Teaching Programming with Tidyverse Koans

A Journey of Successes and Failures

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Vision

Today, software engineers are not the only people who program. People in just about every field write programs to help them do their tasks.
This means that computer scientists are not the only people who *teach* programming anymore.
If you're tasked with teaching people to program, building koans is the best place to start.
Koans are gentle, self-paced, easy to create, and you'll have great results.

My First R Class

Reading in different types of data as tibbles:

- csv: comma-separated values use `readr::read_csv()`
- excel files: use `readxl::read_excel()`
- .dta from STATA: use `haven::read_dta()`

Try these for yourself:

- `View(gapminder)`
- `?gapminder`
- `colnames(___)`
- `head(___)`
- `tail(___, n = 15)`
- `class(___)`
- `str(___)`
- `dim(___)`
- `nrow(___)`
- `summary(___)`
- `skimr::skim(___)`

3.1 Select values

```
# Select the population of Afghanistan in 1952
  # How?
    # Use `head(gapminder)` to find the row __, column __ of the data.
    # To select the element in the 3rd row, 2nd column of a matrix, use my_matrix[3, 2]. As a
n aside, to select the 10th element of a vector, use my_vector[10].

gapminder[1, 5]
```

> **Note:** select value ranges with `gapminder[1:10, 3]`.

3.2 Select columns

```
# Select the entire first column 'country' in gapminder
  # How?
    # my_matrix[, 10] selects all rows of the 10th column
    # my_matrix[10, ] selects the 10th row of all columns

gapminder[, 1]
```

```
# R allows you to extract a named column with the `$` operator
gapminder$country
```

Avoid

- square brackets
- `$`
- `for` and `if` and `while`

The Issue with Live Coding

Engagement comes from TERA [1]

Tribe

Expectations

Rank

Autonomy

1. The Coaching Habit, Michael Bungay Stanier

Version 2: Koans

```
# 1. Make the first element of this numeric vector '6'. Remember to always
# un-comment the line of code (Cmd-Shift-C), execute it (Cmd-Return), and then
# test this file to make sure you passed (Cmd-Shift-T).

#1@

# c(__, 4, 5, 2, 3)

#@1

#::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::

# 2. Make the third element of this character vector 'economics'. --------------
# Note that quotes shouldn't be used with numbers, but should be used with
# character strings.

#2@

# c("apple", "banana", __)

#@2
```

```
# 3d. Multiply a scalar and a vector.

#3d@

# 100 * c(6, 3, 2) == c(__, __, __)

#@3d
```

```r
# To create a vector that does random sampling, use 'sample':
?qelp::sample

# This randomly draws 0's or 1's to create a random vector of length 10.
sample(c(0, 1), size = 10, replace = TRUE)

# 6. Create a random character vector that draws "heads" or "tails". ---------

#6@

# sample(__, size = 5, replace = TRUE)

#@6
```

👩 Outline for instructors

K01_vector.R	Data in R is held in vectors. Did you know that even a single number like `4` is a vector in R, of length 1? Starting with vectors gets learners familiar with the concept of functions being vectorized (many functions work on vectors of any length). This is a powerful first building block for the tidyverse's functional, declarative approach. It's a cardinal sin to let learners believe they need to do something as complicated as looping or mapping over a vector when the function they're applying is already vectorized.	
K02_tibble.R	The next building block to learn about are tibbles: the tidyverse's spreadsheet. Data is still being held in vectors (column vectors specifically). The **tidied data format** is where columns are variables and rows are observations.	
K03_pipe.R	The most commonly used function in the tidyverse. Use it to chain together a sequence of operations.	
K04_dplyr1.R	The first 3 dplyr functions to learn are filter(), select(), and mutate(). Tidyverse literature talks about using dplyr to "manipulate" data. I don't like that. I think it's a lot more useful for learners to think about using dplyr for writing *queries* on	

	their data, like with SQL. That way, they remember that if they have a question about their data, they should reach for dplyr.	
K05_dplyr2.R	The next two dplyr functions are summarize() and group_by().	
K06_dplyr3.R	The final two dplyr functions are arrange() and slice().	
K07_left_join.R	One more function from dplyr: use left_join() to combine two tibbles when you have a variable that acts as a key to match them. This koan sets learners up to solve the dplyr murder mystery I adapted from here. This project has historically been a favorite: to quote my teaching evaluations, "The murder mystery proj was even enjoyable."	
K08_qplot_to_ggplot.R	Koans 8-11 shift the focus from dplyr to ggplot2. In this koan, I've given learners some exposure to `qplot` in their homework, and I introduce some ggplot2 syntax by drawing comparisons between qplot and ggplot2.	
K09_ggplot_aes.R	aes(): aesthetic mappings between variables in the data and visual properties in the plot like axis, color, and size.	
K10_ggplot_geom.R	Histograms, density plots, vertical and horizontal lines and annotations, scatterplots, boxplots, and animations!	
	This koan is a refresher and a reminder for	

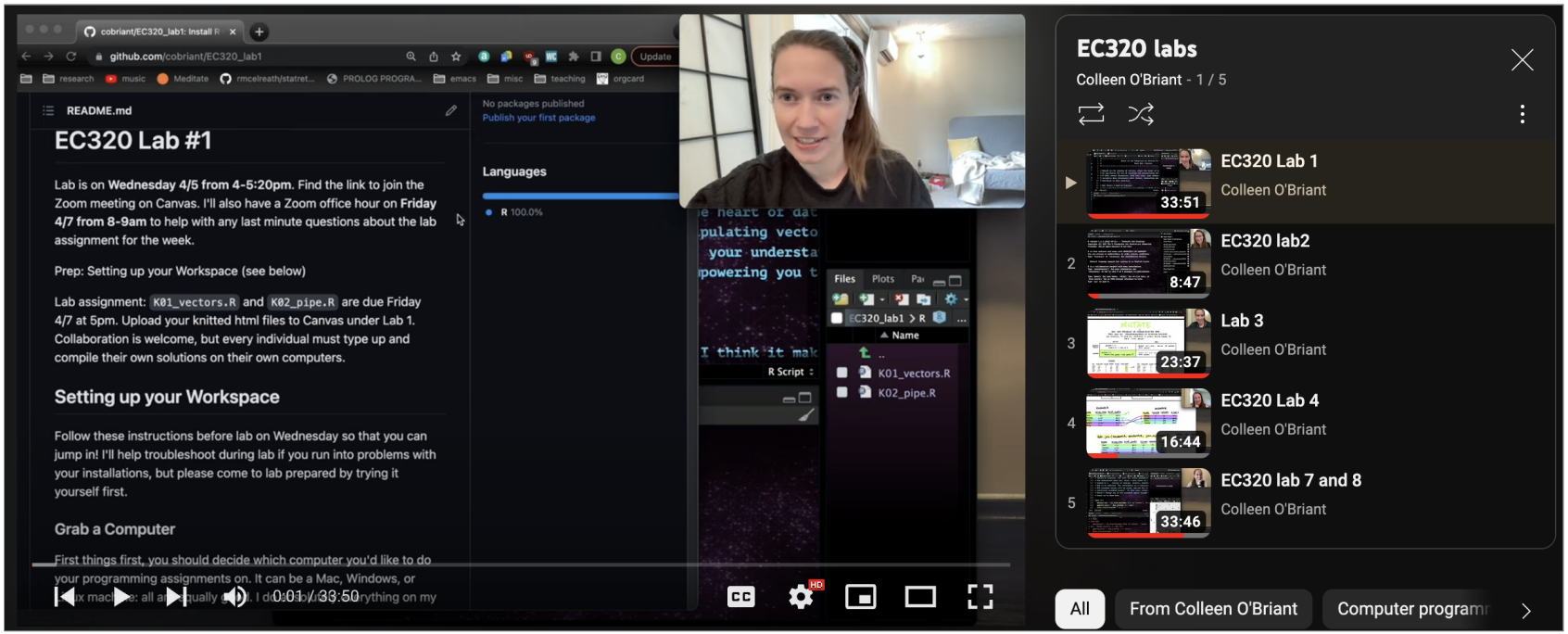
K11_lm.R	learners about running regressions in R, especially using lm() to get an R-squared, the fitted values and residuals, doing log or squared transformations of variables inside the lm() call, interactions, etc.	
K12_stats.R	Exploring the normal distribution, Student's t distribution, and F distribution in R. Randomly generate numbers from each of these distributions. Visualize a hypothesis test from each of these distributions using ggplot.	
K13_functions.R	Learn to write your own functions to make your code more readable and organized.	
K14_functions_dplyr.R	It's fun and valuable to be able to write your own functions on top of tidyverse code that use env-variables just like in dplyr or ggplot2. The error is cryptic (`object not found`), but the solution is simple (`{{ vars }}`). dplyr vignettes call this "indirection".	
K15_map.R	Map: what to do when the functions you want to apply aren't vectorized in the way you want: `map(.x, .f)` applies the function `.f` to each element of `.x` . `map(.x, .f)` is declarative. The imperative analog is a for loop. I don't think it's useful to teach students both map and for loops when they're learning the tidyverse. The first reason is that we want to stay as declarative as possible for consistency. The second reason is that this concept can be difficult, so being	

	given two ways to solve the problem can be really confusing. I'd much rather have learners gain confidence with one way first.	
K16_more_map.R	Use `map(.x, .f)` to do monte carlo simulations with elegance.	
K17_lag.R	By this time in my class, we've transitioned to time series models, where lags are important to be able to compute. A lag is just a previous observation for a variable.	
K18_first_differences.R	Use lags to "first difference" variables in your data and visualize the results in a ggplot with two sets of vertical axis labels.	
K19_reduce.R	Reduce is a powerful functional programming concept. I like to go over the pictures in Adv-R in lecture before learners attempt these last two koans. This concept isn't difficult, but does require a little focused attention.	
K20_accumulate.R	I provide an example of how to use reduce() (and its relative accumulate()) to generate a random walk and then an autocorrelated series.	

Course Evaluations

- *The fastest and best way I've ever learned to code.*
- *I also like the koan exercises very much. They are fun and very useful for learning the R language. Being able to test the answers of the koans before handing in also reduces the stress of the work.*
- *The most impressive aspect of the class was the koans and your approach to coding.*
- *I want more koans!*

New developments: video and zine



LEARNING THE

TIDYVERSE

BY COLLEEN O'BRIANT

FILTER

FILTER OUT ROWS THAT DON'T MEET YOUR CONDITIONS.
FOR EXAMPLE, TO QUERY FOR ONLY THE FEMALE STUDENTS:

	DPLYR	SQL
GENERAL FORMAT	students %>% Filter (condition)	SELECT * ← * = ALL COLUMNS FROM dataset WHERE condition
EXAMPLE	students %>% Filter (sex == "Female")	SELECT * FROM students WHERE sex = "female"

students

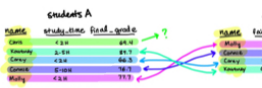
sex	study_time	failures	romantic	grade1	final_grade
female	<2H	0	no	66.3	69.4
female	2-5H	0	yes	94.0	89.7
male	<2H	1	yes	66.1	66.3
female	5-10H	0	no	90.2	76.7
male	<2H	0	no	77.1	77.7

→

sex	study_time	failures	romantic	grade1	final_grade
female	<2H	0	no	66.3	69.4
female	2-5H	0	yes	94.0	89.7
female	5-10H	0	no	90.2	76.7

left_join()

ALSO TAKES AN X AND A Y TIBBLE, BUT IT FILLS OUT THE LEFT HAND TIBBLE WITH THE VARIABLES ON THE RIGHT, MATCHING BY COMMON KEYS (VARIABLES).



students A

name	study_time	final_grade
Chris	<2H	69.4
Kimberly	2-5H	89.7
Carey	<2H	66.3
Connie	5-10H	76.7
Molly	<2H	77.7

students B

name	failures	romantic	grade1
Molly	0	no	77.1
Connie	0	no	90.2
Carey	1	yes	66.1
Kimberly	0	yes	94.0

left_join(studentsA, studentsB, join_by(name))

HERE, THE KEY students A AND students B HAVE IN COMMON IS name.

name	study_time	final_grade	failures	romantic	grade1
Chris	<2H	69.4	NA	NA	NA
Kimberly	2-5H	89.7	0	yes	94.0
Carey	<2H	66.3	1	yes	66.1
Connie	5-10H	76.7	0	no	90.2
Molly	<2H	77.7	0	no	77.1

RECIPE 1: BAR PLOTS

geom_bar()

HOW MANY HOURS DO STUDENTS SPEND STUDYING?
→ DISTRIBUTION OF A SINGLE DISCRETE VARIABLE: USE A BAR PLOT

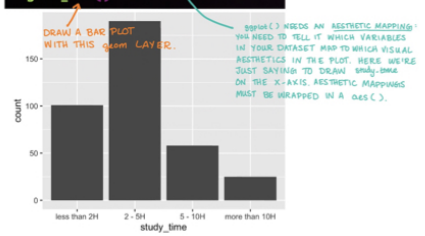
PIPE YOUR TIBBLE INTO THE FUNCTION ggplot()

```
students %>%
  ggplot(aes(x = study_time)) +
  geom_bar()
```

AFTER THE ggplot() CALL, LAYERS ARE ADDED WITH +.

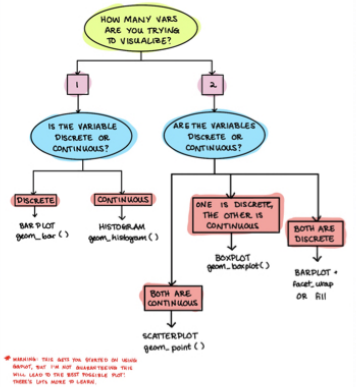
DRAW A BAR PLOT WITH THIS geom LAYER.

ggplot() NEEDS AN AESTHETIC MAPPING: YOU NEED TO TELL IT WHICH VARIABLES IN YOUR DATASET MAP TO WHICH VISUAL AESTHETICS IN THE PLOT. HERE WE'RE JUST SAYING TO DRAW study_time ON THE X-AXIS. AESTHETIC MAPPINGS MUST BE WRAPPED IN A aes().



GGPLOT BASICS: DECIDING BETWEEN:

geom_bar() geom_histogram() geom_point() geom_boxplot()



Final Thoughts

- Keep it as simple as possible (a natural law of the universe is that students will discover fancy stuff when they're ready)
- With koans, test coverage becomes a fundamental first building block
- Don't forget to tell your students they're doing well