More than Methods

Preparing students for data-driven work outside the classroom

Applied Research & Education Seminar
April 8, 2024

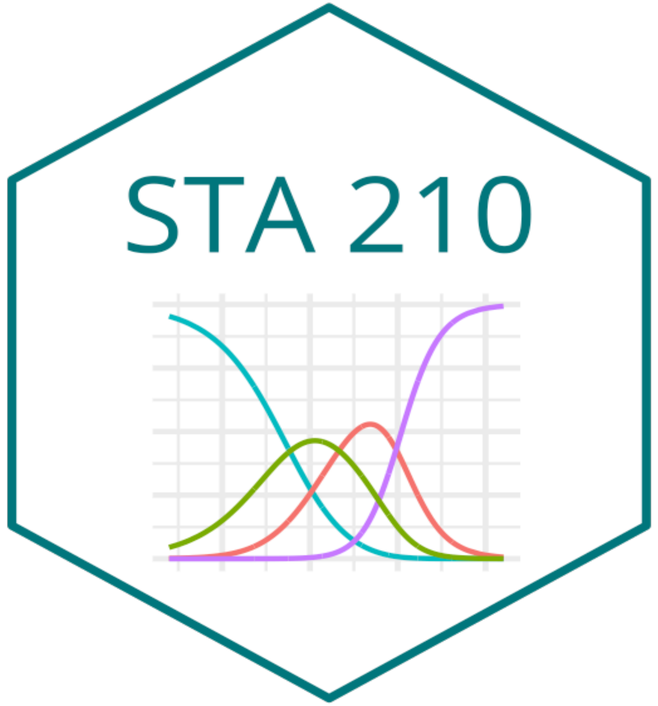
Maria Tackett
Duke University

Image credit: Sketchepedia on Freepik

🔗 bit.ly/ares-modernize-regression

Courses I teach

[Introduction to Data Science]



[Regression Analysis]

[Generalized Linear Models]

Background and Motivation

Three principles

Challenges and next steps

Background and Motivation

Three principles

Challenges and next steps

2014 ASA Undergraduate Curriculum Guidelines

"…concepts and approaches for working with **complex data**...and analyzing non-textbook data."

"…students' analyses should be undertaken in a **well-documented and reproducible way.**"

"…construct effective visual displays and **compelling written summaries**" and "demonstrate ability to **collaborate in teams…**"

ASA Undergraduate Guidelines Workgroup (2014), *Curriculum Guidelines for Undergraduate Programs in Statistical Science*

2017 Curriculum Guidelines for Undergraduate Programs in Data Science

"…work with data from a **variety of sources and formats**…"

"**As members of a team**, data scientists must **communicate to teammates as well as to those with less intimate knowledge of the project particulars**."

"…exposure to and **ethical training** in areas such as citation and data ownership, security and sensitivity of data, consequences and privacy concerns of data analysis, and the **professionalism of transparency and reproducibility**."

De Veaux, R. D., Agarwal, M., Averett, M., Baumer, B. S., Bray, A., Bressoud, T. C., ... & Ye, P. (2017). Curriculum guidelines for undergraduate programs in data science. Annual Review of Statistics and Its Application, 4, 15-30.

Undergraduate research team

- Interdisciplinary team co-led with Dr. Nichole Schramm-Sapyta in the Duke Institute for Brain Sciences
- 5 - 7 undergraduate students + 1 graduate project manager each year
- **Overall goal**: Understand patterns of healthcare utilization and interactions with the criminal justice system to provide data-informed insights to local community stakeholders

The data

Bookings in County Detention Facility

unique_id	race	ethnicity	sex	age_in_2020	confined_date	release_date	charges	release_reason
100001	White	Nonhispanic	M	23	11/10/2019	11/12/2019	Theft	Sentence completed
100002	Black	Hispanic	F	20	2/15/2020	2/17/2020	Assault, Bulgary	Transfer
100003	Asian	Non-Hispanic	M	28	7/22/2020	7/25/2020	Burglary, Drug possession, Assault	Time served
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50	8/12/2020	8/13/2020	Fraud	Secure bond

The tables were generated by ChatGPT for illustrative purposes only.

The data

Bookings in County Detention Facility

unique_id	race	ethnicity	sex	age_in_2020	confined_date	release_date	charges	release_reason
100001	White	Nonhispanic	M	23	11/10/2019	11/12/2019	Theft	Sentence completed
100002	Black	Hispanic	F	20	2/15/2020	2/17/2020	Assault, Bulgary	Transfer
100003	Asian	Non-Hispanic	M	28	7/22/2020	7/25/2020	Burglary, Drug possession, Assault	Time served
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50	8/12/2020	8/13/2020	Fraud	Secure bond

The tables were generated by ChatGPT for illustrative purposes only.

The data

Bookings in County Detention Facility

unique_id	race	ethnicity	sex	age_in_2020	confined_date	release_date	charges	release_reason
100001	White	Nonhispanic	M	23	11/10/2019	11/12/2019	Theft	Sentence completed
100002	Black	Hispanic	F	20	2/15/2020	2/17/2020	Assault, Bulgary	Transfer
100003	Asian	Non-Hispanic	M	28	7/22/2020	7/25/2020	Burglary, Drug possession, Assault	Time served
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50	8/12/2020	8/13/2020	Fraud	Secure bond

The tables were generated by ChatGPT for illustrative purposes only.

Data students work with

Bookings in County Detention Facility

unique_id	race	ethnicity	sex	age_in_2020	confined_date	release_date	charges	release_reason
100001	White	Nonhispanic	M	23	11/10/2019	11/12/2019	Theft	Sentence completed
100002	Black	Hispanic	F	20	2/15/2020	2/17/2020	Assault, Bulgary	Transfer
100003	Asian	Non-Hispanic	M	28	7/22/2020	7/25/2020	Burglary, Drug possession, Assault	Time served
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50	8/12/2020	8/13/2020	Fraud	Secure bond

The tables were generated by ChatGPT for illustrative purposes only.

The data

Encounters with Health System

unique_id	race	ethnicity	sex	age_in_2020	encounter_date	chief_complaint	diagnoses
100001	White	Non-hispanic	M	23	9/20/2020	Headache	G44.0, R51
100002	Black	Non-Hispanic	F	20	10/5/2020	Cough	J44.9, R05, J20.9
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
400001	White	Hispanic	F	50	5/2/2020	Nausea	R11.0, R10.13, R11.9, R11.10, R11.12

The tables were generated by ChatGPT for illustrative purposes only.

The data

Bookings

unique_id	race	ethnicity	sex	age_in_2020
100001	White	Nonhispanic	M	23
100002	Black	Hispanic	F	20
100003	Asian	Non-Hispanic	M	28
. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50

Health System Encounters

unique_id	race	ethnicity	sex	age_in_20
100001	White	Non-hispanic	M	23
100002	Black	Non-Hispanic	F	20
. . .	. . .	. . .	. . .	. . .
400001	White	Hispanic	F	50

The tables were generated by ChatGPT for illustrative purposes only.

The data

Bookings

unique_id	race	ethnicity	sex	age_in_2020
100001	White	Nonhispanic	M	23
100002	Black	Hispanic	F	20
100003	Asian	Non-Hispanic	M	28
. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50

Health System Encounters

unique_id	race	ethnicity	sex	age_in_20
100001	White	Non-hispanic	M	23
100002	Black	Non-Hispanic	F	20
. . .	. . .	. . .	. . .	. . .
400001	White	Hispanic	F	50

The tables were generated by ChatGPT for illustrative purposes only.

The data

Bookings

unique_id	race	ethnicity	sex	age_in_2020
100001	White	Nonhispanic	M	23
100002	Black	Hispanic	F	20
100003	Asian	Non-Hispanic	M	28
. . .	. . .	. . .	. . .	. . .
400001	W	H	F	50

Health System Encounters

unique_id	race	ethnicity	sex	age_in_20
100001	White	Non-hispanic	M	23
100002	Black	Non-Hispanic	F	20
. . .	. . .	. . .	. . .	. . .
400001	White	Hispanic	F	50

The tables were generated by ChatGPT for illustrative purposes only.

Data analysis and more…

- Turn community stakeholder questions into statistical inquiries
- Use a reproducible workflow, with clear and informative documentation
- Explain analysis and results in reports and presentations to community stakeholders
- Differentiate between what is “allowed” and what is ethical
- Collaborate with teammates, project manager, and faculty

Narrow the gap

Data analysis in the classroom

Data analysis in research, internships, and jobs

Narrow the gap

Data analysis in the classroom

Data analysis in research, internships, and jobs

Three principles for modernizing a regression course

Provide opportunities for students to…

Principle 1: Regularly engage with complex (and relevant) real-world data and applications

Principle 2: Develop the skills and computational proficiency for a reproducible data analysis workflow

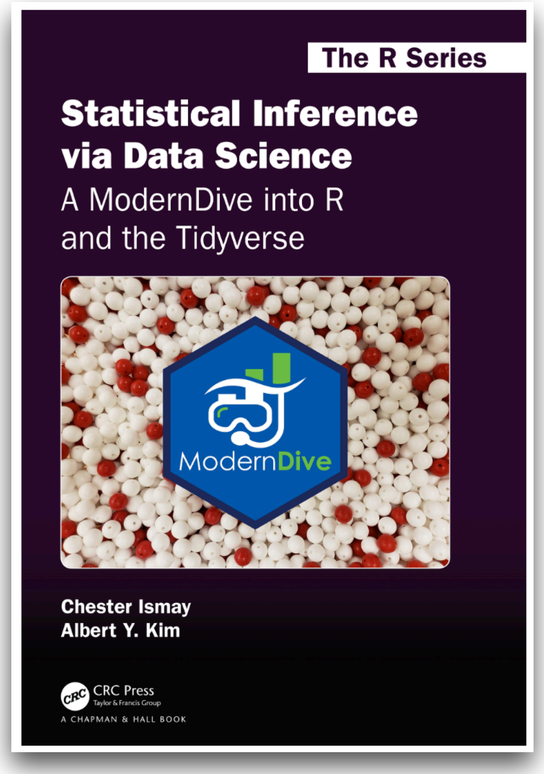
Principle 3: Develop important nontechnical skills, specifically written communication and teamwork

Background
and
Motivation

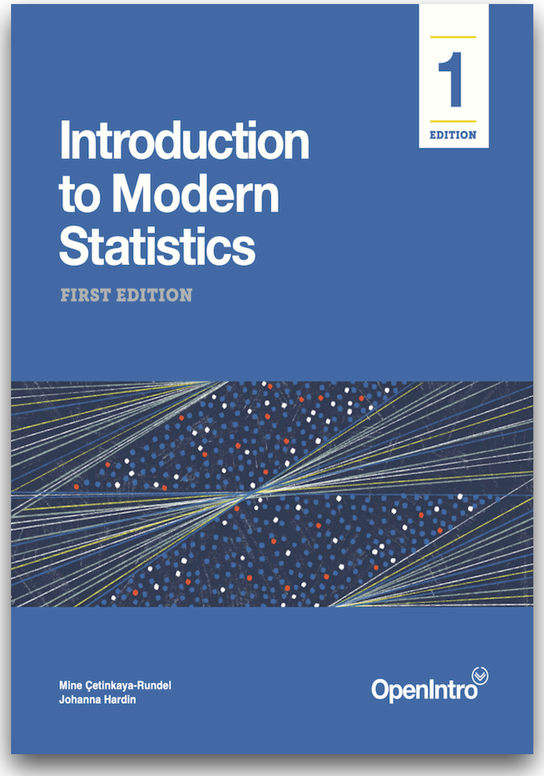
Three principles

Challenges
and
next steps

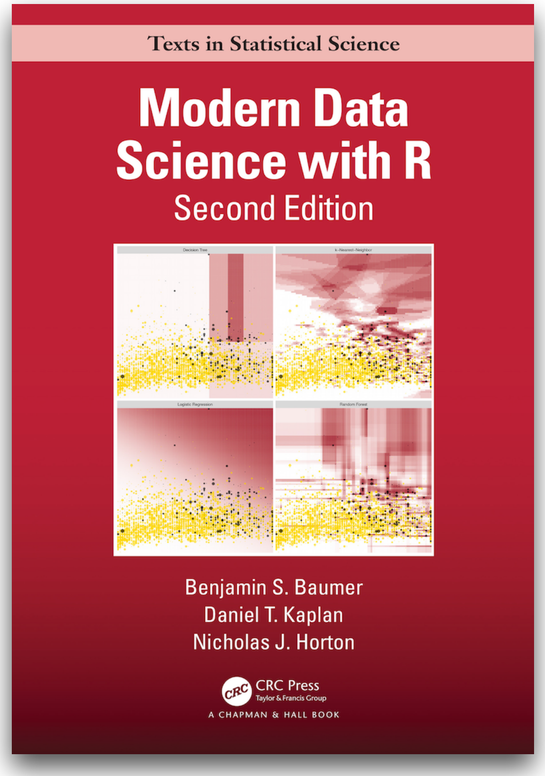
Build on skills from introductory course



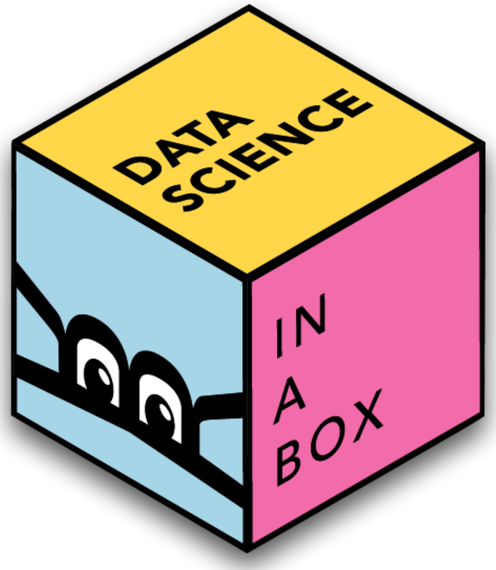
[Modern Dive]



[Introduction to Modern Statistics]



[Modern Data Science with R]



[Data Science in a Box]

STA 210: Regression Analysis

Students: ~100 who have taken introductory statistics, data science, or probability course (majors and non-majors)

Class Meetings: 2 lectures with in-class activities and 1 lab

Teaching team: instructor, undergraduate and graduate teaching assistants

Assessments: labs, homework, exams, final group project

Learning objectives

By the end of the semester, students will be able to…

- analyze real-world data to answer questions about multivariable relationships.
- use R to fit and evaluate linear and logistic regression models.
- assess whether a proposed model is appropriate and describe its limitations.
- use Quarto to write reproducible reports and GitHub for version control and collaboration.
- effectively communicate statistical results through writing and oral presentations.

Principle 1

Regularly engage with complex (and relevant) real-world data and applications

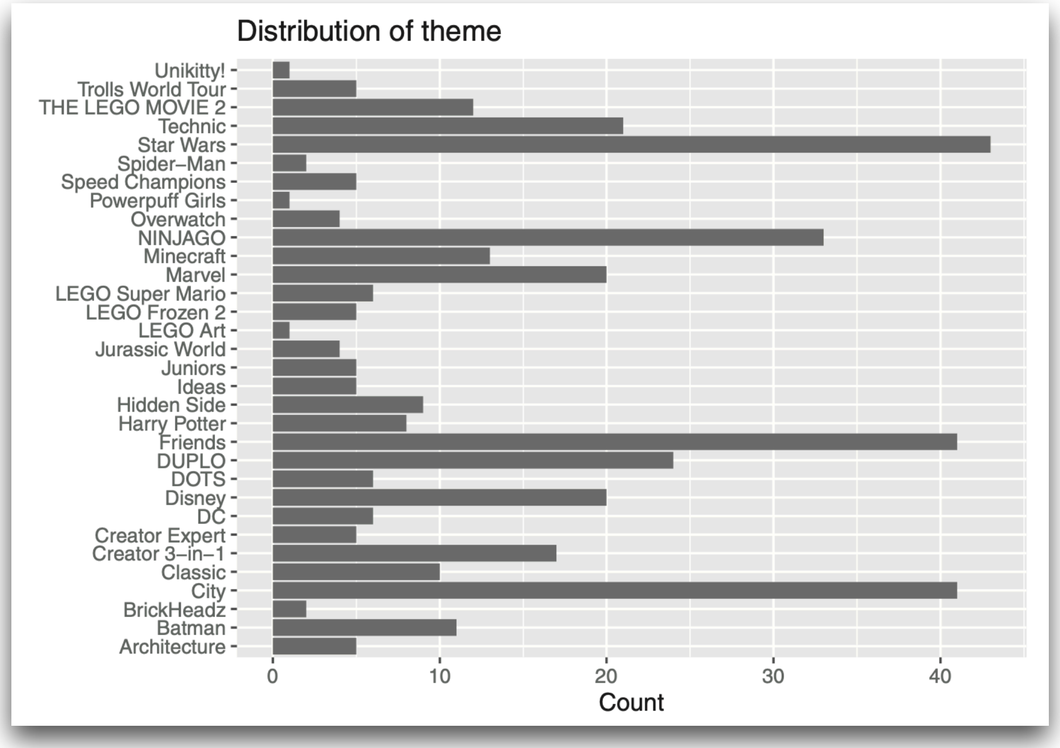
Real-world data and applications

- “**Real-world**”: relevant and messy data that require some pre-processing before analysis
- **Goals**:
  - Give students exposure to data wrangling required before most regression analysis in practice
  - Demonstrates how regression is used in variety of interesting and relevant contexts
- **Where:** lectures, in-class activities, assignments

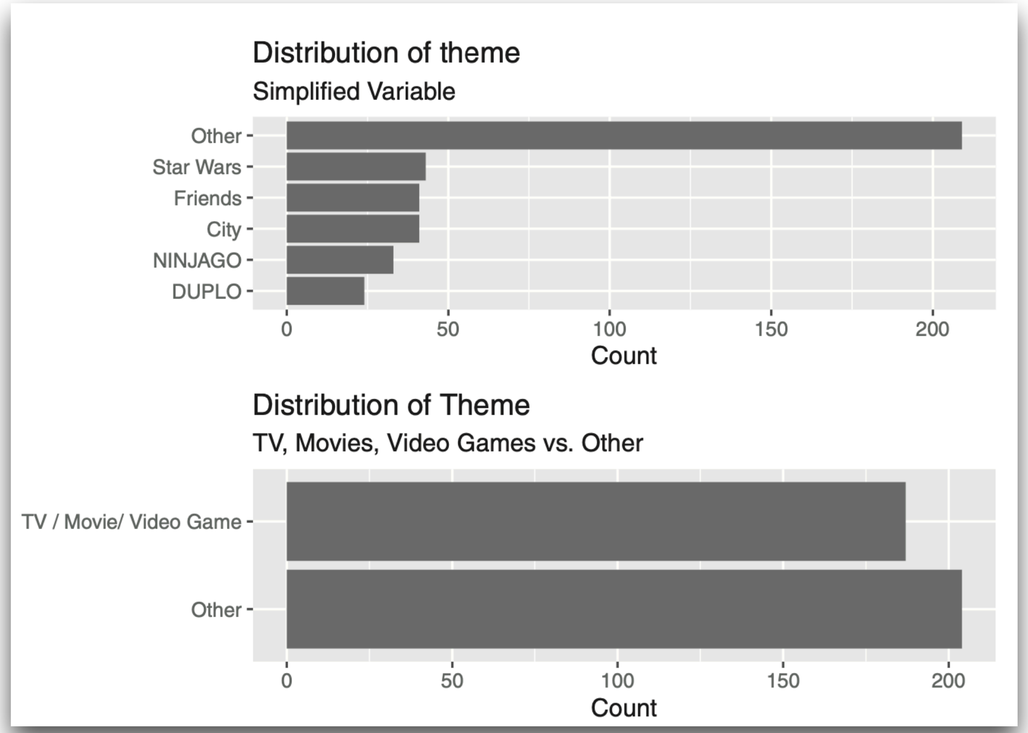
Example: LEGO themes in-class activity

Students use data from Peterson and Ziegler (2021) to explore strategies to collapse levels of categorical variable

Original



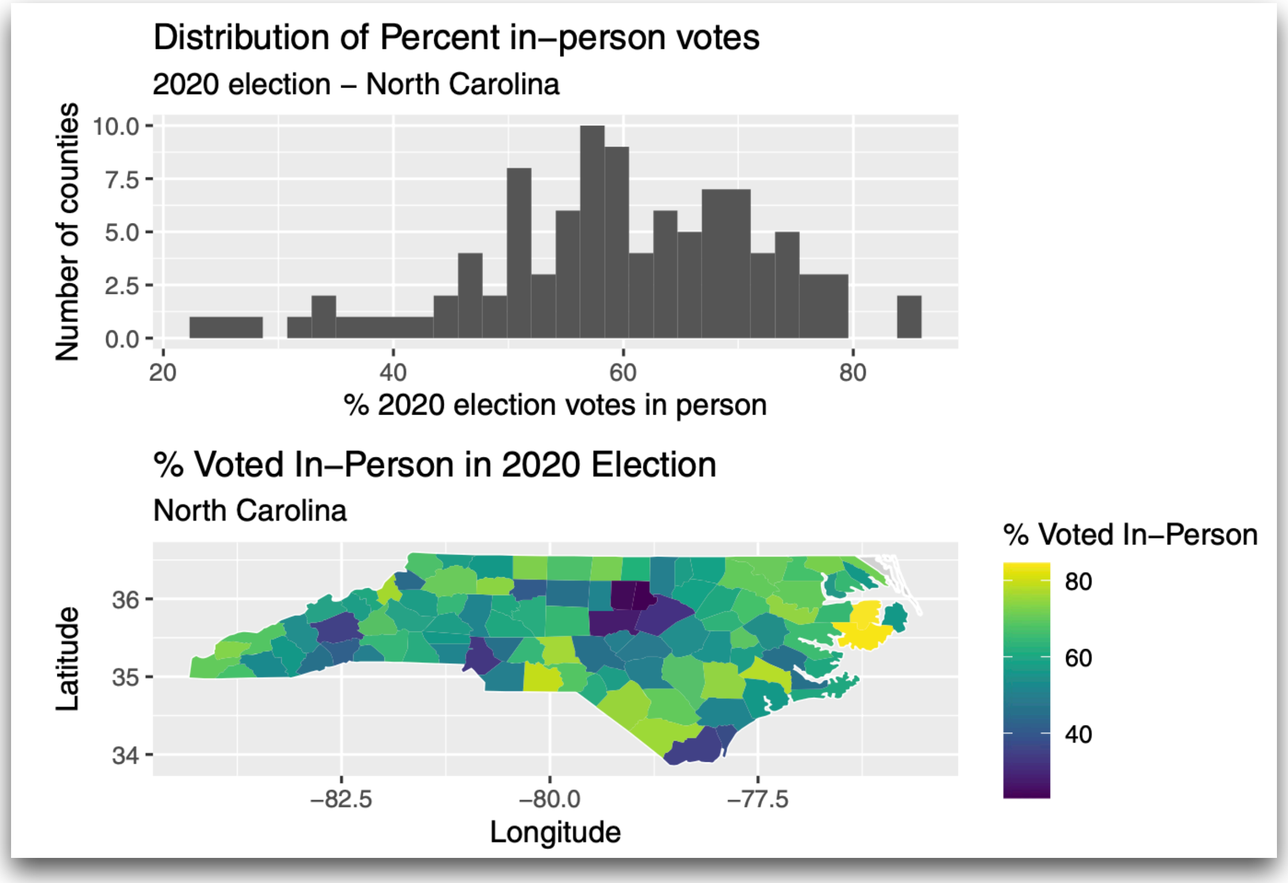
Examples of student strategies



Peterson, A. D., & Ziegler, L. (2021). Building a Multiple Linear Regression Model With LEGO Brick Data. *Journal of Statistics and Data Science Education*, *29*(3), 297-303.

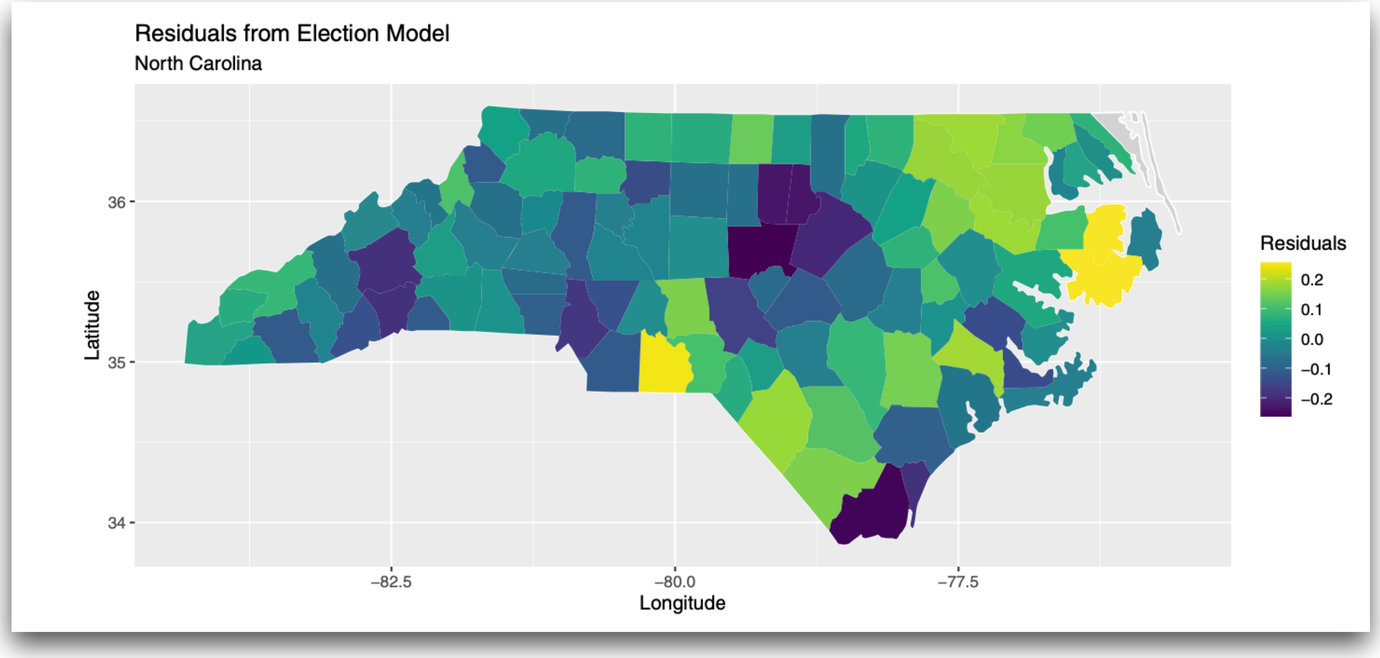
Example: Assessing independence

Students consider potential spatial dependence in North Carolina voting data from the 2020 presidential election



Example: Assessing independence

Students consider potential spatial dependence in North Carolina voting data from the 2020 presidential election



- *Briefly explain why we may want to view the residuals on a map to assess independence.*
- *Briefly explain what pattern (if any) we would expect to observe on the map if the independence condition is satisfied.*
- *Is the independence condition satisfied? Briefly explain based on what you observe from the map.*

Principle 2

Develop the skills and computational proficiency for a reproducible data analysis workflow

What is the goal of teaching reproducibility?

Computing toolkit

- Quarto for assignment write-ups
- Run Git commands using point-and-click interface
- Server-based RStudio*
  - Git already configured
  - Same set up for all students

- Assign and submit assignments
- Facilitates collaboration on group assignments
- Course management using **ghclass** R package (or GitHub Classroom**)

*Çetinkaya-Rundel, M., and Rundel, C. (2018), "Infrastructure and Tools for Teaching Computing Throughout the Statistical Curriculum," The American Statistician, 72, 58–65,

**Fiksel, J., Jager, L. R., Hardin, J. S., and Taub, M. A. (2019), "Using GitHub Classroom to Teach Statistics," Journal of Statistics Education, 27, 100–119.

Motivating why reproducibility matters

- Lecture introducing reproducible workflow and computing toolkit
- Students study a case in which lack of reproducible practices had significant negative consequences (Ostblom and Timbers, 2022)
- They are asked to describe what part(s) of the process were not reproducible, the impact, and their ideas for making the process reproducible

Ostblom, Joel, and Tiffany Timbers. 2022. “Opinionated Practices for Teaching Reproducibility: Motivation, Guided Instruction and Practice.” *Journal of Statistics and Data Science Education* 30 (3): 241–50. https://doi.org/10.1080/26939169.2022.2074922.

Reproduce an analysis

- Students work in groups to reproduce one model from an article in a scholarly journal
- They are asked what could have made the process easier

Having a codebook

Fixing typos and spelling errors

Fixing typos and spelling errors

Consistency between provided data and the process description

Consistency in how variables are handled

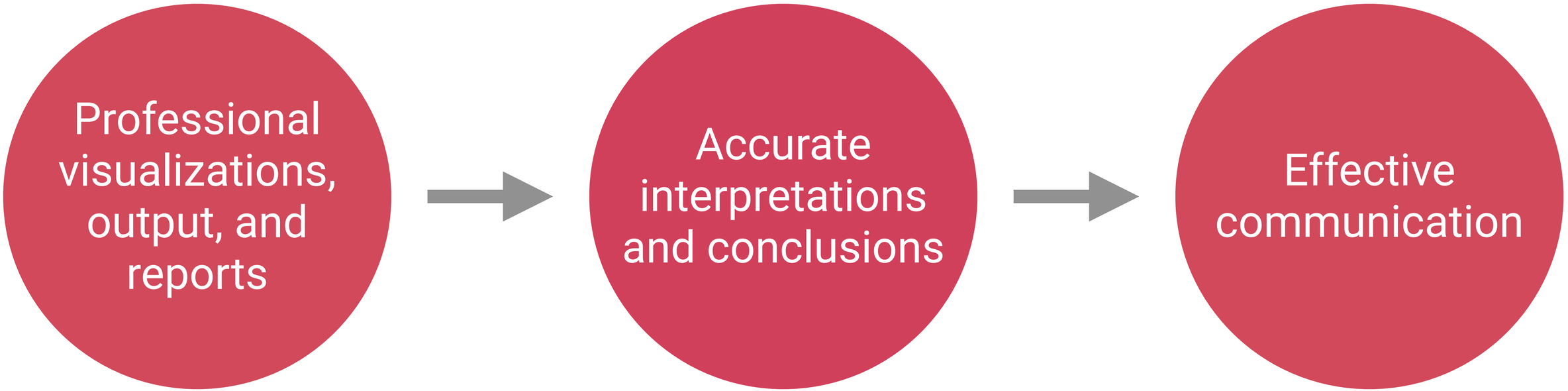
Knowing more about authors' thought process

Using informative variable names and categories

Principle 3

Develop important nontechnical skills, specifically written communication and teamwork

Teaching written communication



Document formatting and presentation

Points on each assignment for…

- ✓ Writing all responses as cohesive narrative
- ✓ Clearly organized document
- ✓ Neatly formatted tables and output
- ✓ Informative titles and axis labels for visualizations

“What’s the ‘so what’ ?”

- Goal is for students to get beyond basic interpretation to…
  - writing interpretations in a meaningful way
  - summarizing results to draw conclusions
- Assess analysis and summary separately to more easily identify student misunderstanding
- Do this first in short assignment questions and eventually in final project

Example: King County, WA houses

Students analyze data about the price and other characteristics of houses in King County, Washington

- *Make a visualization of the price versus square footage with the points differentiated by waterfront. Interpret the visualization*
- *Fit a model with the log-transformed price (see the previous lab to see why we use log-transformed price!) as the response and sqft, waterfront, and their interaction as the predictors.*
- *Interpret the effect of square footage on the price of a house for*
  - *houses with no waterfront view*
  - *houses with a waterfront view*

Conceptual understanding

Example: King County, WA houses

Students analyze data about the price and other characteristics of houses in King County, Washington

Use the results from the previous questions to write a short paragraph (~ 3–5 sentences) about the relationship between square footage and the price of houses in King County, WA, and how (if at all) the relationship differs based on whether the house has a waterfront view. The paragraph should be written in a way that is practical and can be easily understood by a general audience of home buyers.

Effective communication

Teamwork

- Teams of 3 or 4 students assigned based on
  - previous statistics and computing experience
  - major or academic interests
  - at least one point of potential connection with their teammates

- Groups work together throughout the semester on weekly lab assignments and the final project

Teamwork

- The first team assignment includes
  - Completing a team agreement
  - Coming up with a fun team name!

- Teamwork is assessed based on contribution and collaboration
  - GitHub commit history on assignments to assess contribution
  - Periodic team feedback to assess collaboration

Background and Motivation

Three principles

Challenges and next steps

Addressing challenges

Finding data accessible to new learners

- Many data sets fail model conditions / require transformations
- Opportunity to get students excited about later units in the course and get exposure to realistic decision-making

Assessing writing

- Difficult to provide detailed individual feedback in large class
- Provide feedback on shorter writing exercises

Training teaching team

- Challenging to guarantee consistency in grading across multiple people
- Utilize detailed rubrics and regular meetings for discussions about grading

What’s next?

Include data ethics in the learning objectives for the course

Artificial intelligence

Additional information


Article

Three Principles for Modernizing an Undergraduate Regression Analysis Course

Maria Tackett

Pages 116-127 | Published online: 02 Mar 2023

Cite this article https://doi.org/10.1080/26939169.2023.2165989

doi.org/10.1080/26939169.2023.2165989

- STA 210: Regression Analysis Fall 2023 course website: sta210-fa23.netlify.app
- Beckman, M. D., Çetinkaya-Rundel, M., Horton, N. J., Rundel, C. W., Sullivan, A. J., & Tackett, M. (2021). Implementing version control with Git and GitHub as a learning objective in statistics and data science courses. Journal of Statistics and Data Science Education, 29, 132-144. doi.org/10.1080/10691898.2020.1848485
- Çetinkaya-Rundel, M. (2020), "Data Science in a Box," available at www.datasciencebox.org

Thank you!

maria.tackett@duke.edu

Image credit: Sketchepedia on Freepik

🔗 bit.ly/ares-modernize-regression

Resources for finding data

- OpenIntro
- TidyTuesday
- FiveThirtyEight
  - GitHub repo
  - R package
- Data is Plural

STA 210 Course topics

Linear regression	Logistic regression	Looking ahead
Fitting and interpreting linear regression models	Fitting and interpreting logistic regression models	Topics to introduce students to methods beyond the course
Inference	Inference	Missing data imputation
Model conditions and diagnostics	Model conditions and diagnostics	Longitudinal modeling
Categorical predictors, polynomial predictors, interaction terms	ROC curve	Time series
Variable transformations	Prediction and classification	Poisson regression
Model selection	Model selection	Ordinal regression
Feature engineering*	Introduction to multinomial logistic regression	
Cross validation*		