A Mixed-Method Approach to Investigating Difficulty in Data Science Education

Sydney Shearer[1^*], Ellie Strauss[2^*]; Ethan Hawk[3^], Sasha Lioutikova[4^], Marius Orehovschi[5^], Frankie Vazquez[3^]

[1] Juniata College, [2] Bates College, [3] Valparaiso University, [4] Yale University, [5] Colby College

Overview

The purpose of this study was to define a methodology to identify disconnect between students and instructors in data science classrooms through analyzing qualitative data. A combined qualitative and quantitative approach was used for analysis of survey data from three institutions. As a whole, the methods used throughout this research process provide direction for researchers in interpretation and analysis of the survey data in an efficient and time-sensitive manner. Although the research was applied to data science classrooms, this method has the potential to be applied into other fields and areas of study when performed with coordination between a field expert and a data scientist.

Dataset

Survey conducted in data science classrooms about aspects of class

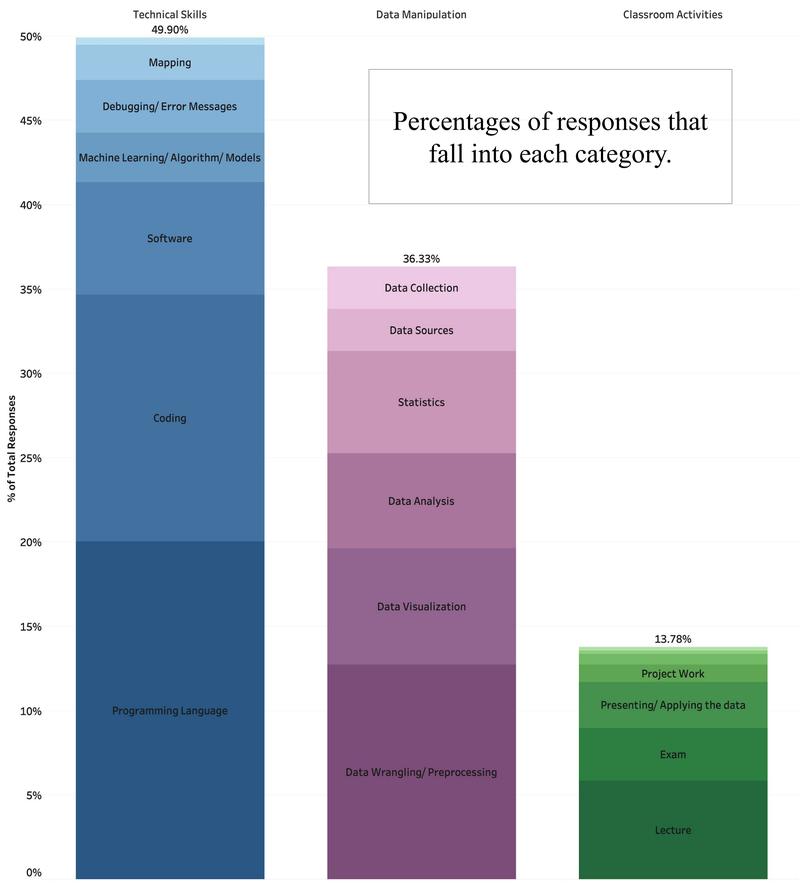
- **Who was surveyed?**
  - Students (304 responses)
  - Faculty/instructors (112)
  - Teaching assistant (63)
- **Where was this conducted?**
  - Brown University
  - Smith College
  - Valparaiso University
- **What was asked?**
  - Six Likert Scale Questions
    - Used for overview of dataset
  - Four Open-Ended Questions
    - What topics were covered in class this week?
    - What concepts/activities/ processes did people struggle most with this week?
    - What questions were raised this week?
    - What questions were surprising this week?

Methods

- **Natural Language Processing**
  - Removed stop words
  - Lemmatization
  - Tokenization
  - Bags of bigrams
- **Quality analysis**
  - Proportion of relevant words in responses
- **Manual Content Analysis**
  - Categories created from inductive reasoning, responses categorized
- **TF-IDF analysis**
  - Frequency of bigrams
  - Manually labeled into categories
- **Corpora**
  - 7 separate corpora used
    - 4 from open-ended questions
    - 3 from respondent roles
  - Responses used as documents
  - Bigrams used as terms

^* denotes equal contribution
^ denotes equal contribution

Category Breakdown



Percentages of responses that fall into each category.

Subcategory Breakdown

Technical Skills		Data Manipulation		Classroom Activities	
Programming Language	96 40.17%	Data Wrangling/ Preprocessing	61 35.06%	Lecture	28 42.42%
Coding	70 29.29%	Data Visualization	33 18.97%	Exam	15 22.73%
Software	32 13.39%	Statistics	29 16.67%	Presenting/ Applying the data	13 19.70%
Debugging/ Error Messages	15 6.28%	Data Analysis	27 15.52%	Project Work	5 7.58%
Machine Learning/ Algorithm/ Models	14 5.86%	Data Sources	12 6.90%	Remote Learning	3 4.55%
Mapping	10 4.18%	Data Collection	12 6.90%	Homework	1 1.52%
Website	2 0.84%			Grading	1 1.52%
GRAND TOTAL:	239 100.0%	GRAND TOTAL:	174 100.0%	GRAND TOTAL:	66 100.0%

Percentages and Counts of responses that fall into each subcategory.

TF-IDF Analysis of Bigrams

- TF-IDF: "Term Frequency, Inverse-Document Frequency"
  - Term Frequency (TF): times a term appears in a document
  - Inverse-Document Frequency (IDF): logarithm of the inverse of the number of documents in which the term appears
  - To calculate, multiply TF by IDF to obtain a weight for each term for each document
- Finds which terms are important within the documents by filtering out words that do not give insight

Grouping	"Technical Skills"	"Data Manipulation"	"Classroom Activities"
"Questions" (n=13)	53.85% (n=7)	30.77% (n=4)	15.38% (n=2)
"Struggles" (n=11)	36.36% (n=4)	54.55% (n=6)	9.09% (n=1)
"Surprise Questions" (n=12)	58.33% (n=7)	16.67% (n=2)	25.00% (n=3)
"Topics" (n=11)	9.09% (n=1)	54.55% (n=6)	36.36% (n=4)
Professor (n=11)	18.18% (n=2)	54.55% (n=6)	27.27% (n=3)
Student (n=14)	14.29% (n=2)	71.43% (n=10)	14.29% (n=2)
Teaching Assistant (n=12)	66.67% (n=8)	16.67% (n=2)	16.67% (n=2)

Top 10 TF-IDF terms for each question/role were manually categorized into subcategories

Quality Analysis

Question	Students	Teaching Assistants	Professors
Questions Asked	35.78%	39.64%	42.77%
Surprise Questions	29.12%	20.73%	35.71%
Topics Covered	50.66%	83.33%	65.39%
Topics Struggled	34.71%	39.26%	39.81%

Percentage of non-stop words by respondent role for each survey question.

Conclusions/Limitations

- Manual content analysis with an automated algorithmic process gives in-depth understanding to datasets
- Data scientists should collaborate with field experts to gain insight of dataset
  - Without collaboration, an in-depth analysis could not be achieved
- Data was collected during COVID-19 pandemic, resulting in a smaller dataset

Acknowledgements

- Valparaiso University
- EPIC
- TRIPODS+X:EDU NSF Grant
  - DMS #1839257, 1839259, 1839270
- Ruth Wertz, Valparaiso University
- Linda Clark, Brown University
- Katherine M. Kinnaird, Smith College
- Karl R. B. Schmitt, Valparaiso University
- Bjorn Sandstede, Brown University

Interested in learning more? Read our paper!