NATIONAL ACADEMIES Sciences Engineering Medicine

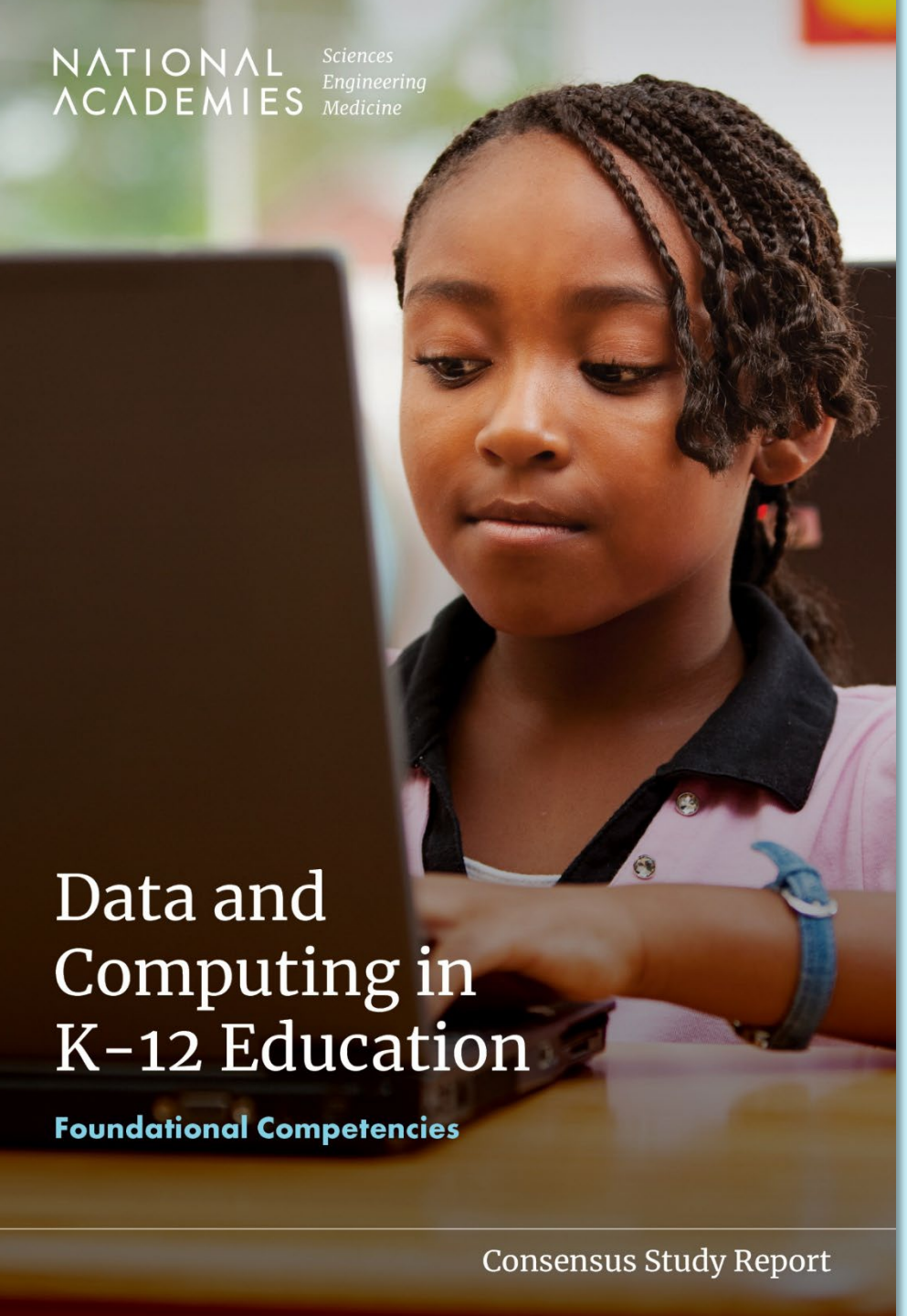
Data and Computing in K–12 Education

Foundational Competencies

Presenter:

Lindsey Henderson

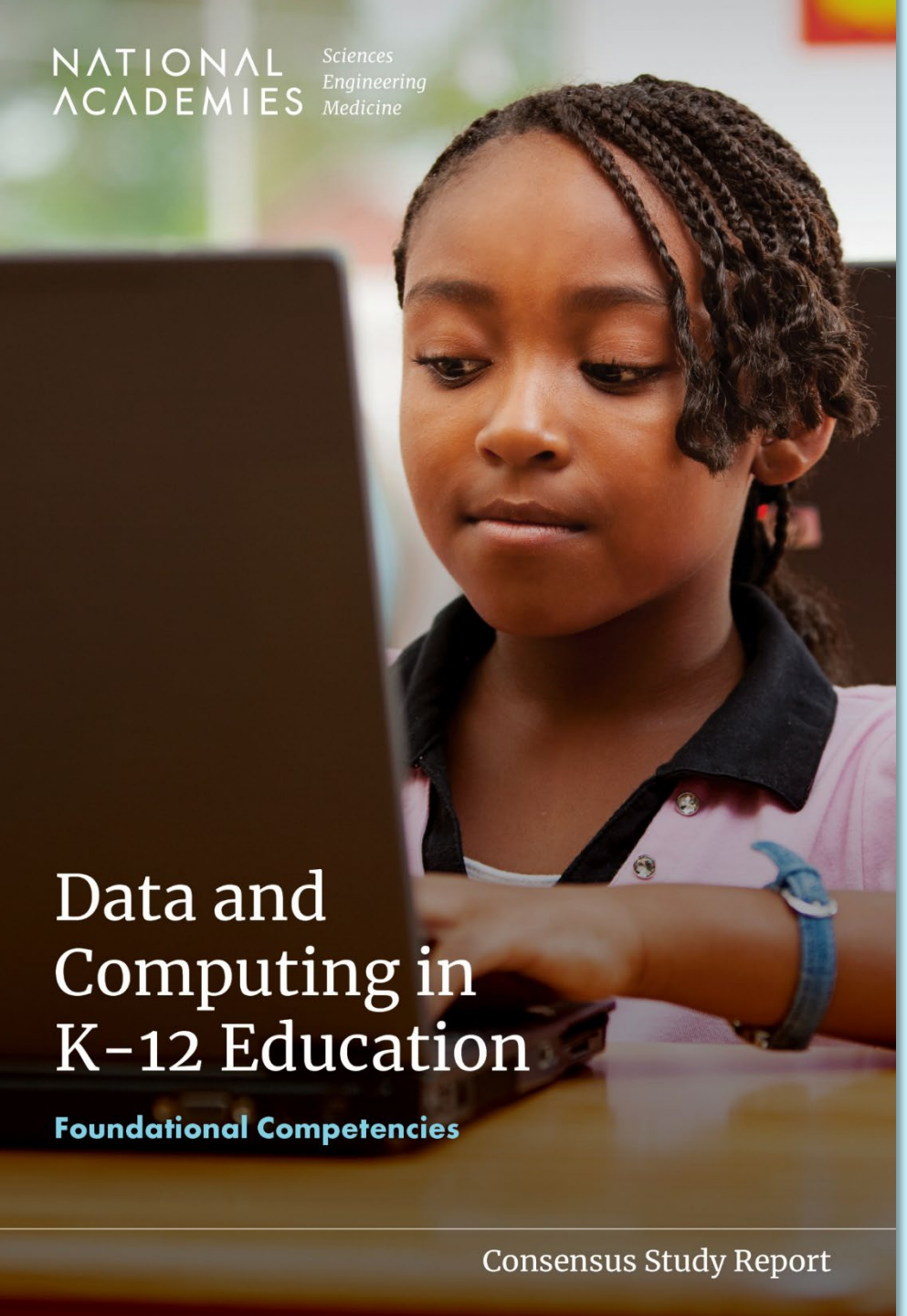
Download the report
nationalacademies.org/data-computing-ed



About this report

Conduct a consensus study that will **identify the competencies needed for students to navigate and succeed in the changing computational landscape and describe the role that K–12 education can play** in the development of these competencies.

- What competencies and awareness are needed for learners to **develop basic literacy in data and computing**?
- How are the foundational competencies for these fields related to foundational competencies in other STEM fields?
- What should **relevant learning experiences** look like in practice and how might these experiences be tailored to meet students' interests and lived experiences?
- What are the implications for K–12 curricula?



Key takeaways

Recent calls for adding computer science, data science, artificial intelligence, and quantum information science to K-12 education **could overwhelm the system if not done carefully.**

Common competencies undergird all these fields and to some extent are already in the K-12 curriculum.

The report identifies multiple ways to engage students, starting in kindergarten, including:

> **integrating data and computing into science and math classes**, explicitly calling attention to data and computing in those classes by **elevating learning goals related to data and computing**, and providing opportunities **for stand-alone courses where appropriate.**

Study committee

STUDY CHAIR

Nicholas J. Horton
Amherst College

Anna E. Bargagliotti
Loyola Marymount University

Shaundra B. Daily
Duke University

Laura G. DeMarco
Harvard University

Emily E. Edwards
Duke University

Susan Gomez-Zwiep
BSCS Science Learning

Shuchi Grover
Looking Glass Ventures

Lindsey Henderson
ExcelinEd

Victor R. Lee
Stanford University

Janice K. Mak
Arizona State University

Joshua M. Rosenberg
University of Tennessee, Knoxville

Andee Rubin
TERC

Nancy B. Songer
University Of Utah

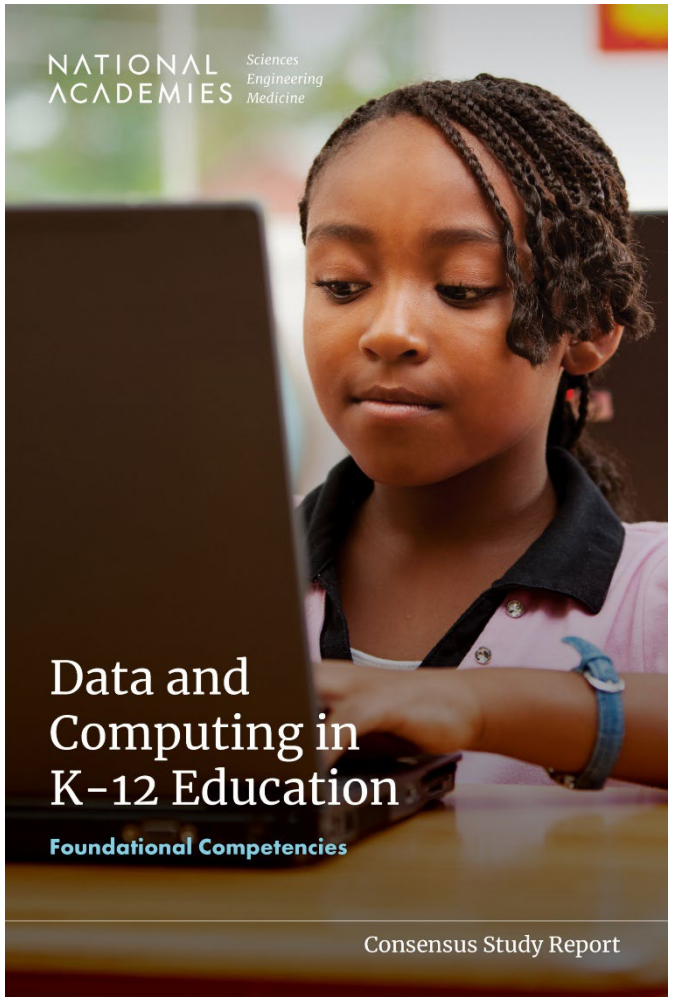
John A. Underwood
Louisiana Department of Education

Sepehr Vakil
Northwestern University

Aman Yadav
Michigan State University

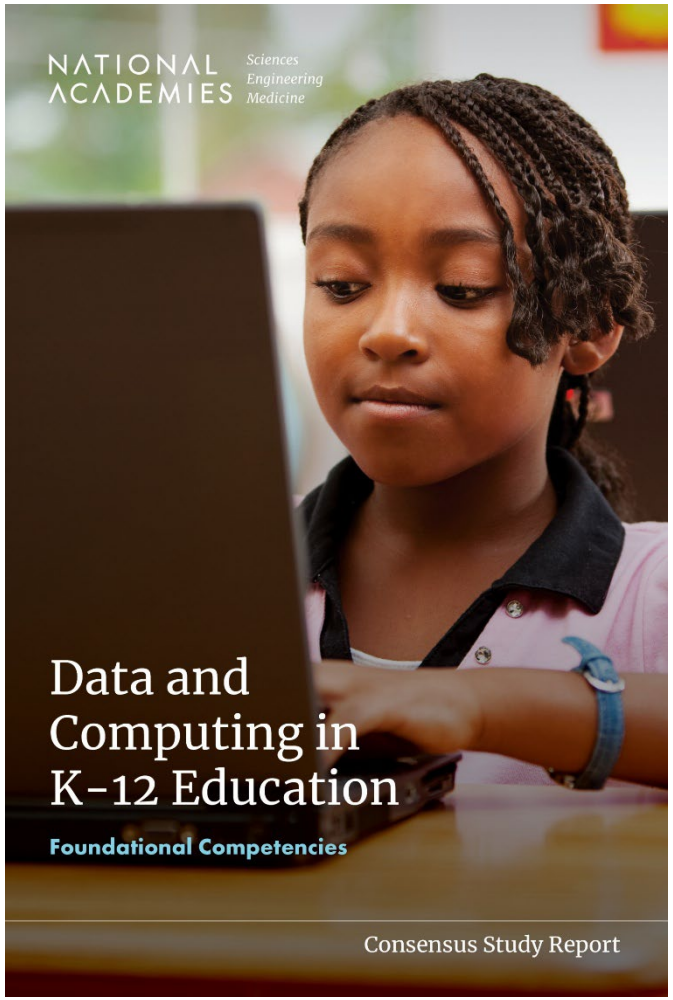
Report Contents

Chapter 2:	Current Context (Organizations and Initiatives)
Chapter 3:	Foundational Competencies
Chapter 4:	Elevating the Foundational Competencies within STEM-related Subjects
Chapter 5:	Effective Learning Experiences
Chapter 6:	Design of Curriculum
Chapter 7:	Preparing and Supporting Teachers of Data and Computing
Chapter 8:	Transforming the K-12 System
Chapter 9:	Recommendations and Research Agenda



Report Contents

Chapter 2:	Current Context (Organizations and Initiatives)
Chapter 3:	Foundational Competencies
Chapter 4:	Elevating the Foundational Competencies within STEM-related Subjects
Chapter 5:	Effective Learning Experiences
Chapter 6:	Design of Curriculum
Chapter 7:	Preparing and Supporting Teachers of Data and Computing
Chapter 8:	Transforming the K-12 System
Chapter 9:	Recommendations and Research Agenda



Foundational Competencies (Chapter 3)

Conclusion 3-3: The foundational competencies identified in this report build upon basic skills **already central to existing school curricula.** To fully engage with the competencies, not only do students need a solid foundation in **mathematics** (e.g., number sense, operations, algebraic thinking, functions, and mathematical modeling) and **science** (concepts, practices, and core ideas), but also other existing school subjects.

Foundational Competency	Description
Problem Posing and Problem-Solving Processes	Students define a problem or question, identify the steps necessary to address it, make an attempt to answer it using tools, reflect on the process, decide on next steps, and iterate.
Producing and Working with Data	Students can both produce data and assess data quality, organize and prepare data for a variety of purposes, and explore and visualize data to begin to answer a question or problem.
Abstraction, Algorithmic Thinking, and Automation	Students deepen their skills with abstraction and logical reasoning to design and express solutions to problems in a systematic, step-by-step way, and to explore concepts and methods of automating data and computing processes.
Probabilistic and Inferential Reasoning	Students identify sources of variability and uncertainty, develop probabilistic understanding, carry out statistical investigations and inference using formal testing procedures, and interpret and generalize results as appropriate.
Models and Representations	Students construct and reason with models and representations to explore phenomena and solve problems. They choose appropriate models for the situation and data available, assess the limitations of models and representations, and recognize the uncertainty inherent in any modeling activity.
Technology and Society	Students recognize, anticipate, and address tensions related to technology and society, values, ethics, and responsibilities.
Data and Computing Systems	Students develop deeper awareness of data and computing tools and systems that provide a foundation to solve more complex problems and address future changes.

Connecting competencies to math curricula

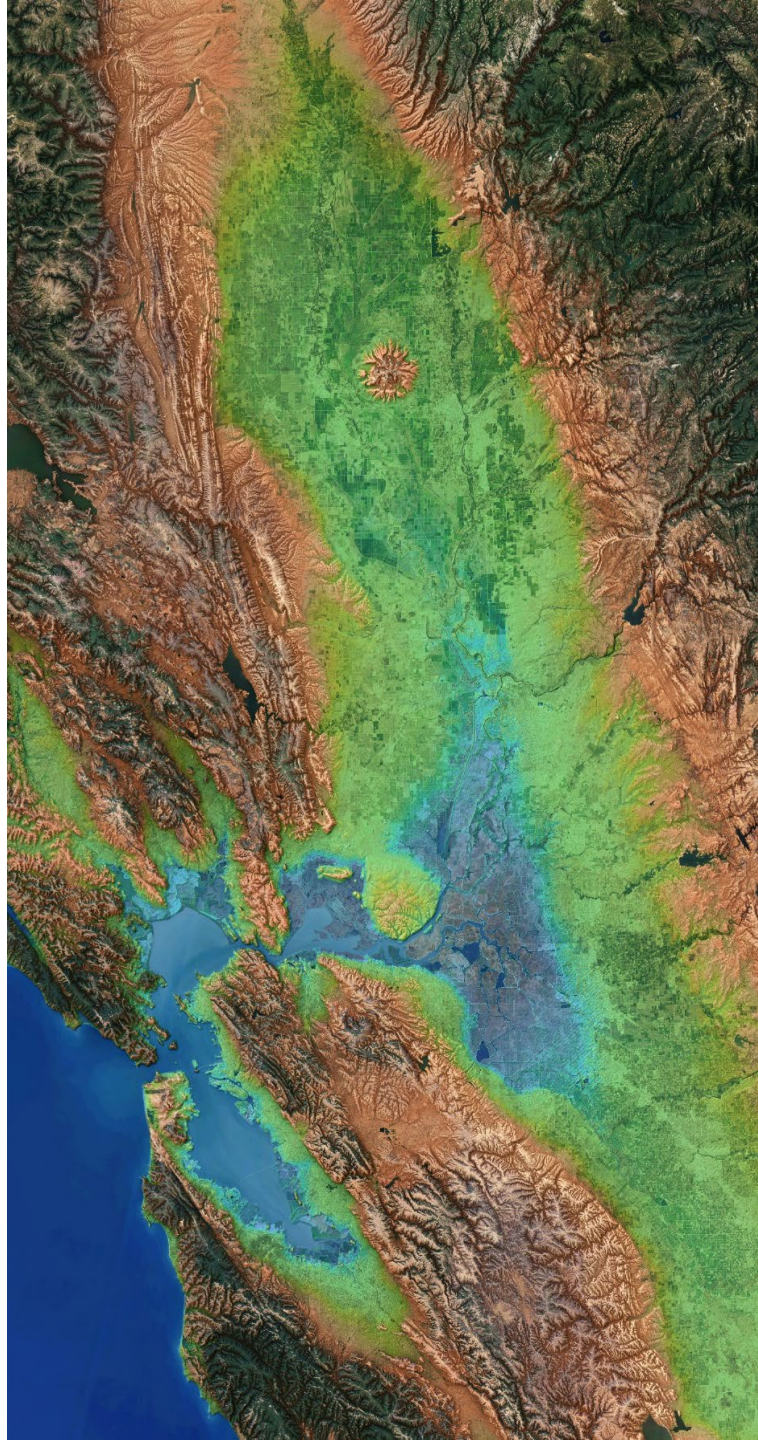
Conclusion 4-2: Mathematics curricula frequently include some teaching of statistics and sometimes a small amount of attention to aspects of computing. Areas of the existing curriculum such **as measurement, algebraic and algorithmic thinking, probability, and modeling** could be enhanced by more focused and more explicit attention to how they connect to data and computing. For some students, **lessons in statistics and work with data can help motivate and ground mathematics education** and help students see how it is relevant to their lives. **Computing tools and technology can effectively support mathematics instruction** in addition to being a topic of instruction for students.

NCTM Process Standards[a]	GAIMME Components[b]	CCSSM Standards for Mathematical Practice[c]	GAISE II Statistical Problem-Solving Process Components[d]
Competency 1: Problem Posing and Problem-Solving Processes			
•Problem solving	•Identify the problem •Make assumptions	•Make sense of problems and persevere in solving them	•Formulate statistical investigative questions
Competency 2: Producing and Working with Data			
•Representation •Connections	•Identifying variables •Do the math	•Reason abstractly and quantitatively	•Collect/Consider the Data •Analyze the data
Competency 3: Abstraction, Algorithmic Thinking, and Automation			
•Reasoning and proof •Representation	•Iterate	•Reason abstractly and quantitatively	•Collect/Consider the Data
Competency 4: Probabilistic and Inferential Reasoning			
•Reasoning and Proof	•Analyze and assess the solution	•Reason abstractly and quantitatively •Construct viable arguments and critique the reasoning of others.	•Interpret the Results
Competency 5: Models and Representations			
•Representation	•Do the math •Implement the model and report results	•Model with mathematics	•Analyze the data
Competency 6: Technology and Society			
•Connections	---	---	•Collect/Consider the data
Competency 7: Data and Computing Systems			
---	---	•Use appropriate tools strategically	---

The Competencies Connect to Science Curricula

Conclusion 4-3: The foundational competencies are related to many concepts that are covered in science curricula, including **scale, proportion and quantity, systems and system models, asking and answering questions, developing and using models, analyzing and interpreting data, and using computational thinking.** Explicitly bringing the foundational competencies into science courses **would help students see connections between the science concepts and topics in data and computing.**

Disciplinary Core Ideas	Scientific and Engineering Practices
Competency 1: Problem Posing and Problem-Solving Processes	
• Engineering design—defining and delimiting an engineering problem • Engineering design—developing possible solutions • Engineering design—optimizing the design solutions	• Science—asking questions • Engineering—defining problems
Competency 2: Producing and Working with Data	
---	• Analyzing and interpreting data
Competency 3: Abstraction, Algorithmic Thinking, and Automation	
---	• Using mathematics and computational thinking
Competency 4: Probabilistic and Inferential Reasoning	



Foundational Competency	Description
Problem Posing and Problem-Solving Processes	Students define a problem or question, identify the steps necessary to address it, make an attempt to answer it using tools, reflect on the process, decide on next steps, and iterate.
Producing and Working with Data	Students can both produce data and assess data quality, organize and prepare data for a variety of purposes, and explore and visualize data to begin to answer a question or problem.
Abstraction, Algorithmic Thinking, and Automation	Students deepen their skills with abstraction and logical reasoning to design and express solutions to problems in a systematic, step-by-step way, and to explore concepts and methods of automating data and computing processes.
Probabilistic and Inferential Reasoning	Students identify sources of variability and uncertainty, develop probabilistic understanding, carry out statistical investigations and inference using formal testing procedures, and interpret and generalize results as appropriate.
Models and Representations	Students construct and reason with models and representations to explore phenomena and solve problems. They choose appropriate models for the situation and data available, assess the limitations of models and representations, and recognize the uncertainty inherent in any modeling activity.
Technology and Society	Students recognize, anticipate, and address tensions related to technology and society, values, ethics, and responsibilities.
Data and Computing Systems	Students develop deeper awareness of data and computing tools and systems that provide a foundation to solve more complex problems and address future changes.