# Introductory Data Science: A Blueprint to Navigate Curricular, Pedagogical, and Computational Challenges

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**Abstract**

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# 1 Introduction

The need for training in data science is clear. An estimated 11.5 million new data science jobs are projected to be created by 2026, while employment of data scientists is projected to grow by 36 percent from 2021 to 2031 (U.S. Bureau of Labor Statistics, 2023). In response, college and university faculty are starting to develop and implement data science courses (Schwab-McCoy, Baker, & Gasper, 2020). The purpose of this paper is to continue to promote conversations and provide recommendations around the development and implementation of data science courses through the lens of a modernized introductory data science course taught at Duke University.

This course is designed for students with little to no statistics, data science, or coding experience, a common hurdle identified by faculty when trying to implement a data science course (Schwab-McCoy, Baker, & Gasper, 2020). By the end of this course, students are expected and able to clean, investigate, and communicate with data in a reproducible manner while answering a targeted research question. Detailed learning objectives of this course include learning to explore, visualize, and analyze data in a reproducible and shareable manner through the use of R-studio and GitHub (R-Core Team, 2022; GitHub, 2022). Through these programs, students gain experience in data wrangling and munging, exploratory data analysis, predictive modeling, and data visualization. These experiences are generated through a Prepare, Practice, and Perform learning model immersed in real-world questions and data.

To continue and progress the conversation around data science courses, we first examine current curriculum recommendations for undergraduate programs in data science and review current pedagogical recommendations on how to teach such courses. Next, we discuss

the creation and implementation of curricular and pedagogical decisions made in designing the introductory data science course at Duke University. This includes detailing the Prepare, Practice, and Perform format, to support a large class of students with a diverse background in statistics, data science, and coding experience. Within this format, we provide examples of and describe activities and assessments given both in and outside of class. We extend discussions and provide recommendations for implementing and integrating computing tools, such as R-studio and GitHub, through our experiences in our course. Lastly, we discuss challenges, and provide insight to help faculty wanting to adopt or adapt a course similar to introductory to data science at Duke University.

# 2 Data Science: A Review

Although the definition of data science is fluid, it can be generally defined the process transforming raw data into understanding, insight, and knowledge (Wickham & Grolemund, 2022). In practice, data scientists often describe their work as a means to "gain insights" or "extract meaning" from data (Hernán … , 2019). In the following sections, we describe the current curricular and pedagogical recommendations for designing a course in data science.

## 2.1 Curriculum

Until recently, data modeling made up the majority of data science curricula through classes housed in statistics and mathematics departments (Donoho, 2017). However, there has been a call to create more well-rounded curricula that better unifies methodology in statistics, mathematics, computer science, and machine learning to prepare students to understand, analyze, and communicate with data. In 2017, Curriculum Guidelines for Undergraduate Programs in Data Science provided six major recommendations as to what practitioners of

data science should be competent in: Computational and statistical thinking; Mathematical foundations; Model building and assessment; Algorithms and software foundation; Data curation; Knowledge transference—communication and responsibility (Veaux, et al., 2017). These guiding pillars offer an approach for students to develop into problem solvers who interact with, investigate, and make meaning with data. Other visions of data science include more broad divisions of class activity. This includes *greater data science*. Coined by Chambers and Clevland, the activities of *greater data science* are classified into six divisions: Data Gathering, Preparation, and Exploration; Data Representation and Transformation; Computing with Data; Data Modeling; Data Visualization and Presentation; and Science about Data Science (Donoh, 2017). They suggest that these activities can be used to guide and assess if data science programs are adequately addressing the entirety of the field.

Additionally, a task force, titled the Association for Computing Machinery (ACM) Education Council, explores and expands discipline-specific conversations around the field of data science (Danyluk & Leidig, 2021). This council acknowledges that data science curricula can be flexible, but suggests that data science curricula should include applications designed towards building skills in computing, statistics, machine learning and mathematics.

Among existing curricular recommendations, there are computational and technological recommendations for data science classrooms. This includes the use of GitHub to ensure the concept of reproducibility and incorporating quantitative programming environments (such as R), to better work with data (Donoho, 2017; Beckman et al., 2021). Among all recommendations, it is suggested to immerse students in real-world data and provide open-ended projects. This allows students "early exposure to and experience with the full data science cycle", in a practical real-world context (Lui & Huang, 2017; CETINKAYA-RUNDEL, et al., 2022, pg. 3).

## 2.2 Pedagogical

Although not specific to data science, national guidelines have recommended the use of more student-centered teaching techniques, such as active learning, in statistics and mathematics classrooms, to better engage students in the learning process (Carver et al., 2016; Conference Board of Mathematical Sciences, 2016). The Guidelines for Assessment and Instruction in Statistics Education College Report further stresses the importance of active learning in the mathematical sciences, encouraging instructors to use active learning to foster and enhance students' understanding and communication of topics taught (Carver et al., 2016). In general, research has shown that the adoption, integration, and implementation of active learning teaching techniques can help promote student learning, achievement, and confidence in science courses (e.g., Freeman et al., 2014). Teaching data science courses through the use of active learning can help better facilitate a more complete understanding of working with data.

As the volume of data continues to grow, the need for those who can make meaning of data are clear. Thus, it is critical that data science education provides programs that adequately prepare and train students in the field of data science. This article adds to the existing literature by describing a modernized introductory data science course and how its taught, at Duke University.

# References