Let them eat cake (first)!

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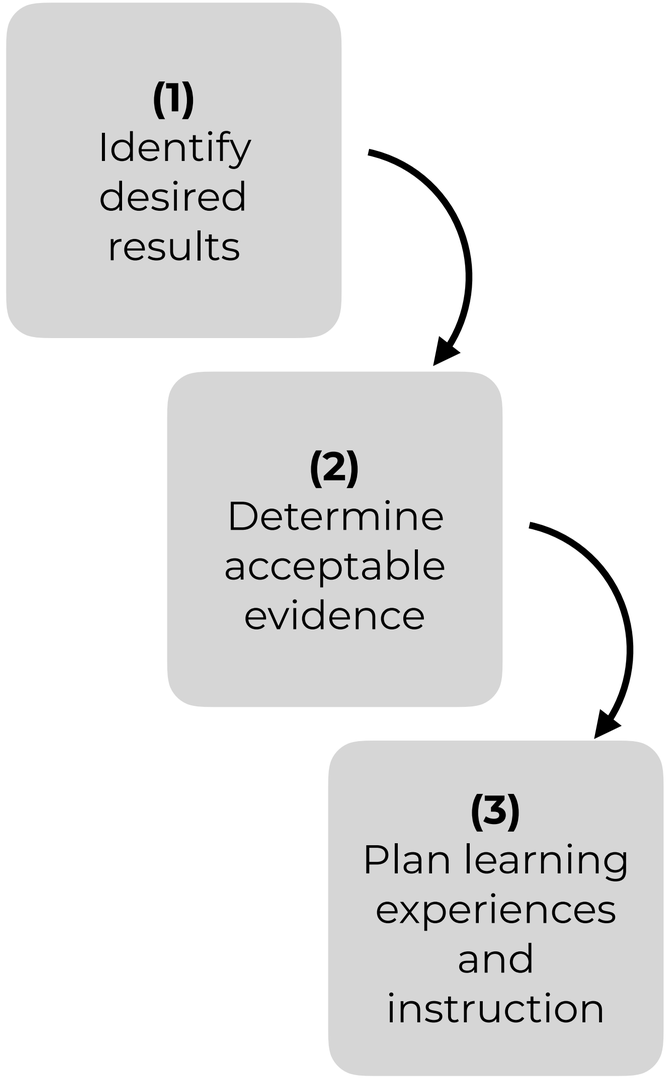
Backward design

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.

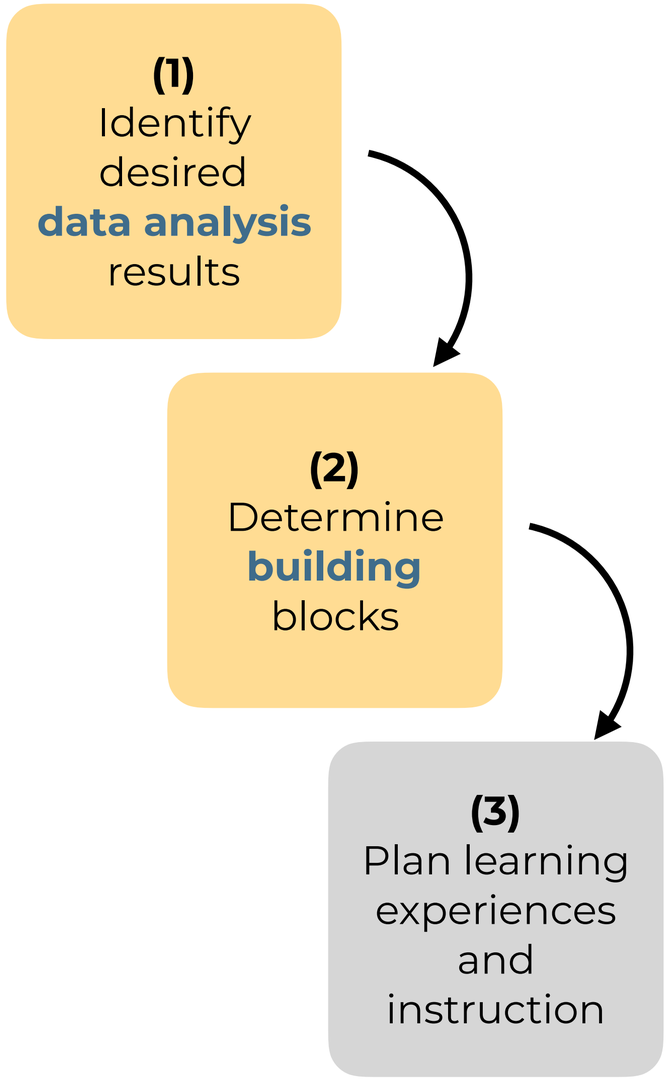
Designing backwards

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

requires reproducibility

emphasizes collaboration + effective communi-cation

uses R as the statistical programming language

Which of the following four descriptions give you a **better sense** of the final product?

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Pineapple and Coconut Sandwich Cake

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Pineapple and Coconut Sandwich Cake

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Pineapple and Coconut Sandwich Cake

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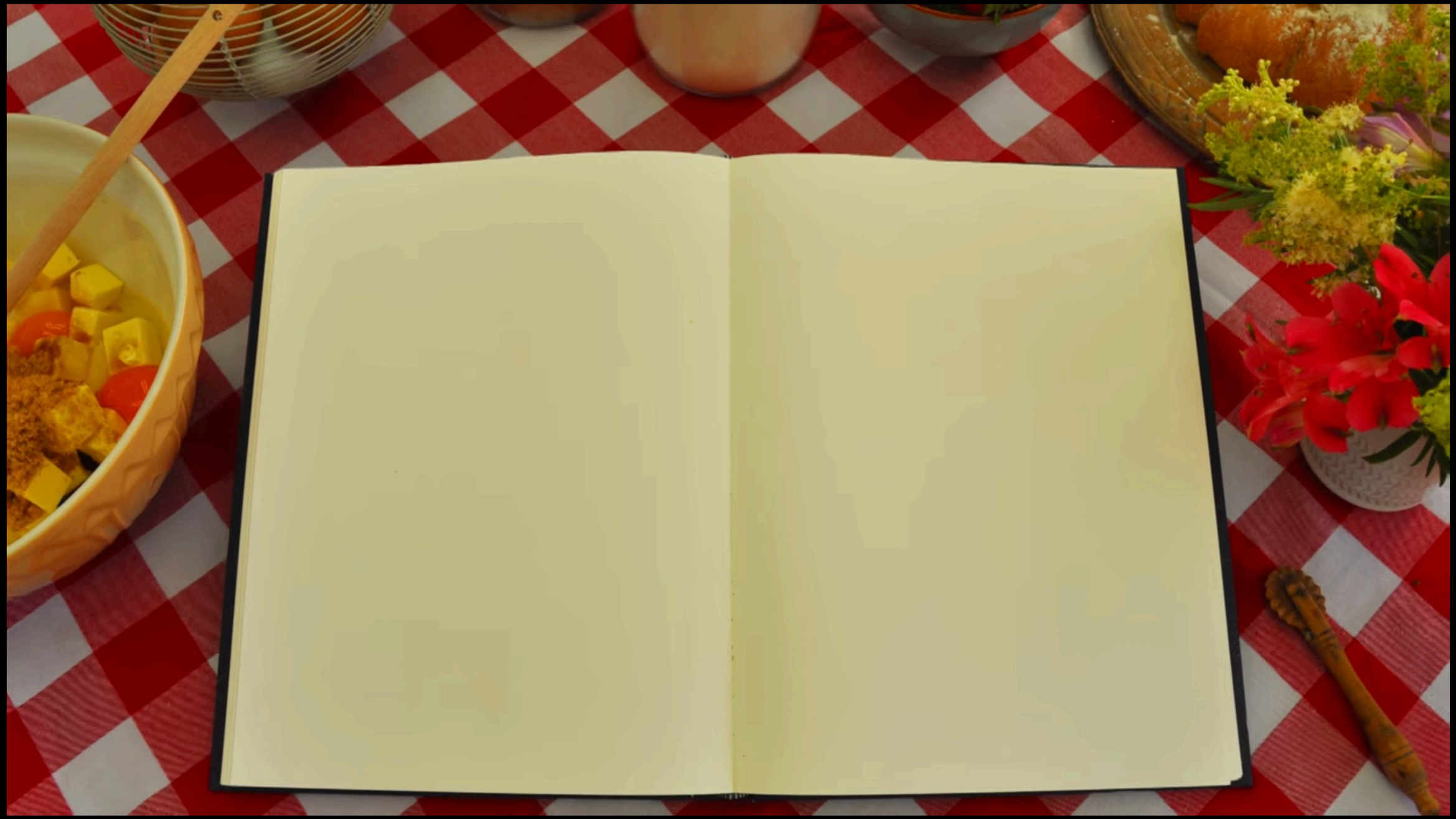

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(a) Pineapple and Coconut Sandwich Cake

(b)

(c) <with audio>

(d)

Toasted Coconut Flakes

Pineapple 'Flower'

start with cake

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ex 1.

visualization

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

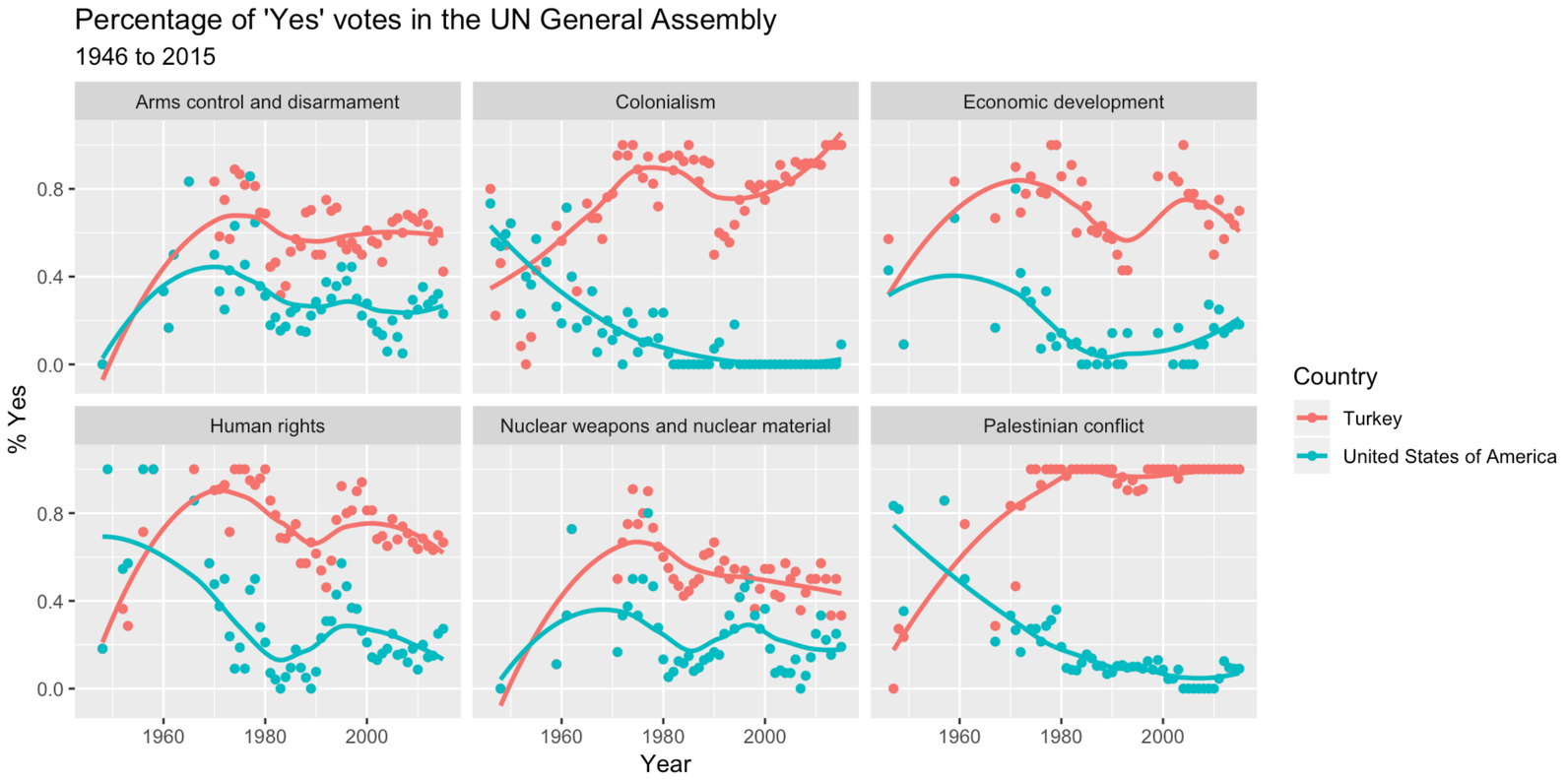
(a)

- 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



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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"
    )
```

```r
un_votes %>%
  filter(country %in% c("United States of America", "Turkey")) %>%
  inner_join(un_roll_calls, by = "rcid") %>%
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  summarize(
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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"
    )
```

```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")
    ) %>%
  filter(votes > 5) %>%  # only use records where there are more than 5 votes
  ggplot(mapping = aes(x = year, y = percent_yes, 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"
    )
```

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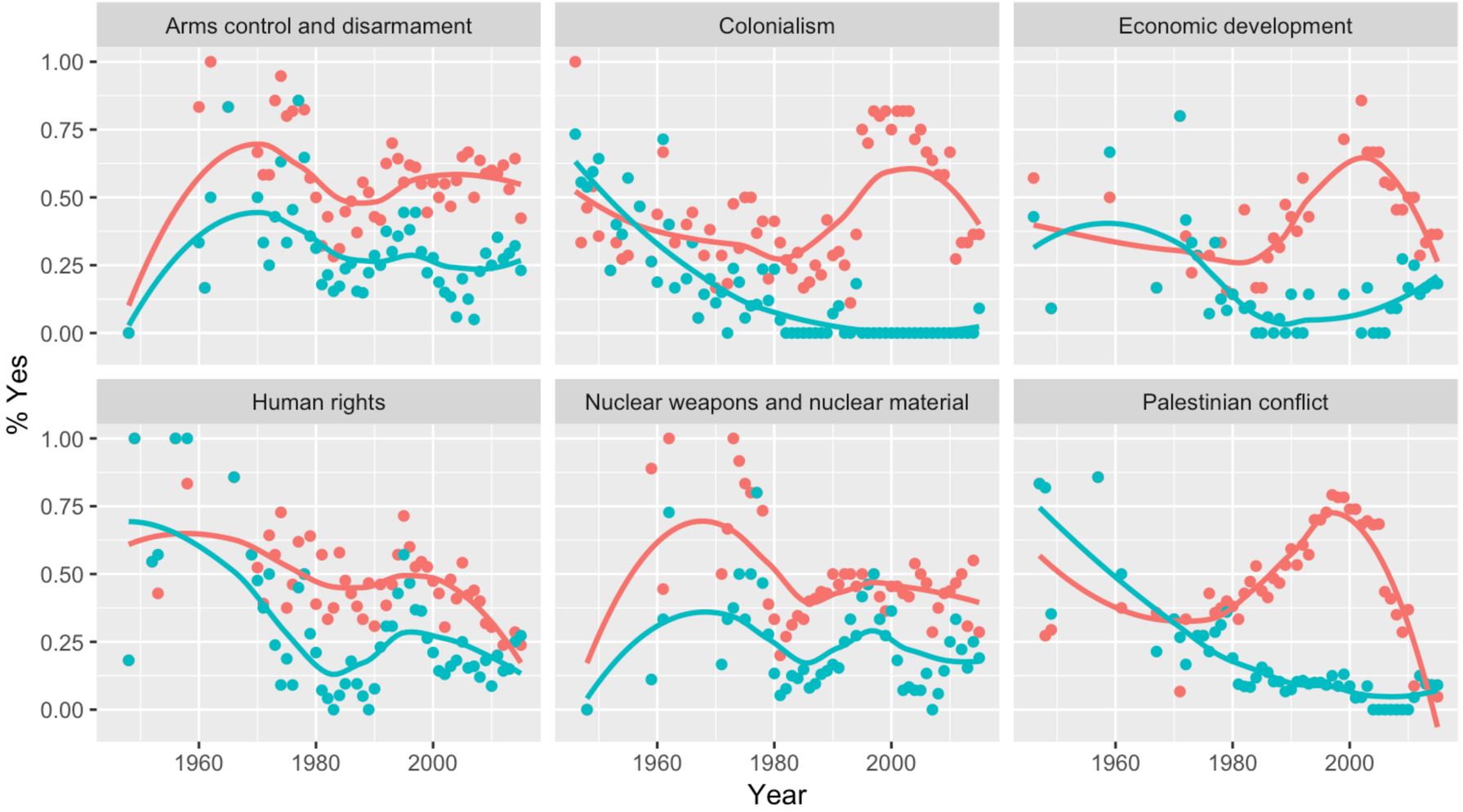
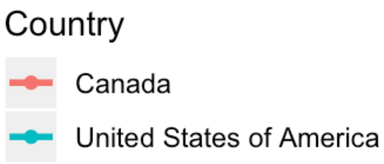
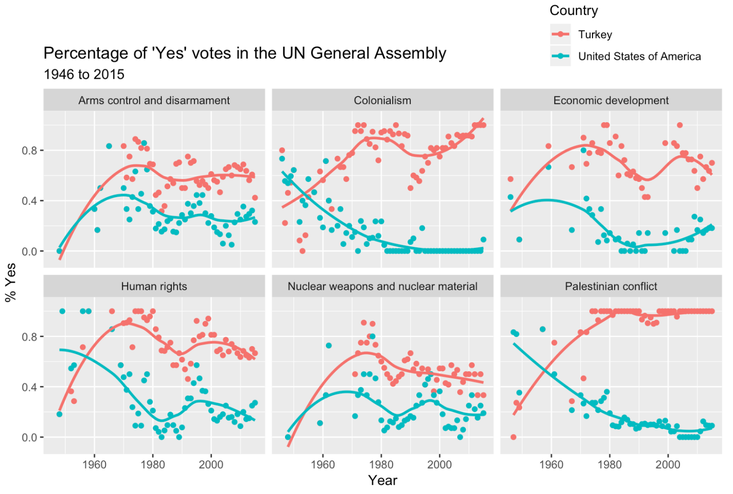
Percentage of 'Yes' votes in the UN General Assembly

1946 to 2015







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Why 🍰 = 📊?

more likely for students to have intuition for interpretations coming in

💡

easier for them to catch their own mistakes

👓

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

😋

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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.

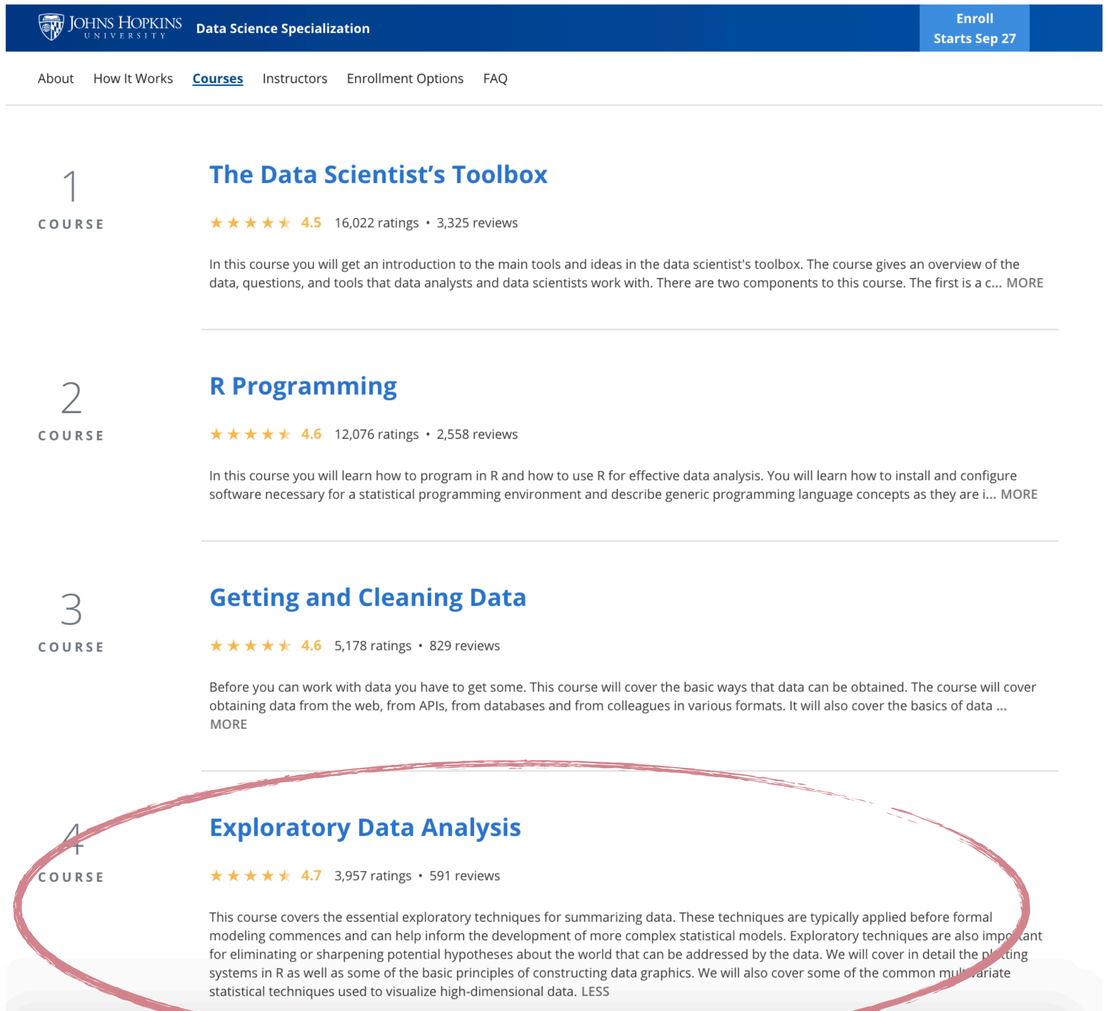
Section 5: Data Frames
When working R, you'll probably deal with Data Frames all the time. Therefore, you need to know how to create one, select the most interesting parts of it, and order them.

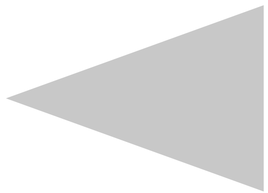
Section 6: Lists
Lists allow you to store components of different types. Section 6 will show you how to deal with lists.

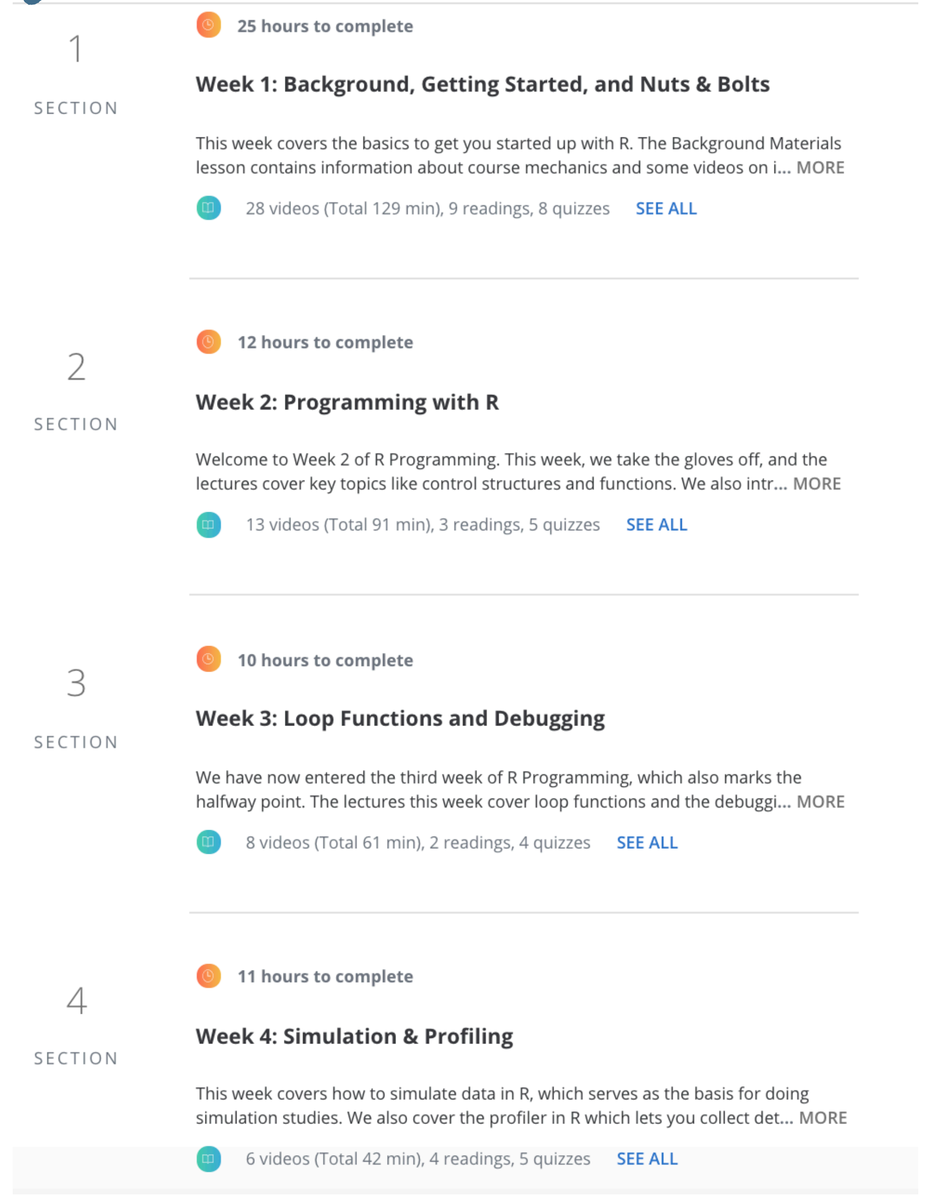
Section 7: Basic Graphics
Discover R's packages to do graphics and create your own data visualizations.

ex: Data Science Specialization

Johns Hopkins University







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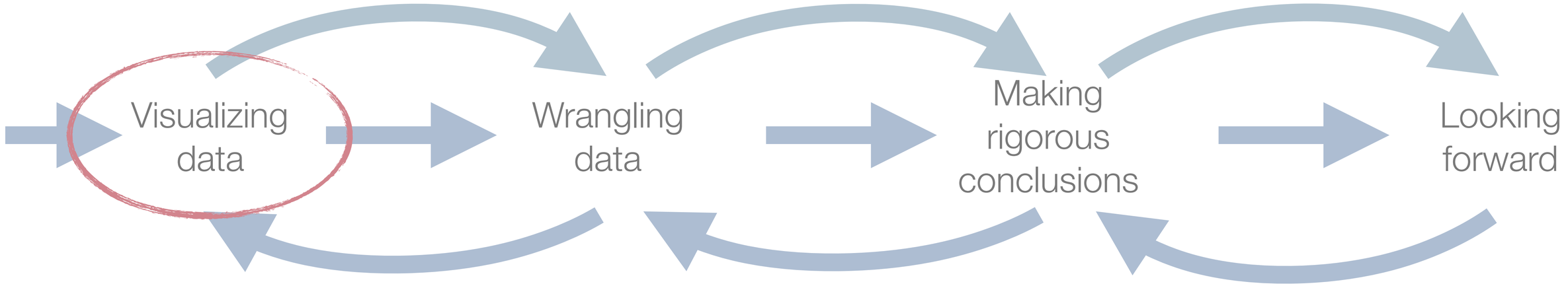
www.coursera.org/specializations/jhu-data-science#courses

ex: Better Living with Data Science

Duke University



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

skip baby steps

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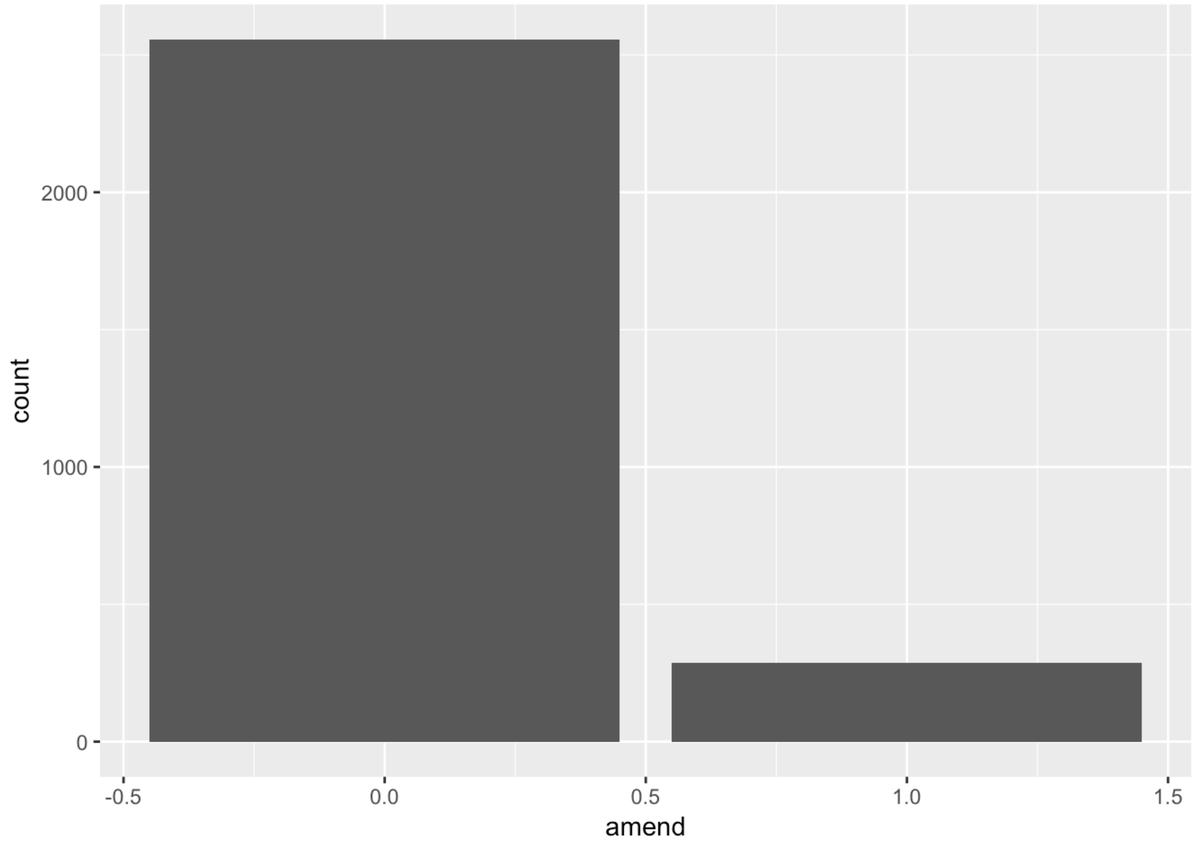
Which of the following two visualizations is more likely to **motivate** students to want to learn more?

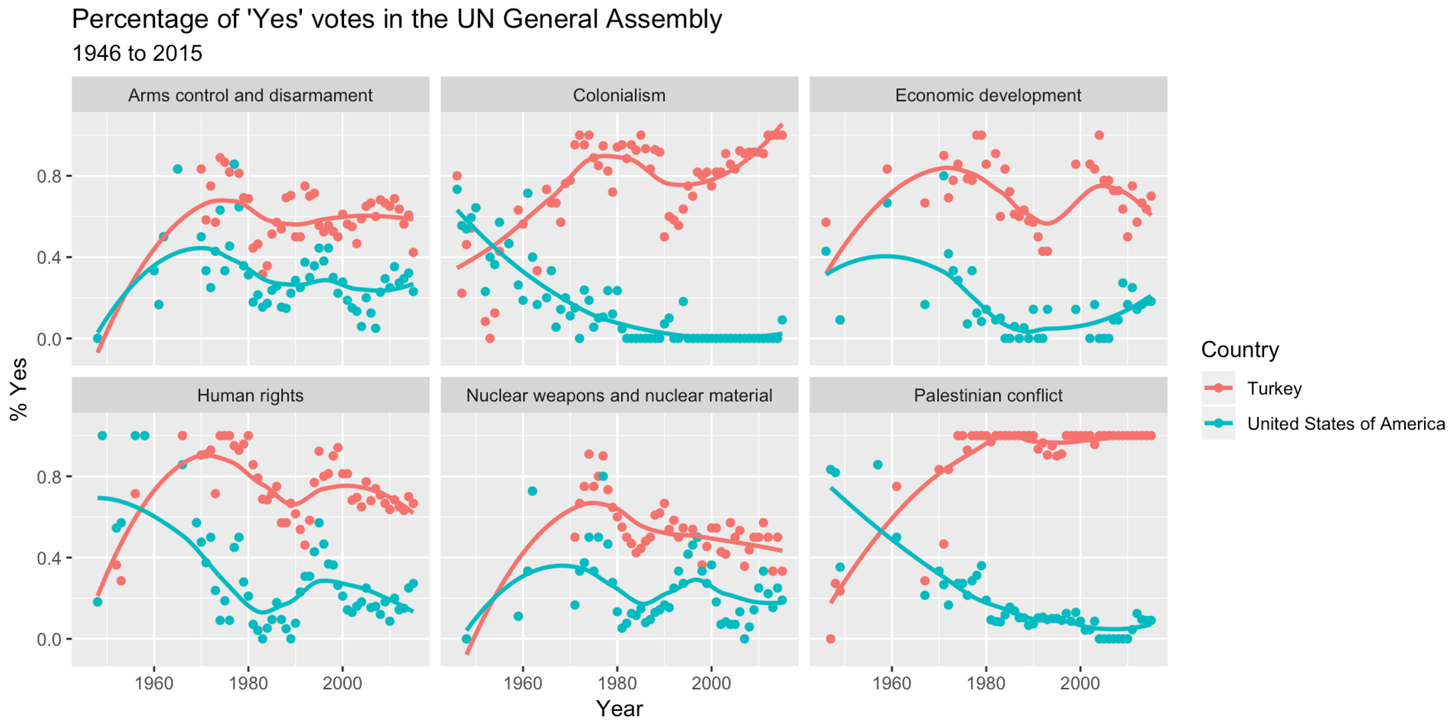
(a)

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

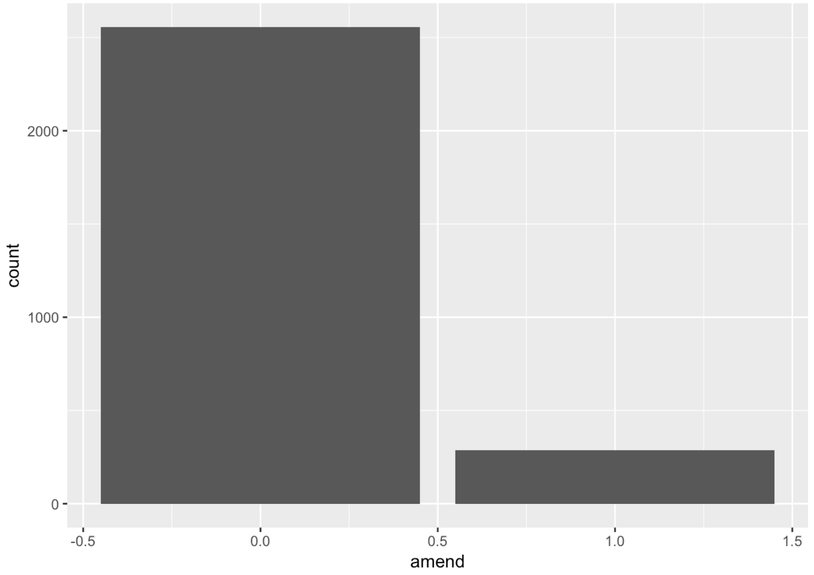


(b)

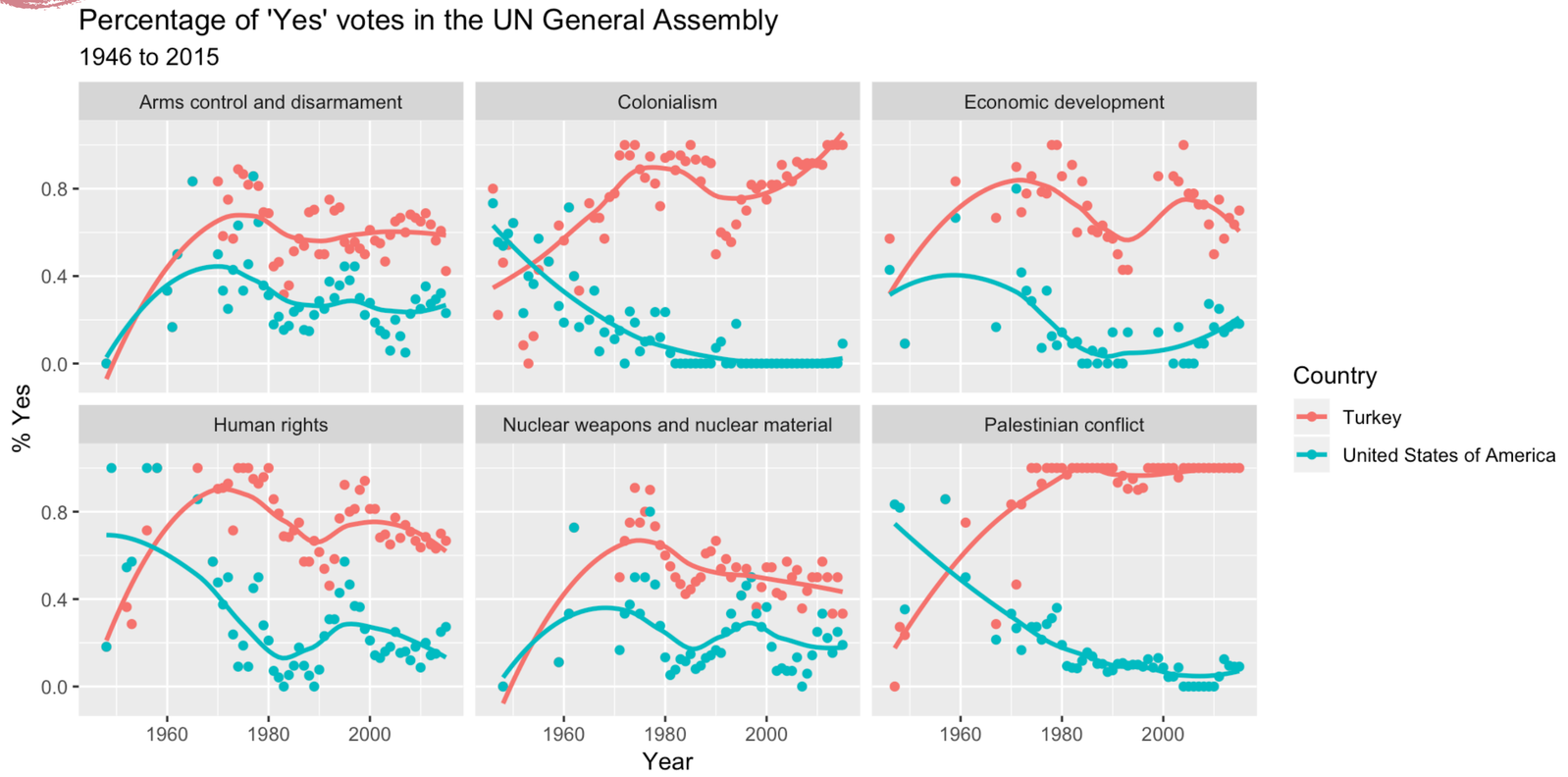
```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes, color = country)) +
  geom_point() +
  geom_smooth(method = "loess", se = FALSE) +
  facet_wrap(~ issue) +
  labs(
    title = "Percentage of 'Yes' votes in the UN General Assembly",
    subtitle = "1946 to 2015",
   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



(a)



(b)



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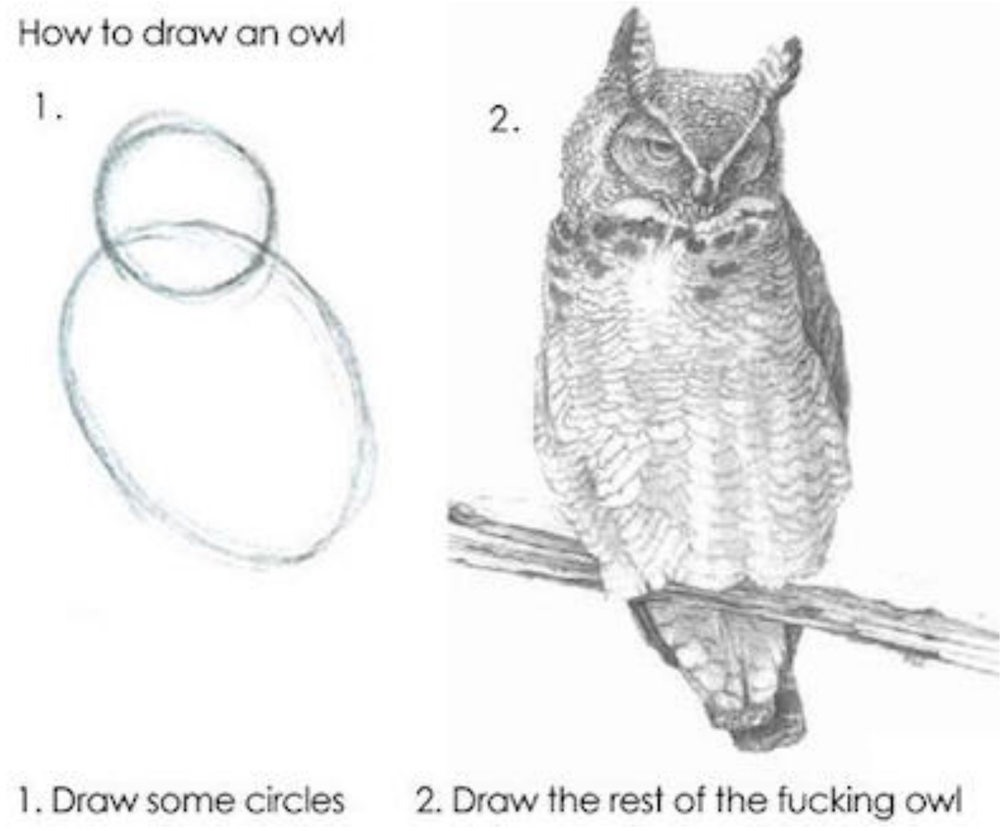
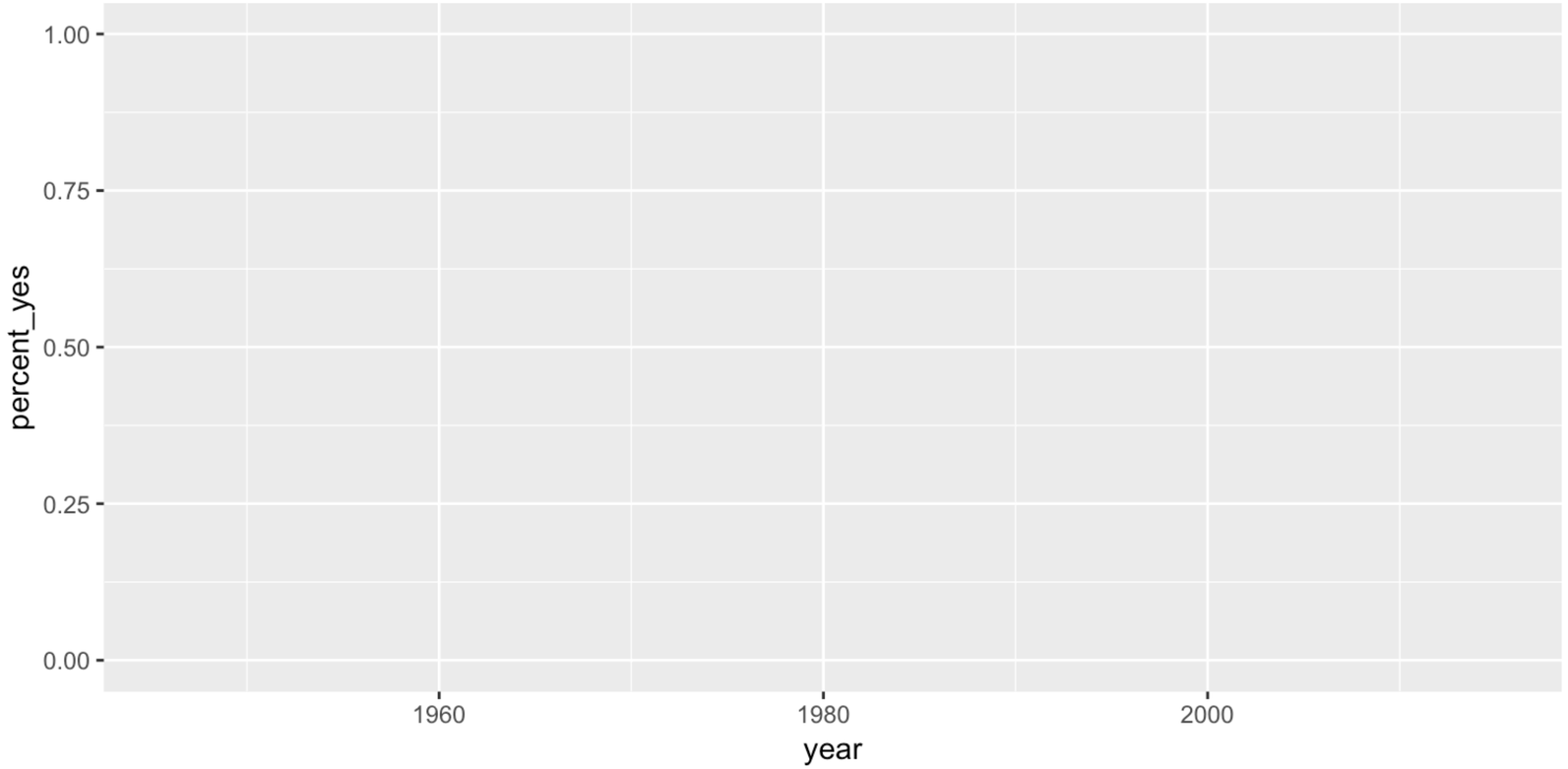
non-trivial examples can be motivating,

but need to avoid 👇!



```
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

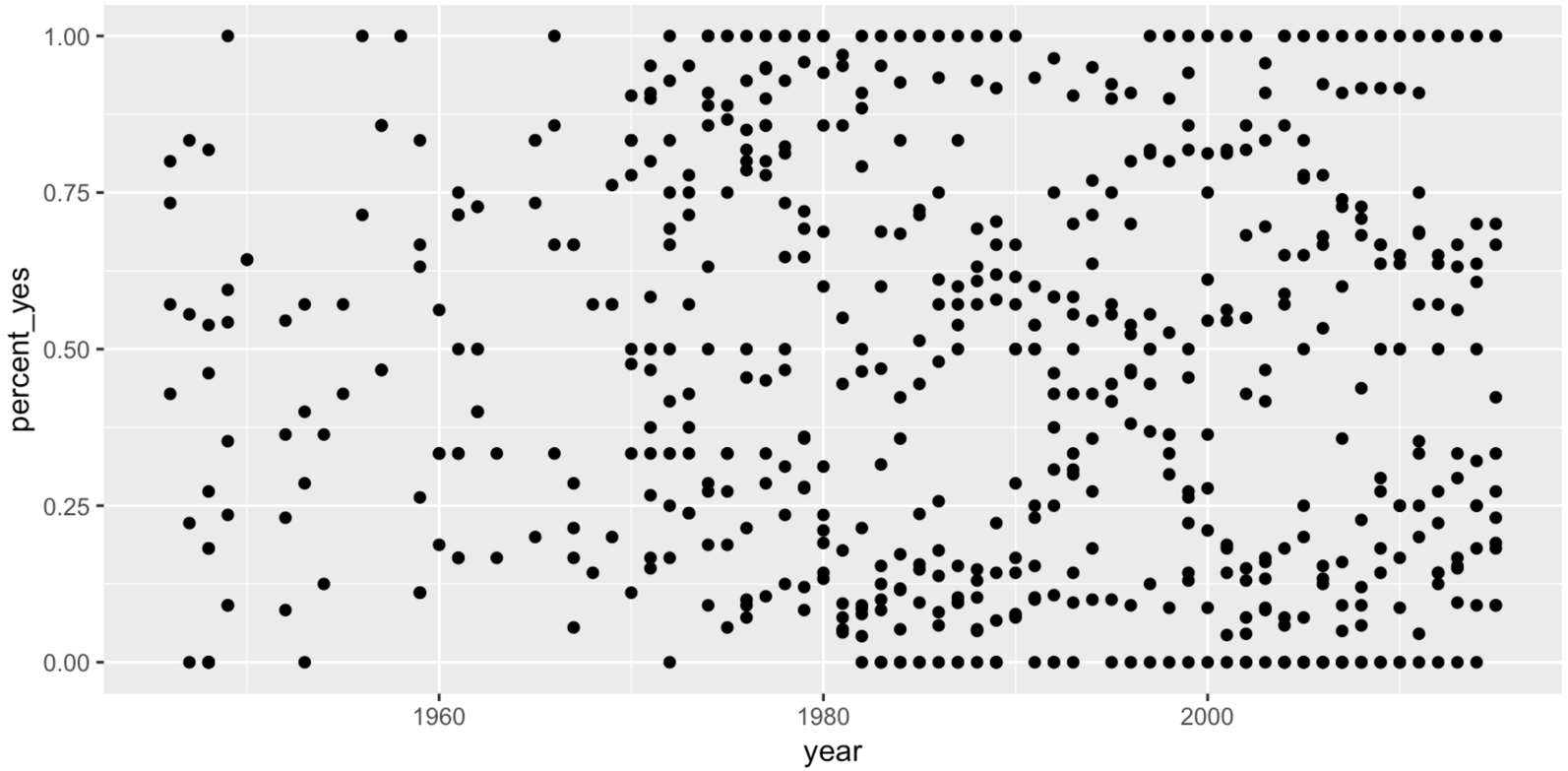
	country	year	issue	votes	percent_yes
1	Turkey	1946	Colonialism	15	0.80000000
2	Turkey	1946	Economic development	7	0.57142857
3	Turkey	1947	Colonialism	9	0.22222222
4	Turkey	1947	Palestinian conflict	6	0.00000000
5	Turkey	1948	Arms control and disarmament	8	0.00000000
6	Turkey	1948	Colonialism	13	0.46153846
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

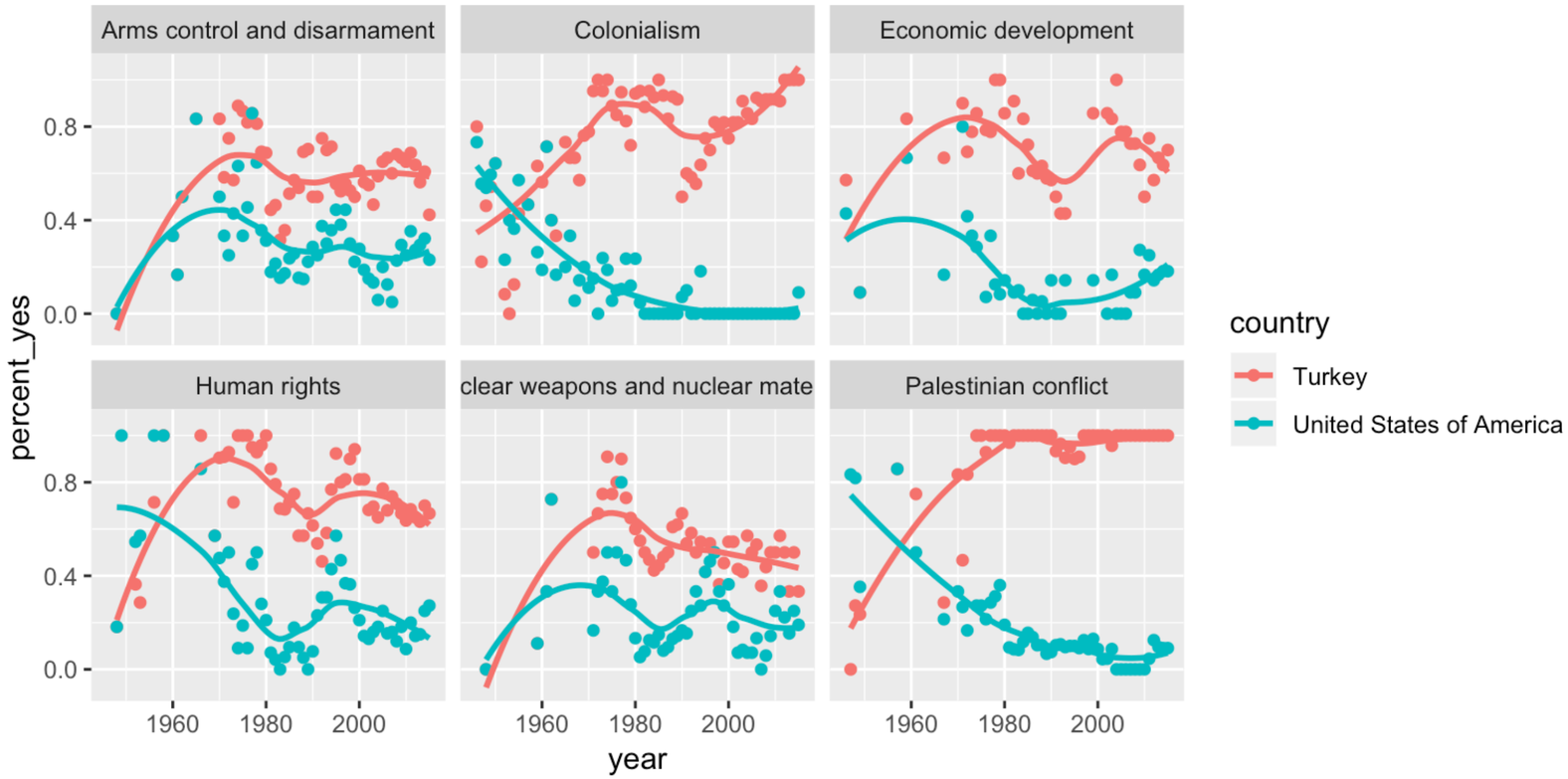
```
ggplot(data = un_votes_joined,
       mapping = aes(x = year, y = percent_yes)) +
 geom_point()
```



```
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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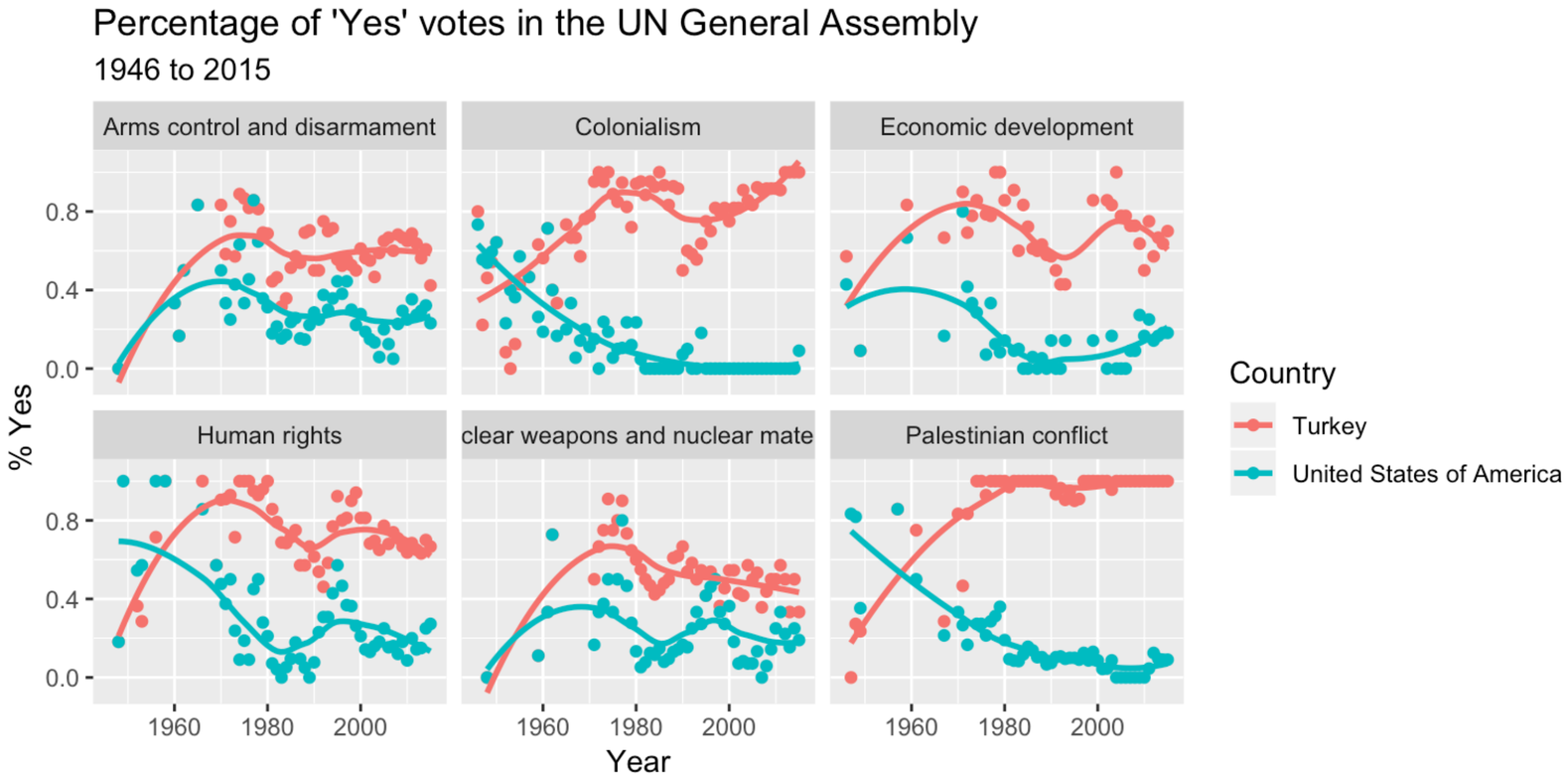
    y = "% Yes",
    x = "Year",
    color = "Country"
  )
```



cherish

day

one

bit.ly/let-eat-cake

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

(a)

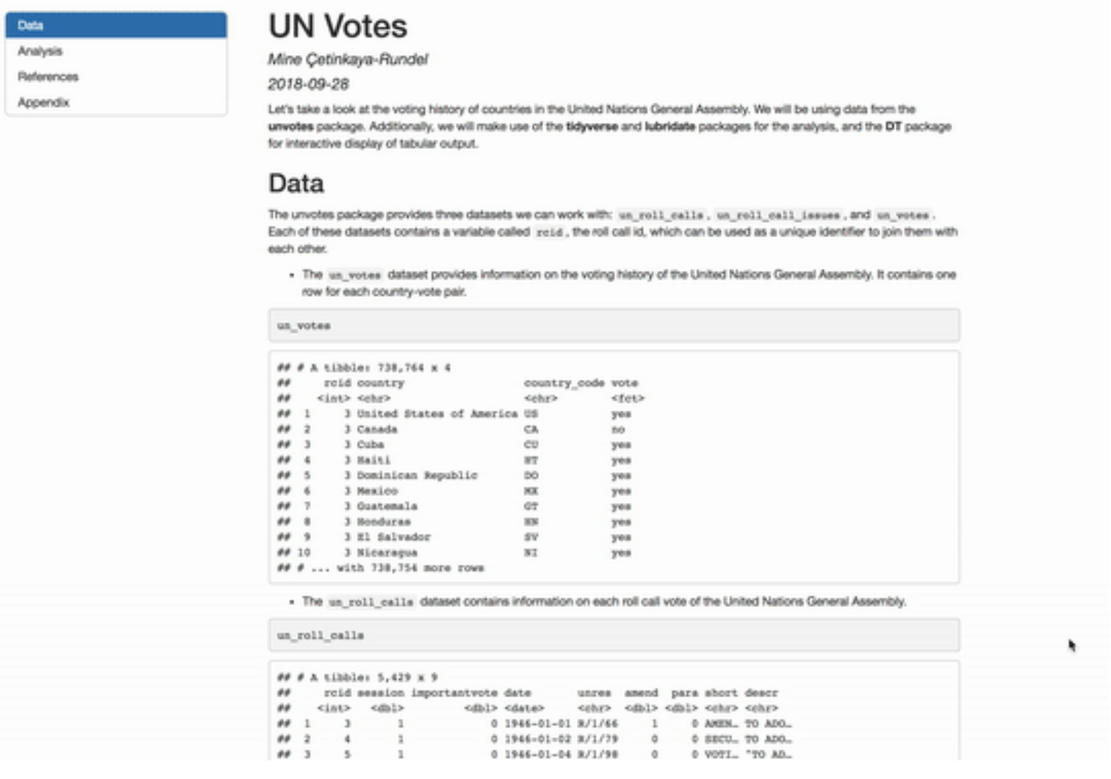
- Install R
- Install RStudio
- Install the following packages:
  - tidyverse
  - rmarkdown
  - ...
- Load these packages
- Install git

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

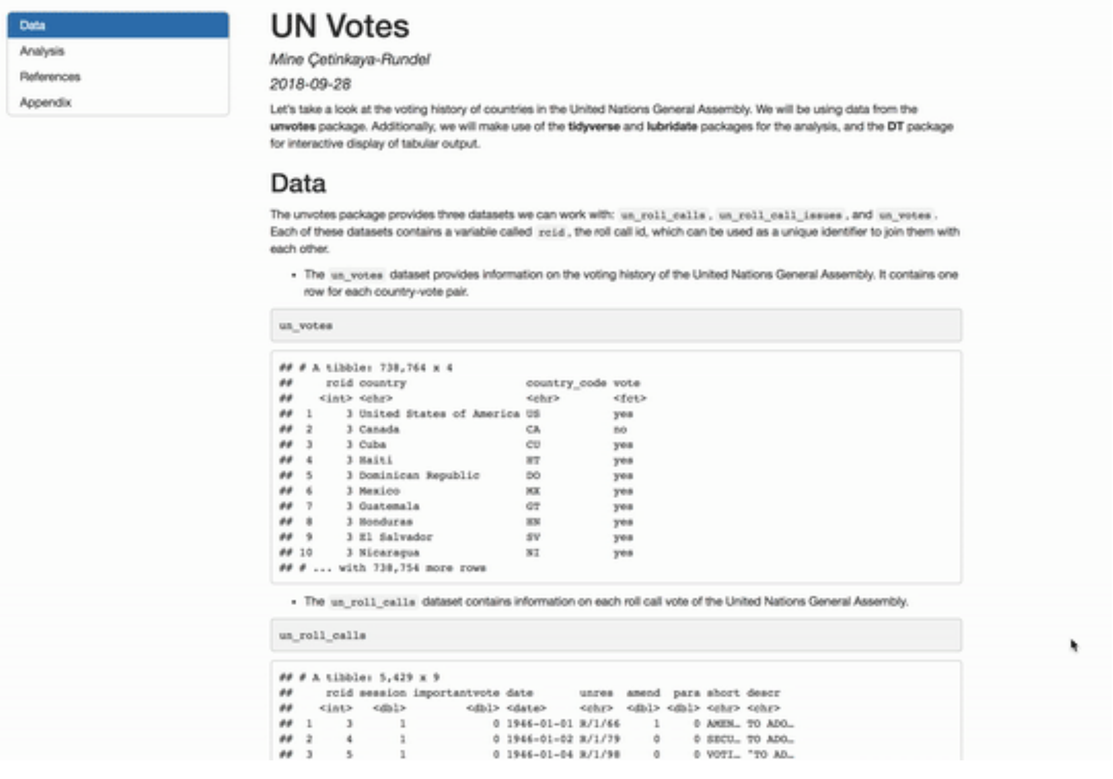
```
> hello R!
```

method of delivery,

and medium of interaction matters



bit.ly/let-eat-cake



bit.ly/let-eat-cake

hide the veggies

bit.ly/let-eat-cake

ex 2.

data acquisition

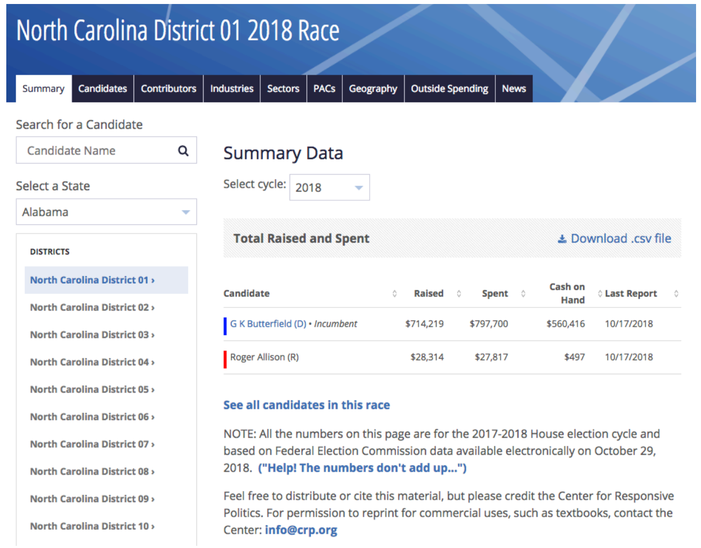
Which of the following two tasks is more likely to be **welcoming** for a wide range of students?

(a)

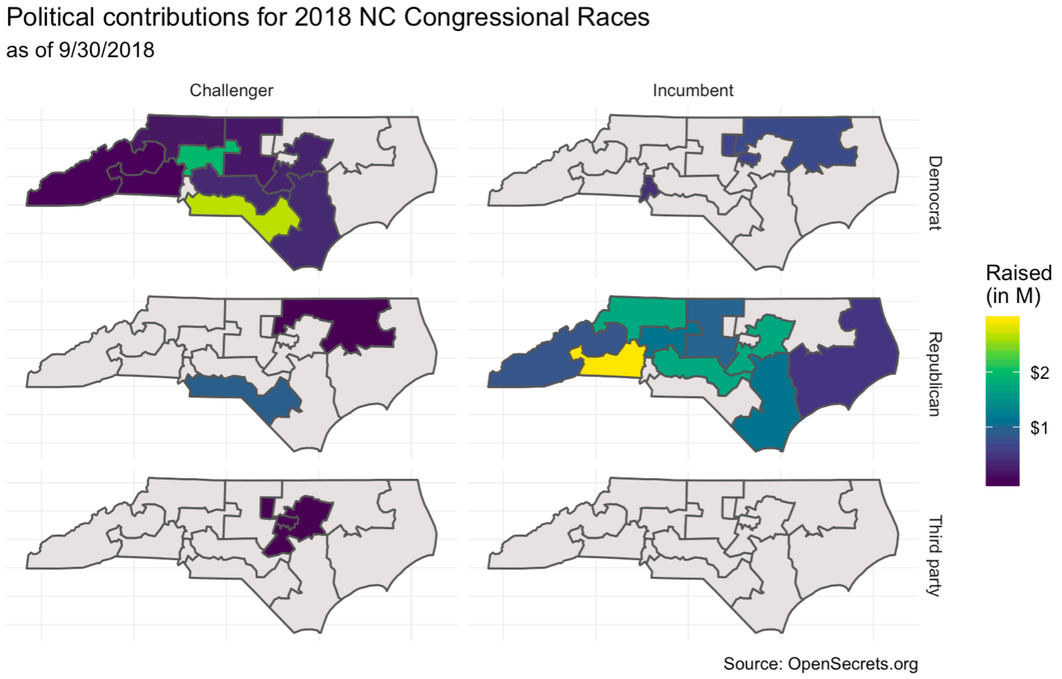
- Topic: Web scraping
- Tools: `rvest` and regular expressions

(b)

- Today we start with this:



- and end with this:



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

bit.ly/let-eat-cake

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.

- **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

bit.ly/let-eat-cake

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↓

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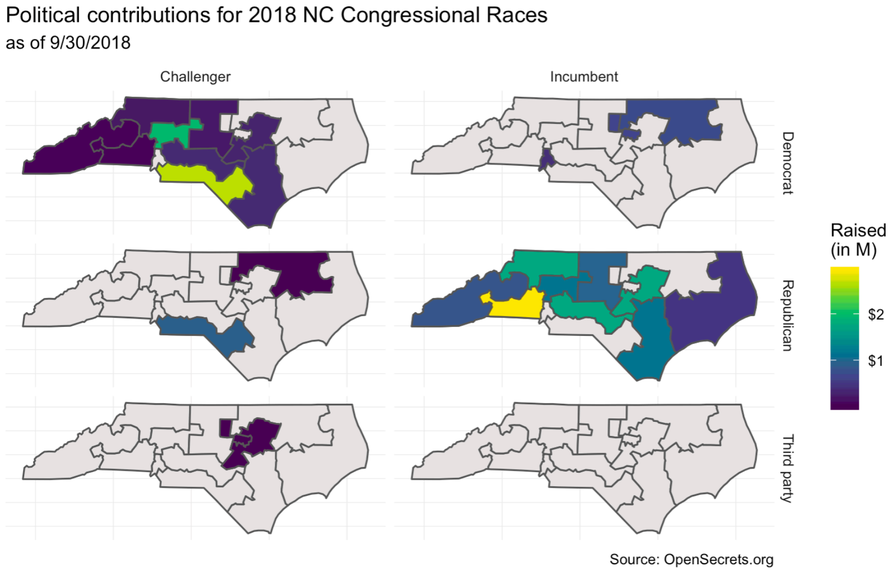
bit.ly/let-eat-cake

- **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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Candidate	Raised	Spent	Cash on Hand	Last Report
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↓

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bit.ly/let-eat-cake

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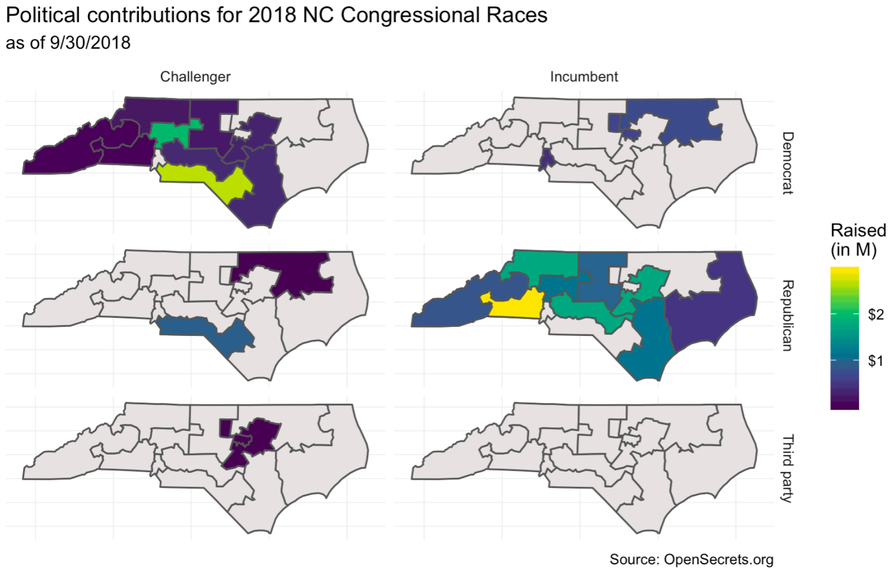

focus on exposure

bit.ly/let-eat-cake

ex 3.

modeling

evaluation score (1-5)

beauty score (1-10)

	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.

```
library(broom)

lm(score ~ rank + ethnicity + gender + bty_avg, data = evals) %>%
  tidy()
```

term	estimate	std.error	statistic	p.value
(Intercept)	3.78	0.114	33	4.84E-123
ranktenure track	-0.12	0.0741	-1.62	1.07E-01
ranktenured	-0.159	0.0625	-2.54	1.14E-02
Ethnicitynot minority	0.1	0.0723	1.39	1.66E-01
gendermale	0.182	0.052	3.5	5.10E-04
bty_avg	0.0728	0.0164	4.45	1.09E-05

- Write the linear model for male professors.
- Write the linear model for female professors.
- Interpret the slope of the beauty score for each.

```
library(broom)

lm(score ~ rank + ethnicity + gender*bty_avg, data = evals) %>%
  tidy()
```

term	estimate	std.error	statistic	p.value
(Intercept)	3.93	0.144	27.2	1.58E-97
ranktenure track	-0.109	0.0742	-1.46	1.44E-01
ranktenured	-0.135	0.064	-2.1	3.6E-02
ethnicitynot minority	0.0764	0.0735	1.04	2.99E-01
gendermale	-0.0793	0.161	-0.493	6.23E-01
bty_avg	0.0416	0.0245	1.7	8.97E-02
gendermale:bty_avg	0.0579	0.0338	1.71	8.73E-02

- Write the linear model for male professors.
- Write the linear model for female professors.
- Interpret the slope of the beauty score for each. What changed?

tl;dr

bit.ly/let-eat-cake

1 start with cake

2 skip baby steps

3 cherish day one

4 hide the veggies

5 focus on exposure

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

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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

Topics :: Data Science in a Box

datasciencebox.org

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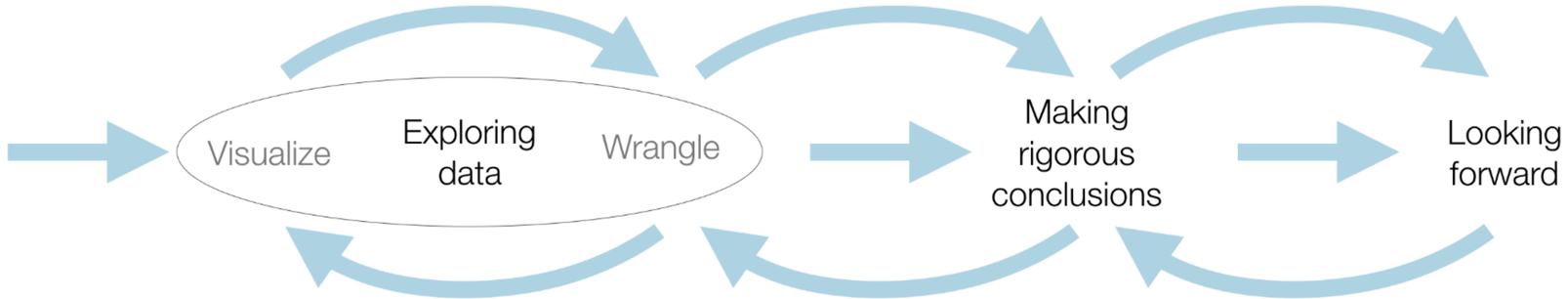
Topics

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.

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Let them eat cake (first)!*

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

* You can tell them all about the ingredients later!

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