Exploring Interdisciplinary Data Science Education for Undergraduates: Preliminary Results

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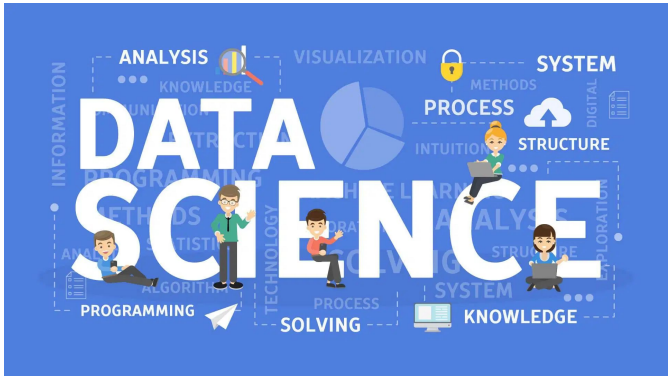
Introduction

- Data Science Community:
  - 624 data science related Higher Education programs as of Aug 2020
  - 69% master-level
  - 10% Bachelor’s
  - 3.7% PhD
- Bachelor’s programs in data science
  - **initial phase**
- This study:
  - probes existing literature and summarize experience
  - **systematic literature review**
  - **semi-structured interviews**



Research Questions

RQ1: How may the existing literature inform the **curriculum design** of emerging **undergraduate data science programs**, especially their practical insights on developing students' **interdisciplinary learning experience**?

RQ2: What are the **challenges and opportunities** in designing and implementing an interdisciplinary data science program for undergraduate students?

Search Strategy

Scopus

ACM DL DIGITAL LIBRARY

- Literature indexed by three databases:
  - **Web of Science (Wos)**, **Scopus**: computing, engineering, education, and social science
  - **ACM Digital Library (ACM DL)**: scientific and educational computing
- Final query on Title, Abstract, Keywords:

  ("data science" OR "big data") AND (education OR teaching OR learning OR curriculum OR curricula) AND (undergraduate OR bachelor)
- No restriction on timeframe; English articles

Study Selection and Citation Search

- Initial database searching: 169 articles
- 19 passed our iterative screening process
- 1 additional paper identified after citation searching

Category	Inclusion/Exclusion Criteria: Title/Abstract → Full-text
Study purpose	Included: Studies that focus on education, including program/course design, curriculum guideline, or pedagogical suggestions, etc.
	Excluded: Studies that discuss programs in fields other than data science.
	Excluded: Studies that use data science methods for analyzing educational data
Target students	Included: The program mentioned should be designed for undergraduate students or be applicable to both undergraduate and graduate students.
	Excluded: Studies discussing programs designed for graduate students.
Article type	Included: Full articles.
	Excluded: Articles with only an abstract or a brief introduction (e.g., posters).

Coding Schema

Category	Codes	Description
Basic information	Year of publication	Year in which the article was published.
	Country (program)	Country where the program was developed.
Program details	Involved department(s)	Department(s) involved in the program.
	Design principles	Principles that guided the program design.
	Learning outcomes	Expected learning outcomes of this program.
	Courses	Courses included in the curriculum.
	Course prerequisites	Prerequisites of courses in the program.
Challenges & opportunities	Challenges	Challenges in program design/development.
	Opportunities	Opportunities in program design/development.

Semi-structured Interviews

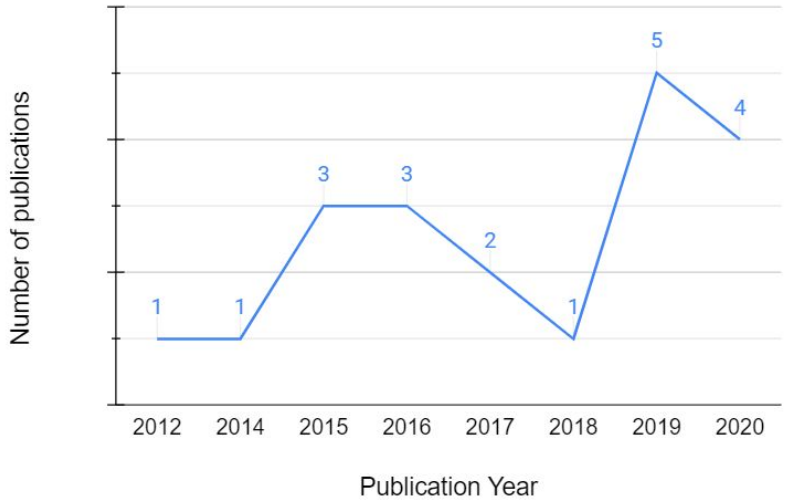
- To elicit **practical insights** and **suggestions** from these authors as **frontier educators** of data science
- Interviews with two authors on Zoom; 20 minutes each

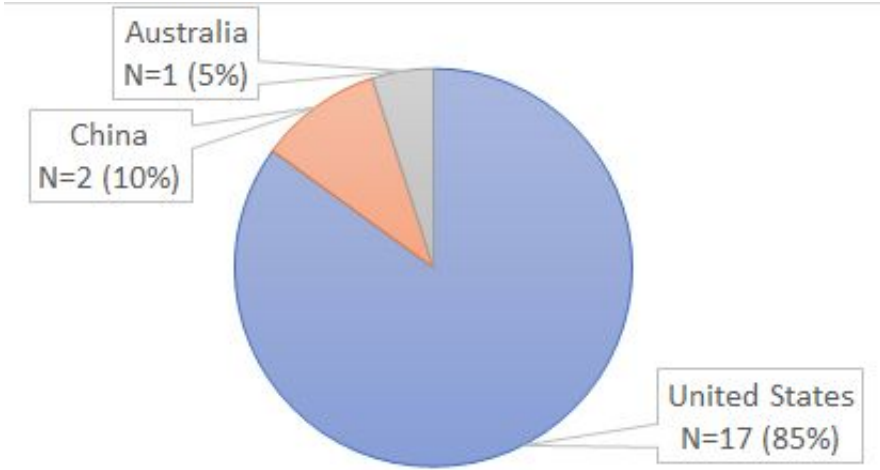
Highlights of interview questions

1. Roles (e.g., director) and courses they teach
2. Opinions on designing an interdisciplinary data science program
3. Challenges and difficulties in curriculum design and program implementation
4. Suggestions for other data science programs

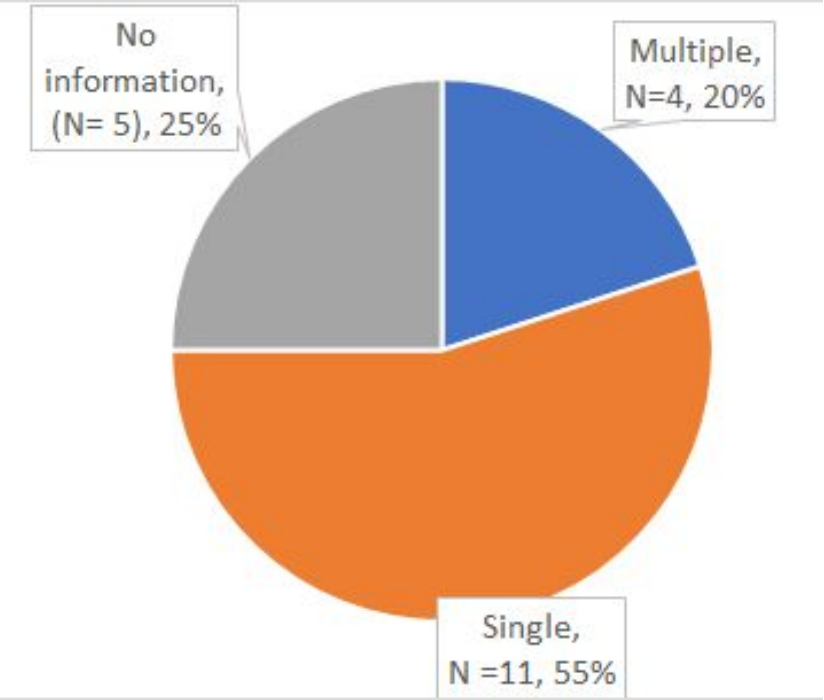
Identified Publications and Programs

- 20 papers, published in 2012 - 2020
- Designed and delivered in United States, China and Australia





Hosting Department: Diverse, Interdisciplinary



Jointly offered by multiple departments:

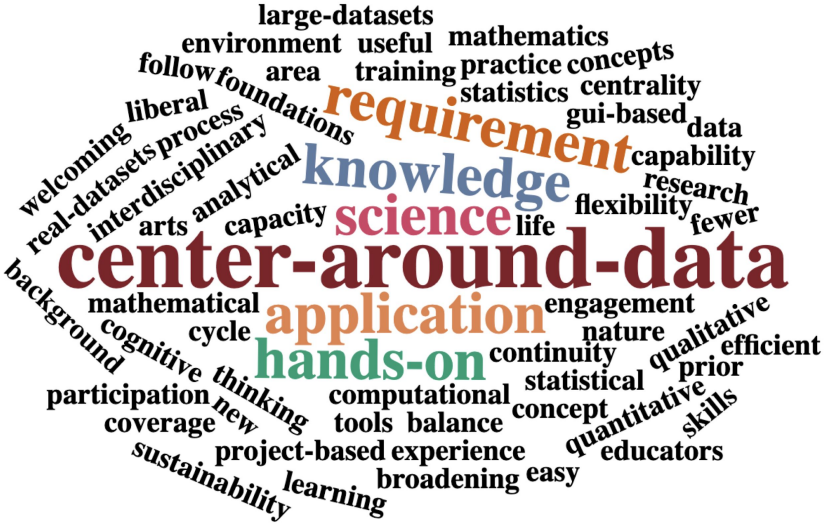
- Mathematics + Computer Science (N=2)
- Business + Science (N=1)
- Committee involving ten disciplines (N=1)

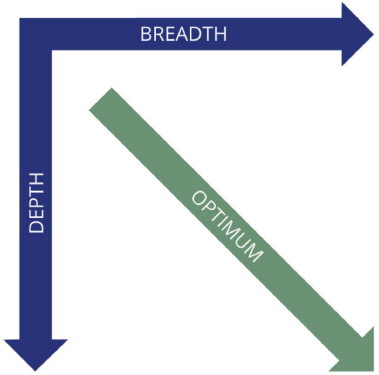
Single departments:

- Computer Science (N=3)
- Mathematics / Statistics (N=3)
- Information Management (N=2)
- Business (N=1)
- Journalism and communication (N=1)
- Liberal Arts (N=1)

Design Principles (N = 16)

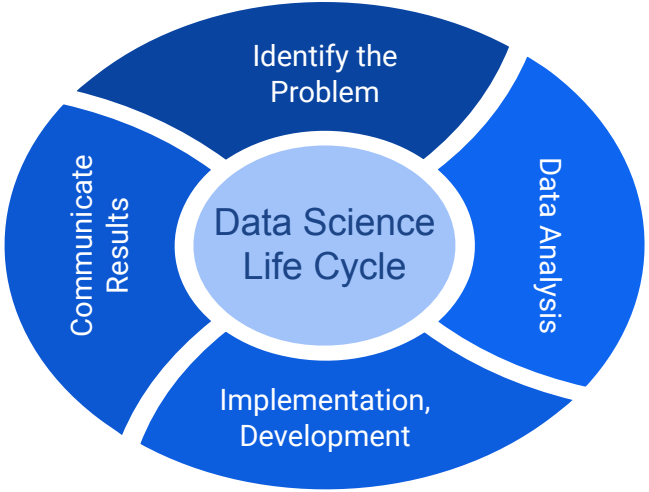
1. **Data at the core** (or “center around data”)
   a. Significance of data (N = 3)
   b. Large, real-world datasets (N = 2)
2. Opportunities for **hands-on practices** with big data (N = 3)
3. **Disciplinary knowledge**;
   a. Mathematical foundation; Statistical, computational thinking
   b. Avoid high-level requirements on mathematics and computer science
   c. Teaching with GUI-based analytic tools
4. **Balanced breadth and depth**





Curriculum Objectives and Learning Outcomes (N = 16)

1. to **acquire** comprehensive knowledge about data science concepts, methods, and tools (e.g., Machine Learning) essential statistical concepts and methods
2. to flexibly **apply** and **transfer** their knowledge and skills for data analysis and problem solving in real-world contexts
3. to **design** and **implement** a standard data processing pipeline in a data-intensive application
4. to effectively **communicate** and **present** the data analysis outcomes using text, table, or other visualization techniques



Courses

- All include courses on **data mining**, **data analytics**, or **big data**

Mathematics Courses	**# Programs**
Statistics	**9**
Calculus	5
Linear algebra	2
Probability theory	2
Discrete structures	1

Computer Science Courses	**# Programs**
Programming / computing	**11**
Machine learning / artificial intelligence	8
Data structures & algorithms	6
Database management system / DB design	4
Information system	3
Introduction to software design	1
Introduction to semantic technology	1
Internet of Things	1

Courses (cont'd)

Data Science Courses	# Prog
Introduction to data science	5
Data analytics / big data / data mining	20
Regression and forecasting models	1
Business intelligence	1
Data visualization	**9**
Data curation	3
Data manipulation	1
Data organization and management	1

Other Courses	# Prog
Ethics and privacy	**4**
Communication	**2**
Asking interesting questions	1
Quantitative decision making	1
Management & organization behaviour	1
Project management	3
Anthropology and sociology, biology, economics, philosophy, physics, political science, psychology	**1**

- Importance of **communication** and **presentation** skills for communicating **reproducible** data analysis
- Misalignment with recent research on **data governance & fair, accountable, and transparent DS**
- Lack of courses in **application areas** (e.g., political science)

Course Prerequisites

- Not assume any prior experience / background knowledge (N = 16)
  - **Novice-friendly** requirement for entering the field
  - **Application-driven** nature
- With courses having computer science / mathematics prerequisites (N = 4):
  - **Programming experience**: Python, Java, C++, or Linux environment
  - Basic knowledge of **mathematics** and **statistics**

Challenges and Opportunities

- Challenges in program design and development (N = 8)
  - Students' difficulty in **fulfilling course prerequisites**
  - **Limited faculty** for course delivery and maintaining engagement
  - Designing **experiential learning activities for intl' students**
  - Covering relevant knowledge within **limited credit hours**
- Problems in **multi-department administration**
  - Hard to control **course set-up** (Interviewee #2)
  - No student **identity** or **community** (Interviewee #1)
- Opportunities (Interviewee #1)
  - Possible **integration** with various other majors (e.g., liberal arts)
  - Focus on **institutional strengths**

Conclusion and Future Work

- Summary
  - Inherently **interdisciplinary** field
  - Joint **collaborations** (e.g., multi-departmental administration)
  - **Hands-on** practices and **experiential learning** opportunities
- Open questions:
  - How to achieve an effective balance between disciplinary **breadth** and **depth**
  - How to **integrate domain knowledge** effectively
- Future Works
  - In-depth analysis of **curriculum**, **syllabus** and **regulations**

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Thank you!

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