

Let them
eat cake
(first)!



@minebocek



mine-cetinkaya-rundel



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bit.ly/let-eat-cake-cfs





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



Pineapple and coconut sandwich cake





Backward design

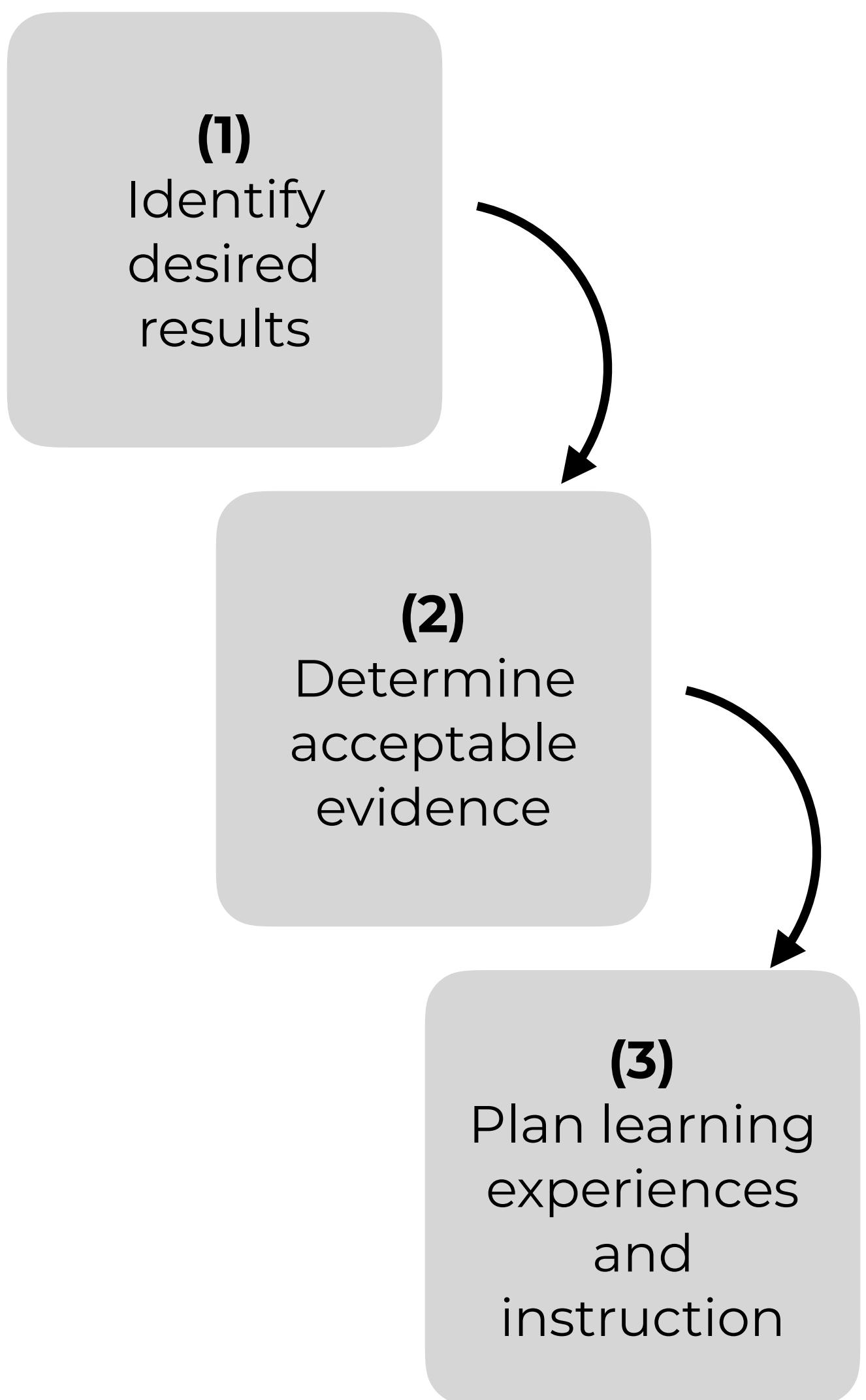
set goals for educational curriculum before choosing instructional methods + forms of assessment



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.

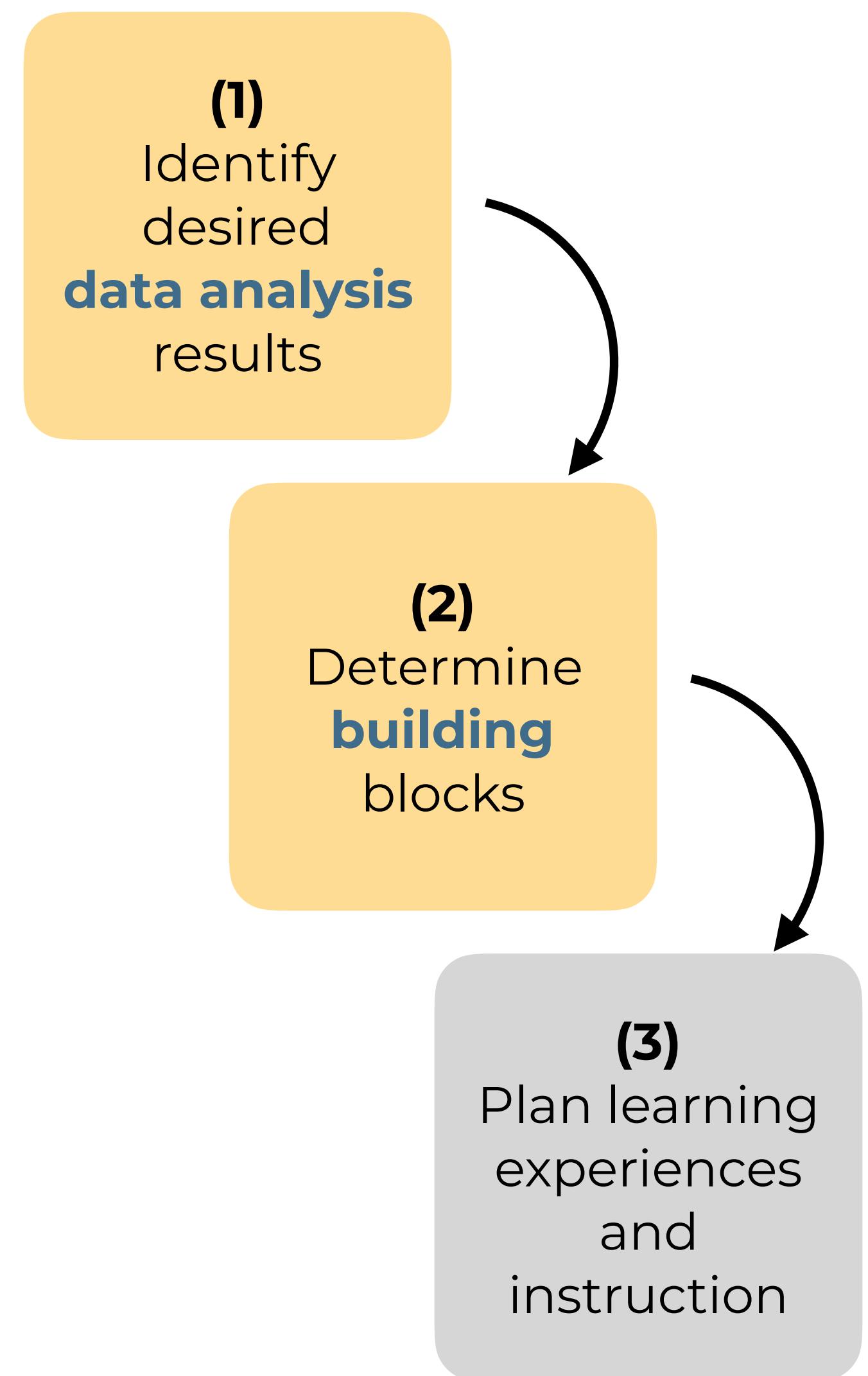


Designing backwards

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

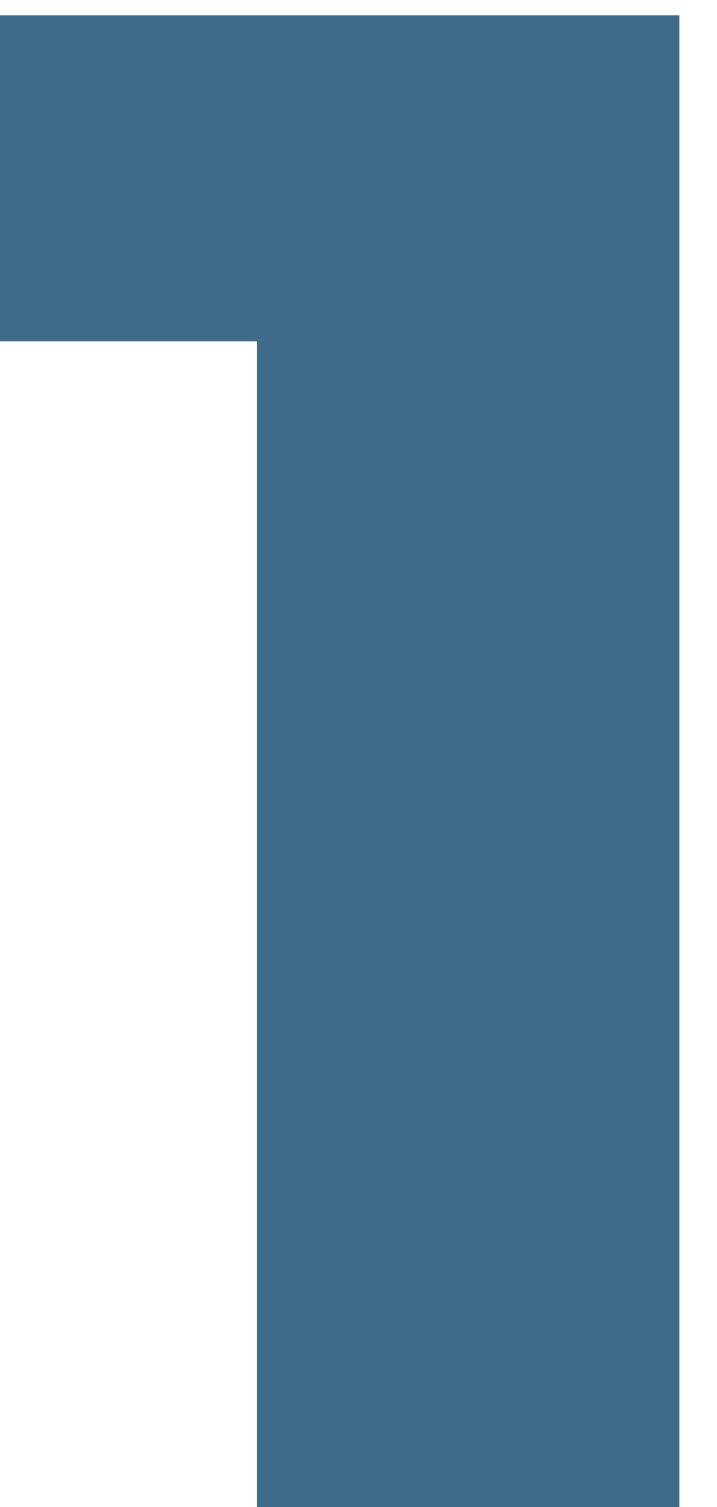
② Multivariate analysis requires the use of computing

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

5 design principles

**start
with
cake**





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

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

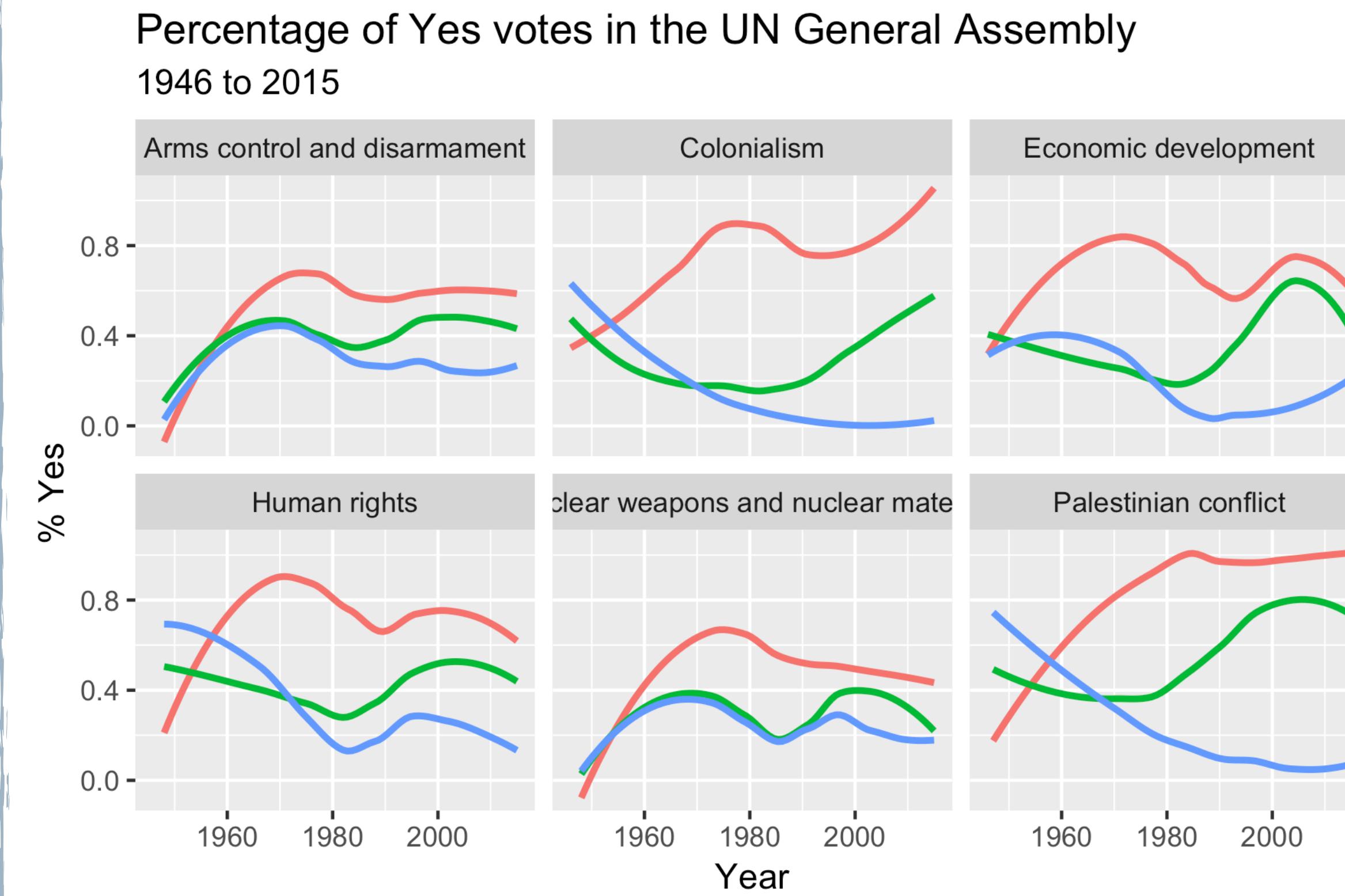
```
# Declare variables
x ← 8
y ← "monkey"
z ← FALSE

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

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

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

- ❑ 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...

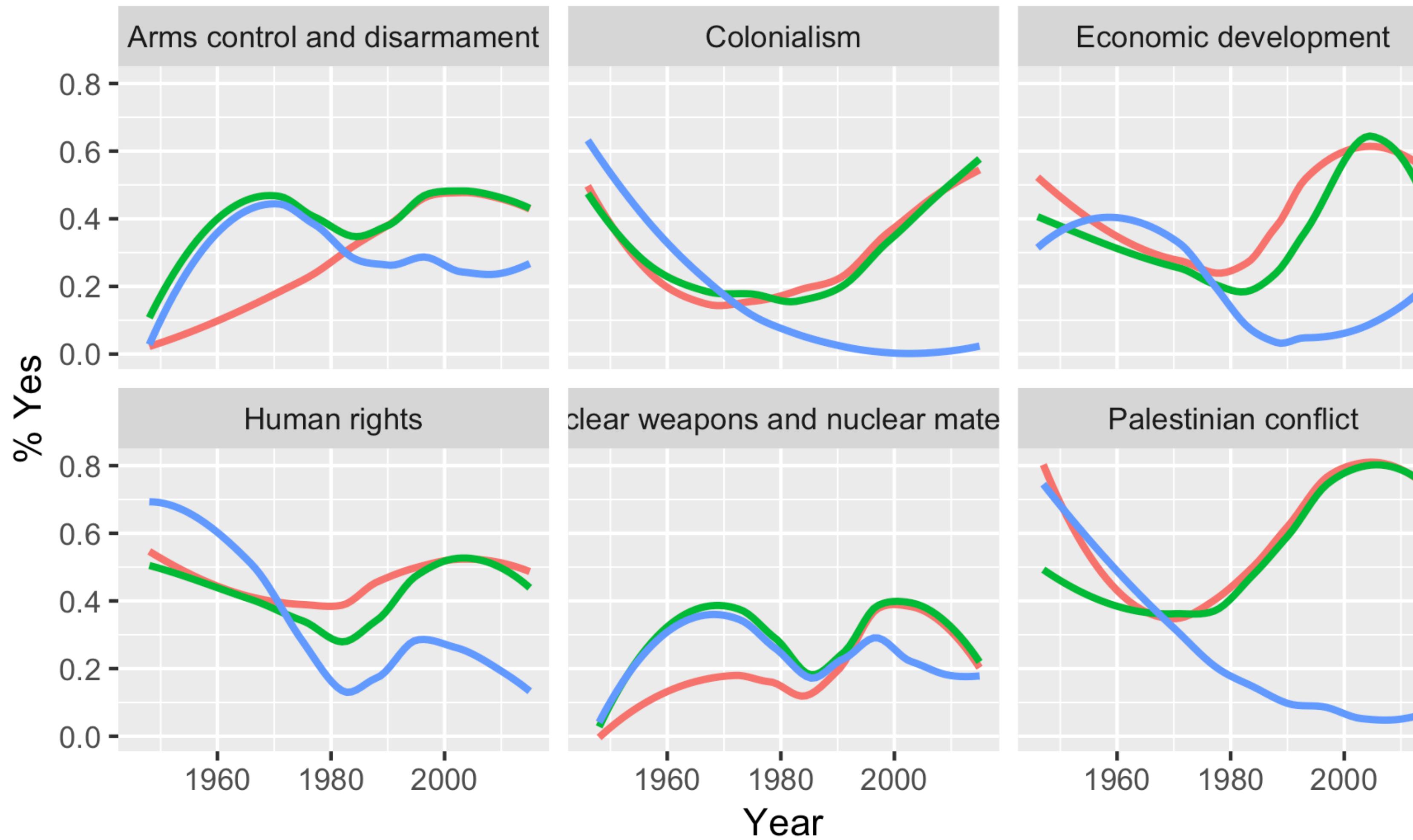
- ❑ Open today's demo project
- ❑ Knit the document and discuss the results with your neighbor
- ❑ Then, change Turkey to a different country, and plot again

```
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"  
)
```

```
un_votes %>%
  filter(country %in% c("UK & NI", "US", "Turkey")) %>%
  inner_join(un_roll_calls, by = "rcid") %>%
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  facet_wrap(~ issue) +
  labs(
    title = "Percentage of Yes votes in the UN General Assembly",
    subtitle = "1946 to 2015",
    y = "% Yes",
    x = "Year",
    color = "Country"
  )
}
```

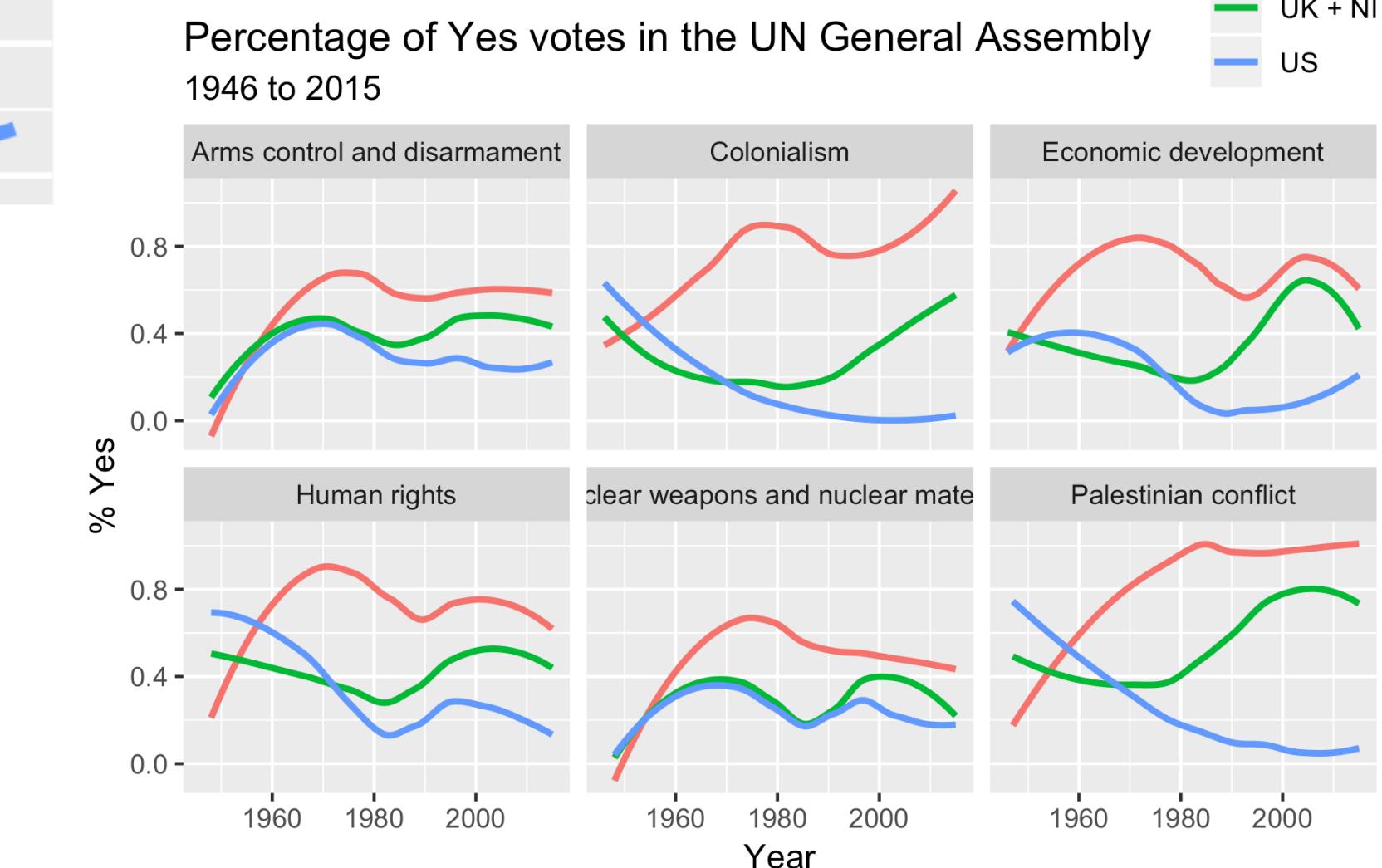
```
un_votes %>%
  filter(country %in% c("UK & NI", "US", "France")) %>%
  inner_join(un_roll_calls, by = "rcid") %>%
  inner_join(un_roll_call_issues, by = "rcid") %>%
  group_by(country, year = year(date), issue) %>%
  summarize(
    votes = n(),
    percent_yes = mean(vote == "yes")
  ) %>%
  filter(votes > 5) %>% # only use records where there are more than 5 votes
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  labs(
    title = "Percentage of Yes votes in the UN General Assembly",
    subtitle = "1946 to 2015",
    y = "% Yes",
    x = "Year",
    color = "Country"
  )
}
```

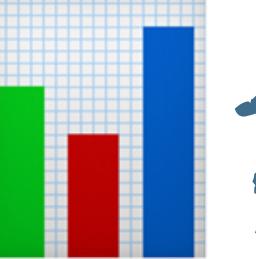
Percentage of Yes votes in the UN General Assembly 1946 to 2015



Country

- France (red)
- UK + NI (green)
- US (blue)



why  = ?

more likely for
students to have
intuition
coming in



easier for
students
to catch their
own mistakes

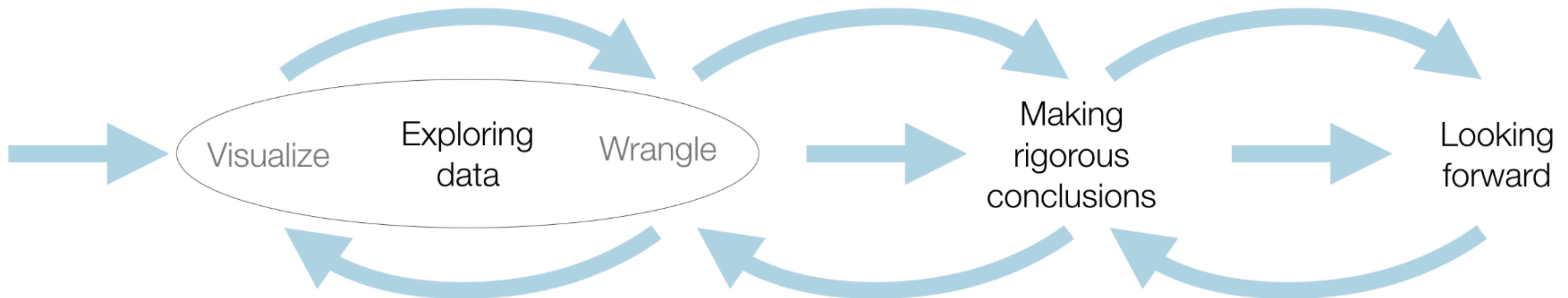


who doesn't
like a good
piece of ~~cake~~
visualization?



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

cherish
day
one





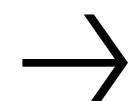
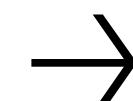
Which of the following is more likely to be **welcoming** for a wide range of students?

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

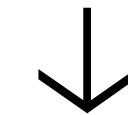
- ❑ Go to rstudio.cloud (or some other server based solution)
- ❑ Log in with your ID & pass

```
> hello R!
```

method of delivery,
and medium of interaction matters



R Studio®



Data
Analysis
References
Appendix

UN Votes

Mine Çetinkaya-Rundel

2018-09-26

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

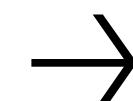
The `unvotes` package provides three datasets we can work with: `un_roll_calls`, `un_roll_call_issues`, and `un_votes`. Each of these datasets contains a variable called `roid`, the roll call id, which can be used as a unique identifier to join them with each other.

- 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.

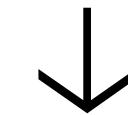
```
## # A tibble: 738,764 x 4
##   roid country      country_code vote
##   <int> <chr>        <chr>     <fct>
## 1 3 United States of America US      yes
## 2 3 Canada          CA      no
## 3 3 Cuba            CU      yes
## 4 3 Haiti           HT      yes
## 5 3 Dominican Republic DO      yes
## 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.

```
## # A tibble: 5,429 x 9
##   roid session importantvote date      unres amend para short descr
##   <int> <dttm>    <dttm> <dttm> <dttm> <dttm> <dttm> <dttm>
## 1 3 1946-01-01 0 1946-01-01 1 0 AMEN. TO ADD.
## 2 4 1946-01-02 0 1946-01-02 0 0 SEC'D. TO ADD.
## 3 5 1946-01-04 0 1946-01-04 0 0 VOT'L. "TO AD.
```



R Studio®



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UN Votes

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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 `roid`, 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
##   roid 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
##   roid session importantvote date      unres amend para short descr
##   <int> <dbl>    <dbl> <date>    <chr> <dbl> <dbl> <chr>
## 1 3     1         1      0 1946-01-01 8/1/66    1     0 AMEN_ TO ADD_
## 2 4     1         1      0 1946-01-02 8/1/79    0     0 SECUD_ TO ADD_
## 3 5     1         1      0 1946-01-04 8/1/98    0     0 VOTI_ "TO AD_
```

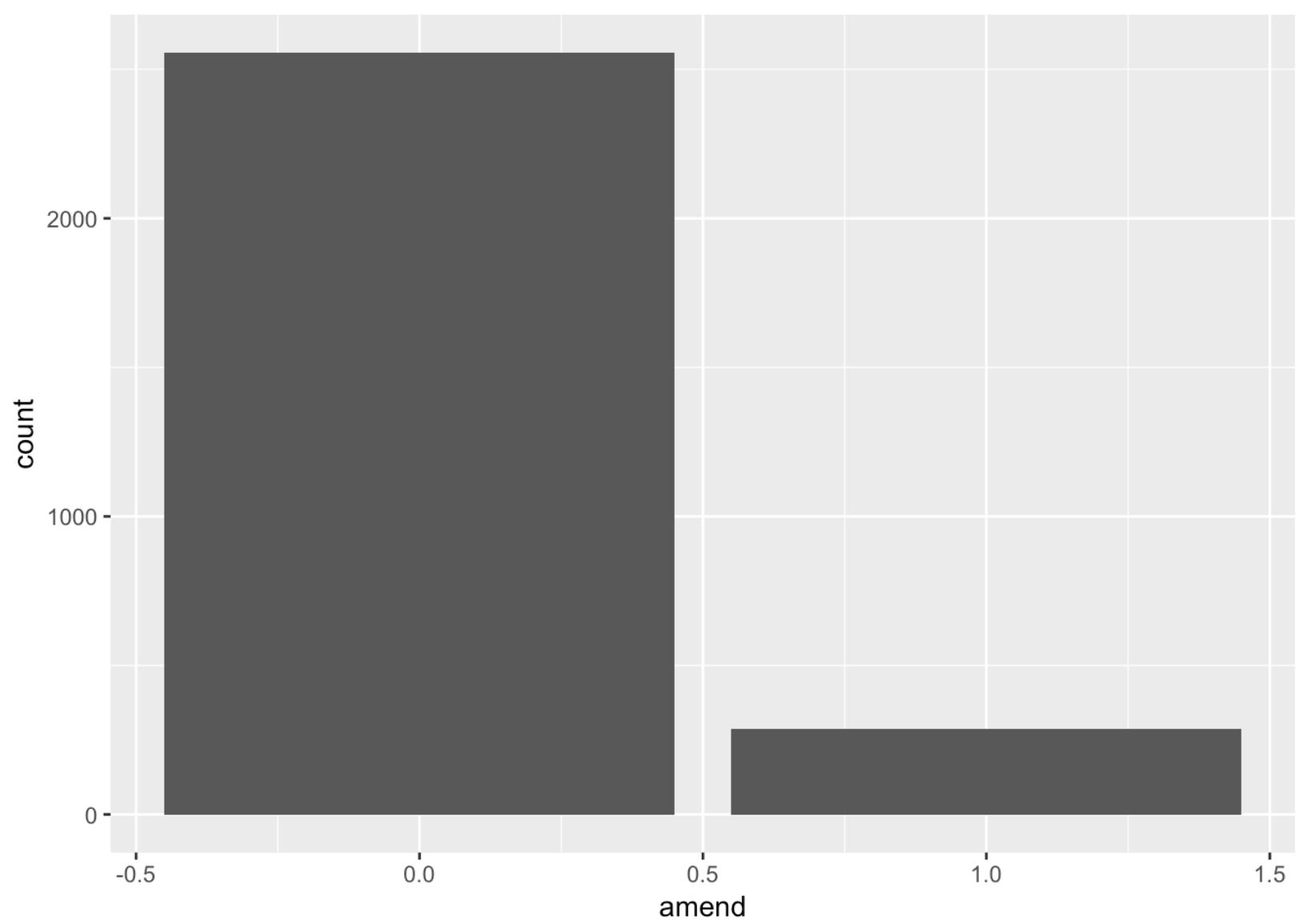
**skip
baby
steps**

75

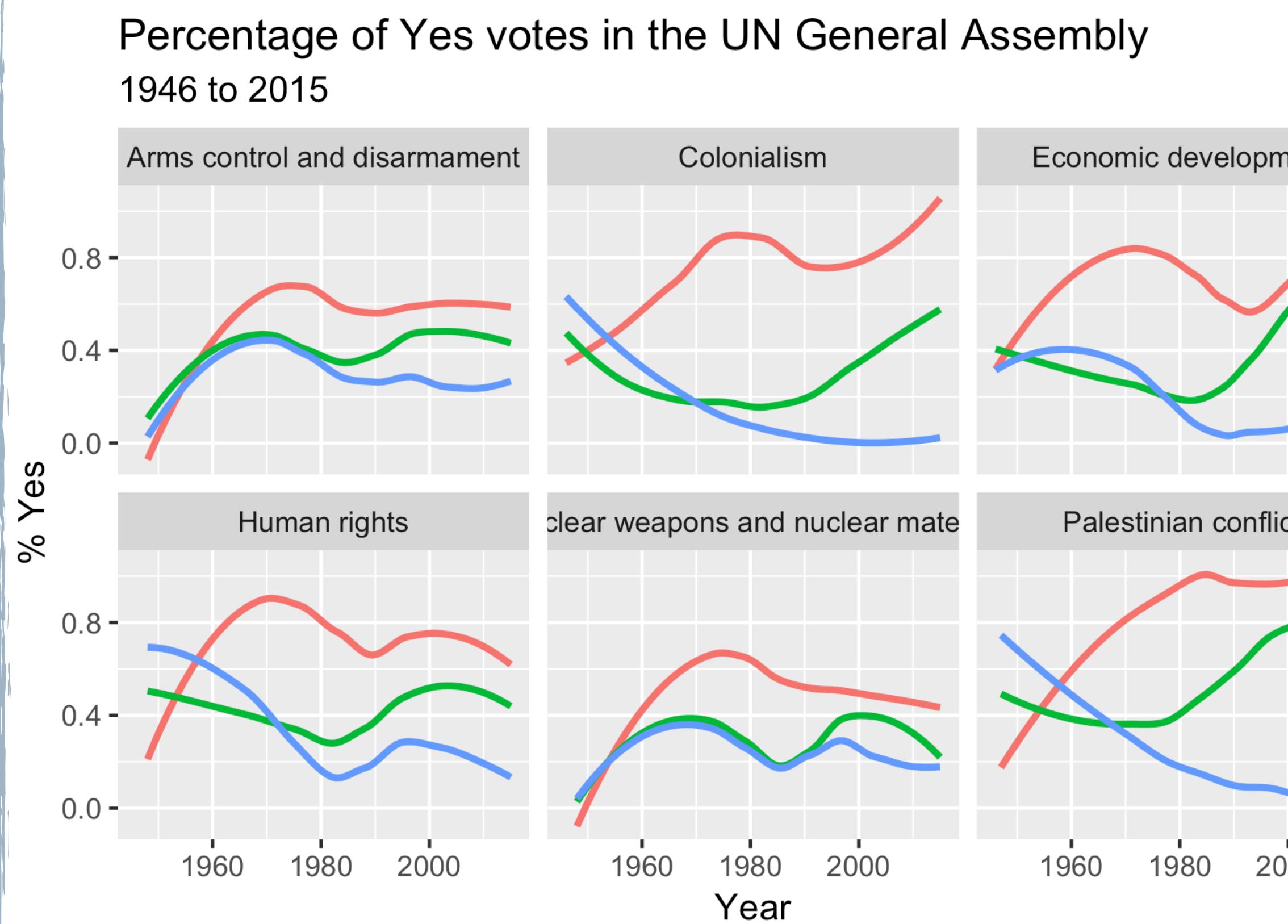


Which of the following is more likely to **inspire** students to want to learn more?

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



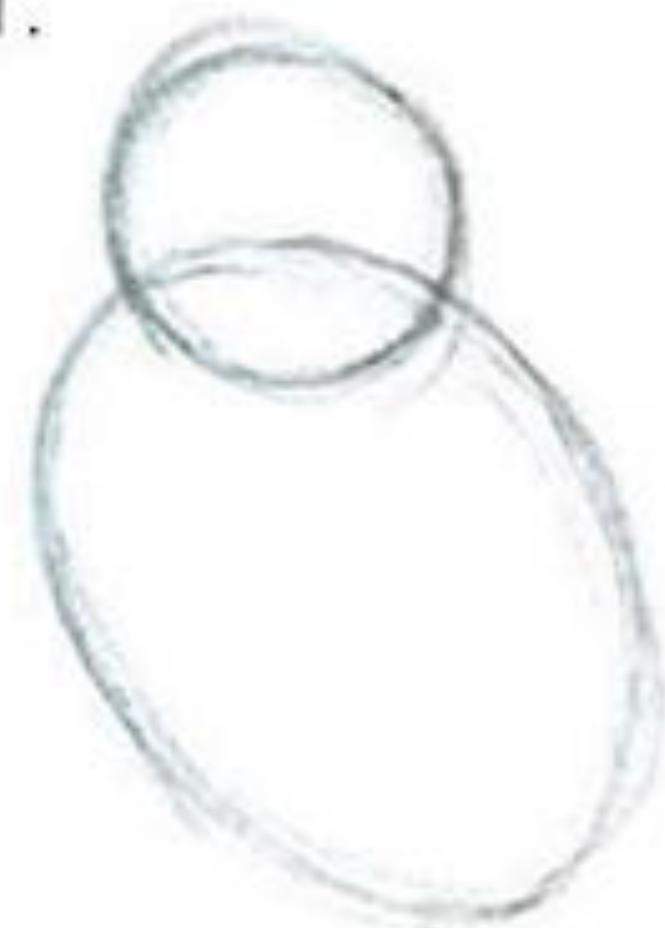
Create a visualization displaying how US, UK, and Turkey voted over the years on issues of arms control and disarmament, colonialism, economic development, human rights, nuclear weapons, and Palestinian conflict.



non-trivial examples can be motivating,
but need to avoid !

How to draw an owl

1.



2.



1. Draw some circles

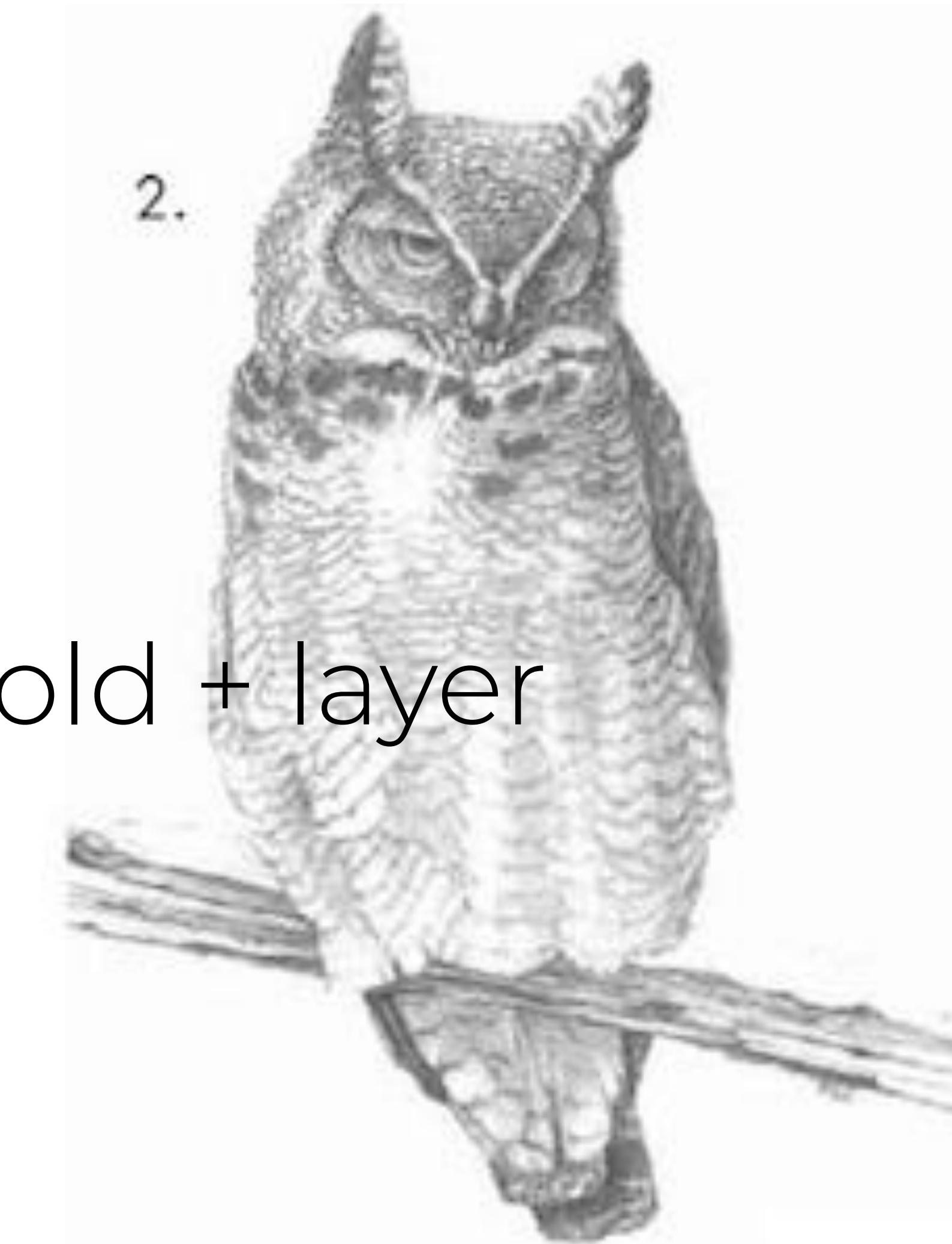
2. Draw the rest of the  owl

How to draw an owl

1.



2.

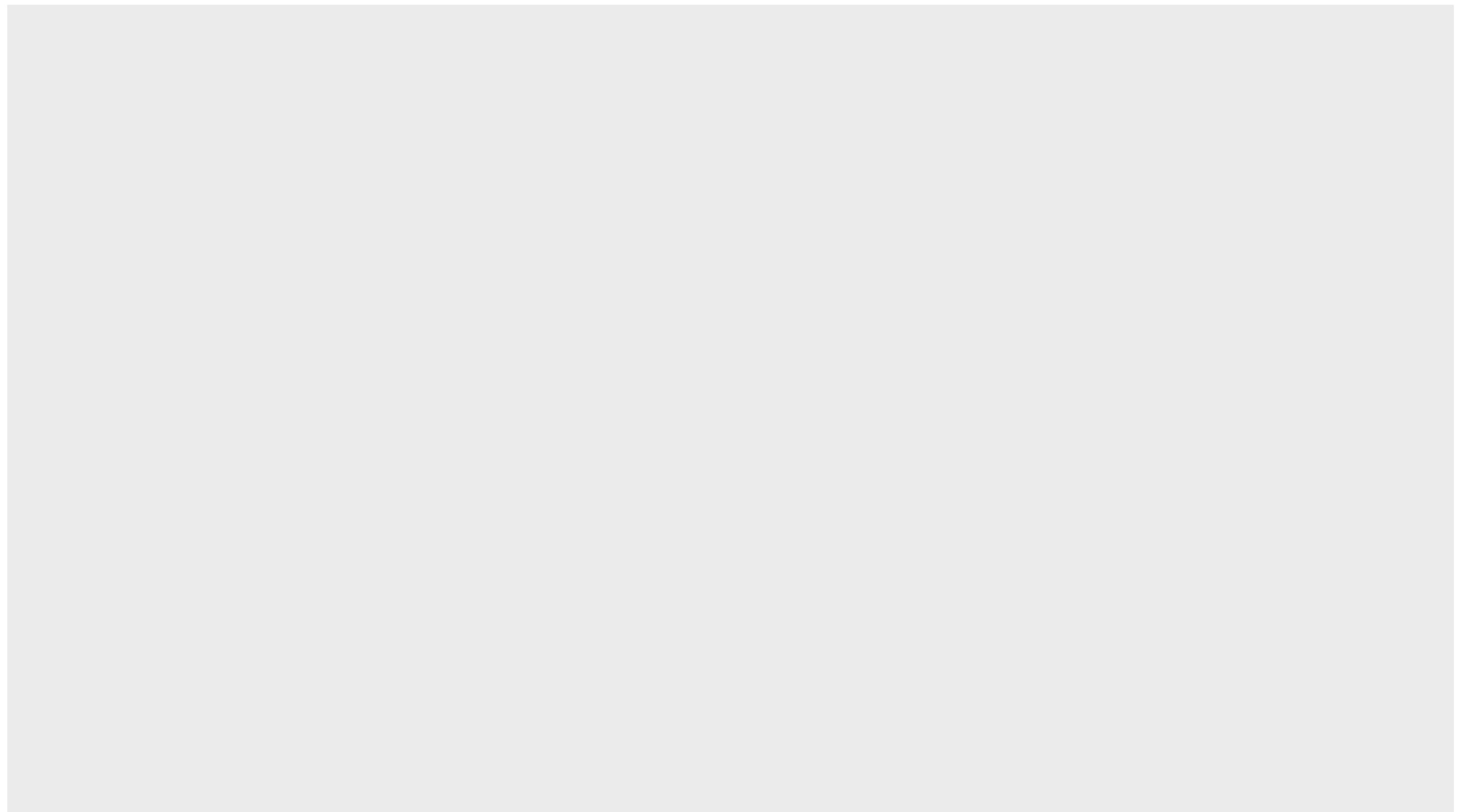


scaffold + layer

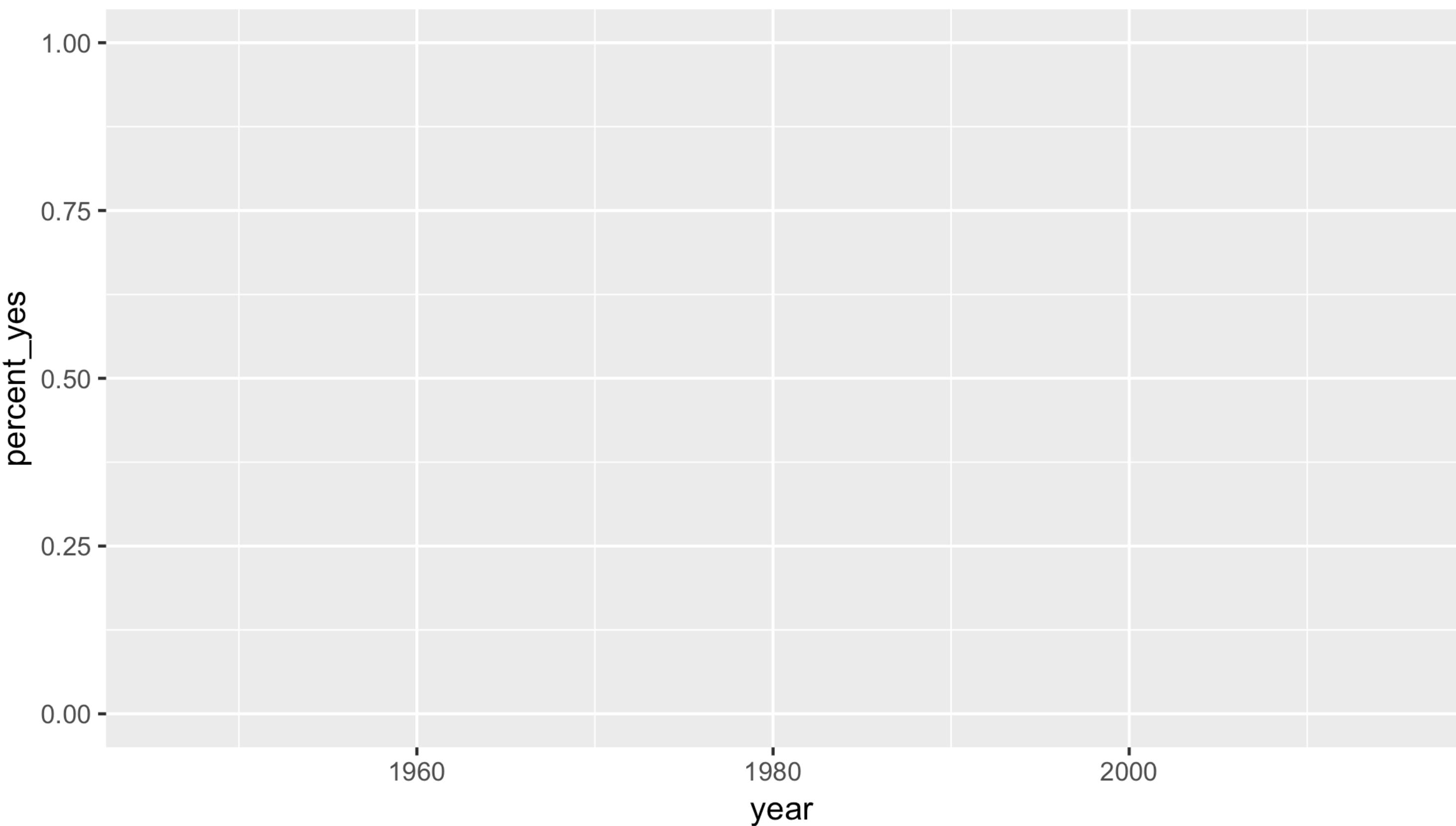
1. Draw some circles

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

```
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

	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

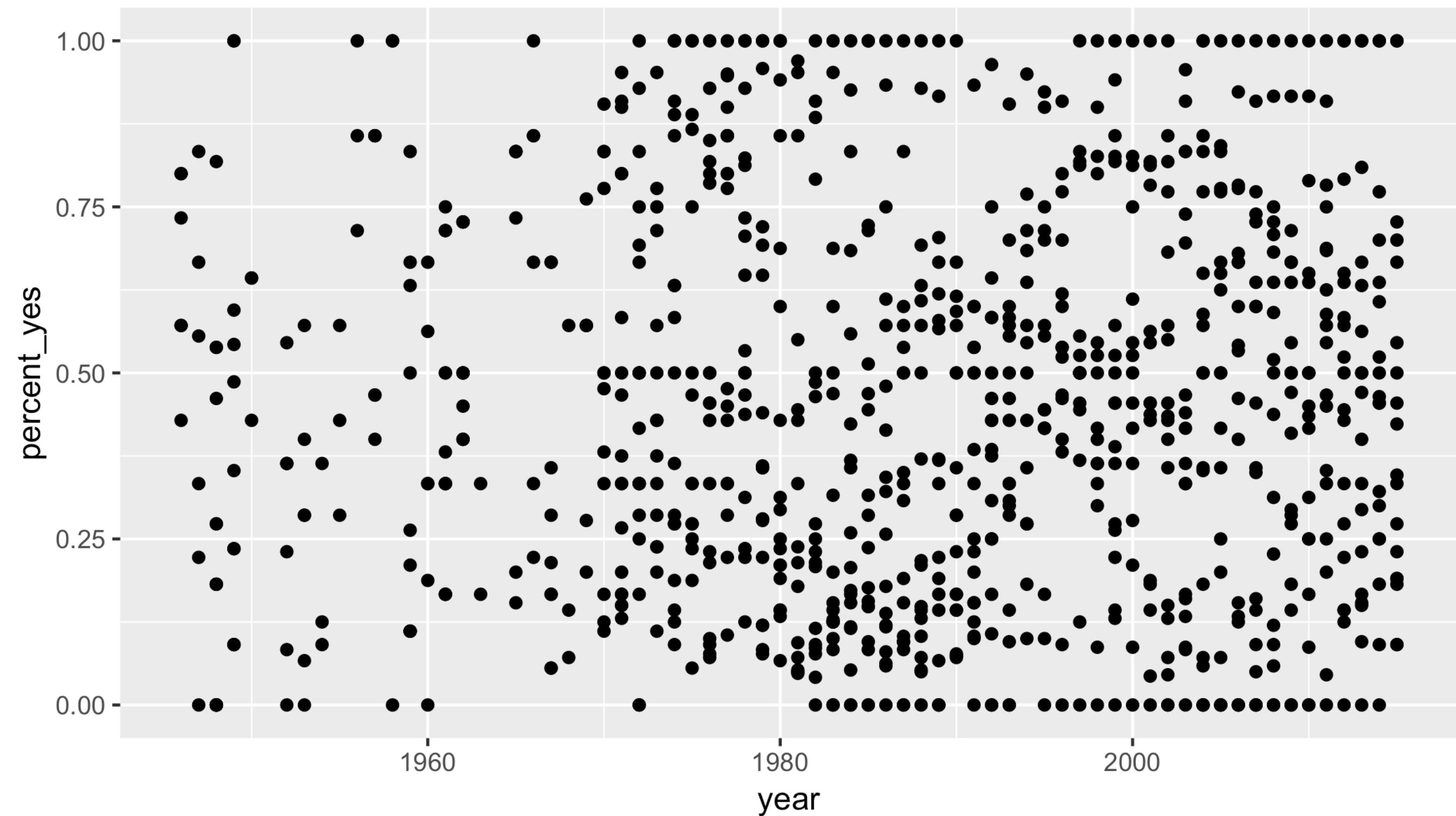
"tidy"
data frame

columns =
variables

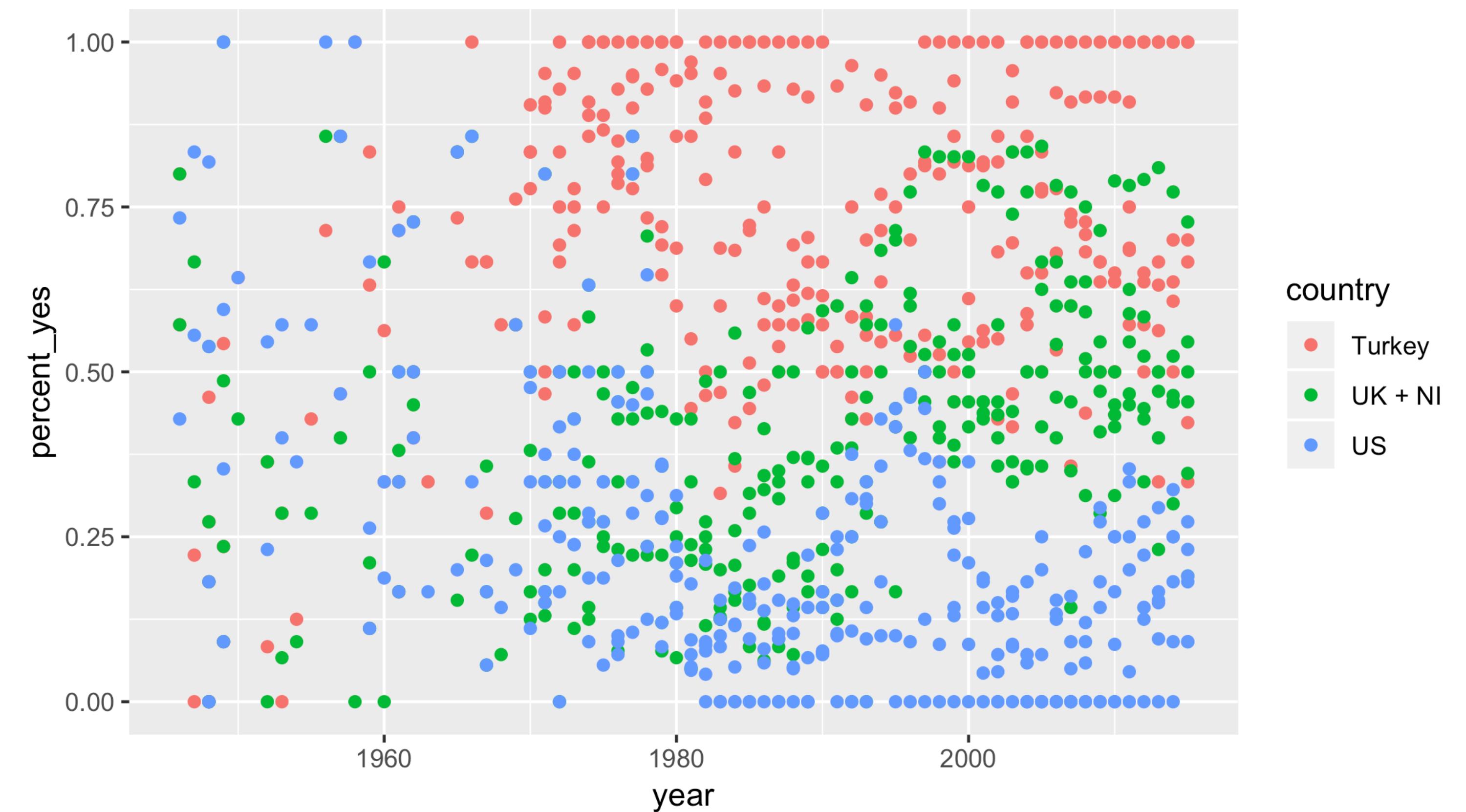


bit.ly/let-eat-cake-cfs

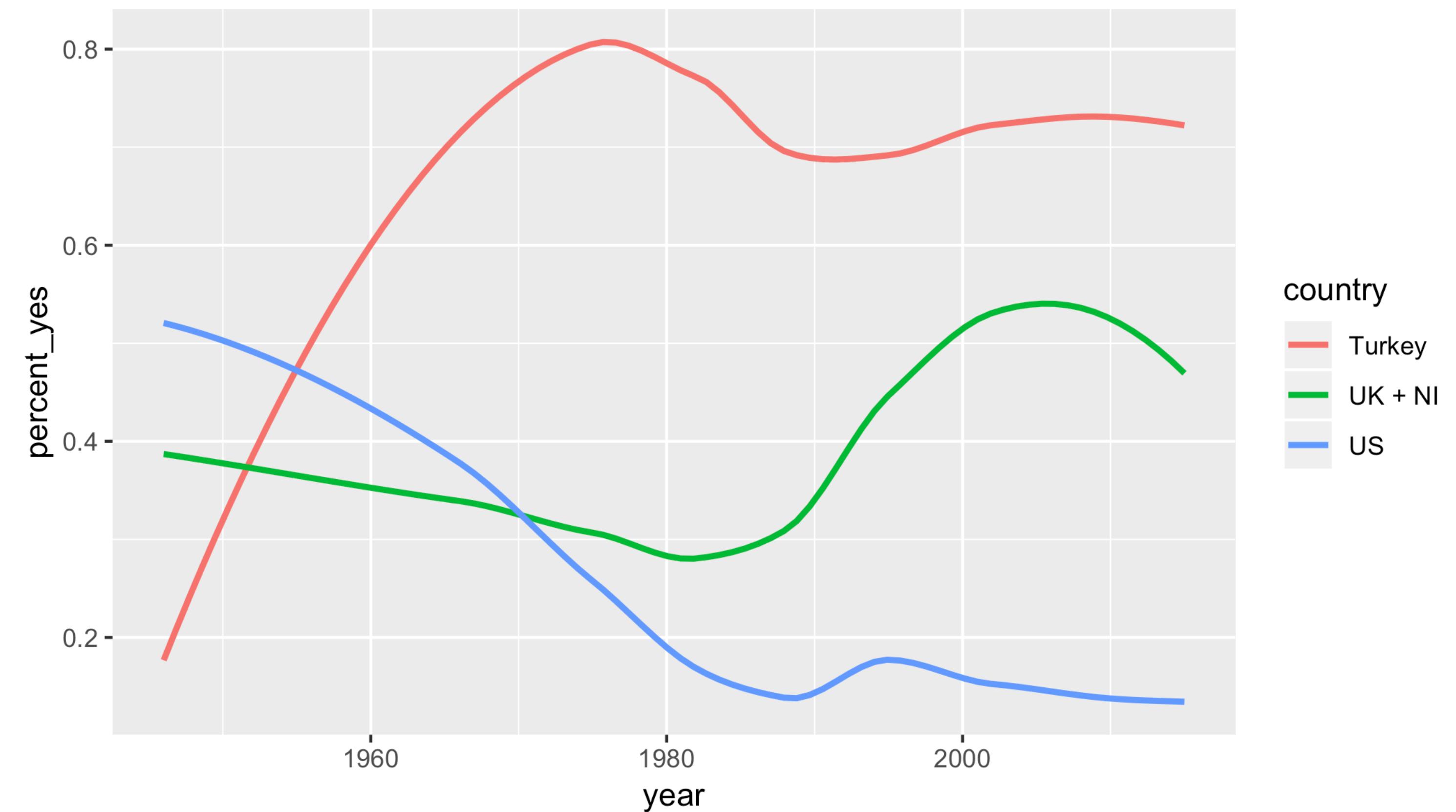
```
ggplot(data = un_votes_joined,  
       mapping = aes(x = year, y = percent_yes)) +  
  geom_point()
```



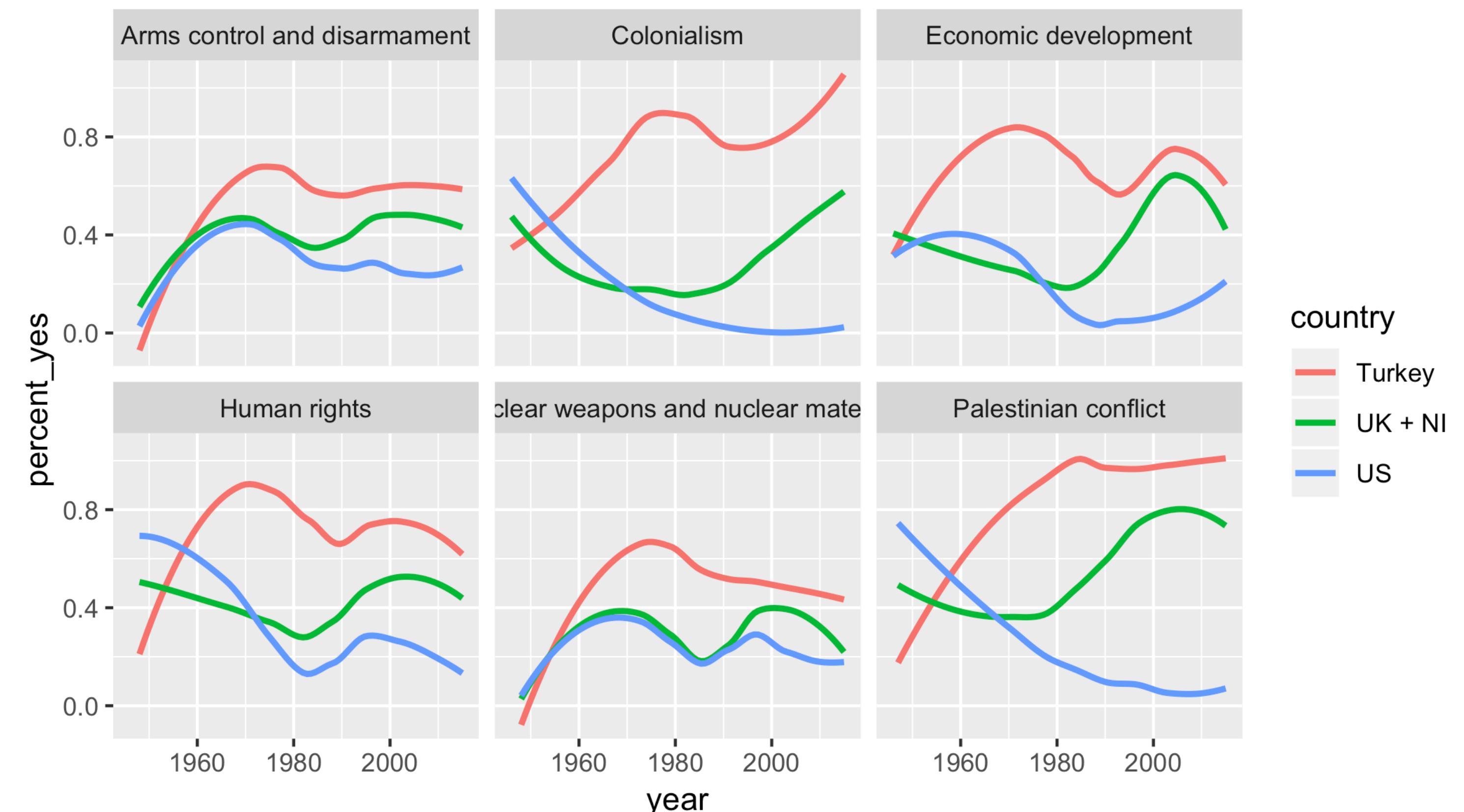
```
ggplot(data = un_votes_joined,  
       mapping = aes(x = year, y = percent_yes, color = country)) +  
geom_point()
```



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



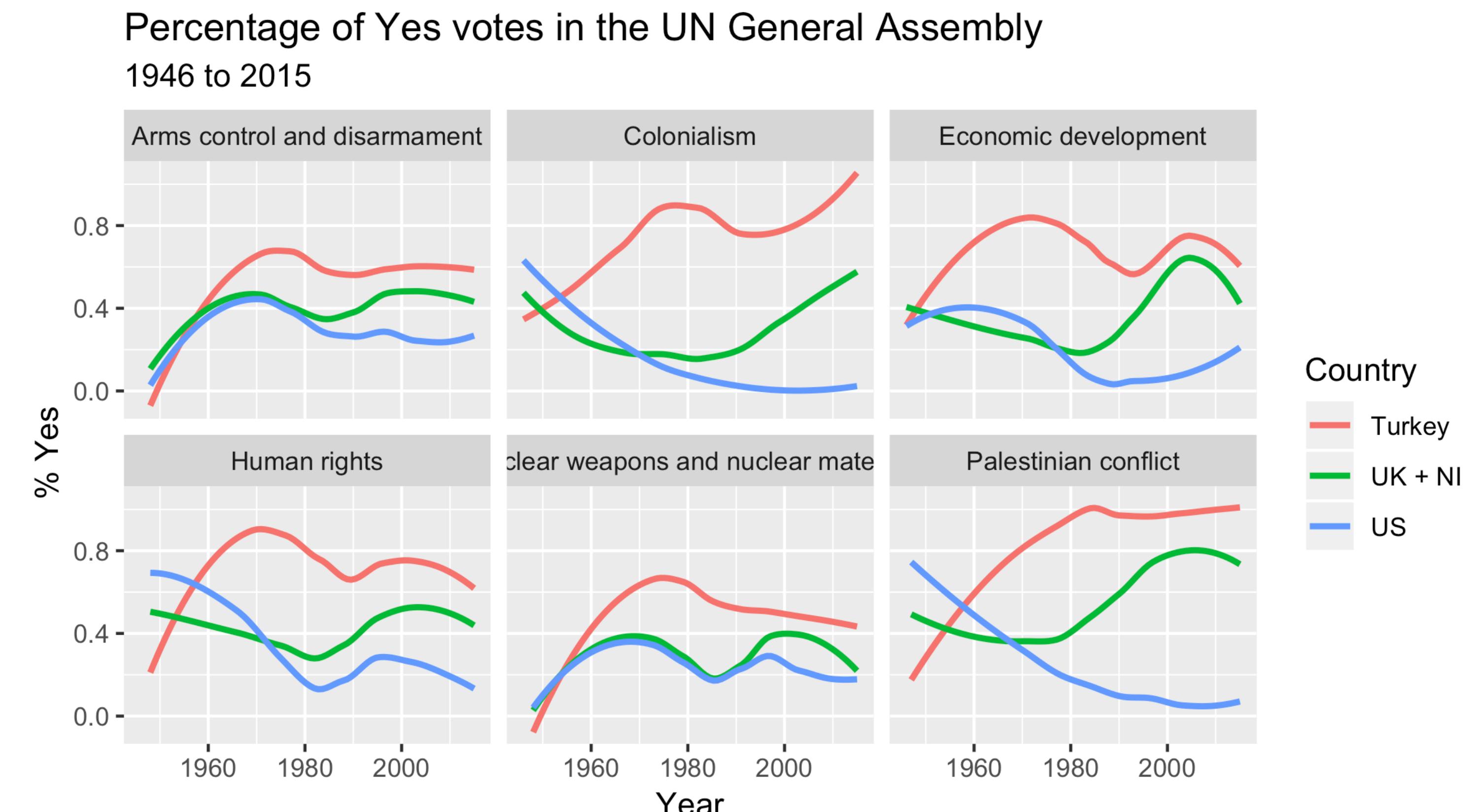
```
ggplot(data = un_votes_joined,  
       mapping = aes(x = year, y = percent_yes, color = country)) +  
  geom_smooth(method = "loess", se = FALSE) +  
  facet_wrap(~ issue)
```



```

ggplot(data = un_votes_joined,
       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"
)

```



hide
the
veggies

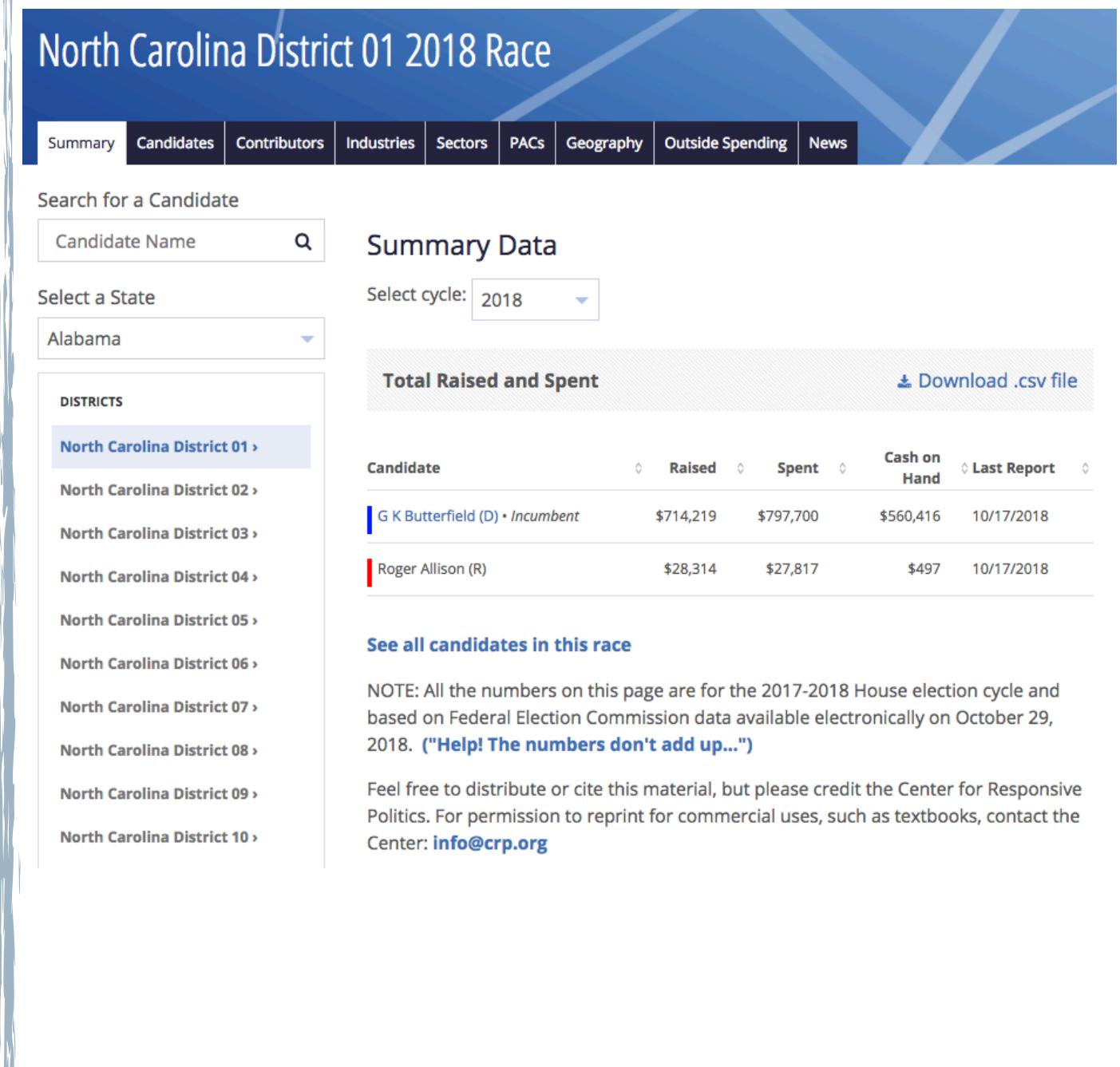




Which of the following is more likely to be **interesting** for a wide range of students?

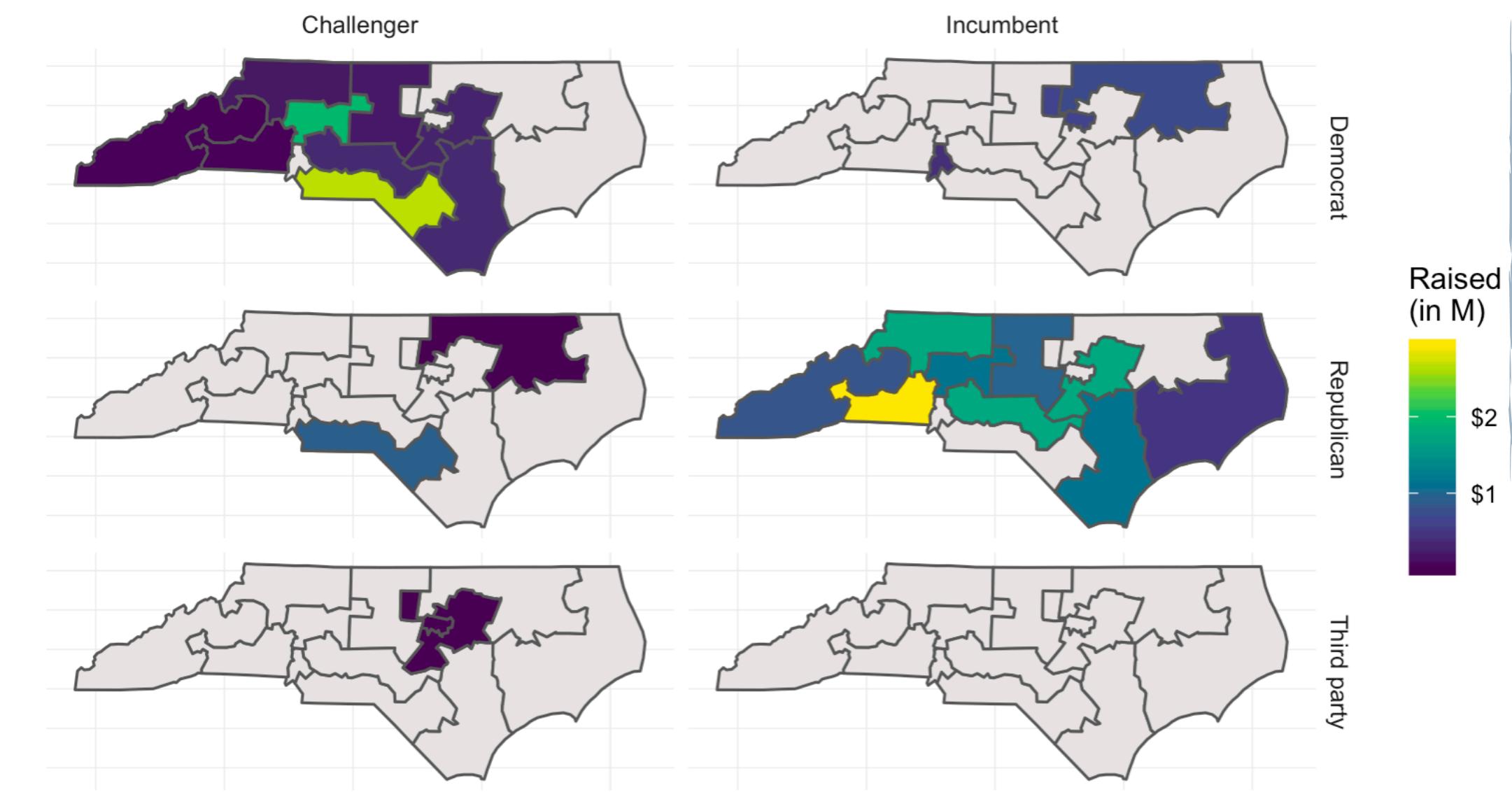
- Topic: Web scraping
- Tools:
 - **rvest**
 - regular expressions

- Today we start with this:



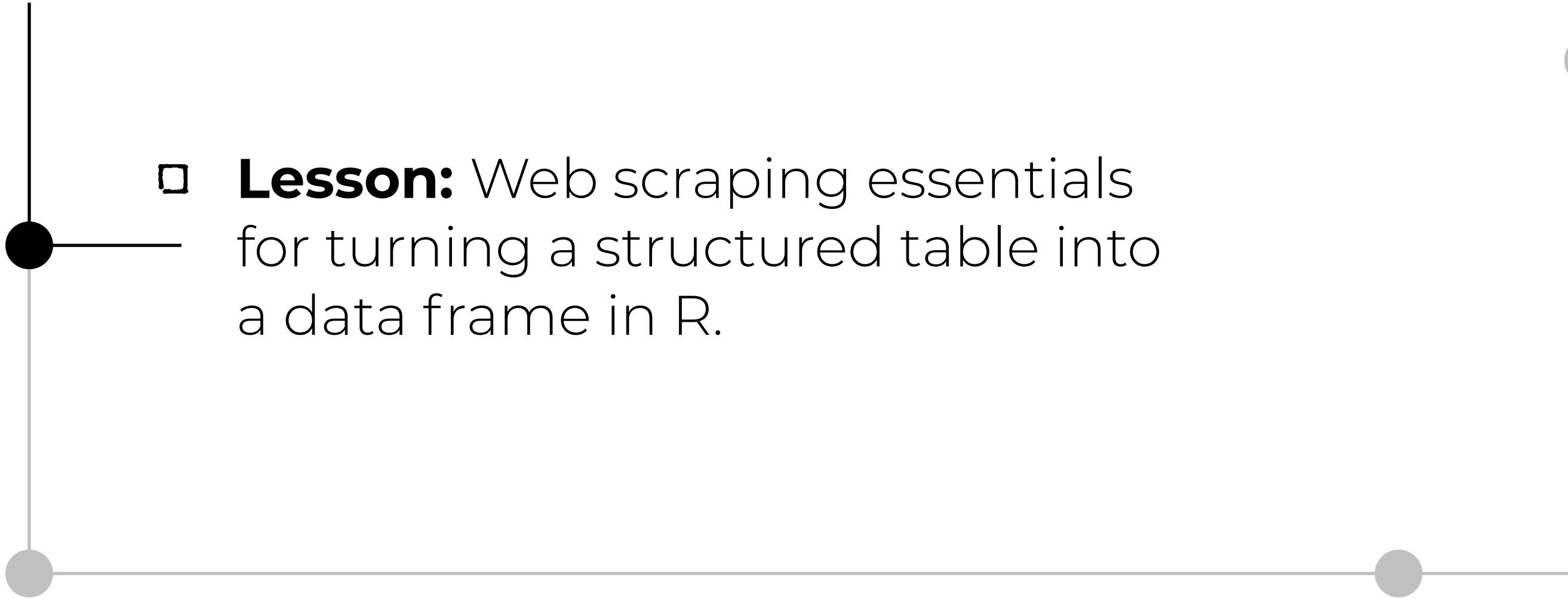
- and end with this:

Political contributions for 2018 NC Congressional Races
as of 9/30/2018



- 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

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

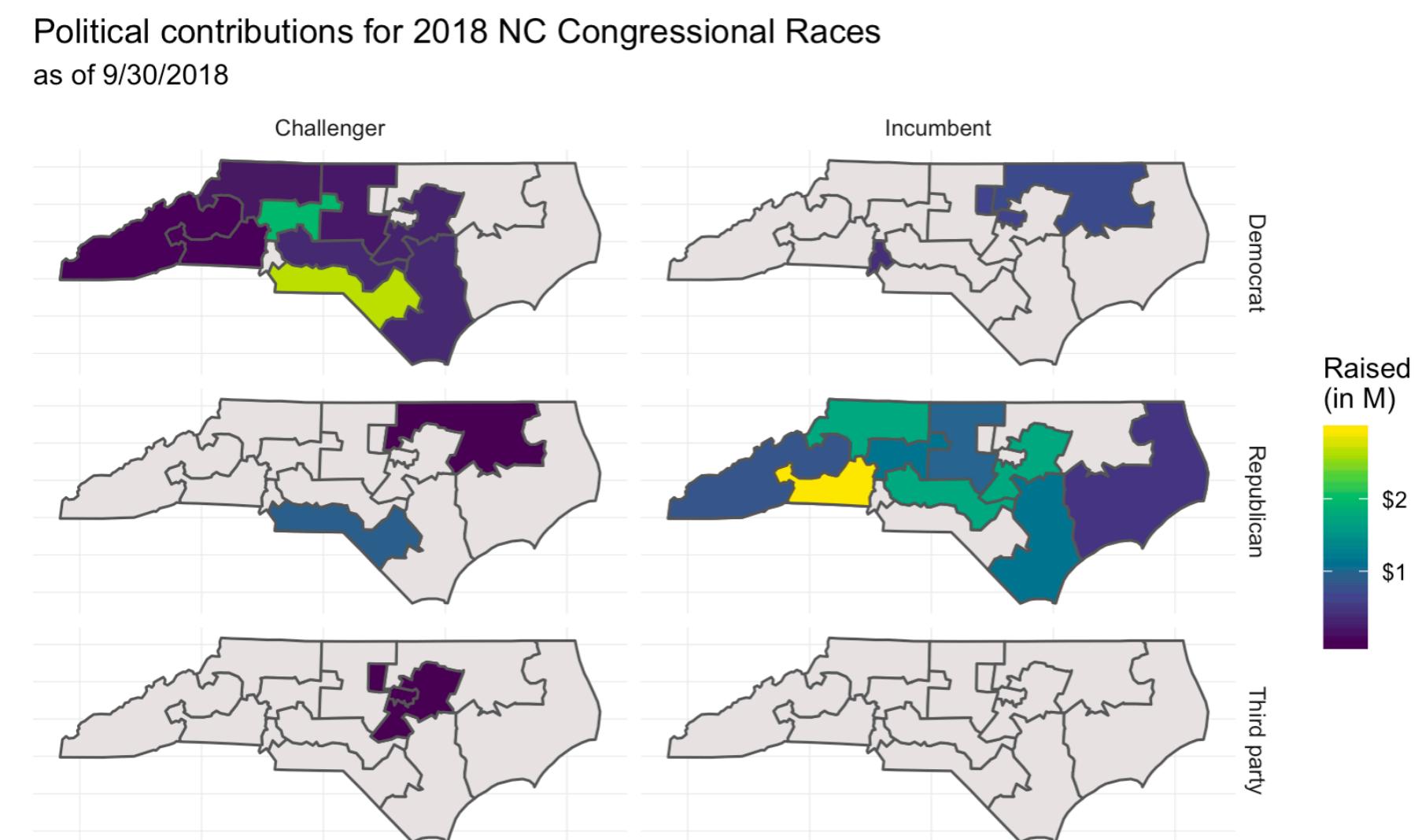
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- **Ex 2:** What other information do we need represented as variables in the data to obtain the desired facets?



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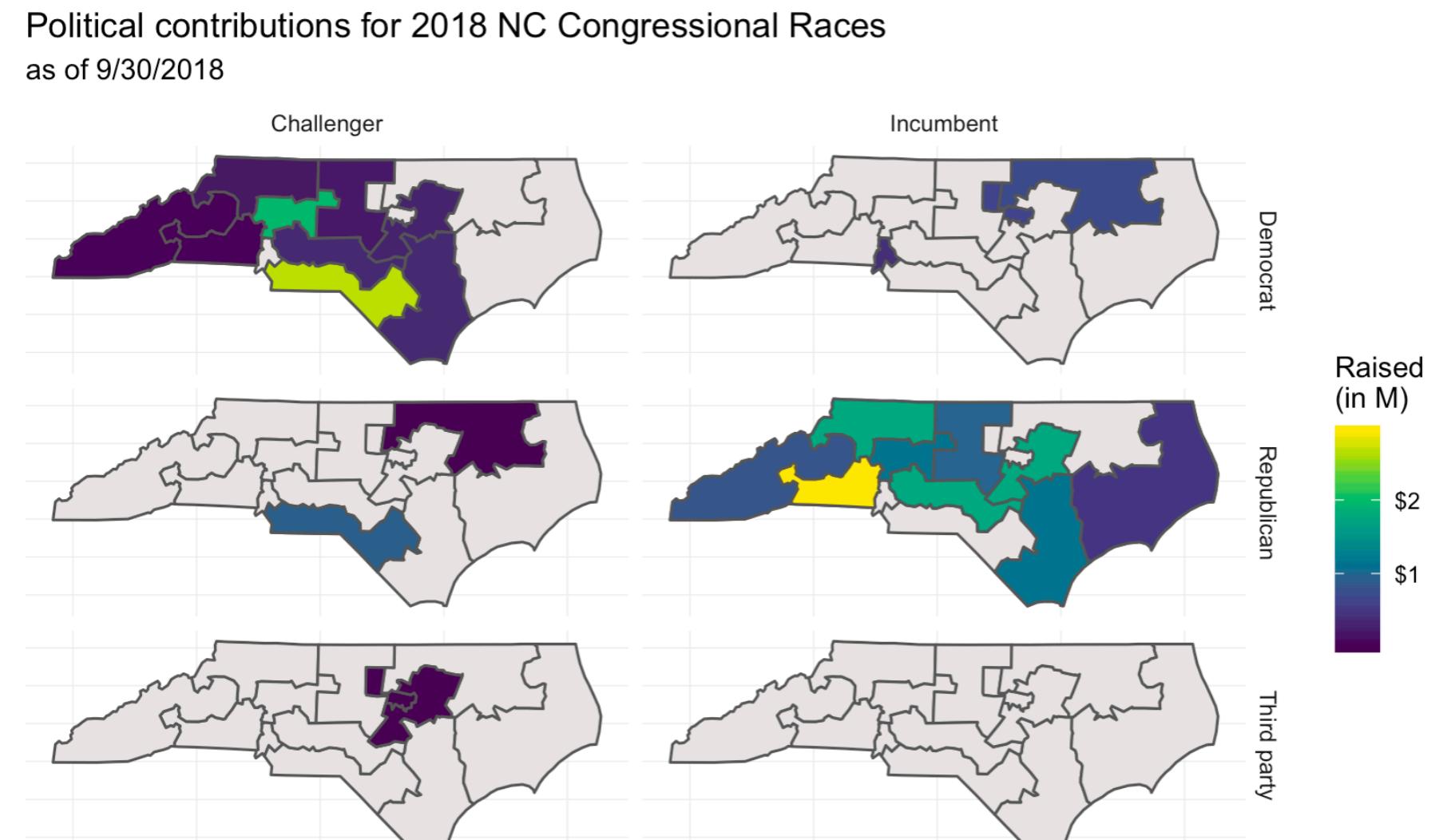
- **Lesson:** “Just enough” string parsing and regular expressions to go from

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

to

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

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



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

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

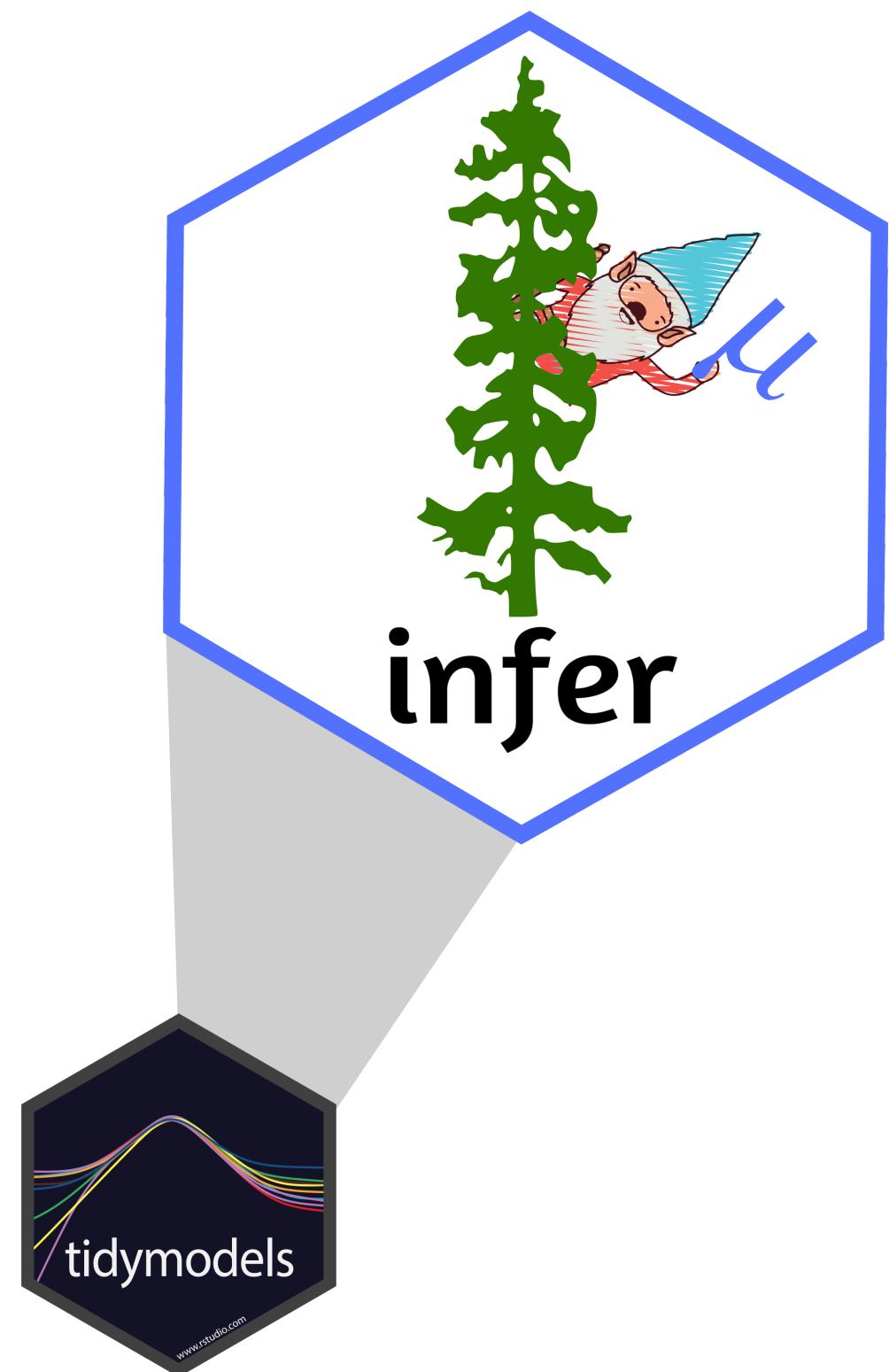
# Welch Two Sample t-test

# 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)
  )

#      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)
```

start with data

```
evals %>%
```

```
library(tidyverse)  
library(infer)
```

specify the model

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

```
library(tidyverse)  
library(infer)
```

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

generate bootstrap samples

```
library(tidyverse)  
library(infer)
```

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

calculate sample statistics

```
library(tidyverse)
library(infer)

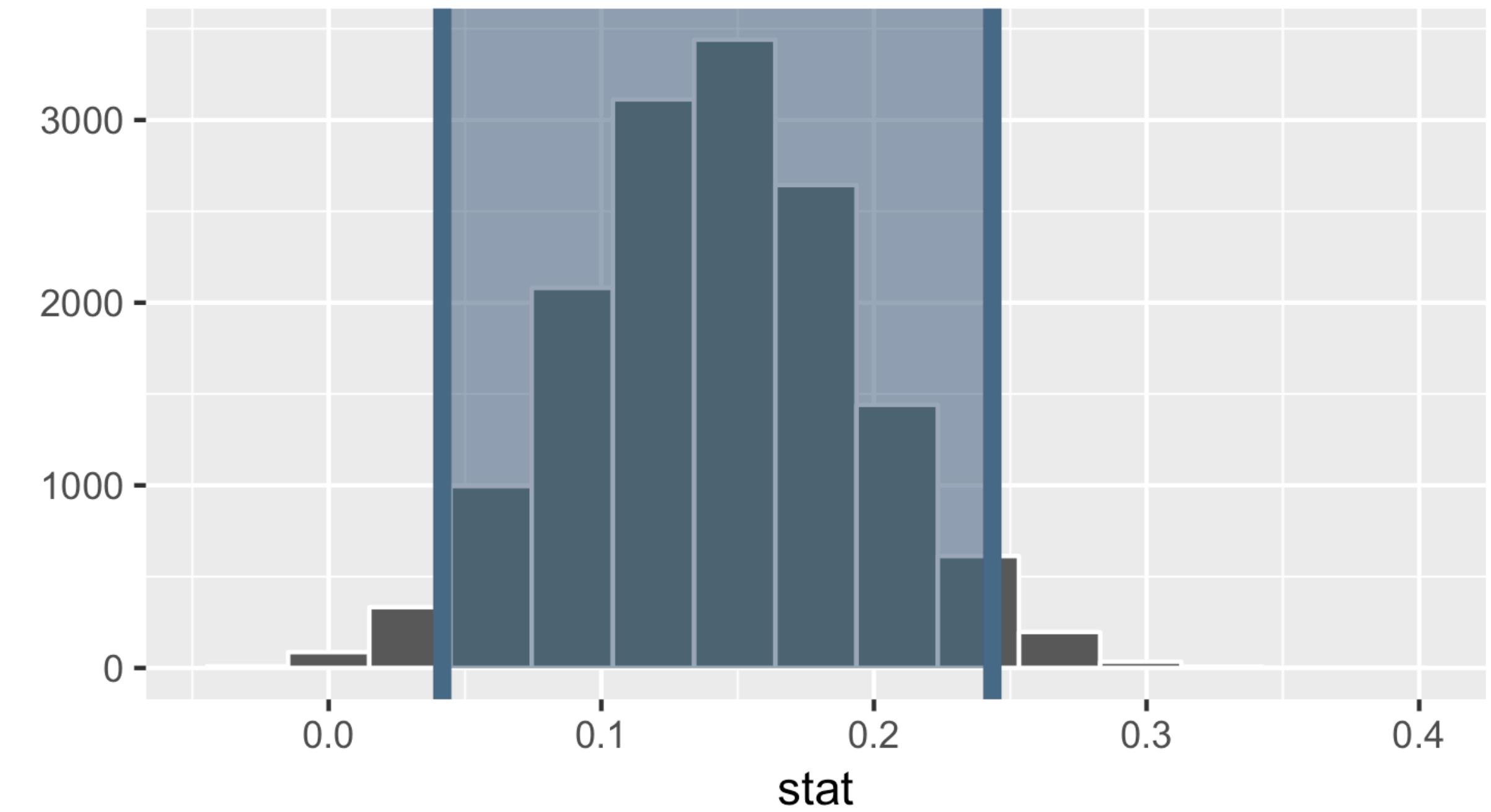
evals %>%
  specify(score ~ gender) %>%
  generate(reps = 15000, type = "bootstrap") %>%
  calculate(stat = "diff in means", order = c("male", "female")) %>%
  summarise(l = quantile(stat, 0.025), u = quantile(stat, 0.975))
```

summarise CI bounds

```
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
```

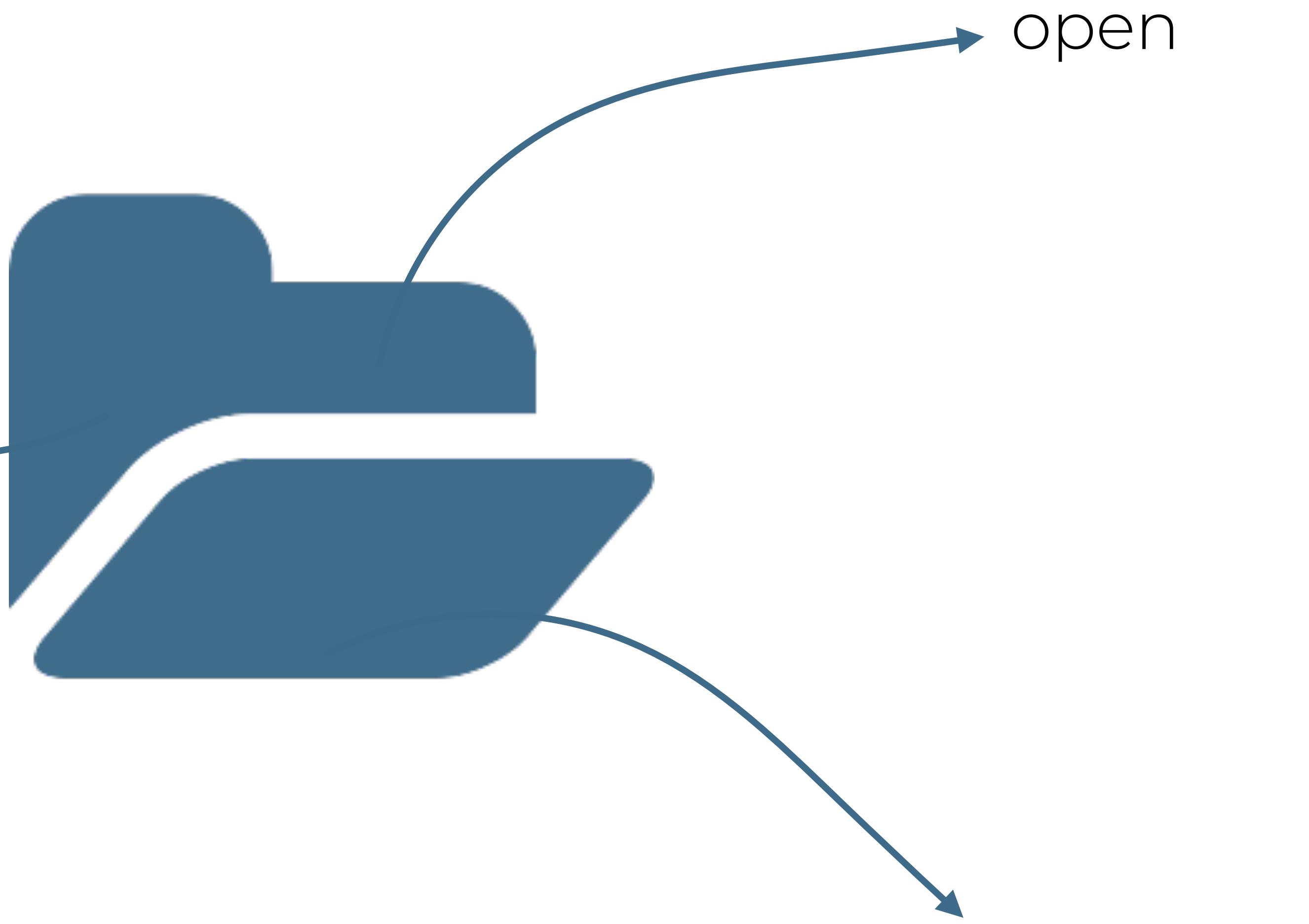


- 1 start with cake
- 2 skip baby steps
- 3 cherish day one
- 4 hide the veggies
- 5 leverage the ecosystem

tl;dr

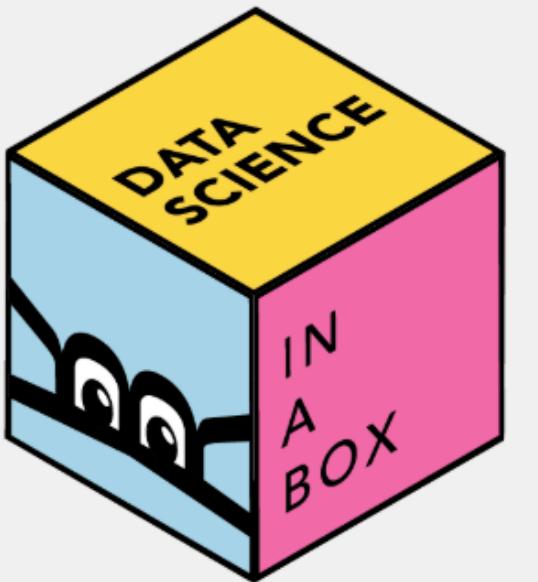
3 goals

scalable



validated

open



Search...

Hello #dsbox

Overview

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bit.ly/let-eat-cake-cfs

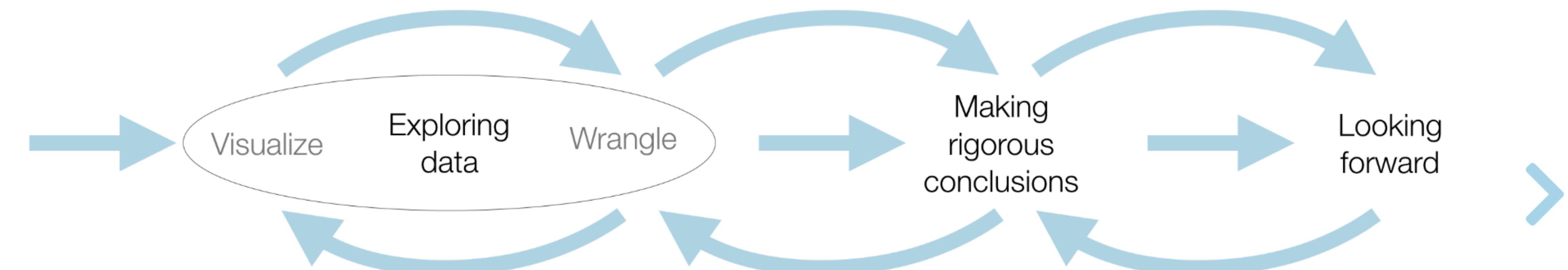


Data Science in a Box > Hello #dsbox > Topics



Topics

The course content is organized in three units:



Unit 1 - Exploring data: This unit focuses on data visualization and data wrangling. 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 visualization 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

Retrospective study of 205 open ended student projects

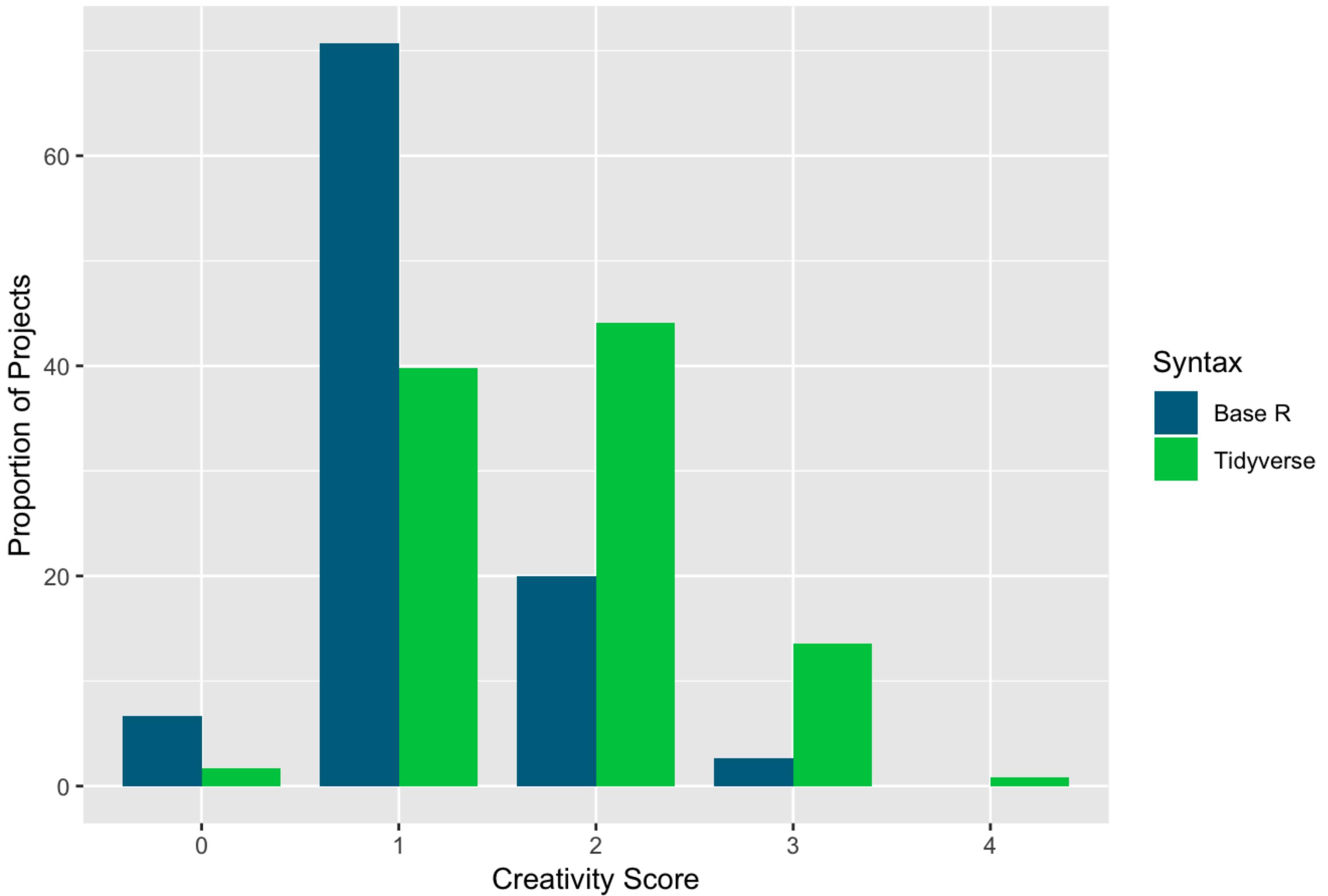
- on **creativity, depth** and the complexity of **multivariate visualizations**
- compared across students who learned R using **base R** syntax vs. **tidyverse**

validated

Creativity:

1. Creation of new variable(s) based on existing variables
2. Transformation of existing variables
3. Existence of a subgroup analysis
4. Use of a subset of the dataset for all steps of the project

Tidyverse Syntax Projects Score Higher on the Creativity Metric on Average

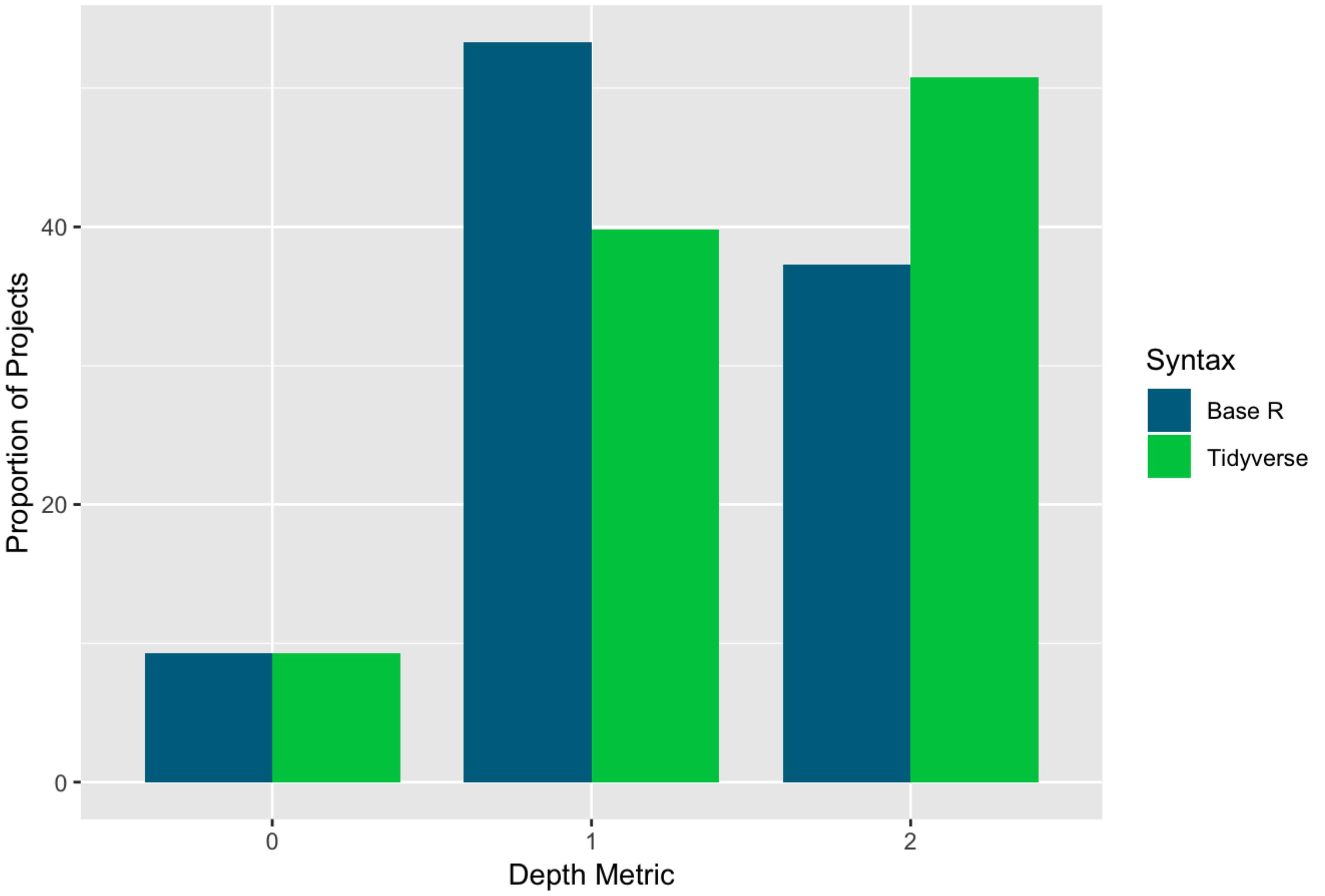


validated

Depth:

1. Presence of consistent theme throughout the project
2. Use of relevant data

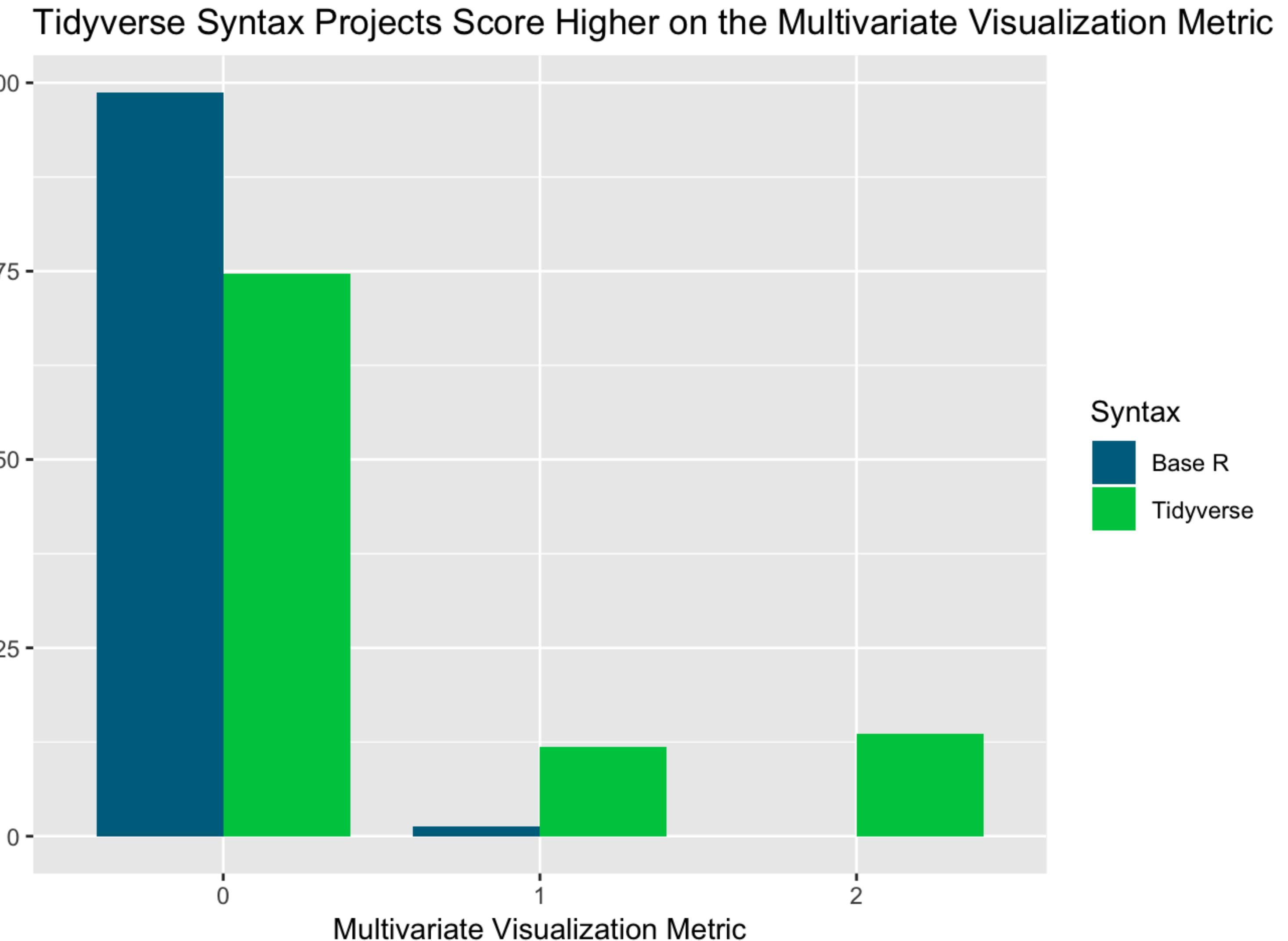
Tidyverse Syntax Projects Score Higher on the Depth Metric on Average



validated

Multivariate visualizations:

1. Presence of a visualization with 3+ variables
2. Interpretation of the multivariate visualization





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

Let them eat cake (first)!*

↳ bit.ly/let-eat-cake-cfs

</> bit.ly/repo-eat-cake

* You can tell
them all about the
ingredients later!



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