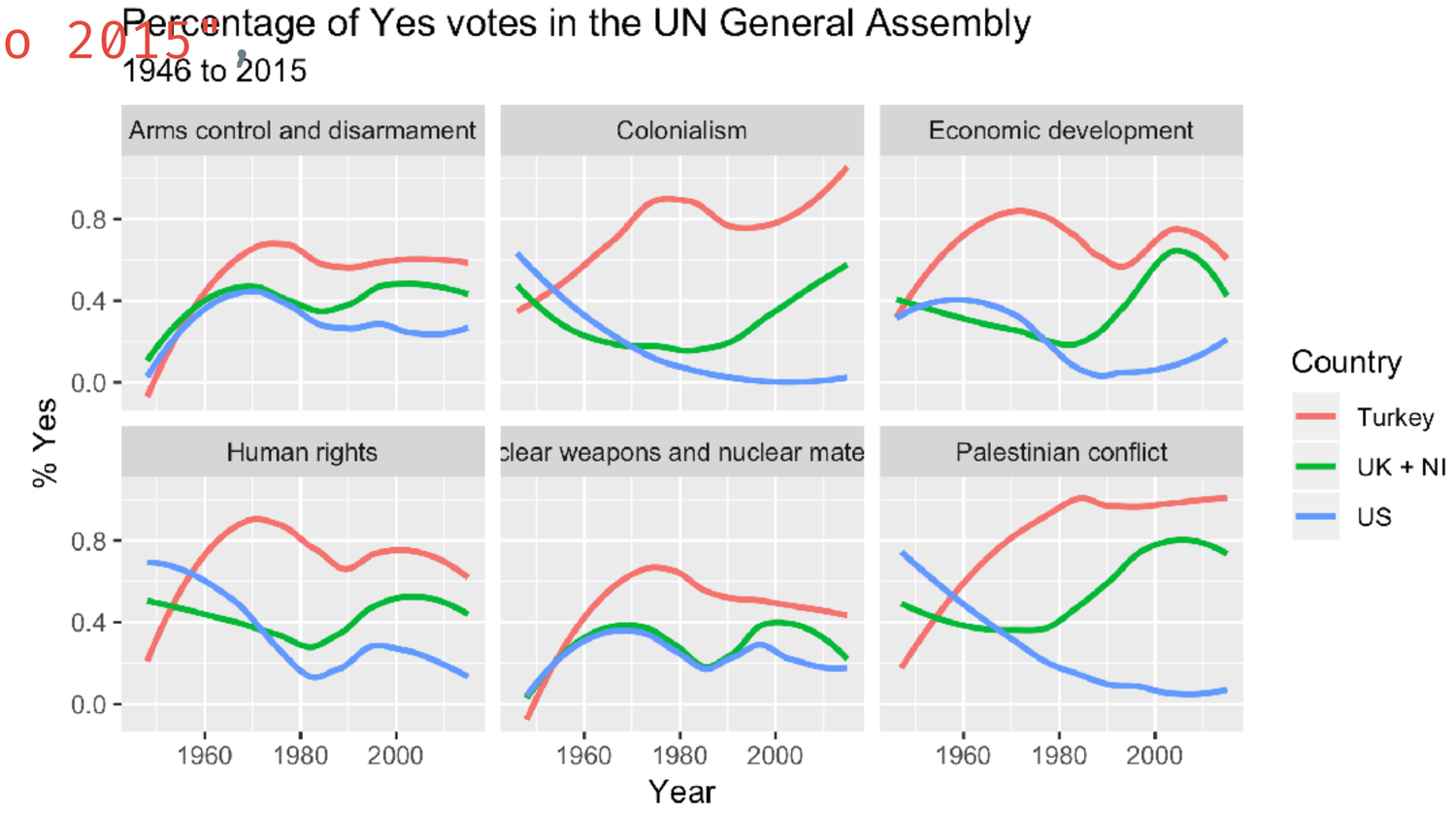
```



re-insert

~~skip~~

baby steps

Visualizing data

- Data visualization with ggplot2
- The data: Star Wars
- Scatterplots
- Setting aesthetic features
- Faceting your visualizations
- Data types
- Univariate analysis

Start Over

Scatterplots

How can we visualize the relationship between characters' heights and masses? Following the structure of the `ggplot` function that we laid out earlier, we pass `starwars` to the `data` argument, and map `height` and `mass` to the *x* and *y* `aes`thetics, respectively. Then, we specify on the next layer that we would like the data points to be represented by points with `geom_point`.

Fill in the blanks below to create the scatterplot.

Code | Start Over | Solution | Run Code | Submit Answer

```
1 ggplot(data = ___, mapping = aes(x = ___, y = ___)) +
2   ___
3
```

Notice the warning that tells us that 28 of the observations have not been graphed, which means that some of the necessary information (height and mass) was missing for those rows.

Your turn!

How would you describe the relationship between height and weight?

- positive and nonlinear
- positive and linear
- negative and nonlinear
- negative and linear

Submit Answer

How many outliers does the graph show?

- 0
- 1
- 2

Submit Answer

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Q

Which is more likely to appeal to someone who has never tried broccoli?

Q

Which is more likely to appeal to someone who has never tried broccoli?

hide the veggies

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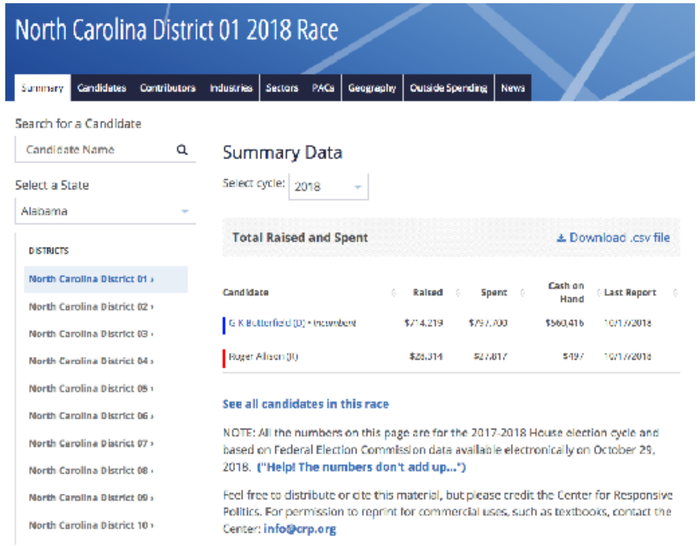
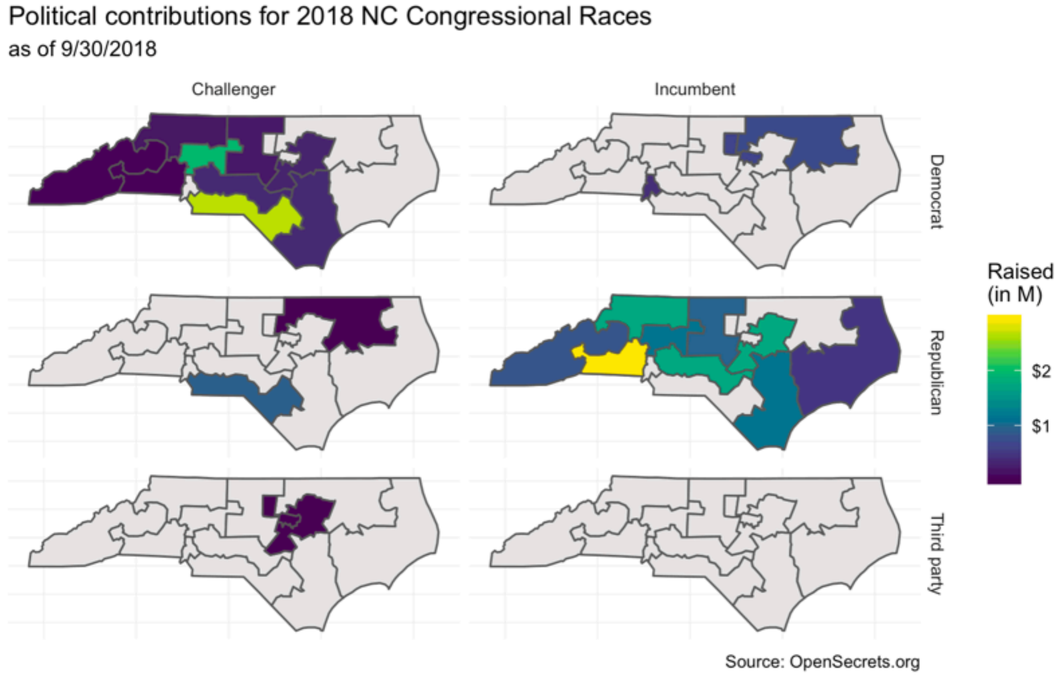
- Topic: Web scraping
- Tools:
  - `rvest`
  - regular expressions

- Today we start with this:



- and end with this:



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

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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

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

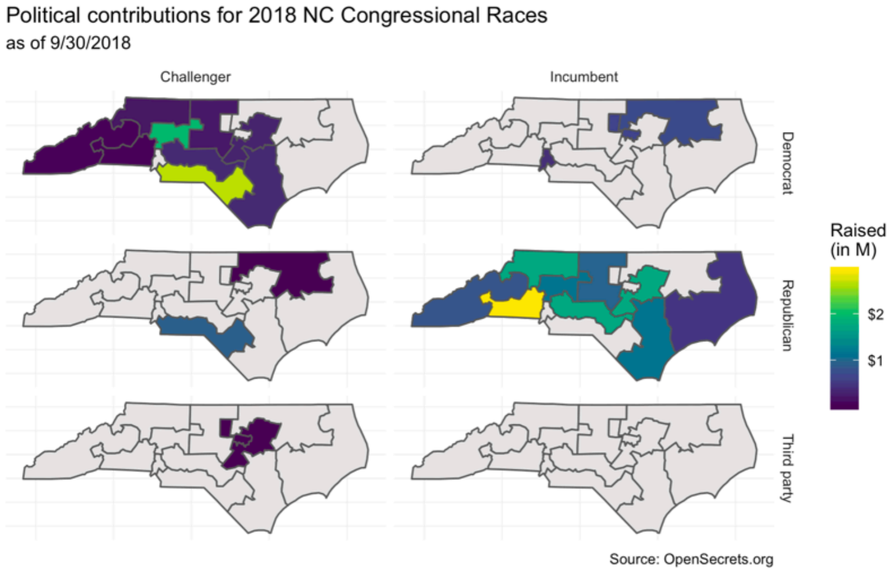
- **Ex 1:** Scrape the table off the web and save as a data frame.

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

- **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

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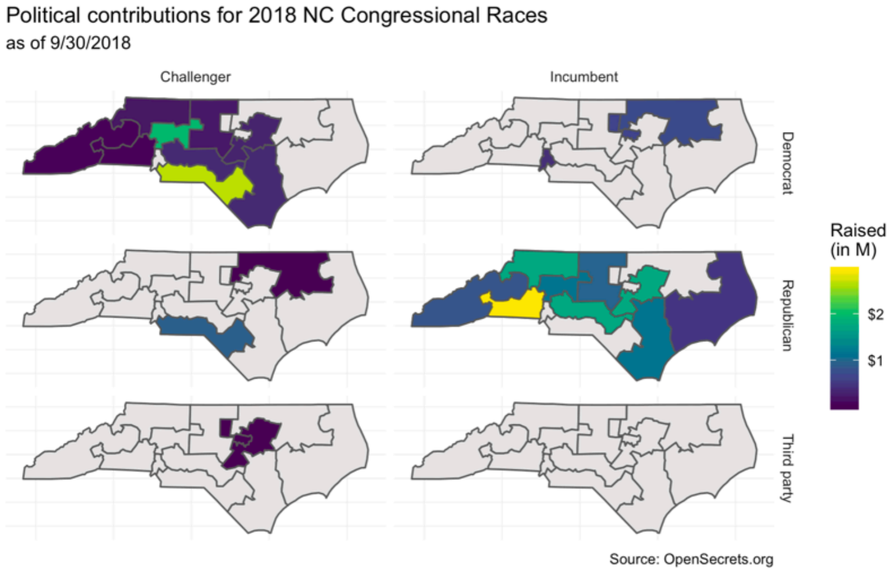

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Q

If you are already taking a baking class, which will be easier to venture on to?

Q

If you are already taking a baking class, which will be easier to venture on to?

leverage the ecosystem

- 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.

```
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
```

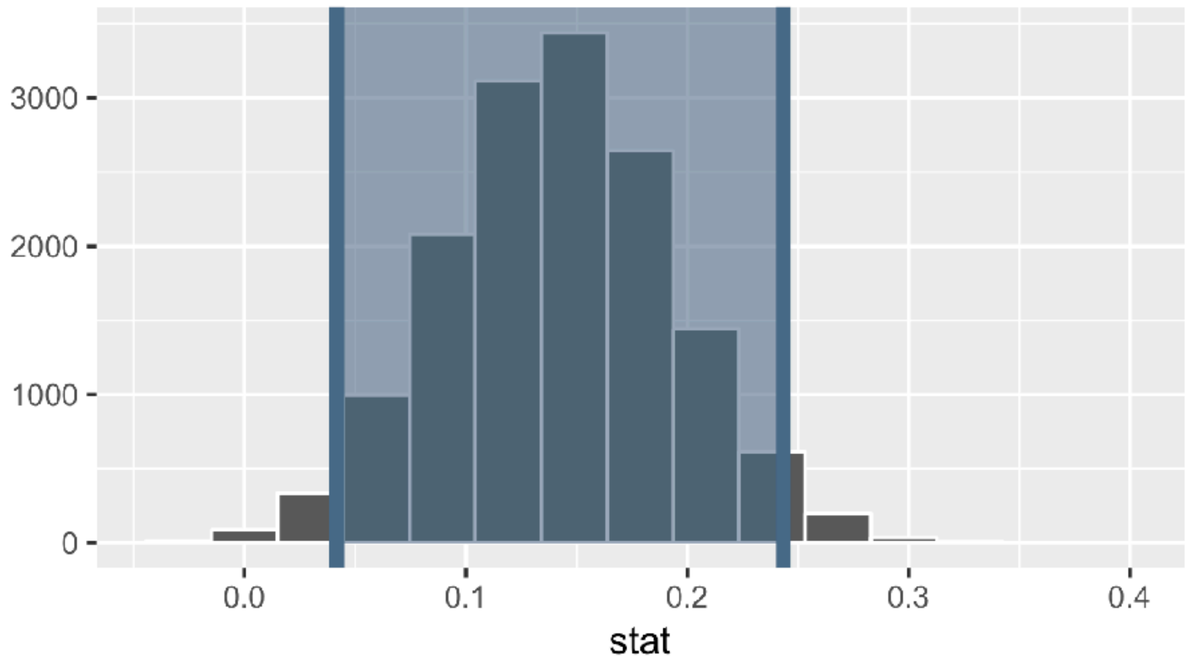
```
library(tidyverse)
library(infer)

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)
    )
```

```r
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, 0.0

#       l      u
# 0.0410 0.243
```

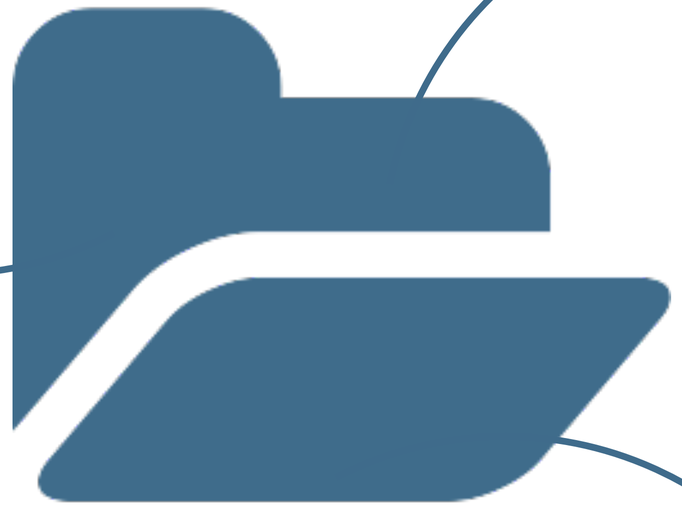


goals

3

scalable

open



validated

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Topics :: Data Science in a Box

datasciencebox.org

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- Hello #dsbox
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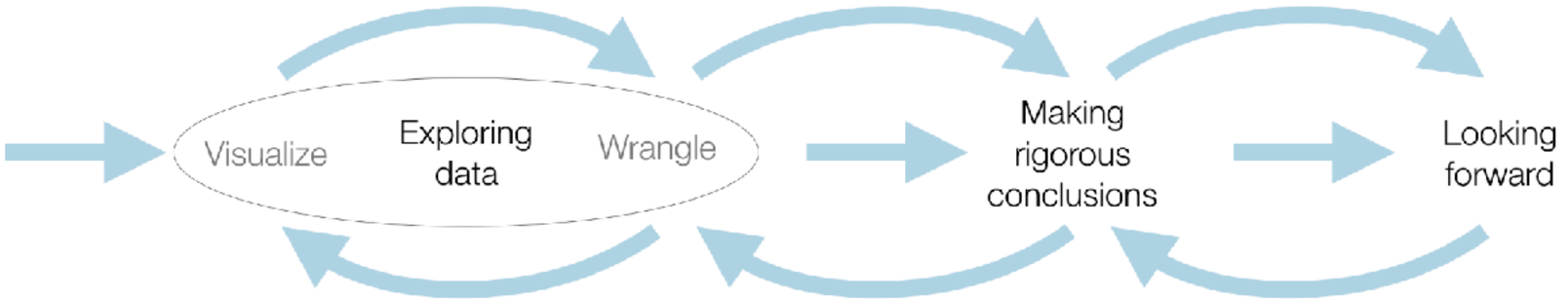
  - Philosophy
  - Topics
  - Tech stack
  - Community
- Course content
- Infrastructure
- Pedagogy

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.

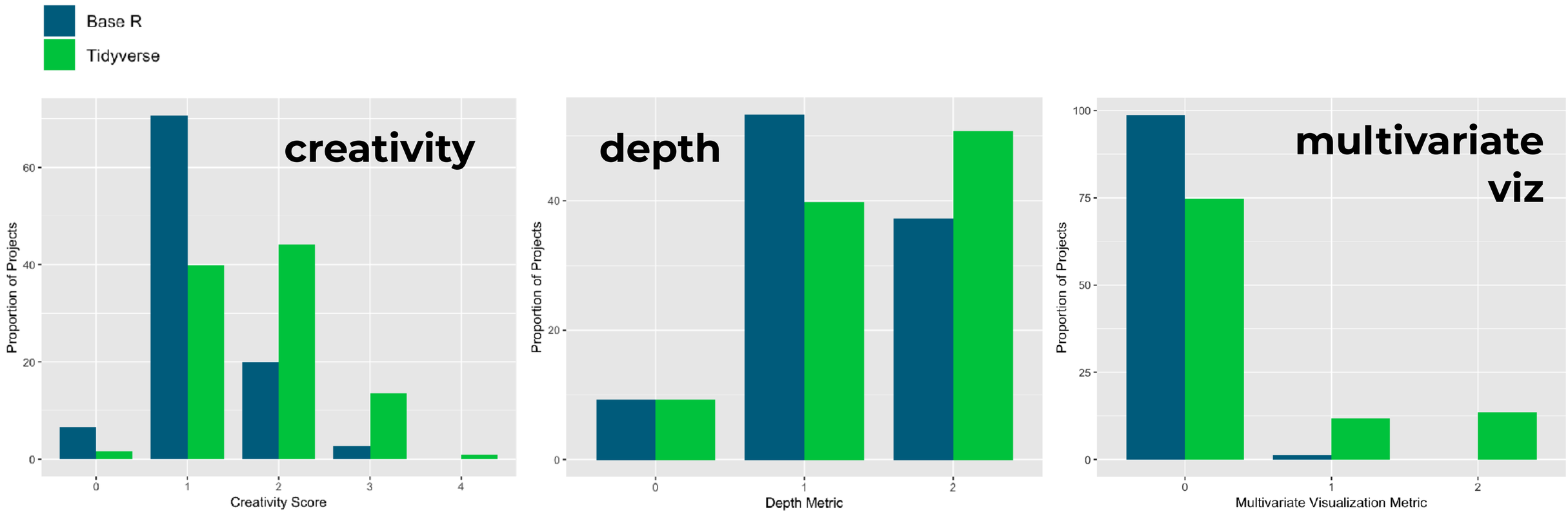
open

rstd.io/teach-ds-latinR

Retrospective study of 205 open ended student projects

- on **creativity**, **depth** and the complexity of **multivariate visualizations**
- compared across students who learned R using **base R** syntax vs. **tidyverse**

validated



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scalable

1. Formative assessments
2. Automated grading
3. Calibrated peer review

> 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)!*

* You can tell them all about the ingredients later!

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