# Data-to-graphs and back: Secondary teachers' reasoning about aesthetic mappings in data visualizations

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## Introduction

As ideas from data science become more prevalent in secondary curricula, it is important to understand secondary teachers' reasoning about data attributes and their corresponding visual aesthetics. The purpose of this multiple case study is to begin to explore how these teachers make sense of aesthetic mappings between data and graphs depicting multivariate relationships.

## Study 1: Data to Graphs

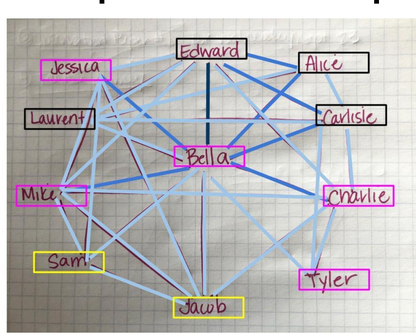
In our first study we asked secondary teachers to create a graph from a series of data tables. Teachers' creations were nearly identical in aesthetic characteristics. Below is an example of one group's creation. The data provided represented information about interactions between characters from the movie *Twilight*.

### Data Provided

| | Frequency of interactions: | | |
|---|---|---|---|
| **Character:** | **A little** | **Some** | **A lot** |
| Alice | Carlisle, Laurent | Bella, Edward | |
| Bella | Jacob, Laurent, Sam, Tyler | Alice, Carlisle, Charlie, Jessica, Mike | Edward |
| Carlisle | Alice, Charlie, Laurent, Tyler | Bella, Edward | |
| Charlie | Carlisle, Edward, Jacob, Mike, Tyler | Bella | |
| Edward | Charlie, Jessica, Laurent, Mike | Alice, Carlisle | Bella |
| Jacob | Bella, Charlie, Jessica, Mike, Sam | | |
| Jessica | Edward, Jacob, Mike, Sam | Bella | |
| Laurent | Alice, Bella, Carlisle, Edward | | |
| Mike | Charlie, Edward, Jacob, Jessica, Sam | Bella | |
| Sam | Bella, Jacob, Jessica, Mike | | |
| Tyler | Bella, Carlisle, Charlie | | |

| Species: | Character: |
|---|---|
| Human | Bella, Charlie, Jessica, Mike, Tyler |
| Vampire | Alice, Carlisle, Edward, Laurent |
| Werewolf | Jacob, Sam |

### Example Teachers' Graph




**Given multivariate data, teachers were able to create effective visualizations.**

**However, given a visualization, they had difficulty producing the multivariate data structure.**

## Conclusions & Future Work

In the first study, teachers were able to easily create visualizations to depict given data and intuitively incorporated many easy-to-interpret aesthetic elements (e.g., color). However, they faced more challenges when asked to create data tables from a given graph. Two moments of impasse led to a variety of decisions and paths of reasoning: (1) whether or not characters should repeat across rows, and (2) how to add character attributes to an adjacency matrix.

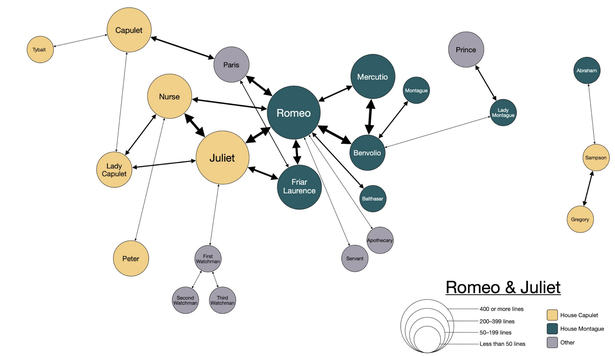
Teachers' decisions led most of our participants away from a case-by-variable form required by many computer programs to create visualizations. This indicated that the teachers' would require more scaffolding to reason about complex data structures related to innovative visualizations.

Given how important computing is for modern statistics courses, additional training and research is required to ensure teachers possess the pedagogical content knowledge to teach data science skills, such as formatting data for computer software.

## Study 2: Graphs to Data

In our second study we asked the same participants to create data tables from a graph. As opposed to the first study, teachers' creations greatly differed in both data structure and their underlying reasoning. The graph depicted interactions between characters from the play *Romeo and Juliet*.

### Graph Provided




### Repeated Attributes Information

| Player | House | Number of Lines | Interaction | Line Thickness |
|---|---|---|---|---|
| Tibault | Capulet | < 50 | Capulet | 1 |
| Mercutio | Montague | 200-399 | Romeo | 2 |
| Mercutio | Montague | 200-399 | Benvolio | 4 |
| Juliet | Capulet | 400+ | Nurse | 4 |
| Juliet | Capulet | 400+ | Friar Laurence | 3 |
| Juliet | Capulet | 400+ | First Watchman | 1 |
| Juliet | Capulet | 400+ | Lady Capulet | 2 |
| Juliet | Capulet | 400+ | Romeo | 4 |
| First Watchman | Other | < 50 | Second Watchman | 1 |
| First Watchman | Other | < 50 | Third Watchman | 1 |
| First Watchman | Other | < 50 | Juliet | 1 |
| Lady Montague | Montague | < 50 | Benvolio | 1 |
| Lady Montague | Montague | < 50 | Prince | 2 |

| Character | Number of Lines | House | Interaction |
|---|---|---|---|
| Romeo | 400 + | Montague | Juliet - a lot |
| Romeo | 400 + | Montague | Paris - a lot |
| Romeo | 400 + | Montague | Servant - very little |
| Juliet | 400 + | Capulet | Nurse - a lot |
| Juliet | 400 + | Capulet | Lady Capulet - some |

Some teachers put each interaction on its own line within a single data table, and repeated character information across rows.

### Visual Aesthetics for a Data Table

| | Fryer Laurence | Nurse | Juliet | Romeo | Paris |
|---|---|---|---|---|---|
| Fryer Laurence | x | 0 | 3 | 4 | 1 |
| Nurse | 0 | x | 4 | 2 | 0 |
| Juliet | 3 | 4 | x | 4 | 0 |
| Romeo | 4 | 2 | 4 | x | 3 |
| Paris | 1 | 0 | 0 | 3 | x |

| | |
|---|---|
| | Interaction Key |
| 4 | A lot of lines together |
| 3 | Many lines together |
| 2 | Some lines together |
| 1 | Very little lines together |
| 0 | Less than 30 lines together |

House
Montegeau
Capulet
Other

Font Size 18
Font Size 14
Font Size 10
Font 8

400+ Lines
200-399 Lines
50-199 Lines
Less Than 50

Some teachers avoided repeating a character across rows by creating an adjacency matrix, and chose to add character attributes to the matrix by giving the table aesthetic characteristics such as size and color.

### Multiple Data Tables

Table 1 Interactions

| | Romeo | Juliet | Mercutio | Capulet | Friar Laurance |
|---|---|---|---|---|---|
| Romeo | 0 | 1 | 1 | 0 | 1 |
| Juliet | 1 | 0 | 0 | 0 | 1 |
| Mercutio | 1 | 0 | 0 | 0 | 0 |
| Capulet | 0 | 0 | 0 | 0 | 0 |
| Friar Laurance | 1 | 1 | 0 | 0 | 0 |

1 = an interaction of at least 30 lines
0 = no interaction

Table 2

| | House | Number of Lines |
|---|---|---|
| Romeo | Montage | 400+ |
| Juliet | Capulet | 400+ |
| Mercutio | Montage | 200-399 |
| Capulet | Capulet | 200-399 |
| Friar Laurance | Montage | 200-399 |

Some teachers appended character attributes as extra columns in their adjacency table, and with gentle prompting separated the information.

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