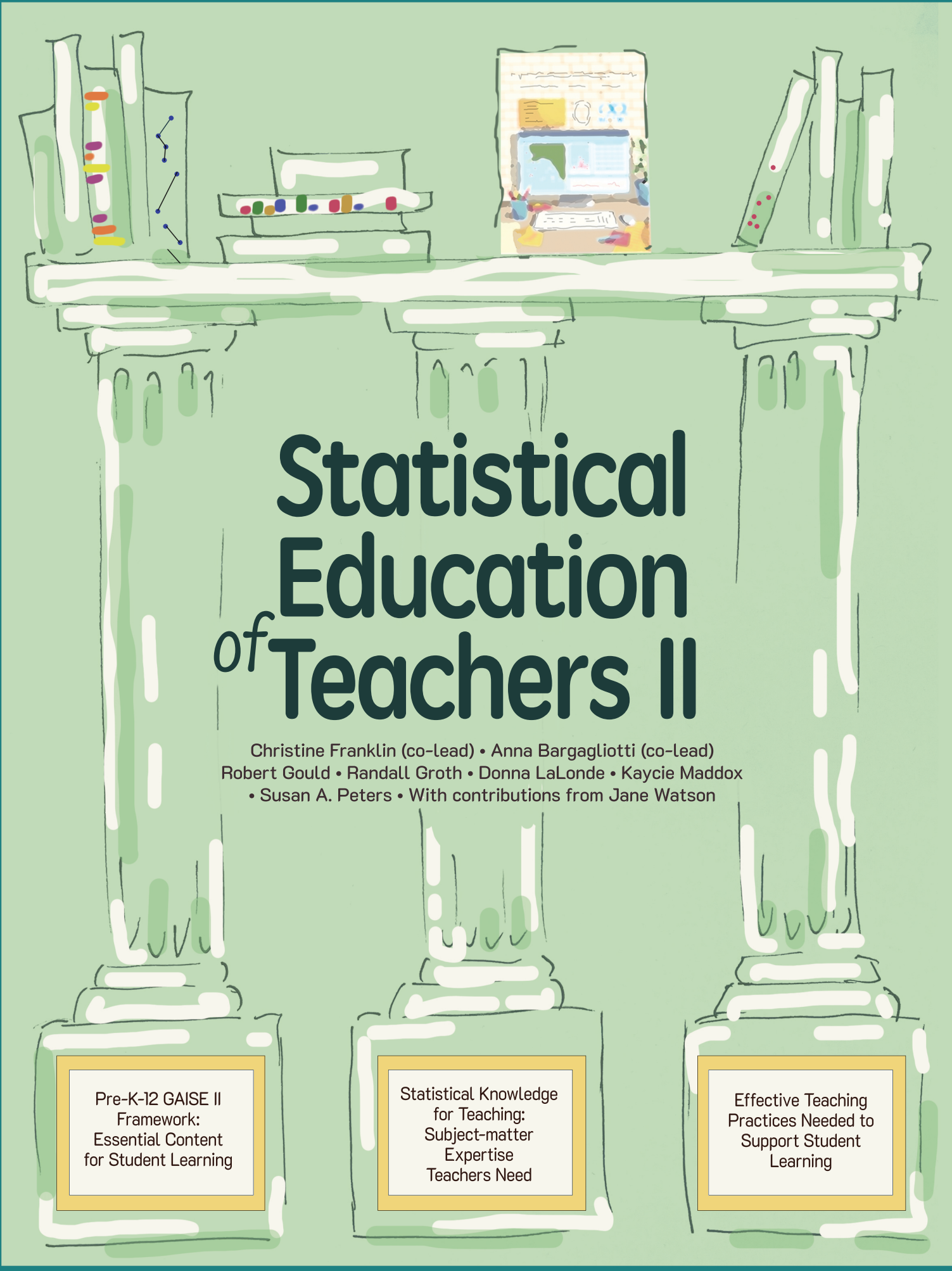




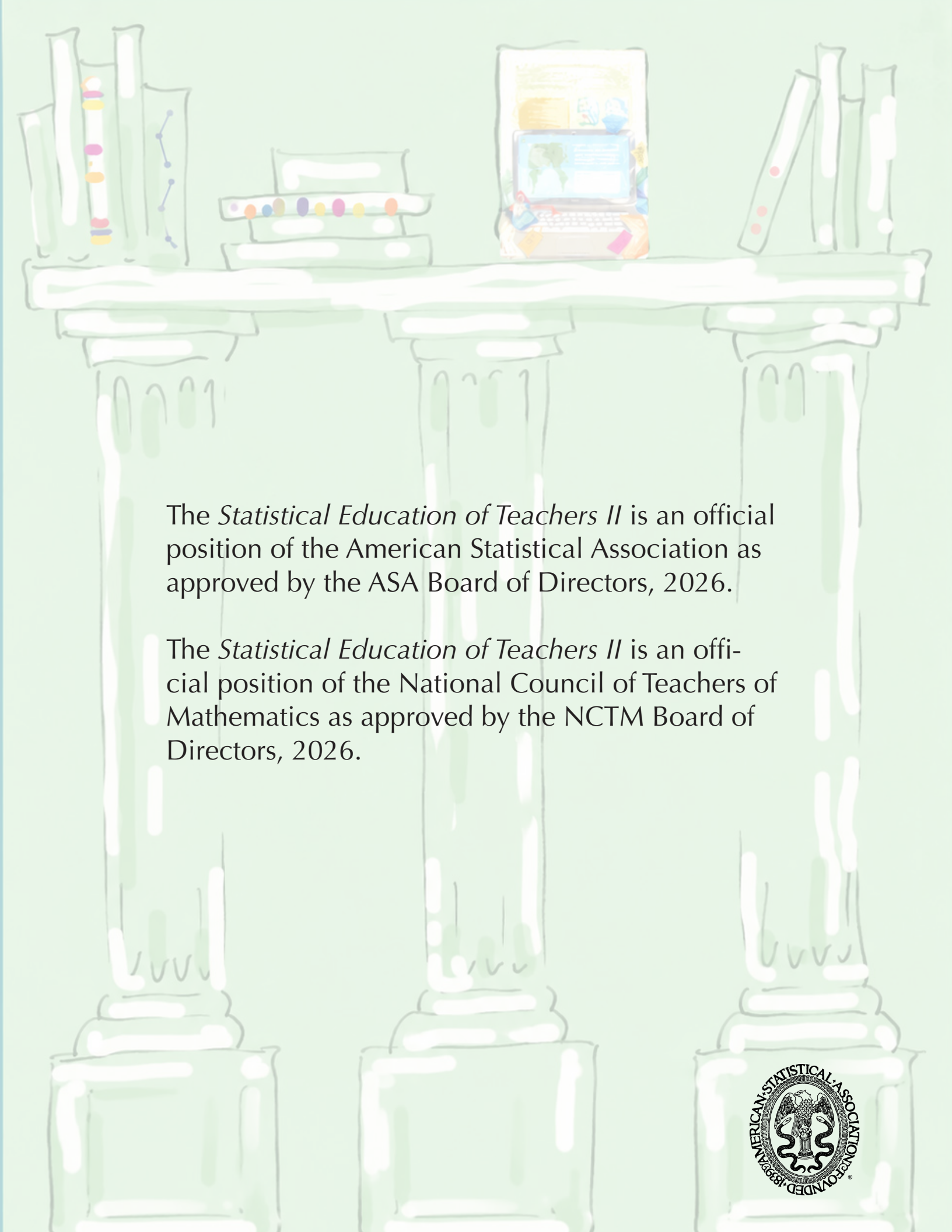
Statistical Education *of* Teachers II

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Pre-K-12 GAISE II
Framework:
Essential Content
for Student Learning

Statistical Knowledge
for Teaching:
Subject-matter
Expertise
Teachers Need

Effective Teaching
Practices Needed to
Support Student
Learning

The background of the page features a light green illustration. At the top, a white shelf holds several books with colorful spines, a laptop displaying a world map, and a tablet with a colorful interface. Below the shelf are three white columns. The text is centered on the page, between the shelf and the columns.

The *Statistical Education of Teachers II* is an official position of the American Statistical Association as approved by the ASA Board of Directors, 2026.

The *Statistical Education of Teachers II* is an official position of the National Council of Teachers of Mathematics as approved by the NCTM Board of Directors, 2026.

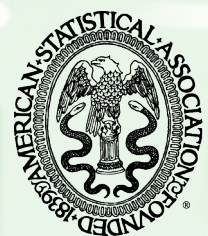


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Executive Summary

The *Statistical (and Data) Education of Teachers (SET II)* Report

With the explosion of data in all facets of society, this is an exciting time for teaching and learning how to explore, investigate, and draw conclusions from data.

The *Statistical Education of Teachers II* report supports the development of pre-K–12 teachers’ content and pedagogical knowledge in statistics and data education. In this report, *statistics* refers to “the science of collecting, analyzing, and interpreting data to answer investigative questions,” and *data education* includes “teaching and learning using any aspect of data within any subject.”

SET II establishes a comprehensive framework for teachers’ statistical and data education by the following:

- Identifying seven foundational concepts that span grade levels and subjects
- Defining clear learning outcomes for teachers at all stages

- Offering targeted recommendations for both prospective and practicing teachers
- Showcasing examples that exemplify high-level teacher preparation

We posit that effective teacher preparation in statistics and data education rests on the interplay of the following three foundational pillars:

1. Essential content for student learning
2. The subject-matter expertise teachers need
3. Effective teaching practices needed to support student learning.

These pillars work together to support the development of teachers’ knowledge of

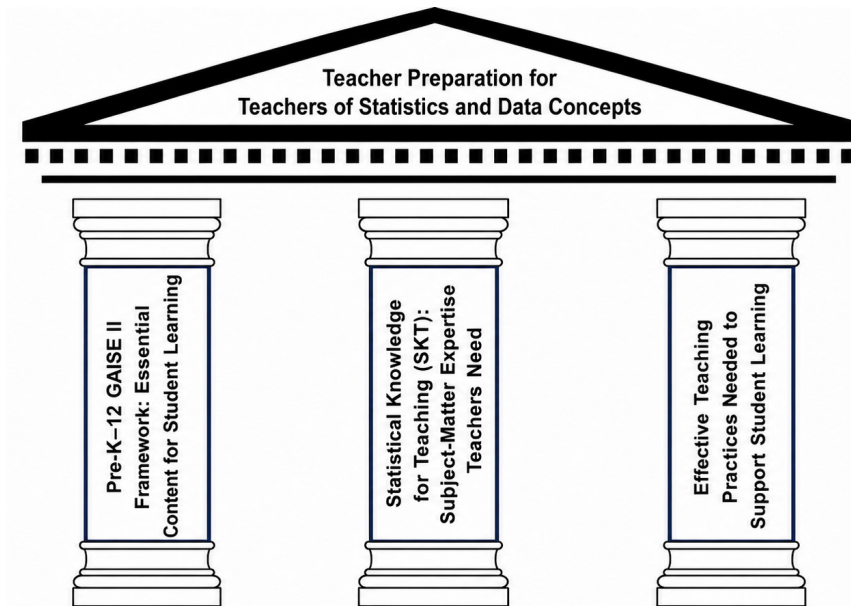


Figure 1.1. Foundational pillars of teacher preparation in statistics and data concepts. Reprinted with permission from *Principles to Actions* copyright 2014, by the National Council of Teachers of Mathematics. All rights reserved.

statistics and data for teaching. They are grounded in research in statistics education that articulates Statistical Knowledge for Teaching, which breaks down the subject-matter and pedagogical knowledge teachers need (Groth, 2007, 2013). **Figure 1** provides a diagram of this conceptualization.

Motivation for the SET II Report

Primary- and secondary-level students must develop a foundational understanding of data, including how to work with it, analyze it, and use it to make decisions. With the explosion of data in

all facets of society, this is an exciting time for teaching and learning how to explore, investigate, and draw conclusions from data. Teachers and students who share enthusiasm for data-based decision-making can help other students develop the statistical thinking and methods they need to learn from data in a world of uncertainty. All students should develop grade-level-appropriate understandings of working with data, so they can engage with the modern world and their communities. Currently, mathematics curricula carry the primary responsibility for developing this in-depth understanding, while standards in other disciplines, notably

science and social studies, rely on statistical reasoning to deepen students' understanding of topics (e.g., see *Next Generation Science Standards*, NGSS Lead States, 2013; *The College, Career, and Civic Life (C3) Framework for Social Studies State Standards*, National Council for the Social Studies, 2013). This is one reason policymakers have pushed to include more data education across subjects and grade levels in schools.

Several guiding frameworks and important ideas exist to help students learn statistics and how to work with data (e.g., National Academies of Science, Engineering, and Medicine, 2023, 2026; Wild & Pfannkuch, 1999). These are well articulated in the American Statistical Association's *Pre-K–12 Guidelines for Assessment and Instruction in Statistics Education II: A Framework for Statistics and Data Science Education* (Bargagliotti et al., 2020).

An integral part of preparing students to meet the *Pre-K–12 GAISE II* objectives is ensuring teachers are ready to help them make sense of data. Although teacher preparation is critically important, it is also extremely challenging. Teachers learn in both prospective and practicing teacher education programs and through job-embedded professional learning. Not only do the needs of these groups vary, but there is also considerable variation within each group in the

This document
supports developing
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and data education.

opportunities and modalities offered for teacher training. Primary teachers are certified as generalists, while secondary teachers are often certified as specialists. This makes it harder to specify the knowledge teachers need to teach statistics and data effectively. In addition, because the teaching profession often experiences shortages, new modes of teacher preparation are constantly being developed and implemented (see, for example, Arizona Department of Education, 2026; Louisiana Department of Education, n.d.).

Despite the variability and challenges of teacher training, teacher-learning theories and research-informed teaching practices for statistics and data education of teachers exist and

help anchor this report—specifically this report uses Statistical Knowledge for Teachers, the National Council of Teachers of Mathematics’ (2014) *Principles to Actions*, and the *Pre-K–12 GAISE II* framework.

This document supports developing teacher knowledge by articulating learning objectives for teachers to deepen their understanding of statistics and data education.

In today’s world, data play a role in all content areas (e.g., mathematics, science, social studies, and the arts), and teachers of all subjects share responsibility for teaching students how to work with data. In turn, teacher educators must ensure that teachers across disciplines are adequately prepared to help students use data to conduct analyses, ask and answer questions, and make decisions appropriate to their fields. This comprehensive report addresses the preparation of teachers in any subject that uses data within a lesson, unit, section, or full course. Because states’ mathematics standards are often the primary home of statistics and data standards, teachers of mathematics and statistics need more in-depth preparation than teachers in other content areas. However, we also encourage teacher educators to help teachers identify opportunities to use data to draw connections across the curriculum. Particularly in the primary grades, teacher preparation spans multiple subjects, which gives

teachers greater flexibility to incorporate data throughout the curriculum.

SET II Outline

The chapters of the *SET II* report articulate several dimensions of teacher preparation, as conceptualized in Figure 1. In particular, *SET II* provides the following:

A. A set of seven cross-cutting big ideas—relevant for working with data in all grade bands—that relate to specific takeaways teachers need (see Chapter 2). The big ideas are:

1. Teachers need to engage with the Statistical Problem-Solving Process and be well-versed in guiding students to work within this process.
2. Teachers need to understand the role of questioning within the SPSP and be able to guide their own students’ questioning.
3. Teachers need to understand the difference between probabilistic and deterministic thinking, their roles within statistics, and working with data and their applications.
4. Teachers need to engage with modeling in all facets of working with data.
5. Teachers need to use technology as a tool for learning, visualizing, and doing statistics, using developmentally appropriate pedagogy and transitioning from hands-on work to computer-driven work to

Student Learning Objectives	Teacher Learning Objectives: What Teachers Need to Know and Be Able To Do
	Formulate statistical investigative questions
	Collect/Consider data
	Analyze data
	Interpret the results

Figure 2. Structure of *SET II* Framework for Teacher Learning Outcomes in Statistics and Data

- ensure that technology is not used as a replacement for conceptual understanding.
- Teachers need to develop statistical habits of mind for themselves and promote the development of these habits in their students.
 - Teachers need to adhere to humanistic practices in the teaching and learning of data and statistics.

B. A framework outlining the knowledge and fundamental learning objectives teachers need to teach in accord with the *Pre-K–12 GAISE II* framework and other important frameworks used in school-level data education (see Chapter 3). This report takes the *Pre-K–12 GAISE II* framework (Bargagliotti et al., 2020, pp. 16–19), adds additional student-level objectives, and builds a parallel teacher-knowledge framework that illustrates the knowledge teachers need to teach students at each level within each *GAISE II* component. **Figure 2** shows the framework organization.

This framework of learning objectives is comprehensive and is intended to identify objectives that teachers can develop and strengthen throughout their careers. As data continue to evolve through modern advances, preparing teachers to be well versed in this subject area should be viewed as an ongoing process. Teacher preparation programs may not be able to address every aspect of teacher learning in this area; therefore, professional development and on-the-job professional learning should be viewed as essential to continued growth in working with data. The framework is outlined in three parts, corresponding to the different *GAISE* levels:

- Framework for Teacher Learning Outcomes in Statistics and Data—
Level A:** Outcomes for primary teachers’ statistical and data knowledge
- Framework for Teacher Learning Outcomes in Statistics and Data—**

SET II Recommendations	
Initial Preparation of Elementary Teachers	
1.	A substantial statistics and data unit within a stand-alone content course for developing teachers' knowledge of the seven cross-cutting big ideas detailed in Chapter 2, all outcomes for Level A, and familiarity with the content associated with the outcomes for Level B that are detailed in the frameworks from Chapter 3.
2.	A substantial statistics and data unit within a methods course for elementary teachers that develops teachers' knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and the outcomes for Level A and aspects of Level B detailed in the framework from Chapter 3.
Initial Preparation of Middle School Teachers	
1.	A stand-alone course that develops teachers' knowledge of the seven cross-cutting big ideas detailed in Chapter 2, all outcomes for Level B, and familiarity with the content associated with the outcomes for Level A and Level C detailed in the frameworks from Chapter 3.
2.	An introductory statistics content course that emphasizes a modern data analytic approach to statistics and working with data.
3.	A substantial statistics and data unit within a methods course for middle school teachers that develops teachers' knowledge to teach the seven cross-cutting big ideas detailed in Chapter 2 and the outcomes for Level B and aspects of Level A and Level C detailed in the framework from Chapter 3.
Initial Preparation of High School Teachers	
1.	A stand-alone course for developing teachers' knowledge of the seven cross-cutting big ideas detailed in Chapter 2, all outcomes for Level C, and familiarity with the content associated with the outcomes for Level A and Level B detailed in the frameworks from Chapter 3.
2.	An introductory statistics content course that emphasizes a modern data analytic approach to statistics and working with data.

3. A foundations of mathematical statistics course using simulations and computing OR an advanced modeling course.
4. A substantial statistics and data unit within a methods course for high school teachers that develops teachers' knowledge for teaching the seven cross-cutting big ideas detailed in Chapter 2, outcomes for Level C, and aspects of Level B detailed in the framework from Chapter 3.
Continuous Preparation of Teachers
1. Take courses that focus on developing teacher knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and all outcomes detailed in the framework from Chapter 3 appropriate for the level and content they teach.
2. Participate in a series of vetted professional learning experiences focused on developing teacher knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and all outcomes detailed in the framework from Chapter 3 that are appropriate for the level and content they teach.
3. Engage in short-term professional learning seminars or webinars to assist in developing knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and all outcomes detailed in the framework from Chapter 3 that are appropriate for the level and content they teach.

Figure 3. Summary of *SET II* recommendations

- Level B:** Outcomes for early secondary teachers' statistical and data knowledge
- 3. Framework for Teacher Learning Outcomes in Statistics and Data—**
- Level C:** Outcomes for upper-secondary teachers' statistical and data knowledge
- C.** A set of recommendations for primary and secondary school teacher preparation, as well as ongoing professional learning. Because teaching statistics and data-related topics is most effective when it is cross-curricular, teachers in different subjects need appropriate preparation for working with and teaching data. *We recommend that all teacher preparation in statistics and data-related topics be centered on the seven cross-cutting big ideas in Chapter 2 and the elements of the framework in Chapter 3 that are relevant to the area of study.* Teacher preparation should be viewed as a continuum of experiences

that culminates in teachers meeting all the learning outcomes. Continuous professional learning is necessary for teachers to continue progressing in their professional education.

The motivation for these recommendations is discussed in more detail in Chapter 4, but the summary in **Figure 3** highlights the key points. For these recommendations, we use the US-centric levels of elementary, middle, and high school teachers because specific course recommendations are organized around those categories. However, we encourage appropriate international adaptations of these recommendations.

In addition, because teachers that teach statistics and data-related topics come from diverse backgrounds, it is important that all teachers be equipped to meet the learning outcomes outlined in Chapter 3, which align with the content their students need and their subjects require. Because statistics and data-related standards are primarily found in the mathematics curriculum, mathematics teachers are often tasked with developing the full scope of statistics and data education for their students. Science standards also include many expectations related to data; as a result, science teachers often use the SPSP to carry out experiments and gather data to illustrate scientific ideas. Therefore, the tables below for middle and high

school teacher preparation should be interpreted as recommendations for STEM teachers. At the elementary level, the recommendations apply to all teachers because they are certified as generalists; therefore, there is no distinction among subjects.

This report includes examples of different types of teacher preparation activities for developing teacher readiness in statistics and data education (see Chapter 5). It includes 17 examples that illustrate different types of researched and tested teacher learning pedagogies from around the world.

This report calls for teacher preparation to be viewed as an ongoing process, beginning with the statistics and data education of the prospective teacher and continuing throughout the career of the practicing teacher. Recognizing that the needs of teachers depend significantly on the level and subject of their practice, this report is purposely flexible to accommodate these evolving needs.

This report provides teachers, teacher educators, administrators, and policy makers with the roadmap needed to transform statistics and data education integrated across the curriculum.

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Preface

Background and Motivation for *SET II* Report

Statistics is a powerful way of thinking—a systematic approach to understanding our world through data, questioning assumptions, and making informed decisions in the face of uncertainty.

Imagine a world that relies on statistics and data to drive discovery and inform decisions. This is the vision of the American Statistical Association. The goal of the *Statistical Education of Teachers II* report is to support the development of pre-K–12 teachers’ knowledge in statistics and data concepts by providing guidance to teachers, teacher educators, administrators, and policymakers on how to prepare teachers to ensure students are able to live, work, and play in a world full of data. As outlined in *Pre-K–12 Guidelines for Assessment and Instruction in Statistics Education II*, statistics is not merely a collection of formulas and procedures to be memorized and mechanically applied. Statistics is a powerful way of thinking—a systematic approach to understanding our world through data, questioning assumptions, and making informed decisions in the face of uncertainty. *SET II* endeavors to prepare teachers to use student-centered methodologies that position students as active ethical investigators and critical thinkers. We imagine classrooms where students pose their own investigative questions, collect and consider data, undertake appropriate analysis, and interpret and clearly communicate their results. *SET II* also aligns and supports the vision put forth by the National Academies of Sciences, Medicine, and Engineering report: *Data and Computing in K–12 Education: Foundational Competencies* (2026) by

further unpacking the competencies defined by NASME. *SET II* builds on the report in more detail to show how each grade-band can approach the competencies and further teacher preparation.

This *SET II* report updates and expands upon the ASA's *Statistics Education of Teachers I* report published in 2015. The original *SET I* report set out to clarify *The Mathematical Education of Teachers* (*MET II*; Conference Board of Mathematical Sciences [CBMS] 2012) recommendations, emphasizing features of teachers' statistical preparation that are distinct from their mathematical preparation. *SET I* called for collaboration among mathematicians, statisticians, mathematics educators, and statistics educators to prepare teachers to teach intellectually demanding statistics in a pre-K–12 curriculum, and it served as a resource to aid those efforts. This updated *SET II* report expands on the goals established in *SET I* to include the use of data in all subjects, anchoring teacher preparation to the *Pre-K–12 GAISE II* report and Statistical Knowledge for Teachers, and attending to every learner within a classroom.

The teacher learning outcomes presented in *SET II* were written to help teachers prepare students to achieve the learning outcomes presented in *Pre-K–12 GAISE II*. Teachers begin with a context and develop investigative

Joint Statement with *MET III* and *SET II*

The American Statistical Association is excited to be publishing the *Statistical Education of Teachers II* report in the same year the Conference Board of Mathematical Sciences is publishing the *Mathematical Education of Teachers III* report. The reports work in tandem to provide recommendations for the preparation and ongoing professional learning of teachers of statistics and all disciplines using statistics as well as those of mathematics. Both reports emphasize the need for teachers to experience learning that models NCTM's Teaching Practices (NCTM, 2014). When implemented, the reports support the advancement of teachers' content knowledge and pedagogical content knowledge, equipping teachers to foster student learning, cultivate positive beliefs, and promote the success of every student.

questions, explore data to understand its structure and limitations, select and apply analytical techniques, interpret results in context, and communicate findings to others. Throughout this process, teachers develop not only technical skills, but also the habits of mind for effective statistical thinking and teaching. Teacher educators can provide experiences that help teachers develop a study around a posed investigative question and experiences that encourage them to explore available data. From that exploration, they develop reasonable investigative questions to answer using that data. The ultimate goal is not simply to make statistics more engaging—though that is certainly an important outcome. The goal is to prepare and enable teachers to support students in becoming thoughtful consumers and producers of statistical information in an increasingly data-informed world.

In concert with the *SET II* report, CBMS is updating their *MET II* report to publish *MET III*. *MET III* again focuses on recommendations for the preparation of teachers in mathematics, including statistics. As statistics is included in mathematics standards for students, mathematics teachers have a responsibility to teach statistics content and should be prepared to do so. The *SET II* team has collaborated with the *MET III* team to embed the summary of *SET II* within *MET III*. This illustrates the commitment from *MET III*

to recommend a comprehensive preparation of teachers in statistics.

Statistics as Defined in *SET II*

Statistics is the science of learning about the world through data in its myriad forms. Statistics is also an art, requiring creativity and intuition to uncover patterns, tell stories, use habits of mind for reasoning and problem solving, and communicate findings (Speigelhalter, 2019). Researchers from all disciplines are guided by theory to determine what to observe and how to measure those observations, but statistics determines how to select units to observe, how to adjust for errors in measurement, and how to generalize findings appropriately from studies involving data.

Some have embraced the term “data science” to describe the science of working with data, while others suggest this new term is simply a rebranding of what statistics has always done: finding information in data (Donoho, 2017). More people are interested in extracting information from data than ever before, but not all consider themselves statisticians. Many work in computer science, social sciences, or physical sciences, etc. Irizarry (2020) describes the term “data science” as an umbrella term that encompasses all activities in which people work to extract information from data.

SET II uses the terminology “statistics education” and “data education”—where statistics is the science of collecting, analyzing, and interpreting data—to answer an investigative question (Agresti, Franklin, and Klingenberg, 2018). “Data education” refers to any teaching or learning concerning any aspect of data sense-making, such as handling, collecting, analyzing, and storing across all disciplines.

The historically procedural approach to statistics education has teachers teaching and students learning, for example, how to calculate standard deviations and perform hypothesis tests without understanding why these tools matter or how they connect to decision-making. This approach produces teachers and students who can carry out computations but struggle to think statistically when faced with authentic problems.

The approach called for in *SET II* stands in contrast to the procedural approach. We call for beginning with questions that matter and connecting to the lived experiences of teachers and students. Whether investigating patterns in social media usage, analyzing environmental data from their community, or exploring relationships between variables they find personally compelling, teachers and students engage with statistics as a tool for understanding rather than as a computational procedure. The approach

for students presented in *SET II* and in *Pre-K–12 GAISE II* recognizes that statistical thinking develops most effectively when teachers and students grapple with real uncertainty, wrestle with messy data, use data to justify claims. Then, they experience the satisfaction of discovering insights through their own analytical work.

Although statistics can be treated as a standalone course in the curriculum, it is also an important tool across school subjects, disciplines, and class levels. **Thus, we believe there is a necessary statistical core to be learned at the pre-K–12 level.** We advocate that courses across all disciplines can mutually reinforce this statistical core. For example, a high school computer science course might emphasize data structures and computational efficiency when analyzing data. Social studies classrooms may analyze political voting patterns throughout US history, using historical election data. Science classrooms may design experiments to collect data in biology, chemistry, and physics.

The teacher’s primary responsibility is to create rich learning environments where statistical thinking can flourish for all students. This involves selecting or guiding students to identify interesting and compelling datasets and statistical investigative questions; structuring activities that promote discovery, while ensuring

students encounter essential statistical concepts; and facilitating discussions that help students articulate and refine their thinking. Teachers who engage in their own statistical reasoning processes can better help students understand that statistical thinking is an investigative process that engages multiple habits of mind rather than a fixed set of skills to be mastered once and applied mechanically. *SET II* provides guidance and recommendations on how to assist teachers in meeting these goals.

Audience

This report is a resource for all involved in the education of teachers who teach statistics and data concepts in pre-K–12 (approximately ages 4–18), both in the initial preparation of prospective teachers and in the professional development of practicing teachers. These audiences include the following:

Teacher Educators

We refer to teacher educators as anyone who contributes to the preparation of teachers in statistics and data education. For example, teacher educators may be two- and four-year higher education faculty members, who teach content and method courses to prospective and practicing teachers related to statistics and data. Such educators might also offer professional development or direct graduate programs for practicing teachers.

These faculty members, whether within colleges of education, mathematics departments, statistics departments, or other academic units, are an important audience for this report. Teacher educators could also be responsible for the pedagogical education of teachers (e.g., methods courses, field experiences for prospective teachers).

Outside of academia, a variety of teacher educators are engaged in professional development for teachers of statistics and data concepts, including state, regional, and school-district specialists or school-based coaches. All those teaching alternative certifications are also included in this group. Teacher educators may be attempting to better equip themselves with content knowledge and skills, or school-level teachers themselves may be attempting to better equip their own content knowledge and skills for teaching statistics.

Administrators and Policymakers

This report informs educational administrators and policymakers at the national, state, school district, and collegiate levels as they work to provide pre-K–12 students with a strong statistics and data education for an increasingly data-driven world. Teachers' preparation to teach statistics and data concepts is central to this effort and is supported—or hindered—by institutional policies. These include

national accreditation requirements, state certifications requirements, and the ways in which these requirements are reflected in teacher preparation programs. State and district supervisors make choices in the provision and funding of professional development. Administrators, such as superintendents, district curriculum coaches, and school principals and assistant principals, play key roles in ensuring classroom-level implementation. At the pre-K–12 level, scheduling and policy affect the type of learning experiences available to teachers. Therefore, these individuals play important roles in the statistical education of teachers.

Terminology

To avoid confusion, the report uses the following terminology:

- *Student* refers to a child or adolescent in a pre-K–12 classroom between approximately 4 and 18 years old.
- *Teacher* refers to a teacher in a pre-K–12 classroom (practicing teacher) and may also refer to someone studying to become a pre-K–12 teacher (prospective teacher).
- *Teacher educator* refers to anyone who contributes to the preparation of teachers in statistics and data education.
- *Primary and secondary levels* are used throughout the document to connect to an international audience.

For a US-centric audience, “primary” refers to elementary grades, and “secondary” refers to the middle and high school grades.

Organization of the Report

Chapter 1 describes the motivation for *SET II* in more detail and provides background on the teacher learning theories the report uses to anchor teacher preparation and development.

Chapter 2 introduces the big cross-cutting ideas for teacher learning, highlighting the pillars of the practice of doing statistics and working with data that are present across all grade-bands.

Chapter 3 presents the frameworks for elementary, middle, and high school teachers. The frameworks include learning objectives for all pre-K–12 teachers matched to the *GAISE II* learning objectives for student learning.

Chapter 4 presents recommendations regarding the shared responsibility for the statistics and data education of teachers within educational structures. This chapter is directed to those in leadership positions in school districts, colleges and universities, and government agencies, whose policies affect the statistical education of teachers.

Chapter 5 provides illustrations and examples of teacher preparation activities

that can lead to teacher learning outcomes described in *SET II*.

Chapter 6 closes the report with future directions and needs.

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Chapter 1

Development of Statistics and Data Teacher Education

Statistics is a powerful way of thinking—a systematic approach to understanding our world through data, questioning assumptions, and making informed decisions in the face of uncertainty.

The goal of the *Statistical Education of Teachers II* report is to support the development of pre-K–12 teachers’ knowledge and skills in teaching statistics and data content. This starts with identifying the big ideas that cut across grade bands and subjects to form the foundation of the statistics and data science knowledge teachers need in the classroom (Chapter 2). It also involves articulating statistical learning outcomes for teachers (Chapter 3), providing recommendations for prospective and practicing teachers (Chapter 4), and examples that illustrate high-level teacher preparation (Chapter 5). The purpose of this chapter is to describe the principles guiding the development of our recommendations for effective teacher preparation in statistics.

Foundational Pillars of Teacher Preparation in Statistics and Data Concepts

We conceptualize the effective preparation of teachers for teaching statistics and data education as the interplay of three important foundational pillars:

1. The *Pre-K–12 GAISE II* report defines the essential content for student learning (Bargagliotti et al., 2020).
2. **Statistical Knowledge for Teaching (SKT)** defines the subject-matter expertise teachers need (Groth, 2007).
3. The eight **Effective Teaching Practices** identified by the National Council

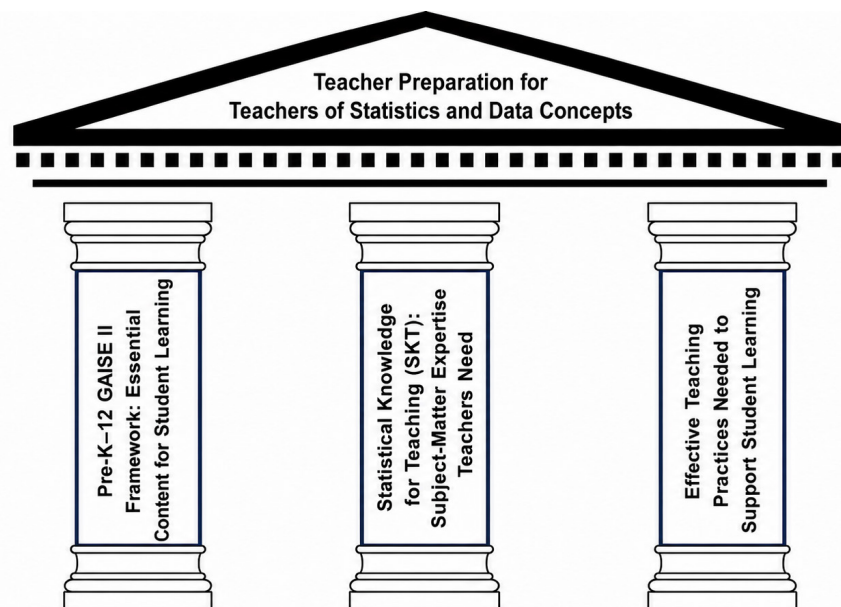


Figure 1.1. Foundational pillars of teacher preparation in statistics and data concepts. Reprinted with permission from *Principles to Actions* copyright 2014, by the National Council of Teachers of Mathematics. All rights reserved.

of Teachers of Mathematics (NCTM) in *Principles to Actions: Ensuring Mathematical Success for All* (2014) provides the framework for the third foundational pillar—effective teaching practices needed to support student learning.

These foundational pillars work together to support the development of capacity in teachers to effectively teach statistics and data content. **Figure 1.1** provides a diagram for this conceptualization. The following sections describe each pillar’s framework and how they guide this report’s recommendations:

Pre-K-12 GAISE II offers the Statistical Problem-Solving Process (**Figure 1.2**),

which describes how to “do” statistics and carry out statistical investigations described in the *Pre-K-12 GAISE II* framework. Widely accepted in the statistics education community, it provides the foundational design for developing pre-K–12 students’ abilities to apply statistical thinking to problem solving in the presence of data (see, for example, (Ben-Zvi et al., 2018)). The process is divided into four interrelated components; **Figure 1.2** shows how the components might be revisited and refined multiple times while progressing through an investigation (blue arrows). The four components are the following:

1. Formulating a statistical investigative question that can be addressed with data

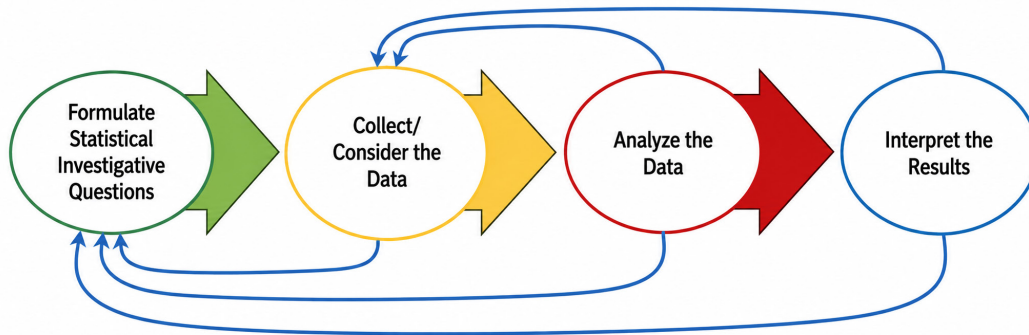


Figure 1.2. The Statistical Problem-Solving Process.

2. Designing and implementing a plan for collecting useful data or, when working with existing data, interrogating the data to understand its provenance
3. Analyzing data by creating and exploring various representations of distributions to identify and describe patterns in the data, summarize and compare various features of distributions, and utilize appropriate analysis methods to help uncover patterns within the data
4. Interpreting the results to provide a statistical evidence-based conclusion to the investigative question posed that considers the variability of the data

SET II primarily uses the *Pre-K–12 GAISE II* framework for describing the statistics and data knowledge students need. *GAISE II* identifies three developmental levels—A, B, and C—for statistical education within pre-K–12 settings. In an ideal environment, where statistics

is present in the standard school curriculum from pre-K to grade 12, these levels match the three grade level bands for elementary, middle, and high school. The *SET II* report presents a set of student learning outcomes for each of these four components of the statistical investigative process across these three levels.

GAISE II continues to be influential in determining what students learn in classrooms across the US—for example, the state curriculum standards in Georgia, Tennessee, and Oregon and national curriculum standards in Spain and New Zealand all use *GAISE* as their guiding document. Additional student learning outcomes stemming from developments in the field since the publication of *GAISE II* have also been added.

Statistical Knowledge for Teaching supports students’ attainment of *GAISE II* learning outcomes. Teachers need knowledge beyond the statistical content and processes they teach, including

Mathematics Teaching Practices
Establish mathematics goals to focus learning. Effective teaching of mathematics establishes clear goals for the mathematics that students are learning, situates goals within learning progressions, and uses the goals within learning progressions, and uses the goals to guide instructional decisions.
Implement tasks that promote reasoning and problem solving. Effective teaching of mathematics engages students in solving and discussing tasks that promote mathematical reasoning and problem solving and allow multiple entry points and varied solution strategies.
Use and connect mathematical representations. Effective teaching of mathematics engages students in making connections among mathematical representations to deepen understanding of mathematics concepts and procedures and as tools for problem solving.
Facilitate meaningful mathematical discourse. Effective teaching of mathematics facilitates discourse among students to build shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments.
Pose purposeful questions. Effective teaching of mathematics uses purposeful questions to assess and advance students' reasoning and sense making about important mathematical ideas and relationships.
Build procedural fluency from conceptual understanding. Effective teaching of mathematics builds fluency with procedures on a foundation of conceptual understanding so that students, over time, become skillful in using procedures flexibly as they solve contextual and mathematical problems.
Support productive struggle in learning mathematics. Effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships.
Elicit and use evidence of student thinking. Effective teaching of mathematics uses evidence of student thinking to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning.

Figure 1.3. Effective Mathematics (and Statistics) Teaching Practices
(NCTM, 2014)

knowledge of how to make that content comprehensible to students. Although there is overlap between the knowledge needed to do statistics and the knowledge needed to teach statistics, the two types of knowledge are not equivalent; there is a need to be mindful of the unique characteristics of SKT. Accordingly, consideration of teachers' SKT is the second foundational pillar of the SET II recommendations for teacher preparation in statistics and data concepts.

Groth (2013) defined SKT as consisting of both subject matter knowledge and pedagogical content knowledge (Hill, Ball, and Schilling, 2008). Subject matter knowledge includes knowledge of the statistics content in and beyond a teacher's curriculum, as well as knowledge of how to unpack and represent the statistical content for students. Pedagogical content knowledge includes knowledge of common student statistical thinking patterns and ways to design lessons, units, and curricula that are responsive to students' thinking. Well-rounded statistics and data teacher education (e.g., courses, programs, continuing education), as conceptualized in *SET II*, attends to building teachers' knowledge of core statistics and data concepts. Statistics and data teacher education also helps teachers develop pedagogically powerful ideas (Silverman and Thompson, 2008), considering content from students' perspectives to identify potential difficulties

and selecting strategies to support students' learning of key developmental understandings (Simon, 2006). Teachers' subject matter knowledge and pedagogical content knowledge are both enhanced in this process.

Effective Teaching Practices

Statistical knowledge for teaching must be translated into practice. The authors of NCTM's *Principles to Actions* (2014) articulates teaching practices for effective mathematics teaching (Figure 1.3) that can be applied and adapted to form the third foundational pillar for teacher preparation for teaching statistics. Although these practices were identified as effective for teaching mathematics, they are written in general terms that can be applied to the teaching of statistics. In addition, "Considering the 5 Practices Through a Statistical Lens" (Smucker et al., 2024) describes lesson planning and classroom implementation specific to the statistics classroom. All these practices align with teachers becoming facilitators of student learning to support "the engagement and learning of each and every student" (Boston et al., 2017, p. 4). They define a set of pedagogical practices central to ambitious teaching that promotes deep, conceptual learning.

Ambitious teaching is further supported when the eight Effective Teaching Practices are combined with the

Equity-Based Mathematics Teaching Practices identified by Aguirre and colleagues (2013, p. 43). These equity-based practices: (1) go deep with mathematics, (2) leverage multiple mathematical competencies, (3) affirm mathematics learners' identities, (4) challenge spaces of marginality, and (5) draw on multiple resources of knowledge. These practices "have been shown to strengthen mathematical learning and cultivate positive student mathematical identities" (Boston et al., 2017, p. 6). *SET II* uses all these practices to meet the needs of every student, as elaborated in NCTM's *High School Mathematics: Reimagined, Revitalized, and Relevant* (pp. 67–69).

Designing Statistics and Data Teacher Education

Pre-K–12 statistics and data teacher education is a relatively new and emerging field. Statistics began to appear in influential standards documents, such as those proposed by NCTM (NCTM, 1989, 2000), across all grade levels in the late 20th century (Jones & Tarr, 2010). Several new and powerful data science tools and methods have emerged in the twenty-first century, and efforts to design appropriate pre-K–12 teacher education experiences have taken shape alongside these recent developments.

Teacher education can be discussed in terms of prospective teacher preparation and ongoing professional learning for practicing teachers. Prospective teacher preparation typically is delivered in university programs and some alternative certification pathways. Practicing teacher preparation may take on several forms, such as district-based professional learning experiences, university courses and graduate degrees, job-embedded training, and informal teacher-initiated learning. Teacher preparation (both prospective and practicing) in statistics is complicated by the fact that data-related concepts are included within every subject with varying degrees of emphasis.

Mathematics and statistics teachers typically are responsible for teaching the bulk of data-related topics; however, science and social studies teachers are responsible for teaching standards that include some data work (see National Research Council [NRC], 2013; National Council for the Social Studies [NCSS], 2013). Therefore, teacher preparation across disciplines should be mapped to the types of data concepts they need to teach. In the section that follows, we discuss key design considerations for such experiences and present frameworks that can help guide teacher learning.

Form, Function, and Features of Statistics and Data Teacher Education

A core idea in design across fields is the distinction between form and function. Form pertains to the characteristics of a structure, whereas function pertains to the purpose the structure is meant to serve. The “Overarching Form” column of **Table 1.1** shows a wide range of possibilities for teacher preparation, including university coursework, classroom research and clinical experiences, professional development sessions (both stand-alone sessions and job-embedded), and online interactions. These forms may serve one or more functions, such as introducing teachers to new content in their curricula. Any given statistics and data teacher education effort can be described as combinations of form and function.

Along with the broad categories of form and function, it is useful to consider specific features of forms meant to serve different functions. A feature pertains to the statistical learning outcomes being addressed. For example, a university course (a form) meant to build teachers’ knowledge of statistics and data concepts (a function) may include tasks based on authentic datasets and technology that can be used to analyze them (features). As another example, a one-day professional development session intended

to enhance participants’ strategies for teaching statistics may feature analysis of lesson videos or journal articles from professional organizations. Job-embedded professional development, meant to serve the function of building teachers’ knowledge of students’ statistical thinking, could feature analysis of artifacts gathered from teachers’ own classrooms, like student work samples. Teachers’ co-design of lessons may also be a feature. Many other combinations of form, function, and features are possible. Forms, such as classroom research (e.g., Groth, 2017) and lesson study (e.g., Leavy, 2015), may include the features of analyzing student work and lesson videos from firsthand classroom experiences. Collectively, these serve the function of enhancing teachers’ knowledge of strategies to build students’ statistical thinking. Statistics teacher education that takes the form of university coursework (e.g., Hudson et al., 2024) or stand-alone professional development (e.g., Zieffler et al., 2021) may be well-suited to intensive development of teachers’ statistics content knowledge by featuring rich tasks, investigative data cycles, and work with technology. In general, features of pre-K–12 statistics teacher education should be selected for compatibility with the overarching form of a given effort and their capacity to serve intended functions.

Table 1.1 Examples of Different Forms, Features and Functions in Pre-K–12 Statistics Teacher Education

Study	Overarching Form	Key Functions	Prominent Features
Fergusson and Pfannkuch (2022)	In-person professional development session	Introduce practicing teachers to code-driven technology for data analysis	A statistical modeling task involving a randomization test
Green and Blankenship (2013)	3-credit hour, noncalculus-based introductory university-level statistics course	Build prospective teachers' knowledge of simulations, data summaries, and group comparisons and how to teach these concepts	TinkerPlots simulations, interactive statistical tasks, lesson plan construction, NCTM article reflections
Groth (2017)	Collaborative, design-based classroom research	Build prospective teachers' statistical knowledge for teaching distributions and measures of center	Analysis of artifacts gathered from their classroom, including students' written work, clinical interviews, and lesson videos
Hudson et al. (2024)	Module embedded in university-level coursework	Help prospective teachers use CODAP to carry out a data investigation and create and interpret visualizations and statistical measures	A statistical task requiring analysis of data on school conditions in different geographic regions (e.g., teacher salaries, student-teacher ratios)
Leavy (2015)	Lesson study embedded in a teacher preparation program	Improve prospective primary teachers' abilities to plan and teach data handling	Clinical experiences that include planning, teaching, and re-teaching data lessons for students

Lee et al. (2020)	Massively open online course for teachers	Introduce an investigative cycle that can be used to teach statistics and help students make evidencebased claims	Analysis of videos from others' statistics classrooms, animations representing students' statistical thinking, and technology-based investigative tasks for teachers
Podworny and Biehler (2022)	Module embedded in university-level coursework	Build prospective primary teachers' knowledge of randomization tests	Group comparison task with data from an experiment provided in TinkerPlots
Schoen et al. (2025)	Workshops focused on lessons teachers later used in their own classrooms	Enhance teachers' quality of instruction for statistics and support associated student learning outcomes	Working through innovative lessons from a student's perspective—practice with teaching the lessons
Serradó Bayés et al. (2014)	Hybrid professional development course with in-person and online components	Improve elementary and middle school teachers' technological, pedagogical, and content knowledge of statistics	Analyses of curriculum documents, articles, and teaching scenarios; data explorations with TinkerPlots
Zieffler et al. (2021)	Series of in-person professional development sessions	Enhance secondary teachers' abilities to build and evaluate statistical models	Collaborative statistics tasks involving classification trees and modeling

Table 1.1 lists some examples of studies that illustrate different combinations of forms, functions, and features. The examples in **Table 1.1** are not exhaustive and are only meant to highlight different combinations. Collectively, they can stimulate thought on how to design pre-K–12 statistics teacher education.

This report does not provide specific recommendations for the form and function that the statistical education of teachers should take across prospective and practicing teacher education in multiple content areas. Rather, it is purposely flexible to allow for preparation of teachers in all subjects according to their

specific needs. The report takes a comprehensive approach to teacher preparation—an ongoing process through a teacher’s career—and identifies learning outcomes appropriate throughout the process. Teacher educators, administrators, and policy makers can use this report to guide the development of teacher knowledge in statistics and data as standalone subjects and within other content areas.

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Chapter 2

Cross-Cutting Big Ideas

A goal of education is ensuring the success of all learners. Such success is contingent upon all students—regardless of background, ability, or prior experience—having access to meaningful learning opportunities.

Seven big ideas that are fundamental for developing teacher knowledge and preparing them to work with data and statistics are described and discussed in this chapter. **Figure 2.1** (Page 36) lists the seven big ideas that cross-cut across the framework presented in Chapter 3. While each of the big ideas are described below in this chapter, it is important to remember they are interrelated and collectively support the development of statistical knowledge for teachers.

I. Engaging with the Statistical Problem-Solving Process

The Statistical Problem-Solving Process (**Figure 2.2**, Page 37) is fundamental to

the advancement of statistical literacy for all Pre-K–12 students. This process is based on Problem-Plan-Data-Analysis-Conclusions, the investigative cycle (Mackay & Oldford, 2000; Wild & Pfannkuch, 1999). The SPSP was initially endorsed by the American Statistical Association in their publication *Guidelines for Assessment and Instruction in Statistics Education Report: A Pre-K–12 Curriculum Framework* (Franklin et al., 2007) and reaffirmed in *Pre-K–12 GAISE II* (Bargagliotti et al., 2020). In a future driven by data, “every person should be able to use sound statistical reasoning to intelligently make evidence-based decisions” (Bargagliotti et al., 2020, p. 5).

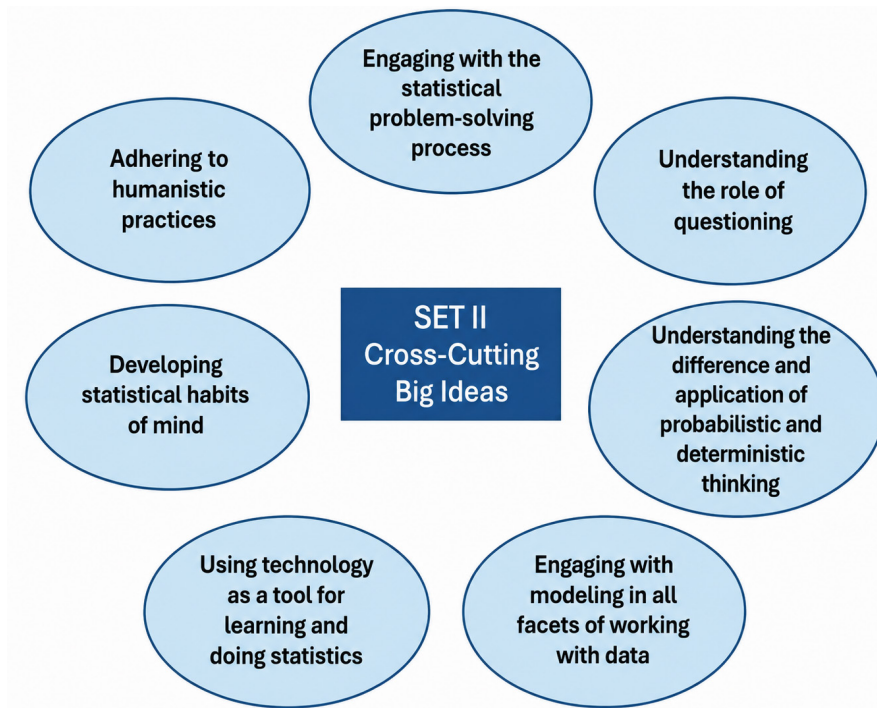


Figure 2.1. Cross-cutting big ideas for teacher preparation

The SPSP has the following four interrelated components:

- **Formulate:** Formulate a statistical investigative question that can be addressed with data.
- **Collect:** Design a plan for collecting useful data, implement the plan, and collect the data. When working with existing data, interrogating the data through questioning helps establish its provenance.
- **Analyze:** Analyze data by creating and exploring various representations of distributions to identify and describe patterns in data variability,

summarize various features of a distribution, and utilize appropriate analysis methods to help uncover patterns within the data.

- **Interpret:** Interpret the results to provide a statistical answer to the investigative question posed that takes the variability of the data into account.

At first glance, the main arrows connecting the components of the SPSP appear to create a linear progression in **Figure 2.2**. However, as the graphic shows, it actually works in a non-linear way. The blue connecting lines in **Figure**

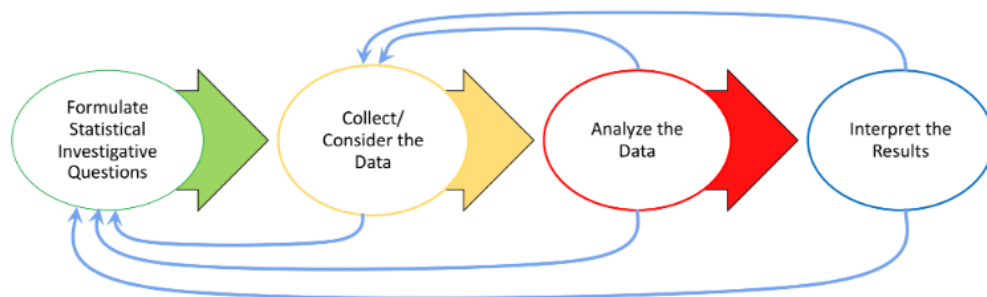


Figure 2.2. The Statistical Problem-Solving Process (Bargagliotti et al., 2020)

2.2 indicate the need for teachers (and students) to interrogate their actions for each component and encourage them to step back into previous components to question their decisions and findings before proceeding to subsequent ones, making changes as necessary. This process of interrogative questioning applies to any and all components of the process. Other notable similar investigative processes exist and are used for classroom instruction and teacher preparation in the United States and across the world (e.g., Census at School, 2024; Lee et al., 2022; Mojica et al., 2021; NCTM, 2024; Wild & Pfannkuch, 1999).

The SPSP guides primary and secondary students to conduct statistical investigations through reasoning and inquiry, not procedures. A procedure is defined as a series of actions conducted in a certain order or manner to achieve a specific result. But a process includes problem-solving, reasoning and proof, communications, representations, and connections (NCTM, 2000).

The goal of teaching with the SPSP is “statistical literacy for all” (Bargagliotti et al., 2020). We also strive for critical statistical literacy (Weiland, 2017; Weiland & Sundrani, 2022) when carrying out investigations with community-based contexts. It is essential for teachers to develop fluency with this process and, in turn, provide students at all educational levels defined in *GAISE II*—Level A, Level B, and Level C—with opportunities to engage in age-appropriate statistical investigations. Teacher educators should provide teachers with opportunities to engage with the SPSP themselves to develop a big-picture, holistic view of statistics.

Peters (2014) found that teacher engagement in the SPSP helps them develop a big-picture view of working with data. Teachers should experience this process for several reasons:

- It provides an overarching landscape or design that can be applied to any statistical context or dataset.

- The application of the SPSP serves to broaden the focus of making sense of data beyond just the analysis phase.
- It is a process that incorporates higher order skills and critical thinking with every component through questioning and reasoning.
 - It has direct applications in other academic areas of study, such as science and social studies (see Chapter 4, Figure 1 of this report). The Appendix F for Science and Engineering Principles from the Next Generation Science Standards (National Research Council, 2013) aligns to the Statistical Problem-Solving Process, as do the competencies for inquiry literacies from the *College, Career, and Civic Life Framework for Social Studies State Standards* (National Council for the Social Studies, 2013).
 - Assessments for teachers and students should be based within the SPSP to match the instructional modality of the process. Teachers invested in this process gain sound statistical questioning and reasoning abilities that can be showcased in appropriate assessments.
 - Questioning throughout the use of the SPSP should be encouraged and expected by teachers and students.

II. Understanding the Role of Questioning

Statistical questioning plays a foundational role in the SPSP; the process is inherently driven by a cycle of inquiry. By engaging teachers with the content in the rich examples of *SET II*, teacher educators can help teachers experience how modeling effective statistical inquiry drives meaningful data exploration, supports valid conclusions, and nurtures critical thinking across all stages of a statistical investigation.

Therefore, teacher educators should engage teachers in these key ideas regarding the SPSP:

- The SPSP should be used by teachers with their students for any statistical context or dataset. As teachers apply the process, they empower students to take ownership of their own investigations and make sound data decisions. Understanding and implementing this process is fundamental to statistical literacy.
- The SPSP begins with the posing of a statistical investigative question—a question that requires data to answer and anticipates variability in the data. This type of question is the anchor for designing studies, collecting data, performing analysis, and interpreting results. Importantly, the *SET II* examples demonstrate that questioning is not limited to the beginning of the process. It

Table 2.1. Question Types Throughout the Statistical Problem-Solving Process
(adapted from “What Makes a Good Statistical Question”)

	Formulate Question	Collect/ Consider Data	Analyze Data	Interpret Results
Question Posing	Investigative Questions	Survey/Data Collection Questions		
Question Asking	Interrogative Questions	Interrogative Questions	Analysis Questions Interrogative Question	Interrogative Questions Analysis Questions

is a continuous activity, evolving as new insights emerge by asking interrogative questions. For instance, during the question-asking phase, which creates appropriate graphical representation and numerical summaries of the data, patterns in the data may prompt new or refined investigative questions. In this way, statistical questioning fuels an evolving loop of learning and discovery. Developing the art of questioning enables a teacher to develop and naturalize the habits of mind and dispositions necessary for making sense of data and, in turn, guiding students as they attempt to make sense of data.

The *SET II* document also underscores the importance of questioning existing data. By providing teachers with activities designed around exploring available secondary datasets, teacher educators can provide experiences for teachers to

help them recognize that when using data collected for other purposes, it is vital to interrogate the data with interrogative questions about how measurements were made, what types of data are included, who is included and who is left out, what the variables represent, and why and how the study was designed. As teachers develop this deeper understanding, it can lead to investigative questions to be considered with that dataset or in determining whether the dataset is suitable for a previously posed investigative question. In an observational study of a small group of teachers, Gould et al. (2017) found that groups who asked frequent, well-crafted investigative questions made greater progress in a statistical investigative process. The article “What Makes a Good Statistical Question” (Arnold & Franklin, 2021) provides teachers a practical framework for identifying and constructing effective

statistical questions that are appropriately scoped for the investigation. It also offers guidance on how to model questioning in the classroom. Key takeaways from Arnold and Franklin (2021) are elaborated in **Table 2.1**.

Teachers should feel comfortable with the different forms of statistical questions and applying those questions as the SPSP is carried out. Teacher educators should engage teachers by conducting different investigations that require teachers to use questioning throughout the process. They should also reflect on the appropriateness of the questions asked or if there are better questions that should have been asked.

There are four types of statistical questions employed throughout the four components of the SPSP: investigative; survey/data collection; analysis; and interrogative. Throughout the process, one is either posing questions or asking questions. Arnold and Franklin define question posing as proposing investigative questions that need data to be answered or proposing survey/data collection questions used to collect the data. Question asking is a continual and spontaneous interrogative process throughout the SPSP that serves as a refinement check on posed questions and data quality. Analysis questions are also an example of question asking as the data is explored. **Table 2.1** summarizes

question posing and question asking within the SPSP.

Constructing a good investigative question can be challenging for both teachers and students. It is essential for teacher educators to guide teachers in developing the skill to construct investigative questions that provide clarity necessary for allowing a meaningful investigation. The goal is for teachers to carry this skill to their classroom, where they begin by first guiding students to understand the difference between a deterministic/mathematical question (e.g., What is $2+2$?) and a statistical/data question. For example, at the primary level, students might ask, “What is a typical backpack color for Miss Green’s classroom at Hope Elementary?”

Another important distinction that can be challenging is the difference between an investigative question (e.g., What is a typical backpack color for Miss Green’s classroom at Hope Elementary?) and a survey/data collection question (e.g., What is your backpack color?). The posed data-collection question results in one data point for an individual. The posed investigative question requires data for the group members of the population under consideration.

Teachers should use developed criteria for posing good investigative questions

as they facilitate students in generating potential investigative questions. The six criteria from Arnold and Franklin (2021) are listed and applied to the backpack color investigative question.

1. Is the variable of interest clear and clearly defined? Yes, the variable of interest is backpack color.
2. Is the group or population that we are investigating clear? Yes, the question is about the students in Miss Green's class at Hope Elementary.
3. Is the intent of the question clear? Yes, the investigative question is a summary-type question; we will summarize and describe the data collected to answer the investigative question of what is typical.
4. Can we answer the question with data we can collect? Yes, we can ask students about their backpack or observe their backpack color.
5. Is the question about the whole group? Yes, our question considers the responses from all students.
6. Is the question interesting and/or purposeful? Yes, Miss Green may be gathering the information for a school project or the parents of children may have an interest.

Applying these criteria is an example of asking interrogating questions about the investigative question. One interrogates at each stage of the SPSP to consider if and how they may need to improve the

SPSP. For more examples of questioning within the statistical process, see Bargagliotti and Franklin (2021, pp. 15–23).

Secondary teachers should recognize that, from primary to secondary school years, investigative questions will become more specific and less simple, moving from exploring only one characteristic (variable) of a population to exploring multiple characteristics together, and moving from summary/descriptive questions to comparison, association, time series, causal, and predictive questions (see Arnold, 2022, pp. 56–61).

By providing teachers with ample opportunities to explore a variety of datasets and practice formulating appropriate investigative questions for that data—or by having teachers pose investigative questions and determine how to collect the data needed to answer those questions—teacher educators can help teachers gain confidence in both question posing and question asking.

With the advancement of artificial intelligence (AI will be further discussed in the technology section), teacher educators should highlight that questioning plays a crucial role in how we interact with and shape AI. Increasingly, generative AI tools are integrated into our work patterns, and teachers (and perhaps students) are no exception. The

practice of posing good questions is an essential skill for developing productive GAI prompts and evaluating GAI outputs. Teacher educators should make the connection for teachers between posing well-crafted statistical questions and productive AI prompts. The ability to craft strong prompts is important since GAI can hallucinate or make errors, and is not, generally, trained for work in statistics education (Alexandrowicz, 2024).

Cultivating the ability to ask and evaluate statistical questions empowers teachers to think critically about data and engage meaningfully with real-world problems. Whether designing a study or working with existing data, questioning serves as the compass that keeps the SPSP purposeful and valid. Teacher educators are key to creating this mindset and culture for teachers.

III. Understanding the Difference Between Probabilistic and Deterministic Thinking

Authentic statistical investigations are underpinned by probabilistic, rather than deterministic, thinking. Probabilistic processes involve chance and variation. Deterministic processes deal with certainty. For example, calculating the equation for the least-squares line of best fit for a given dataset is a deterministic task. It is done with a calculation procedure

that leads to a given result that does not vary as long as the procedure is executed correctly. However, using a least-squares line to make predictions about a real-life, data-dependent process should be done with a probabilistic mindset. Although such a line can be useful for making viable predictions and drawing tentative conclusions, these predictions and conclusions cannot be stated with absolute certainty since the data on which they are based contain variability. Instead, such predictions and conclusions must allow for a reasonable amount of uncertainty (e.g., reporting prediction intervals or interval values) due to the context of the data and multiple sources of variability (Cobb & Moore, 1997). Adopting a probabilistic stance to data investigations is a non-trivial matter. To do so, one must navigate a middle ground between expressing too much or too little confidence in the results of their statistical investigations. This skill is not necessarily intuitive; it needs to be learned and perfected (Ben-Zvi et al., 2012; Henriques & Oliviera, 2016; Nilsson, 2013).

Teacher educators should help teachers develop and recognize probabilistic orientations to data throughout the SPSP. As noted earlier, teachers need to pose investigative questions that anticipate variability and help students learn to pose their own investigative questions. Since questioning has an impact on all

other phases of investigation, teacher educators should support teachers on how to recognize deterministic and probabilistic questions and steer them in the right direction for authentic statistical investigations. Some questions about data will trigger deterministic processes (e.g., “What is the mean number of text messages in this dataset?” or “What is the probability of rolling a six on a fair standard die?”) Other questions catalyze probabilistic processes (e.g., “How many texts do students in our class typically send each day?” or “Is the die included with this board game actually fair?”).

As teachers work to interpret data, probabilistic thinking continues to be important. To steer teachers away from deterministic interpretations, teacher educators can help teachers compare when deterministic thinking is appropriate (e.g., proofs in pure mathematics) and when it is not. Learning and deploying this distinction as needed can be challenging, especially for mathematics teachers, who need to switch between deterministic and probabilistic modes at various points in their work (Burrill & Biehler, 2014). Hence, teacher educators should be cognizant of helping teachers understand both modes of thought and when each is appropriate to use (see Conner & Peters, 2023 for distinctions between the two types of thinking in the classroom). Student work samples (Groth, 2014) and classroom videos of statistics lessons

Since questioning has an impact on all other phases of investigation, teacher educators should support teachers on how to recognize deterministic and probabilistic questions and steer them in the right direction for authentic statistical investigations.

(Russell et al., 2018) can also be used to help teachers recognize when students adopt deterministic or probabilistic orientations to problem-solving. Such artifacts can then catalyze discussions about how students might be guided back to probabilistic processes when they drift toward other modes of thought.

Another particularly helpful resource for helping teachers learn to navigate the deterministic/probabilistic distinction is *Pre-K–12 GAISE II* (Bargagliotti et al., 2020). The *Pre-K–12 GAISE II*

introduction chapter provides an accessible discussion on the role of probability in statistics and why deterministic questions should be avoided during statistical investigations. Meanwhile, the *Pre-K–12 GAISE II* framework chapter underscores the importance of anticipating variability when framing questions. *Pre-K–12 GAISE II* then goes on to give an example, in its Level A chapter, of how teachers can guide students to pose investigative questions that anticipate variability, rather than deterministic questions, when investigating data on family sizes from students in their class. Having teachers read, reflect on, and discuss these portions of *Pre-K–12 GAISE II* can help them understand the difference between both deterministic and probabilistic questions and why the difference matters in their students’ statistical investigations.

IV. Engaging with Modeling in All Facets of Working with Data

Modeling takes on many forms while working with data, and the term modeling can be applied in different ways. The SPSP is itself a modeling cycle because engaging it requires converting real-world problems into well-defined statistical investigative questions and identifying data visualizations and statistics that must be computed to help address these questions. This leads to

evaluating the appropriateness of these computations and, eventually, communicating an interpretation that addresses the initial questions. Engaging in this process is a modeling activity. Data are models of reality, and statistical models that model relationships among variables and simulations effectively model real-world probabilistic scenarios.

Statistical modeling is based on data, and data are themselves models of reality. Data are collected through measurement and observation, and a host of decisions and challenges must be made to collect data. Such choices are fundamental in creating data that represent the world and are appropriate for the investigative questions one is trying to answer. Humans decide *what* to measure and observe as well as *how* to measure and observe. For example, teachers measure student achievement (what) by the percentage of points obtained on a test (how). Also, deciding to measure the types of shoes students in a class wear (what) as a categorical variable necessitates deciding how to define categories (sneakers with velcro, sneakers with laces, etc.). Competency 2 in the NASME (2026) report states, “Measurement, broadly, is the process by which we turn ‘life’ into data.” The collection of such measurements and observations is, therefore, an abstraction of the more complex reality it represents. Teachers need experience

guiding data collection and the host of decisions that go along with it. It is important for teachers to conceptualize data as a model for reality as it allows them to understand the types of interpretations and conclusions that can be drawn from a statistical investigation.

Statistical models are important in that they describe relationships and variability, and they can be thought of as consisting of two components that go by several names: signal and noise (Chatfield, 1995), deterministic and probabilistic components, trend, and variation. A statistical model usually contains a mathematical model of some sort within it. For example, a physicist might say that the distance a car has traveled in a specific amount of time can be determined precisely from the mathematical model $D = St$, where D is the distance a car has traveled from the origin, S is the speed, and t is the time. But from a statistical perspective, measured speed might not be constant throughout the time interval, possibly because of conditions due to the road, the car, the driver, or possibly due to measurement error in assessing the speed. To account for uncertainty, a statistician might propose the statistical model $D = St + e$, where e is a random quantity that follows a specified probability distribution. St is the deterministic (or mathematical model) component, and e , along with the specification of the

probability distribution, is the probabilistic component.

Statistical models are used to describe real-world processes with a goal towards better understanding those processes. An ice cream parlor owner, for example, might be interested in understanding the extent to which the daytime high temperature explains variation in the amount of ice cream sold. A statistical model might estimate that each additional 10 degrees Fahrenheit in a daytime high temperature is associated with an increase of 40 pounds of ice cream sold, on average. Increasingly, however, statistical models are concerned with prediction. The ice cream parlor owners might not care which factors drive demand, provided the model accurately predicts how much ice cream to stock. Such predictive models drive the field of machine learning and often lead to model forms with no simple closed-form expression. The ice cream parlor owner might never see the predictive model, but instead, has an app that takes into account various factors the owner is never aware of. The app uses these to provide a prediction for how much ice cream will be sold. The app contains a model, but before the app could be deployed, its creators engaged in a modeling process to determine which model or algorithm best used the available data to solve the problem of predicting ice cream sales.

Teachers need to understand that models are incomplete representations of reality, as they often focus only on a specific aspect of a system. A famous maxim in statistics (generally attributed to George Box) is, “All models are wrong, but some are useful.” This emphasizes that a model is not judged by its representation of reality alone, but also by its usefulness. “The map is not the territory” (attributed to Alfred Korzybski) is another maxim that reminds us that models (maps) differ from reality, so they must be interpreted with the understanding of their limitations and their strengths. A “good” model might be a good match for the provided data, but it’s no guarantee that the model is a good match for reality if the data itself falls short.

Models may be represented in different fashions. Traditionally, statistical models have been represented mathematically. But the same models can also be represented through code in a programming language or through a physical mechanism. Code follows specific syntax and structure determined by the language being used (R, Python, etc.). Such syntax structure can be thought of as a model. Code carries out estimations of statistical models and serves as the foundation for carrying out human languages through computers.

Simulations are also models. A simulation is a model of a random process found

Modeling activities
provide excellent
opportunities for
synthesizing content
knowledge.

in the real world by using hands-on manipulatives, applets, or computers. A simulation is designed to mimic a real-world scenario. While simulating random processes, teachers can use physical randomizing devices (e.g., balls in bags, coins, dice, spinners) to build models that answer questions about random systems. These physical experiences are limited in the number of repetitions we can expect to accomplish within the time constraints (and physical constraints) of a classroom. However, they should precede software-driven simulations, which can allow modelers to carry out hundreds of thousands of repetitions of their experiments. For example, see Podworny (2018) or Bargagliotti and Franklin (2021) for a series of simulation-based investigations for teachers. Teachers should be able to design simulations to be carried out by their students. This entails mapping a real-world random process to a model of that random process that can be tested and

repeated. Such simulations not only provide experience in model-building, but also it deepens conceptual understanding.

While applets and software provide tools for modeling, programming languages can also be used at more advanced levels. Software programs are models of systems and can be used not only to “fit” specified models, but also to create dynamic models that update over time and adjust to new situations. Schulte (2024) refers to these as “representational” and “transformative” models, respectively. Generative AI (e.g., ChatGPT) is an extreme example of a transformative, data-driven model. By engaging in the modeling process, teachers will better understand these “transformative” models as the incomplete representations of reality that all models are.

Teacher educators should offer frequent experiences to teachers to engage in modeling activities of all sorts—the SPSP, simulation-based activities, statistical modeling of all types, data collection, and data consideration. Modeling activities provide excellent opportunities for synthesizing content knowledge. Model-eliciting activities are an approach for designing classroom activities that make communication explicit about modeling, and, as such, are useful for formative assessments of student learning (Lesh et al., 2000).

V. Using Technology as a Tool for Learning and Doing Statistics

The practice of statistics is closely tied to computing technology. Technology, as *Pre-K–12 GAISE II* recommends, should be used for teaching, learning, doing statistics, and working with data. The rise of generative AI tools means teachers and students now have technology tools that can improve productivity, although this report recommends caution when using these tools for teaching and learning due to very little available research on the impact on learning and understanding. Emerging work on the effects of AI on brain development and learning indicate the accumulation of cognitive debt when using GAI due to weaker neuron connectivity (Kosmyna et al., 2025).

There are various software tools available that assist in working with data. Teacher educators should be aware of what is available and be able to introduce teachers to such tools and have them explore the benefits and drawbacks of various tools. Teacher educators can help teachers sift through decision factors when selecting appropriate technology for their classrooms. These factors may include cost (there is plenty of free software available), whether the technology runs in the cloud or installs locally, whether it runs on mobile

devices or requires a computer, whether a login is required, whether the security protocol is supported by the district, and whether the technology's features are conducive and grade-level appropriate for the statistics and data concepts one is trying to teach. McNamara (2019) wrote that educational software should be designed as accessible and simplified tools for students in early grades. Then, a gradual scaffolding to complex programming languages is appropriate. Ideally, she wrote, students would use a single software tool that would be capable of accommodating students at all levels and be capable of meeting their needs no matter which developmental level they had achieved. Such software does not yet exist, so teacher educators must help teachers recognize which technology is appropriate for specific topics and levels. Biehler (1997) distinguished between “microworld” software, which are applications designed to help students understand a single concept or a small collection of related concepts, and “tools,” which are software designed for students to analyze and/or examine data. McNamara emphasized that, particularly at early stages, software should have a low barrier for entry and should not stand in the way of learning statistical concepts. The Common Online Data Analysis Platform (CODAP; The Concord Consortium, 2026) is a current software package designed specifically to develop students' reasoning in the

presence of complexly structured data types. It includes many features of earlier generation software such as Fathom and Tinkerplots (Konold et al., 2017).

Currently, there are several secondary-level curricula in which students use either R or Python programming languages. It's important to note: There is no right or wrong tool. When teachers and students learn any kind of programming, the knowledge transfers to other current tools and those of the future. These curricula are carefully structured with the intention that “coding” is introduced slowly and does not interfere with learning statistical concepts—although there is, to date, little literature that supports whether such an approach improves students' understanding of core statistical concepts. Most of these curricula rely on specially designed libraries (R) or packages (Python) that provide scaffolding to novice programmers. One advantage of using these packages and libraries is that they achieve many of the goals that McNamara (2019) says are important for “doing” statistics, including respecting the data as an object that can be re-structured and altered, while retaining the original information. These packages also provide flexibility in creating graphics, support for designing randomization-based procedures (*GAISE II* Level C), user interactivity, support for creating reports, and support for achieving “reproducibility,” where outsiders

can review all steps of an analysis and pass judgment on its validity. However, the barriers-to-entry for users of programming languages are high and often reserved for postsecondary studies.

A primary challenge of technology is also accessibility. Even “free” software often requires infrastructure that may or may not exist in all classrooms. This fact raises equity issues and challenges educators to find “unplugged” alternatives. In many cases, hands-on manipulatives can carry substantial educational weight, but the fact remains that modern statistical practice relies on technology—in particular for the secondary level. Unplugged exercises should be used primarily to create meaning and understanding for computationally implemented procedures. One area in which technology is routinely used, at least in secondary curricula, is data cleaning (Kim et al., 2018). Data cleaning refers to the practice of preparing data for analysis and often requires the application of “data moves” (Erickson et al., 2019, Hudson et al., 2024), such as filtering data (focusing on specific rows of a dataset), renaming variables, correcting incorrect values, and creating new values from old. Secondary teachers should be familiar with introductory data moves and be able to carry them out using technology. While students may or may not carry out these data moves using technology, teachers should have

this experience since they will likely, at some point, need to clean data before sharing the datasets with students. They should be able to demonstrate how data almost always needs some cleaning before analysis. Therefore, teacher educators should assist teachers in assessing which level of “cleanness” is appropriate for their students and in acquiring basic data-cleaning “data moves.”

Key content in statistics that lends itself to technology is developing simulations to estimate probabilities and carry out randomization tests. The notion of probability as a frequency lends itself nicely to “algorithmic thinking,” which is the ability to create algorithms that solve problems and to recognize when an algorithm is required. Algorithmic thinking (Knuth, 1985) is seen as a key component of computational thinking, which is itself an important aspect of statistics. When asking about the probability of an event, the probability-as-frequency approach implicitly assumes an action that can be repeated over and over. Computers excel at that repetition. *Pre-K–12 GAISE II* recommends that students begin their simulations with hands-on, tactile objects (e.g., rolling a pair of dice many times to answer whether it is more likely to get a sum of seven or eight) before using technology to simulate such scenarios (see Bargagliotti & Franklin, 2021, for the development of teacher knowledge in probability using simulations).

Developing computational thinking in the presence of data is important, since it leads to understanding the tools used in machine learning (a field that develops, deploys, and refines predictive models at large scale) and AI. Naturally, not all teachers and students will become machine learning specialists or developers of AI tools, but such tools are increasingly present in our society and have large and lasting impacts. There is a sizable and growing literature of the harmful effect of predictive algorithms on college rankings, criminal recidivism, and disparities in personal loans (e.g., Noble, 2018; O’Neil, 2016). However, computational thinking, coupled with statistical thinking, can help teachers understand how these algorithms are “trained,” and the role data plays in that training, which is necessary for all teachers.

One particular group of AI tools—GAI—are now widely known and used (e.g., ChatGPT, Microsoft Copilot, Claude). Such tools mimic human language and can provide uncannily human-like solutions to complex issues. For this reason, there is much discussion about how, when, and if at all, to integrate GAI into education. Because these tools are trained on datasets, their ability to be useful depends strongly on the quality of the data used to develop them. Teacher educators and teachers of statistics bear particular responsibility for considering how, when, and whether

to integrate them into the classroom (as noted above, see Kosmyna et al., 2025 for research on the effects of GAI on the brain). This report considers two main roles for which the teacher educator must prepare teachers: (1) to help students understand how GAI “works” at a conceptual level, so they can be critical consumers and proficient users of GAI tools and (2) to help students appreciate GAI as a productivity tool that might assist or harm (Miao et al., 2024) both teachers and students.

Statistics is the science of data, and because GAI are, in one sense, very complex functions, whose parameters have been determined based on specific datasets (training data), statistical science can help understand how GAI works. GAI are functions in the sense that they accept input and produce output. Teacher educators can help teachers develop a sophisticated understanding of the importance of data quality when using models designed to address specific research questions or attend to specific purposes. The practice of statistical modeling, as exemplified by the SPSP, leads to and includes studying predictive modeling, albeit at a fairly small scale. These experiences build a foundation for understanding the inner workings of many large-scale predictive engines now part of our everyday lives. Good examples of these engines are the algorithms that predict which TV shows one will

like and which advertisements you're shown, and even whether an applicant should be given a loan.

Many issues discussed in the media, such as facial recognition software that fails more frequently with women or people of color, or voice-recognition systems that fail to work for people with specific accents, can be understood and anticipated (and, one hopes, prevented) through the lens of statistical concepts embedded throughout the framework of this report (Chapter 3). For those who wish to develop GAI or (for the rest of us) those who will be working alongside GAI tools, these all play a fundamental role: the notion of statistical bias, the need for representative samples of data, the importance for high-quality data, the potential disconnect between intended populations and actual populations of a study, the notion of margin of error, and the role of probability in measuring successful classification.

If appropriate, GAI may be used as a productivity tool, for example, by generating lesson plans or content material for lessons. However, we advise extreme caution. Lack of evidence exists to show that such usages actually produce high-quality teaching materials or foster learning in students. GAI lesson plans may, for example, fail to meet statistical education guidelines endorsed by this document (see example in Chapter 5 of this report).

One reason for this is that GAI applications are likely trained on lessons from the internet that did not meet the rigorous standards of *GAISE II* and other quality, peer-reviewed research. So, suggestions made by GAI may not meet our quality standards, and they may not meet learning outcomes in the classroom. Teacher educators could provide opportunities for teachers to critically review lesson plans generated by GAI to determine if they meet reputable guidelines and are appropriate for the classroom and students. See *MET III*, Chapter 2, for a discussion on teaching with AI.

Increasingly, GAI “copilots” are used to assist in data analysis activities and may be integrated into the SPSP. For example, a copilot AI might notice that your statistical investigative question involves comparing two groups and might make suggestions for analytical tools for making this comparison. The sophistication of these tools is changing rapidly, and it is difficult to predict, at the time of writing, whether such tools will alter the way statistical analyses are carried out and whether those using such tools develop any meaningful understanding of what they are doing. For teacher educators, it's important to recognize that little research exists on how well such tools actually promote learning statistics and how to work with data. While it is tempting to draw parallels with

the introduction of the calculator into mathematics classrooms, calculators merely compute based on provided formulas. GAI goes far beyond this by choosing a formula to compute based on vague and imprecise prompts. Our hope, at the time of this writing, is that research on the impact of GAI on learning expands.

VI. Developing Statistical Habits of Mind

Chapter 1 described the three pillars of teacher preparation in statistics: (1) the essential content for student learning, (2) the subject matter expertise teachers need, and (3) effective teaching practices needed to support student learning. Based on these three pillars, teacher educators should strive to engage teachers with data problems that encourage them to develop and internalize practices or dispositions in making sense of the problem at hand. These dispositions (or practices or strategies) can be thought of as habits of mind. They are dispositions that problem-solvers utilize to work through challenging or unsolved problems. Habits of mind are naturalized, fine-tuned, and continually practiced, always providing guidance as one solves problems (Costa & Kallick, 2009). Teachers must develop dispositions for engaging in statistical reasoning like curiosity and desire to seek deeper meaning. It is also

important that teachers have a healthy disposition toward valuing the role of statistics in society (CBMS, forthcoming). They should consider it important to a student's K–12 education.

SET I introduced the eight Mathematical Practices Through a Statistical Lens (Franklin et al., 2015, pp. 9–12) and interpreted them through the lens of practices or dispositions necessary to acquire and apply statistics knowledge. Teacher educators should model these habits of mind in their teaching as they support teachers experiencing the statistical knowledge recommended in the learning outcomes frameworks. **Table 2.2** presents these practices.

Teacher educators are encouraged to use these eight practices and the corresponding interpretations from *SET I* (found in the appendix) as a foundation for introducing the concept of statistical habits of mind. *SET II* has enhanced the importance of statistical habits of mind with the seven cross-cutting themes and pillar three that encourages best teaching practices (see Chapter 1, Figure 1.3). It is important for teacher educators to emphasize the role of teacher practice in the classroom to guide students in developing statistical habits of mind for reasoning with data.

Statistical habits of mind should be automatic—naturally occurring without

Table 2.2. Mathematical Practices Under a Statistical Lens

Mathematical Practices Under a Statistical Lens			
Make sense of problems and persevere in solving them.	Reason abstractly and quantitatively	Construct viable arguments and critique the reasoning of others	Model with mathematics (data).
Use appropriate tools strategically.	Attend to precision.	Look for and make use of structure.	Look for and express regularity in repeated reasoning.

thought. When presented with an investigative problem that requires data, a habit of mind should be to automatically implement the SPSP. As the SPSP is being carried out, other habits of mind should naturally be a part of the reasoning process.

For example, “make sense of problems and persevere in solving them” is a habit of mind necessary for students and teachers to critically reason using their statistical knowledge (pillars one and two). Another necessary habit of mind is continual questioning throughout the SPSP. Pillar three recommends teachers implement effective teaching practices in the classroom to create an environment for students to naturally develop these necessary statistical habits. One such teaching practice is to implement tasks that promote reasoning and problem solving, support productive struggle, and pose purposeful questions that encourage making sense of problems and perseverance. Another automatic disposition should be to use appropriate tools

strategically. A standard teaching practice should be to consider incorporating such tools as visuals in the classroom that document learning as it occurs, hands-on manipulatives (spinners, snap cubes), or some form of technology (calculators, computer software, applets).

Habits of mind are critical for becoming a sound statistical thinker who makes sense of our world through data. The practices in **Table 2.2**, the discussions of the cross-cutting themes, and the Chapter 5 examples are excellent resources to help teachers recognize that developing and refining these habits is a continuous learning journey. For more reading on statistical habits of mind, see Lee and Tran (2015).

VII. Adhering to Humanistic Practices

A goal of education is ensuring the success of all learners. Such success is contingent upon all students—regardless

of background, ability, or prior experience—having access to meaningful learning opportunities. By integrating specific strategies to meet the needs of every learner in statistics education, teachers can move closer to ensuring that all students can develop skills necessary for success in a data-driven society. For teachers to be able to do so, teacher educators might take what Lee and colleagues (2021) refer to as a humanistic stance. Humanistic aspects of working with data involve attending to three intertwined layers—personal, cultural, and sociopolitical—that influence learners’ opportunities to learn with data (Lee et al., 2021).

The personal layer (PL) “focuses on the immediate experiences, interests, prior knowledge, and other personal aspects that inform learners’ reasoning about a dataset” (Lee et al., 2021, p. 665). The cultural layer “involves the sociotechnical tools, artifacts, and cultural practices that guide and maintain a community of participants in activity” (Lee et al., 2021, p. 666). The sociopolitical layer “speaks to the ways in which a given dataset, and the ways data are collected and used more generally, reflect and are shaped by power dynamics” (Lee et al., 2021, p. 667). The following table provides some specific learning outcomes for students and teachers that attend to PL, CL, and SL for the components of the SPSP.

Beyond what teachers should know and be able to do with each component of statistical problem solving to adapt to human dimensions of students’ engagement with data, teachers should develop overarching knowledge and skills that relate to the whole process. Here is a non-exhaustive list of examples of humanistic practices related to the whole process:

- (PL, CL, and SL) Use effective teaching practices and strategies (NCTM, 2014, 2018, 2020a, 2020b) to meet the needs of all learners.
- (PL) Engage students with tasks for statistical investigation that involve students in the entire problem-solving process, are culturally relevant, draw on students’ funds of knowledge, and allow multiple paths for success (e.g., NCTM, 2018).
- (PL) Pose purposeful questions to support student participation, position students as capable, and listen and respond to students to show that their thinking is valued (e.g., NCTM, 2018).
- (PL) Empower students to take ownership of their learning by focusing on sensemaking and offering choice in learning (Seda & Brown, 2021).
- (CL) Use culturally relevant data (Weiland & Williams, 2024) and data that allow learners to see themselves in the data (Schwabish &

Table 2.3. Humanistic Practices Within the Statistical Investigative Process

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do for Sstudents to Engage with Data from the Identified PL, CL, and SL Layers
I. Formulate statistical investigative questions	
• Identify and generate appropriate investigative questions. • Consider how other students could see themselves differently with respect to an investigative question. • Identify cultural assumptions that might underlie investigative questions. • Identify what expertise is beneficial to answer investigative questions.	• Determine questions that should not be pursued, given their context, versus those that could be improved (PL, CL, SL). • Anticipate the type of data that aligns with answering the investigative question, considering, for example, informed consent or whether the question is appropriate for all students (PL). • Design instruction for students—regardless of background, ability, or prior experience—to help build their statistical agency (PL, SL) to participate in generating investigative questions that are both personally and socially meaningful. • Identify investigative questions about societal systems that students can appropriately consider with variables available (PL, CL, SL). • Help students recognize cultural assumptions and biases in the questions they pose (PL, SL). • Recognize context knowledge differences among students for a given statistical investigation and design the launch of the investigation accordingly (CL). • Develop strategies to support some students in gaining understanding of the context for investigation, including tapping into other students’ funds of knowledge (PL, CL). • Use student-generated questions as opportunities to learn about students, and build upon their funds of knowledge (PL, CL). • Identify strategies that can help students see themselves as learners and doers of statistics by, for example, developing appropriate investigative questions that can build on their funds of knowledge in order for students to develop positive statistical identities (PL).

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do for Students to Engage with Data from the Identified PL, CL, and SL Layers
II. Collect/Consider Data	
• Consider how other students could see themselves differently in data used to answer an investigative question. • Interrogate the data to find missing or underrepresented variables or populations within datasets. • Identify biases that might occur during data collection, or are held by data collectors, by comparing multiple datasets related to the same context and/or to answer the same question.	• Identify how different students might see themselves differently in relation to data (PL, CL). • Use representations that make data analysis accessible to all students, including those with physical differences like blindness (e.g., Schwabish & Feng, 2021) (PL, CL) • Identify students' familiarity with data context and recognize that not every context or dataset needs to be of interest or relatable to the lives of every student, but students should be able to learn enough about the context to engage in the investigative process (PL). • Recognize that students often have different degrees of knowledge about a given context; use students to leverage their funds of knowledge in the classroom to familiarize all students with the context (PL, CL). • Provide experiences for students to consider the representativeness of the data in relation to the question (SL). • Describe the fidelity of the provenance of the data when, for example, it comes from a particular advocacy group (SL). • Identify biases in data gathered by students or in pre-existing data to be used for investigation (SL). • Provide students with examples of data with specific biases (SL). • Attend to ethical aspects of data collection, such as privacy and informed consent, as necessary when collecting data and recognize when students' data collection plans need such elements (SL). • Foster classroom discourse to develop norms for data collection and data sharing that maintain privacy and respect student autonomy and to investigate ethical considerations in data collection with human and animal subjects (SL). • Describe ways privacy can be maintained or violated (e.g., even data files without names might include identifying information) and the benefits/harm of privacy keeping, particularly in a classroom data collection context for students (SL).

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do for Students to Engage with Data from Identified PL, CL, and SL Layers
III. Analyze Data	
• Use accommodations as needed to analyze data. • Interrogate data visualizations/ displays for potential biases.	• Consider ways that students with physical differences (e.g., blindness) might analyze data, such as through data visualizations (see, for example, Schwabish & Feng, 2021), and develop strategies to address their needs (PL). • Provide students with examples of biased visualizations. For example, D'Ignazio and Klein (2020) presented bar charts depicting mental illness diagnostic rates by race for incarcerated individuals in New York that differed only by their title and framing. The chart with a generic title of "Mental Health in Jail" failed to fully communicate the context of the data, the focus of the study, and the findings from the study that produced the data, namely the disparate diagnoses associated with race and ethnicity (SL). • Recognize the limits of the analysis that can be accomplished with the data at hand in terms of, for example, analytical skills, missing variables, bias from missing values, etc. (SL). • Recognize how students' context knowledge can influence their analysis of data (PL, CL). • Provide multiple access points for students to analyze data (e.g., technology use), and use multiple representations of data (PL, CL).
Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do for Students to Engage with Data from the Identified PL, CL, and SL Layers
IV. Interpret	
• Describe how different people might interpret conclusions from data differently.	• Encourage students to consider their conclusions from multiple perspectives, and, when appropriate, point them to valid research that shows alternative points of view (CL, SL). • Use scaffolding strategies to provide multilingual learners with multiple ways to interpret their results (PL).

- Feng, 2021) for student engagement in the SPSP.
- (CL) Negotiate classroom norms for participation (implicit or explicit expectations for classroom behavior) that position students as valuable contributors.
 - (CL) Know and follow professional ethical guidelines for statistics practitioners (e.g., ASA, 2022).
 - (SL) Use the SPSP to better understand societal issues and make decisions from data.
 - (SL) Describe the importance of human-to-human interaction throughout the SPSP to minimize biases and enrich conclusions.

Teacher educators can support teachers' development of humanistic practices by engaging teachers as students in learning statistics, modeling effective instructional strategies, and making the learning and teaching that occurred explicit (e.g., Conference Board of the Mathematical Sciences, 2012). For teacher educators, this means engaging teachers in the SPSP and the components of the process that help teachers achieve the identified student learning outcomes. It also means providing teachers with learning opportunities to achieve teacher learning outcomes. Teacher educators also can provide teachers with resources, such as culturally relevant data and social justice tasks, that support the teaching and learning of statistics content

(e.g., Bartell et al., 2022; Berry et al., 2020; Consortium for the Advancement of Undergraduate Statistics Education, 2026; Conway et al., 2022; D'Ignazio & Klein, 2020; ESTEEM, 2025; Koestler et al., 2022; Mathematics of Doing, Understanding, Learning, and Educating for Secondary Schools (MODULE(S2), n.d.); Proponents of Civil Statistics, n.d.; Schwabish & Feng, 2021; Weiland & Williams, 2024).

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Chapter 3

Introduction to the Framework for Teacher Learning Outcomes in Statistics and Data

This framework serves as a bridge between established student learning standards and the complex realities of classroom instruction.

Overview and Purpose

The landscape of education continues to evolve and demand that educators not only master their subject matter but also develop sophisticated understanding of how students learn, grow, and demonstrate competency. This Framework for Teacher Learning Outcomes in Statistics and Data outlines a developmental approach to teaching pre-K–12 school level statistics. Using the *Pre-K–12 GAISE II* developmental progression of statistical thinking, teacher educators are encouraged to engage teachers as learners in the complete Statistical Problem-Solving Process. This provides teachers with opportunities

to experience the *Pre-K–12 GAISE II* student learning outcomes firsthand. This framework provides educators with a structure for understanding and supporting student learning outcomes, matched with additional outcomes specifically for teachers. The Cross-Cutting Big Ideas presented in Chapter 2 should be integrated throughout this framework. Teacher educators should model effective instructional strategies encompassing the Cross-Cutting Big Ideas and make the learning and teaching explicit.

This framework serves as a bridge between established student learning standards and the complex realities of classroom instruction. Rather

than prescribing rigid methodologies or establishing minimum competency requirements for teachers, it offers an illustrative guide that deepens professional understanding of how teaching practices can be intentionally aligned with student knowledge, skills, and abilities. The framework recognizes that effective teaching is both an art and a science, requiring educators to draw upon pedagogical content knowledge, understanding of learning processes, and awareness of individual student needs.

The primary purpose of this framework is to enhance teacher effectiveness by providing clear connections between what students are expected to learn and how teachers can structure their practice to support that learning. It acknowledges that student success depends not merely on curriculum coverage or instructional delivery, but also on the quality of teacher decision-making, the depth of pedagogical understanding, and the ability to adapt instruction based on ongoing assessment of student progress. This framework provides teacher educators a structure to guide course design and professional development design in statistics and data literacy for all school-level teachers, regardless of subject field.

The Framework for Teacher Learning Outcomes in Statistics and Data is organized as a crosswalk that systematically

The primary purpose of this framework is to enhance teacher effectiveness by providing clear connections between what students are expected to learn and how teachers can structure their practice to support that learning.

connects the *Pre-K–12 GAISE II* student learning progression with corresponding teacher-practice elements. This crosswalk structure serves multiple purposes. It honors the extensive work already done in defining what students need to know, it provides familiar reference points for educators already working with *Pre-K–12 GAISE II*, and it creates clear pathways for professional development and instructional planning for teachers and teacher educators.

As described in Chapter 1, the Effective Teaching Practices framework deliberately positions itself as a complement to *GAISE II*; the crosswalk structure allows

teacher educators to see direct connections between familiar student learning outcomes and the corresponding teacher practices that support those outcomes. For example, where *Pre-K–12 GAISE II* states, “Understand when a statistical investigation is appropriate,” the corresponding teacher-practice elements address instructional strategies for supporting student learning to meet this outcome.

This alignment serves several important functions. First, the alignment helps teachers understand that their professional practices are not separate from student learning outcomes, but are integral to achieving them. Second, it provides a systematic way for teachers to analyze their current practices against student learning expectations and identify areas for growth and development. Third, it creates a common language and structure for professional conversations about teaching effectiveness and student success. Fourth, it provides a mapping for teacher educators to use in teacher-learning opportunities. The crosswalk structure allows for flexibility in application while maintaining coherence with *Pre-K–12 GAISE II*.

As noted earlier, it is crucial to understand that this Framework for Teacher Learning Outcomes in Statistics and Data is designed to be illustrative rather than prescriptive. The framework does not establish minimum competencies

or create rigid requirements for teacher practice. Instead, it provides guidance that educators can adapt. This approach acknowledges that there is no single “right” way to teach any particular concept or skill. Teacher educators should reinforce and demonstrate that effective teachers draw upon a repertoire of strategies and make professional judgments about which approaches will be most effective for their specific students. The framework also recognizes that effective teaching is responsive to student needs and learning contexts. What works well in one classroom may not be appropriate in another.

The framework is structured so that each *Pre-K–12 GAISE II* student outcome is listed for the four components of the Statistical Problem-Solving Process and recommended outcomes for “what teachers need to know and to do” to develop corresponding student learning outcomes. The teacher framework is subdivided for each level (A, B, and C), encouraging vertical alignment of using developmentally appropriate strategies to take students through the evolution of developing statistical thinking.

The framework’s emphasis is on illustration rather than prescription; its flexibility for adaptation to different contexts and its focus on deepening understanding of student learning processes position it as a resource. For teacher educators, this

means engaging teachers in the Statistical Problem-Solving Process that includes data collection and analysis in meaningful contexts for a relevant investigative question. It also means developing teachers' identities and agency by engaging teachers in reasoning and sensemaking with data. Teacher educators also can provide teachers with resources such as relevant tasks, high-level questions that support the teaching and learning of statistics content, case studies to evaluate, and student work samples to critique and reflect upon. Teacher educators are encouraged to help teachers recognize how to align the *Pre-K–12 GAISE II* student learning outcomes with state and national standards and to support cross-curricular integration in all subjects. Developing into a mature statistical thinker is a lifelong journey for everyone. The framework for teacher learning outcomes aims to provide teacher educators with well-researched guidance to build strong foundations in statistical thinking and data literacy for school-level teachers and their students.

The ultimate goal of the Framework for Teacher Learning Outcomes in Statistics and Data is to deepen teacher understanding of how to support student development of knowledge, skills, and abilities. It's a guiding resource for teacher educators to help teachers develop what might be called "learning-focused expertise"—the ability to see their instructional practices through the lens of student learning outcomes. The framework also emphasizes the importance of understanding learning as a process rather than a product. The Framework for Teacher Learning Outcomes in Statistics and Data helps teacher educators understand the developmental progressions that lead to the desired *Pre-K–12 GAISE II* outcomes. This includes understanding how knowledge and skills develop over time, how different types of learning build upon one another, and how to support teachers (and students) who may be at different points in their learning journey.

Chapter 3A

Framework for Teacher Learning Outcomes in Statistics and Data—Level A

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
I. Formulate Statistical Investigative Questions	
Understand when a statistical investigation is appropriate.	- Describe how data helps people make decisions and answer questions. - Compare and contrast deterministic/mathematical questions and statistical/data questions. - Design appropriate statistical investigations. - Pose purposeful questions to evaluate and advance students' understanding of statistical/data questions and how they differ from deterministic/mathematical questions.
Pose statistical investigative questions of interest to students where the context is such that students can collect or have access to all required data.	- Use the entire dataset as the defined population for statistical investigative questions. - Explain that statistical investigations require more than one data point to answer the investigative question. - Evaluate whether it is possible to answer a posed statistical investigative question. - Evaluate whether the context of a posed statistical investigative question is age-appropriate and developmentally appropriate for students.
Pose summary (or descriptive) statistical investigative questions about one variable regarding small, well-defined groups (e.g., subset of a classroom, classroom, school, town) and extend these to include comparison and association statistical investigative questions between variables.	- Explain the progression of statistical investigative questions, from descriptive to comparison questions, where the population goes from small (e.g., a subgroup of the class) to large (e.g., the whole class, several classes, the whole school, community). - Identify datasets for students to pose descriptive versus comparative questions.

Experience different types of questions in statistics: those used to frame an investigation, those used to collect data, and those used to guide analysis and interpretation.	• Explain how statistical questions include, but are not limited to, statistical investigative questions. • Create statistical questions beyond the investigative question for each phase of the Statistical Problem-Solving Process. • Facilitate meaningful discourse to distinguish between statistical investigative questions and other types of statistical questions.
Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
II. Collect/Consider Data	
Understand that data are information; recognize that to answer a statistical investigative question, a person may collect data themselves specifically for that purpose, or a person may use data that have been collected by other people for another purpose.	• Describe how a dataset can have attributes (variables) of different types, traditional (numerical, categorical), or non-traditional (e.g., photos, texts, sound). • Collect, organize, record, and store different types of data in different forms appropriate for statistical investigations. • Guide students to make connections among multiple, age-appropriate representations of a dataset, including sticky notes, data cards, and data tables. • Explain how a representation, such as a data card or sticky note, can represent a case in a dataset. • Explain the difference between raw data and summary data.
Understand how to collect and record information from the group of interest using surveys and measurements collected from observations and simple experiments.	• Explain that the statistical investigative question posed determines the type of study design necessary to collect/consider the appropriate (traditional/non-traditional) data. • Distinguish between survey questions and statistical investigative questions. • Recognize that the phrasing of a survey question can influence the response. • Pose tasks that lead students to recognize the importance of having a comparison group in data collection for simple experiments.
Understand that a variable measures the same characteristic on several individuals or objects and results in data values that may vary among individuals and objects.	• Create tasks that guide students to describe the population for a given statistical investigative question, identify the unit of observation (case), and recognize that variables provide characteristics of the case. • Determine implausible values, if any, of different variables due to variability within a dataset.

Understand that within a dataset, there can be different types of variables (e.g., categorical or quantitative).	Facilitate discourse to encourage students' multivariable thinking by taking multiple measurements on the same observational unit.
Interrogate the dataset to understand the context of the variables and how they may relate to statistical investigative questions.	- Demonstrate a variety of strategies for questioning the quality of the data. - Determine if the data collected/considered will lead to answering the statistical investigative question that will be used with students.
Understand that data are not always pristine but may contain errors, have missing values, and that decisions must be made about how to account for these issues.	- Identify different sources of errors such as data entry errors or measurement errors as opposed to true outliers. - Demonstrate a variety of strategies for cleaning/correcting datasets (e.g., categorical data for color with separate categories blue and blue and incorrect data values like an individual's height of 5 in).
Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
III. Analyze the Data	
Understand that the distribution of a categorical variable or a discrete quantitative variable describes the number of times a particular outcome occurs.	Develop opportunities for students to explain what the distribution of a categorical or quantitative variable represents or summarizes.
Represent the variability of categorical variables or quantitative/numerical variables using appropriate displays (e.g., tables, picture graphs, dotplots, bar graphs).	- Explain appropriate techniques for representing categorical or quantitative variables (e.g., graphs using actual objects, picture graphs, data cards, tables, bar graphs for categorical variables and tables, dotplots, histograms for quantitative variables). - Provide students with datasets that include categorical or quantitative data for students to appropriately represent the data. - Create/curate tasks that compare and contrast different representations of categorical or quantitative data.

Describe key features of distributions for quantitative variables such as: • Center: mean as the equal share, and median as the middle-ordered value of the data • Variability: range as the difference between the greatest and least value, and dispersion as how many units from the equal share value • Shape: number of clusters—symmetric or not—and gaps	• Pose assessing and advancing instructional questions for students to explain the center, variability, and shape of a distribution within the context of the statistical investigative question. • Facilitate discourse for students to identify outliers informally by providing opportunities to explain unusual observations in a distribution and provide justifications.
Recognize that distributions can be used to compare two groups.	• Explain the difference between describing distributions and comparing distributions. • Pose assessing and advancing instructional questions for students to use comparative language (i.e., less than, greater than, equal to) to compare distributions of two groups for center, variability, and shape within the context of the statistical investigative question.
Observe whether there appears to be an association between two variables.	• Create/curate scatterplots that address statistical investigative questions, and ask students to make informal observations about trends and the strength of trends for two quantitative variables, justifying any association between the two variables.

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
I. Interpret the Results	
Make statements about the group or population from which the data were collected, recognizing that these conclusions are limited to these groups and cannot be generalized to other groups.	• Assess students' sampling methods in terms of how likely they are to produce representative samples of populations (teachers can use their knowledge of simple random sampling as a starting point for making such assessments). • Ask questions that prompt students to recognize limitations to the scope of their interpretations (e.g., one classroom may not be representative of an entire school). • Identify possible sources of variability within and across student-generated datasets. • Create early opportunities for students to consider data collection methods that support more generalizable interpretations than collecting data from a single classroom.
Describe the difference between two groups with different conditions.	• Build lessons that include simple experiments comparing two groups with different imposed conditions. • Have students interpret results of simple experiments where the difference in conditions is clearly meaningful versus those where the difference is not clear in preparation for comparing groups at Level B.

Chapter 3B

Framework for Teacher Learning Outcomes in Statistics and Data—Level B

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
I. Formulate Statistical Investigative Questions	
Recognize that statistical investigative questions can be used to articulate research topics and that multiple statistical investigative questions can be asked about any research topic.	• Generate multiple statistical investigative questions from a research topic. • Distinguish between statistical investigative questions that lead to categorical variables or quantitative variables.
Understand that statistical investigative questions consider context as well as variability present in data.	• Facilitate discourse for students to compare deterministic/mathematical questions and statistical/data questions that anticipate variability. • Identify contexts that are age and developmentally appropriate for students to develop statistical investigative questions.
Pose summary, comparative, and association statistical investigative questions about a broader population, using samples from the population and from secondary data sources (e.g., online sources, websites, other digital resources).	• Anticipate the types of statistical investigative questions that students might generate for a given realistic, approachable context. • Evaluate student-generated statistical investigative questions using the characteristics of good statistical investigative questions described in the Questioning section of Chapter 2. • Demonstrate strategies for guiding students as they struggle productively to improve their initial questions into appropriate statistical investigative questions. • Create tasks with authentic opportunities for students to engage in formulating their own questions during statistical investigations.

Pose statistical investigative questions that require looking at a variable over time.	Identify the types of statistical investigative questions that lead to collecting data over time.
Understand that there are different types of questions in statistics: those used to frame an investigation, those used to collect data, and those used to guide analysis and interpretation.	- Identify and exemplify multiple types of statistical questions: statistical investigative questions, survey/data collection questions, analysis questions, interpretive questions, and interrogative questions. - Critique different types of statistical questions found in existing curricula.
Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
II. Collect/Consider Data	
Understand that data are information collected and recorded with a purpose and can be organized and stored in a variety of structures (e.g., spreadsheets).	- Collect/consider data (with or without the aid of technology) and organize, record, and store different types of data in different forms appropriate for statistical investigations. - Justify how collected/considered data connect to the statistical investigative question posed. - Engage students in activities to identify and describe populations of interest for specific investigative questions. - Recognize that students bring their own notions of data representations and describe scaffolding to bring them from one representation to another.
Understand that a sample can be used to answer statistical investigative questions about a population. Recognize the limitations and scope of the data collected by describing the group or population from which the data are collected.	- Compare and contrast censuses with samples. - Compare and contrast the statistical meaning of “sample” with the everyday usage of the term and identify implications for curricular design. - Engage students in activities to explore if and how a sample might be representative of a population for a particular variable of interest. - Recognize that relatively small samples can be representative of the population.
Understand that data can be used to make comparisons between different groups at one point in time and the same group over time.	- Collect/consider data to compare two groups. - Collect/consider data from a single group to consider characteristics that change or remain the same over time. - Compare and contrast comparisons between two groups at one point in time with comparisons made for a single group over time.

Recognize that data can be collected using surveys and measurements, and develop a critical attitude in analyzing data collection methods.	• Distinguish among surveys, observational studies, and experiments, and describe defining characteristics of each. • Create/curate examples for students to distinguish between statistical investigative questions and survey questions. • Describe and exemplify how the phrasing of a survey question can influence the response (e.g., open versus closed questions; leading questions, etc.) and different biases that can result from the phrasing of survey items. • Pose multiple survey questions to address multiple aspects of a particular topic; demonstrate strategies appropriate for guiding students to pose appropriate survey questions to address statistical investigative questions. • Identify potential biases in data gathered by students or in pre-existing data to be used for an investigation.
Understand that quantitative variables may be either discrete or continuous.	• Describe different forms that quantitative variables might take (e.g., discrete or continuous).
Understand how to interrogate the data to determine how the data were collected, from whom they were collected, what types of variables are in the data, how the variables were measured (including units used), and the possible outcomes for the variables.	• Facilitate discourse that encourages students to question the quality and appropriateness of a dataset.
Understand that data can be collected (primary data) or existing data can be obtained from other sources (secondary data).	• Engage students with explorations that use primary data (data collected by the students) and explorations that use secondary data (data obtained from other sources) to answer statistical investigative questions.
Understand how random assignment in comparative experiments is used to control for characteristics that might affect responses.	• Engage students in activities that enable them to see how random assignment controls for potentially confounding factors. • Design experiments that are age- and development-level appropriate for students to collect data.

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
III. Analyze the Data	
Represent the variability of quantitative variables using appropriate displays (e.g., dotplots, boxplots).	• Describe the affordances and constraints of different types of data representations for quantitative variables (e.g., case value plots, histograms, boxplots), and represent distributions using multiple representations to tell the story of the data. • Elicit students' interpretations of commonly used data displays and use advancing questions to move students to normative interpretations. (Potential things to look for are how students might misinterpret the frequency of a data value as the data value for histograms and how boxplots can be counterintuitive for students because quarters with large ranges do not encompass more data than quarters with small ranges.) • Identify age-appropriate technology tools that can aid students with representing data and how they can be used to do so.
Learn to use the key features of distributions for quantitative variables, such as: • Center: mean as a balance point, and median as the middle-ordered value • Variability: interquartile range and mean absolute deviation • Shape: symmetric or asymmetric and number of modes	• Describe the meanings of mean as a leveling value, mean as fair share, mean as a balance point, and mean as an algorithm; make connections between and among the various definitions associated with the mean. • Explore different measures of center (mean or median) and measures of variability (MAD or IQR). • Describe the affordances and limitations of each measure for describing a distribution. • Create/curate strategies to engage students in activities to select the measures of center and variability that best summarize a distribution based on the shape of the distribution. • Recognize how students tend to reason about individual data values rather than the aggregate collection of data that can be described by characteristics such as shape, center, and variability, and understand how to help students transition from the former to the latter. • Connect how the mean absolute deviation (MAD) lays a foundation for the interpretation of standard deviation. • Recognize that the mean, median, IQR, MAD, and other numerical summaries are called "statistics" if summarizing a sample and called "parameters" if summarizing a population.

Use reasoning about distributions to compare two groups based on quantitative variables.	• Recognize that comparing a quantitative variable across two groups is the same as exploring the relationship between a quantitative variable and a two-group categorical variable. • Create/curate tasks to engage students in exploring the relationship between a quantitative variable and a categorical variable with two categories using boxplots, dotplots, and histograms to compare centers, variability, and shape across categories, including strategies that involve the use of age-appropriate technology.
Explore patterns of association between two quantitative variables or two categorical variables: • Measures of correlation: quadrant count ratio • Comparison of conditional proportions across categorical variables	• Use two-way tables, two-way graphs, stacked bar graphs, and mosaic plots to represent and consider the association between two categorical variables in response to a statistical investigative question. • Use relative frequencies conditioned on one categorical variable to compare relative frequencies within categories and across the categories for a second categorical variable to consider the association between two categorical variables in response to a statistical investigative question • Use scatterplots to represent and consider the association between two quantitative variables; use the QCR to consider the strength of that relationship in response to a statistical investigative question. • Describe the association of quantitative variables and time using line plots. • Create sequences of lessons using learning progressions to develop students' covariational reasoning.
Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
IV. Interpret the Results	
Use statistical evidence from analyses to answer the statistical investigative questions and communicate results with comprehensive answers and some teacher guidance.	• Ask analysis questions that prompt students to interpret data, statistics, and visual summaries in the context of the investigative question posed. • Recognize how language and culture impact students' interpretations of the results of statistical investigations. • Facilitate classroom discourse during which students compare their interpretations.
Acknowledge that looking beyond the data is feasible.	• Pose tasks that require students to compare characteristics of multiple samples drawn from the same population with corresponding characteristics of the population.

Generalize beyond the sample providing statistical evidence for the generalization and including a statement of uncertainty and plausibility when needed.	• Arrange sequences of classroom activities and lessons that allow students to observe and discuss relationships between sample size and the confidence of one's conclusions. • Guide students in comparing simple random sampling to other sampling strategies and the potential for each strategy to yield a representative sample.
Recognize the uncertainty caused by sample-to-sample variability.	• Know and use technologies (e.g., CODAP) that allow students to simulate drawing many samples of different sizes from a population to facilitate observation and analysis of sample-to-sample variability.
State the limitations of sample information (e.g., a sample may or may not be representative of the larger population, measurement variability).	• Anticipate contexts, situations, and cognitive biases that may lead students to have too much or too little confidence in their interpretations of data. • Assess the appropriateness of the qualifiers students use in stating their conclusions (e.g., possibly, probably, certainly, etc.) and provide feedback as needed.
Compare results for different conditions in an experiment.	• Implement lessons that allow students to compare multiple results for the same experiment. • Lead classroom discourse about why multiple results from the same experiment can differ.

Chapter 3C

Framework for Teacher Learning Outcomes in Statistics and Data—Level C

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
I. Formulate Statistical Investigative Questions	
Formulate multivariable statistical investigative questions and determine how data can be collected, considered, and analyzed to provide an answer.	• Generate multiple statistical investigative questions from a research topic. • Distinguish between statistical investigative questions that lead to categorical variables or quantitative variables.
Pose different types of multivariable statistical investigative questions: summary, comparative, associative, causal, and predictive.	• Create opportunities for students to distinguish among the various types of statistical questions (e.g., summary, descriptive, comparative, associative, causal, and predictive). • Anticipate and identify student difficulties in distinguishing between comparative relationships (one categorical variable and one numerical), associative relationships (two numerical or two categorical variables), and associative and causal relationships—for example, identifying potential confounding factors when examining an association and recognizing that causality has a probabilistic aspect (a vaccine might truly prevent the flu, but that doesn't mean everyone with the vaccine will remain flu-free).

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
II. Collect/Consider Data	
Apply an appropriate data collection plan when collecting primary data or selecting secondary data for the statistical investigative question of interest.	• Relate data collection plans to the posed statistical investigative question (causal questions need experiments to collect data; inferential questions need random sampling; predictive questions need representative data). • Interrogate the provenance of a secondary dataset and determine: What are the units of observation (what is a case)? What are the variables (what is an attribute)? What types of variables are there in the dataset? Is the study design appropriate for the intended use? What is the source of the data? Who funded the data collection? • Recognize that the messiness of the data might interfere with the desired learning outcome and, therefore, needs more cleaning prior to showing it to students. • Select datasets that provide the appropriate amount of challenge for students to clean data into a usable form.
Distinguish between surveys, observational studies, and experiments.	• Curate examples from a variety of sources (media articles, case studies), and use assessing and advancing instructional questions to guide students to distinguish among surveys, observational studies, and experiments.
Understand what constitutes good practice in designing a sample survey, an experiment, and an observational study.	• Provide opportunities for students to use characteristics of good practices to critique and create survey designs, observational studies, and experiments.
Understand common study designs in the disciplines (e.g., psychology, biology) and relate those to statistical experimental designs.	• Identify connections with other disciplines that collect data through surveys, observation, and experiments.
Understand the role of random selection in sample surveys and the effect of sample size on the variability of estimates.	• Engage students in designing and implementing the process of simple random sampling. • Recognize that the Simple Random Sample (SRS) paradigm is rarely possible to implement, but understanding of the SRS paradigm applies toward understanding the more complex paradigms used in actual practice.

Understand the role of random assignment in experiments and its implications for cause-and-effect interpretations.	• Explain why causality is difficult to establish, and critique designed experiments to determine whether causality is a possibility. • Curate historical and contemporary examples, where causal claims have been made, and what needed to happen to establish them (e.g., smoking causes cancer, cholera epidemic, hand-washing in surgery). • Design classroom opportunities for students to engage in controlled experiments and practice random assignment.
Understand the issues of bias and confounding variables in observational studies and their implications for interpretation.	• Facilitate discourse with students to identify and explain possible confounding variables. • Illustrate how non-representative samples may cause bias in observational studies.
Understand practices for handling data that enhance reproducibility and ensure ethical use, including descriptions of alterations, and an understanding of when data may contain sensitive information.	• Develop data documentation (codebook) and data cleaning documentation. • Design lessons for students to see the challenges of following others' work based on documentation. • Recognize that ethical guidelines for working with data exist (e.g., ASA Ethical Guidelines).
Understand how concerns about privacy and human subjects may affect the collection and distribution of data.	• Describe types of protections that exist for data privacy and why they're needed. • Discuss the role of privacy in data within the public sector (e.g., government, schools) and private sectors (e.g., marketing, sales). • Lead student discussions about famous case studies that highlight data privacy, informed consent, and other ethical issues in data collection.
Understand who owns your data, when ownership changes, and the choices you have in ownership.	• Lead student discussions about famous case studies and data used by popular apps to highlight ethical issues in data ownership.

Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
III. Analyze the Data	
Use technology to subset and filter datasets and transform variables, including smoothing, for time-series data.	• Demonstrate basic data moves and the ability to filter and subset datasets according to multiple variables. • Facilitate discourse to help students decide which types of data moves and filtering are necessary to answer the statistical investigative question.
Identify appropriate ways to summarize quantitative/ numeric or categorical data using tables, graphical displays, and numerical summary statistics, which include using standard deviation as a measure of variability and a modified boxplot for identifying outliers.	• Map statistical investigative questions to specific statistical analyses, such as numerical summaries, graphical summaries, tables, etc. • Create opportunities for students to explore and compare various summary methods used to address a statistical investigative question. • Compare MAD and standard deviation as summaries of variability in a quantitative distribution. • Discuss how the measures of center, variability, and shape of distributions evolve from Level B to Level C.
Summarize and describe relationships among multiple variables.	• Identify and demonstrate techniques for summarizing relationships between two or more variables. • Identify functional relationships (e.g., linear, exponential) between quantitative variables using scatterplots. • Create/curate lessons that require students to examine statistical graphs and summary outputs to answer statistical investigative questions involving relationships between two or more variables.

Understand how sampling distributions (developed through simulation) are used to describe the sample-to-sample variability of sample statistics.	• Recognize that the concept of a sampling distribution is an abstract notion that is not directly tied to data and cannot be observed in a single sample, which makes it challenging for students to understand. • Recognize that the term “sampling variability” refers to “sample-to-sample” variability. • Create/curate sequences of lessons to move students from building empirical sampling distributions through tactile hands-on experiences to software tools like applets (that allow for thousands of repetitions) to theoretical probability distributions for deepening understanding of sampling variability. • Construct empirical sampling distributions for common sample statistics such as the sample mean and sample proportion through hands-on simulations and technology-assisted simulations. • Make connections among probability distributions (e.g., binomial distribution, normal distribution, chi-squared distribution) and sampling distributions.
Develop simulations to determine approximate sampling distributions and compute (approximate) p -values from those distributions.	• Illustrate the connections between sampling distributions, confidence intervals, and p-values. • Make explicit the connections between p-values derived from theoretical sampling distributions and those drawn from approximate, simulation-derived sampling distributions. • Facilitate activities for students to set up simulations, find approximate p-values from the simulation, and then use the p-value to draw statistical conclusions. • Create/curate lessons for students to distinguish a population distribution from a sample (data) distribution and a sampling distribution.
Describe associations between two categorical variables, using measures such as differences in proportions and relative risk.	• Compare and contrast the role of proportions to relative risks. • Generate and interpret two-way tables and graphs (e.g., stacked bar graphs or side-by-side bar graphs) that summarize associations between categorical variables. • Facilitate discourse to help students understand the interpretations of row and column conditioning in a contingency table.

Describe the relationship between two quantitative variables by interpreting Pearson's correlation coefficient and a least-squares regression line.	• Relate the correlation coefficient to the least squares regression line. • Provide examples to help students understand the difference between correlation and causation. • Create/curate lessons to help students build conceptions for the line of best fit and subsequently interpret the slope and y-intercept in a least-squares regression line.
Use simulations to investigate associations between two categorical variables and to compare groups.	• Create/curate a sequence of lessons using hands-on manipulatives and move to technology to carry out randomization-based testing. • Use randomization-based testing to address comparative statistical investigative questions.
Construct prediction intervals and confidence intervals to determine plausible values of a predicted observation or population characteristic.	• Recognize how students commonly interpret confidence intervals and guide students toward normative interpretations. • Facilitate discourse for students to identify when a statistical investigative question calls for a prediction or an estimation in the context of linear regression.
Student Learning Outcomes	Teacher Learning Outcomes: What Teachers Need to Know and Be Able to Do
IV. Interpret the Results	
Use statistical evidence from analyses to answer the statistical investigative questions and communicate results through more formal reports and presentations.	• Identify and describe components of a comprehensive statistical report, such as statistical investigative questions, valid and complete analyses, conclusions that address research questions, descriptions of limitations, and discussions of provenance and validity of the data. • Design shorter written assignments that require interpretations that address a single statistical investigative question. • Guide students in finding published results from reputable sources that relate to their statistical investigative questions and research questions. • Discuss the appropriateness of using generative AI for a given project. • Ask questions that prompt consideration of how observations, interpretations, and conclusions relate to the context of an investigation and chance. • Assess students' abilities to communicate statistical results through written and oral presentations. • Evaluate the strength of evidence in reports of empirical studies and explain why a binary (valid/invalid) judgment is rarely appropriate.

Evaluate and interpret the impact of outliers on the results.	• Identify and locate potential outliers in a multivariate context (e.g., through examination of residuals). • Lead classroom discourse about when it is and is not appropriate to remove outliers. • Explain how the inclusion/exclusion of outliers affects interpretations of results.
Understand what it means for an outcome or an estimate of a population characteristic to be plausible or not plausible compared to chance variation.	• Explain differences between statistics and parameters. • Use various tactile hands-on and technology-based simulation methods to generate data according to a model under consideration to determine plausibility of an outcome. • Compare distributions established using chance mechanisms to other distributions. • Anticipate, assess, and provide feedback on students' reasoning about statistics that lie in the tails of distributions generated under null hypothesis models.
Interpret the margin of error associated with an estimate of a population characteristic.	• Explain when it is desirable to calculate a margin of error from a sampling distribution (or approximate sampling distribution), including theoretical, bootstrapped, and simulated distributions. • Demonstrate how margin-of-error estimates are impacted by changes in sample size and population variability. • Anticipate and critique common misinterpretations of margin of error.
Acknowledge the presence of missing values and understand how missing values may add bias to an analysis.	• Prompt students to identify missing values in a dataset and explain when generalizations may be biased due to missing values. • Use classroom technology to explore the impact of missing values in a variety of contexts. • Evaluate the amounts and patterns of missingness in datasets to decide whether the data should be used to answer a given investigative question. • Engage students in using advanced concepts, such as missing at random, as opportunities arise.

Use multivariate thinking to understand how variables impact one another.	• Prompt students to examine associations between multiple variables to provide more comprehensive interpretations of their results. • Lead classroom discourse about confounding variables to draw out how they offer alternative explanations for observed associations. • Identify opportunities within classroom discourse for exploration of advanced multivariate regression techniques and ideas, such as how strongly correlated predictor variables impact analyses.
Communicate statistical reasoning and results to others in a variety of formats (verbal, written, visual).	• Create assignments that require students to report to different audiences for various purposes (e.g., letter to school principal, oral report to classmates, article for newspaper). • Help students identify information and visual representations, based on all analyses they produced, that should be included in a report. • Assess and critique students' written and oral presentations in terms of statistical content, compatibility between investigative questions and techniques used, appropriate length, suitability to audience, and overall quality of presentation.
Understand how to interpret simulated p -values appropriately.	• Explain how to compute and interpret p-values from (approximate) sampling distributions through simulations, theory, or bootstrapping. • Anticipate and respond to common misinterpretations of p-value. • Use teaching strategies that illustrate relationships between p-value and sample size. • Prompt students to create arguments about plausibility of hypotheses that include p-values and contextual considerations as justifications. • Leverage opportunities that emerge during classroom discourse to introduce professional research concerns such as p-hacking and the reproducibility crisis. • Recognize the difference between statistical significance and practical significance within a given context.

Chapter 4

Recommendations for Teacher Preparation in Statistics and Data Concepts

*Teaching statistics and data-related topics is cross-curricular;
thus, teachers of different subjects need data-related preparation.*

Teacher preparation encompasses primary and secondary teacher education. In this chapter, we refer to United States-centric levels of elementary, middle, and high school; however, we encourage international adaptations to these recommendations as appropriate.

Elementary, middle, and high school teacher education includes initial preparation and ongoing professional learning. Teaching statistics and data-related topics is cross-curricular; thus, teachers of different subjects need data-related preparation. Because statistics and data-related standards are primarily found in the mathematics curriculum, mathematics teachers are often tasked with

developing the full scope of the seven cross-cutting ideas outlined in Chapter 2 and the Framework for Teacher Learning Outcomes in Statistics and Data in Chapter 3. However, science standards also include standards related to data, and science teachers often use the Statistical Problem-Solving Process to do experiments and gather data to illustrate scientific ideas. Other subjects, such as social studies, economics, psychology, geology, and anthropology, etc., also have data as part of their content and standards. For example, social studies standards include standards related to using economic data, constructing maps, and using geographical data. **Figure 4.1** provides a mapping of the Statistical Problem-Solving Process to

Statistical Problem-Solving Process	NGSS Science and Engineering Principles	C3 Inquiry Arc Competencies
Formulate Statistical Investigative Questions	• Asking questions (for science) and defining problems (for engineering) • Planning and carrying out investigations	• Questioning • Making claims
Collect/Consider Data	• Developing and using models	• Selecting sources • Gathering information from sources • Evaluating sources
Analyze Data	• Analyzing and interpreting data • Using mathematics and computational thinking	• Analyzing social problems • Assessing options for action • Using evidence
Interpret: Answer the Statistical Investigative Question	• Constructing explanations (for science) and designing solutions (for engineering) • Engaging in argument from evidence • Obtaining, evaluating, and communicating information	• Constructing arguments and explanations • Adapting arguments and explanations • Presenting arguments and explanations • Critiquing arguments and explanations • Taking informed actions

Figure 4.1 Mapping of *GAISE II* Statistical Problem-Solving Process to NGSS and C3 Framework

the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) and to the College, Career, and Civic life (C3) framework from the National Council for the Social Studies (NCSS, 2013). Therefore, teachers of these subjects also must be well-versed in the cross-cutting

ideas and framework tables as they apply to their disciplines. Hudson et al. (2025) found that current teacher preparation programs across the United States have very few courses and very little time dedicated to statistics and data-related topics. Specifically, through surveying 89

programs, the authors found that 70% of programs have no courses on statistical topics specifically for teachers. While a majority of methods courses touch upon statistical and data-related topics, such courses tend to spend at most 10% of their time on teaching these topics.

Given the diverse backgrounds of those who teach statistics and data-related topics, it is important that all are equipped to meet the learning outcomes outlined in the framework of this document. These outcomes are aligned to the content students need and that subjects require. To clarify, as they develop into statistics teachers, mathematics teachers should strive to meet all the learning outcomes because their role is large in developing students' data and statistical knowledge. Science teachers should be prepared to match the student standards in NGSS to those presented in *Pre-K–12 GAISE II*, and in turn, should be prepared according to the framework in Chapter 3 and what is appropriate for that mapping. Social studies and other teachers should be prepared to do the same with the social studies standards. For all teachers, it is important that the seven cross-cutting big ideas be prevalent in all disciplines when working with data.

Whatever teachers' experiences are at each level, they should have exposure to the seven cross-cutting big ideas and learning outcomes relevant to their

discipline goals. Teacher experiences should be based on the three pillars of teacher preparation outlined in Chapter 1 (see also Figure 1.1)—the essential content that students need to be taught, subject matter expertise teachers need to teach that content, and effective pedagogical practices needed to support student learning. Teachers need a collection of experiences to develop and meet learning outcomes in the framework appropriate for their grade levels. We recommend teachers experience one or more of the recommendations listed in Figure 4.2. Learning outcomes for teachers encompass the content students need to know at their current level and levels beyond, so that teachers can have a wide understanding of how student knowledge in statistics and data-related topics develops as they move forward.

Our general recommendation is that all teacher preparation in statistics and data-related topics should be centered on the seven cross-cutting big ideas in Chapter 2 and elements of the framework pertinent to the area of study.

Learning outcomes in the framework are ambitious. Teacher preparation should be viewed as a continuum of experiences that culminate in teachers meeting all of the learning outcomes. If the learning outcomes are not met in initial preparation, then ongoing professional learning

SET II Recommendations	
Initial Preparation of Elementary Teachers	
1.	A substantial statistics and data unit within a stand-alone content course for developing teachers' knowledge of the seven cross-cutting big ideas detailed in Chapter 2, all outcomes for Level A, and familiarity with the content associated with the outcomes for Level B that are detailed in the frameworks from Chapter 3.
2.	A substantial statistics and data unit within a methods course for elementary teachers that develops teachers' knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and the outcomes for Level A and aspects of Level B detailed in the framework from Chapter 3.
Initial Preparation of Middle School Teachers	
1.	A stand-alone course that develops teacher knowledge of the seven cross-cutting big ideas detailed in Chapter 2, all outcomes for Level B, and familiarity with the content associated with the outcomes for Level A and Level C detailed in the frameworks from Chapter 3.
2.	An introductory statistics content course that emphasizes a modern data analytic approach to statistics and working with data.
3.	A substantial statistics and data unit within a methods course for middle school teachers that develops teachers' knowledge to teach the seven cross-cutting big ideas detailed in Chapter 2 and the outcomes for Level B and aspects of Level A and Level C detailed in the framework from Chapter 3.
Initial Preparation of High School Teachers	
1.	A stand-alone course for developing teacher knowledge of the seven cross-cutting big ideas detailed in Chapter 2, all outcomes for Level C, and familiarity with the content associated with the outcomes for Level A and Level B detailed in the frameworks from Chapter 3.
2.	An introductory statistics content course that emphasizes a modern data analytic approach to statistics and working with data.
3.	A foundations of mathematical statistics course using simulations and computing OR an advanced modeling course.
4.	A substantial statistics and data unit within a methods course for high school teachers that develops teachers' knowledge for teaching the seven cross-cutting big ideas detailed in Chapter 2, outcomes for Level C, and aspects of Level B detailed in the framework from Chapter 3.

Figure 4.2 Recommendations for the initial preparation of teachers.

SET II Recommendations	
Continuous Preparation of Teachers	
1.	Take courses that focus on developing teacher knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and all outcomes detailed in the framework from Chapter 3 appropriate for the level and content they teach.
2.	Participate in a series of vetted professional learning experiences focused on developing teacher knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and all outcomes detailed in the framework from Chapter 3 that are appropriate for the level and content they teach.
3.	Engage in short-term professional learning seminars or webinars to assist in developing knowledge of the seven cross-cutting big ideas detailed in Chapter 2 and all outcomes detailed in the framework from Chapter 3 that are appropriate for the level and content they teach.

Figure 4.3 Recommendations for the continuous preparation of teachers.

is necessary to continue their progress. Lessons and activities with teachers can be designed to address and develop many of the learning outcomes. See the examples in Chapter 5 of this report.

Recommendations for Continuous Preparation of Teachers

Practicing teacher preparation in statistics and data-related content must be treated differently than prospective teacher preparation. Practicing teachers may have received their teaching credentials through a regular pathway or an alternate certification pathway, or they may be working towards certification of some sort. Practicing teachers may or may not have had prior coursework or experience in statistics. Teachers seeking

to deepen their knowledge and preparation to teach statistics and data-related concepts may do so in different modalities. They might take courses related to statistics and data-related content if they are enrolled in a graduate program or take single courses related to data on their own. Formal learning opportunities might also be provided by school districts or as components of research/development programs at universities. All of these approaches are welcome and needed to further teacher knowledge of statistics and data-related content.

Practicing teachers may have had an introductory statistics class in their educational background, but we cannot assume that this class included exposure to and engagement with the Statistical Problem-Solving Process. Professional

learning opportunities must, therefore, provide opportunities for all teachers to experience the cross-cutting big ideas and learn the framework outcomes appropriate for the level they teach. Those opportunities must also make explicit ties to discipline-specific needs. Even for teachers with more statistics experience in their backgrounds, continued in-depth preparation allows their statistical and pedagogical knowledge to evolve at a pace compatible with the field.

For practicing teachers who want or need to further their content knowledge and pedagogical content knowledge to meet the learning outcomes recommended in this document, we recommend they experience one or more of the recommendations listed in **Figure 4.3**.

References

Hudson, R.A., Mojica, G., Abel, R., Kuhlman, A., Casey, S., & Lee, H. (2025). Preparing secondary mathematics teachers for data science and statistics: A survey of teacher education programs [Unpublished manuscript]. Mathematical Sciences Department. University of Southern Indiana.

National Council for the Social Studies. (2013). The college, career, and civic life (C3) framework for social studies state standards: Guidance for enhancing the rigor of K–12 civics, economics, geography, and history. [tinyurl.com/3xtxh7ey](https://www.tinyurl.com/3xtxh7ey)

NGSS Lead States. (2013). Next generation science standards: For states, by states. www.nextgenscience.org

Chapter 5

Examples of Teacher Learning Experiences in Statistics and Data Education

The goal of these examples is to provide a broad range of forms, features, and functions of teacher preparation geared toward teacher educators, administrators, and policymakers to show what successful, well-thought-out, and evidence-based teacher preparation looks like.

In this chapter, we present a list of summaries of examples of teacher learning experiences contributed by leading practitioners who prepare prospective and practicing teachers in statistics and data education. These experts bring an international perspective, with contributors from countries around the world. These contributed examples illustrate a variety of tested, peer-reviewed, published, and successful approaches to educating teachers in statistics and data concepts. The *SET II* writing team solicited contributors to provide examples. Those examples were adapted by the *SET II* team into teacher educator facilitator guides. Contributors then reviewed, edited, and approved their examples for inclusion.

The examples illustrate the complexities of teacher preparation and the wide variety of approaches to, and constraints on, preparing both prospective and practicing teachers. Therefore, the goal of these examples is to provide a broad range of forms, features, and functions of teacher preparation geared toward teacher educators, administrators, and policymakers to show what successful, well-thought-out, and evidence-based teacher preparation looks like.

The following table summarizes the examples organized by level. To fully realize the potential of these examples, we recommend implementing them alongside the cross-cutting themes described in Chapter 2 of this report.

Cross-Cutting Levels Examples	Level A	Level B	Level C
<i>Engaging with Professional Readings (Levels A and B):</i> Jennifer L. Green; Erin E. Blankenship	<i>Exploring Distributions Through Physical Movement:</i> Andee Rubin	<i>Census at School:</i> Susan A. Peters	<i>Line of Best Fit:</i> Stephanie Casey; Andrew Ross; Samantha Maddox; Melody Wilson
<i>Writing Prompts to Support the Development of Statistical Knowledge for Teaching (Levels A and B):</i> Randall Groth	<i>Licorice:</i> Jane Watson	<i>Comparing Food Projects: Investigating Crowdfunding with Data:</i> Amy Brodesky; Emily Fagan; Josephine Louie	<i>From German Tanks to Chickpeas: Estimating the Size of a Population:</i> Laura Morera; Marcel Algueró; Bernat Portell; Learning Team at Innovamat
<i>Kelvin's Teaching Case (Level A and B):</i> Leticia Perez; Kevin Ortiz; Kathy Huncosky; Nicole Wong; Kirsten Daehler; Rasha Elsayed; Sara Salisbury; Frieda Reichsman; Corynn Del Core	<i>Mapping Our Community:</i> Sarah Burns; Jeanne Di Domenico; Debbie Leslie	<i>Students' Reasoning About a Segmented Bar Graph:</i> Stephanie Casey; Rick Hudson; Hollylynne Lee; Gemma Mojica; William Finzer; Emily Thrasher; Rachel Abel	<i>A Lesson Study Using ESTARS:</i> Beth Chance; Soma Roy
<i>Assessment Examples from LOCUS (Levels A, B, and C):</i> Tim Jacobbe; Kaycie Maddox; Christine Franklin; Anna Bargagliotti	<i>Taking Risks:</i> Lisa Green; Christine Franklin	<i>Learning About Students' Statistical Thinking Through Interviews:</i> Randall Groth	<i>American Time Use Survey:</i> Anna Bargagliotti; Robert Gould; Christine Franklin; Pip Arnold
<i>InSTEP Online Professional Learning for Teaching Statistics and Data Science (Levels A, B, and C):</i> Hollylynne Lee, Gemma Mojica, Emily Thrasher		<i>Engaging in the Problem Solving Process:</i> Pip Arnold	

In each example summary below, we specify its form, function, and features and provide citations for those who wish to view the source materials upon which the examples were derived. As described in Chapter 1: Form pertains to the characteristics of the teacher preparation; function pertains to the purpose that teacher preparation is meant to serve; and specific features pertain to the types of modalities, techniques, and tools being used in the teacher preparation. Full materials for each example are linked and provided online. As evidence-based practice develops, additional examples may be added to the online repository, in particular with new AI technologies and other topics related to statistics and data education.

Cross-Cutting Level Example Descriptions

Example: Engaging with Professional Readings

Authors: Jennifer L. Green and Erin E. Blankenship

Citation

Green, Jennifer L., and Erin E. Blankenship. "Primarily Statistics: Developing an Introductory Statistics Course for Pre-Service Elementary Teachers." *Journal of Statistics Education* 21, no. 3 (2013). doi.org/10.1080/10691898.2013.11889683.

Form

- Audience: Prospective elementary and middle school teachers (can be adapted for practicing teachers and all grade levels)
- Type: Activity (~20–30 minutes) based on research

Function: Introduce teachers to professional readings about research on statistics education teaching practices and student learning across different grades and statistical levels. Begin developing teachers' reflective practice of unpacking statistics education research results and findings, and discuss how to translate them to classroom practice.

Features

- Article review
- Collaborative group work
- Research-based
- Reflection

Description: Throughout the learning experience, teacher educators assign teachers to read chapters from the book Burrill, Gail F., and Peter C. Elliott, eds. *Thinking and Reasoning with Data and Chance: Sixty-Eighth Yearbook*. Reston, VA: National Council of Teachers of Mathematics, 2006. Teacher educators provide teachers with prompts and directions that guide collaborative work and reflection.

Example: Writing Prompts to Support the Development of Statistical Knowledge for Teaching

Author: Randall Groth

Citation

Groth, Randall E. “The Role of Writing Prompts in a Statistical Knowledge for Teaching Course.” *Mathematics Teacher Educator* 1, no. 1 (2012): 23–40. *doi.org/10.5951/mathteacheduc.1.1.0023*.

Form

- Audience: prospective elementary and middle school teachers
- Type: writing and discussion prompts that can be done during a 60-minute session

Function: Prospective teachers develop content knowledge and pedagogical content knowledge related to the median and categorical data. They learn about nominal categorical datasets, for which the median cannot be computed, and they study common student misunderstandings of the median for such data. Prospective teachers also learn pedagogical strategies designed to address these student misunderstandings.

Features

- Article review
- Reflection
- Research-based activity

Description: Prospective teachers read an article from *Mathematics Teaching in the Middle School* entitled “It’s a bird! Can you compute a median of categorical data?” and they answer reflective writing prompts about it. The prompts are designed to develop both content knowledge and pedagogical content knowledge. The article was about the common student error of computing a median for nominal categorical data. For instance, in the article, some children ordered nominal category labels (e.g., “fish,” “bird,” etc.) alphabetically and then looked for the middle one, thinking it would be the median of the dataset. In addition to describing this student error, the article offered teaching strategies to help students overcome it. Prospective teachers can complete the reading and prompts collaboratively in class or as an individual homework assignment.

Example: Assessment Examples from LOCUS

Authors: Tim Jacobbe; Kaycie Maddox; Christine Franklin; Anna Bargagliotti

Citation

Jacobbe, Tim, Beth delMas, Beverly Hartlaub, Jennifer Haberstroh, Christine Case, Stephen Foti, and Deb Whitaker. “Establishing the Validity and Reliability of the LOCUS Assessments.” *Numeracy* 16, no. 1 (2023): Article 5, 1–29. *digitalcommons.usf.edu/numeracy/vol16/iss1/art5*

Form

- Audience: Prospective or practicing teachers in elementary, middle, and high schools
- Type: Activity of approximately ~45 minutes

Function: This activity provides teachers with a rich discussion about assessment, an integral part of their work as teachers. Using the research-based LOCUS items, teachers will have the opportunity to explore common student misunderstandings. Depending on the LOCUS items chosen, teachers will go in-depth on specific statistical concepts.

Features

- Collaborative group work
- Research-based
- Student artifacts

Description: Teachers will be introduced to the Levels of Conceptual Understanding in Statistics assessment items. They will complete specific research-based LOCUS assessment items and then review student work answering the same questions. Teachers will discuss how to elicit statistical understanding from students with specific work samples and review instructional decisions to implement the assessment items with students. Note that depending on the LOCUS items chosen to work on, teachers will go in-depth on specific statistical concepts.

This activity selects specific LOCUS items; however, others may be selected to cover different statistical topics.

Example: Kelvin's Teaching Case

Authors: Leticia Perez, Kevin Ortiz, Kathy Huncosky, Nicole Wong, Kirsten Daehler, Rasha Elsayed, Sara Salisbury, Frieda Reichsman, Corynn Del Core

Citation

WestEd. (2023). Activity: Kelvin's Case, Part I. tinyurl.com/exha6rwr

Form

- Audience: Prospective or practicing elementary or middle school teachers
- Type: A case study activity lasting approximately 60 minutes

Function: Teachers study ways to support students in making sense of scientific phenomena by analyzing and interpreting data. Teachers explore affordances and challenges associated with having students gather and represent their own data. Technology tools to facilitate students' work with data are considered.

Features

- Case of teaching practice
- Collaborative group work
- Reflection
- Research-based
- Student artifacts
- Technology

Description: In this teaching case, Kelvin seeks more effective ways to support his students as they learn science content through the practice of interpreting and analyzing data. He recognizes that data are an integral part of facilitating content learning. As teachers read Kelvin's Case, guiding questions are provided to help focus on his pedagogical strategies, which are used to achieve the learning objective and students' responses to those strategies.

Example: InSTEP Online Professional Learning for Teaching Statistics and Data Science

Authors: Hollylynne Lee; Gemma Mojica; Emily Thrasher

Citations

NC State University. (n.d.). InSTEP. *instepwithdata.org*

Lee, Hollylynne S., Gemma M. Mojica, and Emily Thrasher. Designing online professional learning to support advances in teaching strategies in statistics and data science. In *Statistics and Data Science Education in STEAM: Proceedings of the Satellite Conference of the International Association for Statistical Education*, edited by L. Birk, G. Loth, L. Jotzo, K. Binder, and D. Frischmeier. Münster, Germany, 2026. *doi.org/10.52041/iase25.137*.

Lee, Hollylynne S., Gemma M. Mojica, and Emily P. Thrasher. Digging into data: Illustrating a data investigation process. *Statistics*

Teacher, Spring 2022. *www.statisticsteacher.org/2022/03/23/diggingdata*

Thrasher, Emily, Hollylynne S. Lee, Brittany Graham, Mark Grossman, and Gemma Mojica. Making sense of data visualizations: A toolkit for supporting student discussions. *Statistics Teacher*, Fall 2024. *www.statisticsteacher.org/2024/12/09/data-visualizations*

Form

- Audience: Practicing middle school and high school teachers
- Type: Self-directed, self-paced learning where teachers can earn certificates of completion for every 5 hours of learning

Function: The InSTEP online professional learning platform supports learning to teach statistics and data science in grades 6–12. InSTEP is envisioned and designed to be a place where teachers of any subject can enroll and independently learn at their own pace, on their own time. InSTEP is not a static course to complete but is designed to allow educators to drop in and engage for short periods of time and return later to pick up where they left off. Practicing teachers engage in data investigations to experience investigations as a learner and doer of statistics and data science, and the self-paced modules allow teachers to dig deeper to advance their content knowledge and pedagogical skills in targeted ways.

Features

- Modular experiences
- Videos
- Multivariate data
- Online data tools
- Self-paced
- Personalized recommendations
- Progress tracking
- Certificates awarded
- Community building

Description

The InSTEP resource is organized by anchoring professional learning in seven Dimensions of Teaching Statistics and Data Science, which describe important aspects that support teaching and learning environments for statistics and data science. Those seven dimensions are data and statistical practices, central statistical ideas, tasks, data, tools, argumentation, and assessment. The seven dimensions are interconnected, so advancing learning in each can support teachers' development in building expertise for the teaching of statistics and data science. On the Learning Hub page in the InSTEP platform, teachers are presented with a series of tiles labeled as either "data investigations" or "self-paced modules," organized by the seven dimensions.

Level A Example Descriptions

Example: Exploring Distributions Through Physical Movement

Author: Andee Rubin

Citation

Metz, M. Lee. Using *GAISE* and NCTM standards as frameworks for teaching probability and statistics to pre-service elementary and middle school mathematics teachers. *Journal of Statistics Education*, 18, no. 3 (2010). <https://jse.amstat.org/v18n3/metz.pdf>

Form

- Audience: Practicing elementary and middle school teachers
- Type: Professional learning activity of approximately 45 minutes. This activity works best with a minimum of 10 teachers (cannot work with smaller groups).

Function: This activity introduces the concept of distributions. Teachers focus on data collection, measurement, analysis of patterns in distributions, and different representations of distributions. Teachers also consider how to adapt the activity for use with students in their own classrooms.

Features

- Collaborative group work
- Real teacher data

Description: This activity invites elementary and middle school teachers to represent data physically. Teachers determine a measurable attribute and then arrange themselves into a line from smallest to largest value. After the distribution is captured with a picture or drawing, teachers can observe, discuss, and analyze a distribution together. This activity allows teachers to get to know one another while exploring how to represent a distribution. It also surfaces issues of measurement and, in particular, how important it is to be clear about definitions when “turning life into data.” The data represented describe a participant attribute about the teachers, so it provides a shared example to reference later in the professional development.

Example: Licorice

Author: Jane Watson

Citation

Watson, Jane, Neil Fitzallen, Lyn English, and Sue Wright. Introducing statistical variation in year 3 in a STEM Context: Manufacturing licorice. *International Journal of Mathematical Education in Science and Technology* 51, no. 3 (2020): 354–387. doi: 10.1080/0020739X.2018.1562117

Form

- Audience: Prospective or practicing elementary teachers
- Type: Professional learning activity of approximately two hours

Function: Teachers will experience different types of variability and evaluate students’ thinking about different types of variability while engaging in the Statistical Problem-Solving Process. Teachers will then build lessons for similar statistical objectives to use in their own classrooms.

Features

- Article review
- Collaborative group work
- Research-based
- Student artifacts
- Student-gathered data
- Technology

Description: Teacher educators will have prospective or practicing teachers read the two published Licorice articles describing an elementary student activity in which students (and teachers) investigated the variation in mass of licorice sticks by creating their own sticks using Play-Doh by hand and by using a mold, which is called a “factory.” The teacher-posed investigative questions anchoring the activity are:

- “If we make licorice by hand, how exact can we be? Would you expect every piece to be the same?”

- “If we make licorice using a “factory” mold, how exact can we be? Would you expect every piece to be the same?”
- “How do the two methods of making licorice compare?”

Participants are asked to make predictions about their abilities to make licorice pieces that would be the same size. They then compare the mass found, when creating their sticks, on their own versus using the factory mold. Then, they engage in a discussion about different types of variability (measurement variability and group to group variability) that arise in statistics.

After reading the articles, prospective or practicing teachers will engage in a think-pair-share activity around the evaluation of responses presented in the papers. The Year 3 student responses within the framework of the Statistical Problem-Solving Process are listed in the Teacher Educator Facilitator Guide table.

Prospective or practicing teachers will then design a lesson plan for their own classrooms based on the activity. They will then share their lessons, including a discussion of the student responses, with the whole group and reflect upon feedback.

Example: Elementary Data Science Explorations—Mapping Our Community

Authors: Sarah Burns; Jeanne Di Domenico; Debbie Leslie

Citation

University of Chicago STEM Education. Mapping Our Community: Elementary Data Science Exploration. 2024. *stemed.uchicago.edu/tool-development/elementary-data-science-explorations*

The professional learning activities in Sessions 1, 2, and 3 are based on the links to relevant excerpts from the Mapping our Community Elementary Data Science Exploration that are included with each session description below. You can also request access to complete EDSes at *tinyurl.com/2eb29978*.

Form

- Audience: Practicing elementary school teachers
- Type: Three professional development sessions of approximately 30 minutes each.

Function: The sessions help teachers learn how to introduce central ideas of data science, including data science practices and real-world uses of data, to their students. Teachers also examine how elementary school students engage with data science content and practices.

Features

- Article review
- Curriculum material analysis
- Reflection
- Research-based activity
- Student artifacts

Description: Sessions can be used separately or in combination. In Session 1, small groups of teachers brainstorm and chart what types of data different organizations might collect and how they might use these data. Teachers examine work artifacts from Grade 5 students and discuss what the artifacts show about what students know and understand about data and real-world uses of data. For Session 2, teachers read the article “Investigating Data Like a Data Scientist: Key Practices and Processes” and then reflect on how they might teach their own students about data science practices and traits. In Session 3, teachers review lesson activities and accompanying student work, discuss the data science content and practices students engaged with in the activities, consider what data science concepts students appear to be thinking about and what they may still be learning, and connect the activities and student work back to the real-world practices of data scientists.

Example: Taking Risks

Authors: Lisa Green; Christine Franklin

Citation

Arnold, Pip, ed. *Probability | tūponotanga: A guide for teaching probability (ages 5–18)*. New Zealand Statistical Association Education Committee, 2026. new.censusatschool.org.nz/teaching-probability-book/

Form

- Audience: Practicing and prospective elementary teachers
- Type: Professional learning experience of approximately 1.5–2 hours

Function: This activity is designed to provide the opportunity for teachers to develop a research-based activity on a statistical learning objective(s) to implement with students. Using a classroom-tested lesson focused on developing conceptual understanding of risk, teachers explore the essential role of research in both informing instructional strategies and guiding teacher practice.

Features

- Article review
- Collaborative group work
- Reflection
- Research-based
- Student artifacts

Description: In this professional learning activity, teachers engage directly with statistics education research as a springboard for instructional design. Prior to the professional learning experience, participants read an article that provides complementary research around

the concept of risk using Kobi Yamada's "What Do You Do with a Chance?" After forming small groups during the professional learning experience, drawing on the insights from the article, each small group develops a classroom-ready lesson or activity that puts the research into practice. This part of the activity culminates in a brief share-out, where teachers present their lessons alongside an explanation of how the research informed their design choices. The teachers then review a lesson and associated sample student work and do a teacher reflection carried out by an elementary teacher with students in grades 2–5. The goal is to gain insight into how teachers might refine their lessons. The final discussion will provide a transferable framework for turning research into classroom practice.

Level B Example Descriptions

Example: Census at School

Author: Susan A. Peters

Citations

Peters, Susan A., and Amy Stokes-Levine. Secondary teachers' learning: Measures of variation. In *Topics and Trends in Current Statistics Education Research: ICME-13 Monographs*, edited by Gail Burrill and Dani Ben-Zvi, 245–284. Springer, 2019. *doi.org/10.1007/978-3-030-03472-6_11*

Peters, Susan A. Professional development to transform middle and high school teachers' knowledge about distribution. In *Looking Back, Looking Forward: Proceedings of the Tenth International Conference on Teaching Statistics* (ICOTS-10, Kyoto, Japan), edited by M. A. Sorto, A. White, and L. Guyot. International Statistical Institute, 2018.

(This work was supported in part by the National Science Foundation under Grant No. 1149403. The ideas expressed here are those of the author and do not necessarily reflect the views of NSF.)

Form

- Audience: Practicing middle and high school teachers
- Type: Series of nine 1- to 2-hour activities integrated into a multi-day professional learning experience

Function: Teachers experience the Statistical Problem-Solving Process and develop content knowledge about important concepts such as center, variability, and distribution. Teachers also develop pedagogical content knowledge as they explore activities similar to those they could use with current or future students, and they consider students' reasoning about the concepts.

Features

- Collaborative group work
- Real, uncleaned student-focused data
- Research-based

- Student artifacts
- Technology
- Traditional and non-traditional statistical measures

Description: Teachers engage in a series of nine activities (not needing to enact all of them). Teachers select a sample from Census at School, an international project in which teachers of grades 4–12 can have their students complete a survey and analyze class responses to survey items, using the Random Sampler, and share what they notice and wonder about their sample data. They also consider the provenance of the data and interrogate the variables included in the dataset. Teachers consider the statistical investigative questions they might ask using the data and population associated with the data and analyze data accordingly. Teachers then engage with a research-informed activity to consider how to build developing notions of distribution. The activities cover typical values, conventional and unconventional measures of variability, the interquartile range, data represented in boxplots, and comparing distributions.

Example: Comparing Food Projects: Investigating Crowdfunding with Data

Authors: Amy Brodesky; Emily Fagan; Josephine Louie; Data Paths team at Education Development Center *datapaths.edc.org*

Citation

Brodesky, Amy, Emily Fagan, Josephine Louie, K. Bjork, and J. Nikula. Investigating crowdfunding with data: Middle grades module. The Data Paths Project. Education Development Center, Inc., 2026.

The Data Paths Project has been funded by the state of Massachusetts.

Form

- Audience: Practicing middle school teachers; Prospective middle school teachers (with adaptation)
- Type: Professional learning activity of approximately two hours

Function: Teachers go through an investigation that develops their content knowledge on comparing distributions, using technology, calculating and interpreting measures of center and variability, and making and interpreting graphical representations. Then, teachers read an article discussing statistical teaching practices and use it as guidance to design an appropriate lesson for their students that is aligned with the Statistical Problem-Solving Process and based on the same investigation.

Features

- Article review
- Collaborative group work
- Real data
- Technology
- Video

Description: Teacher educators will engage middle school teachers with the activity, Compare Successful and Unsuccessful Food Projects. The activity uses the context of crowdfunding to engage teachers in working with real data about crowdfunded projects and building important data skills and understandings. The activity focuses on using technology to help represent and analyze data, create dot plots and box plots to compare two groups, and analyze distributions and measures of spread and center.

Example: Students' Reasoning About a Segmented Bar Graph

Authors: Lee, Hollylynne; Mojica, Gemma; Hudson, Rick; Casey, Stephanie; Finzer, William; Thrasher, Emily; Abel, Rachel

Citations

ESTEEM II Curriculum Team. Enhancing Statistics Teacher Education Through E-Modules: Teaching Statistical Association Module Set. 2025. tinyurl.com/yf7kx7n95

Casey, Stephanie, Rick Hudson, and L. Ridley. Students' reasoning about association of categorical variables. In *Looking Back, Looking Forward: Proceedings of the Tenth International Conference on Teaching Statistics* (ICOTS10, July 2018). Kyoto, Japan: International Statistical Institute, 2018. tinyurl.com/bdfn2uwm

Jacobs, Victoria R., Lisa L. C. Lamb, and Randolph A. Philipp. Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education* 41, no. 2 (2010): 169–202.

Smith, Margaret, and Mary Beth Stein. *5 practices for orchestrating mathematics discussions*. Reston, VA: NCTM, 2011.

Form

- Audience: Prospective or practicing middle school or high school teachers
- Type: A two-part activity—part 1 takes an estimated 20 minutes and part 2, an estimated 60 minutes.

Function: This two-part activity provides the opportunity for developing both teachers' content and pedagogical knowledge related to analyzing bivariate categorical data. The data are represented as segmented bar graphs as well as two-way tables. Emphasis on developing teachers' pedagogical content knowledge for teaching bivariate categorical data, specifically knowledge of content on how students reason and associated professional noticing skills.

This is adapted from activity B.1.f from tinyurl.com/yf7kx7n95.

Features

- Real data
- Reflection
- Research-based
- Student artifacts
- Videos
- Professional noticing

Description: Students' interpretations of graphs are essential in drawing accurate inferences from a dataset. As

teachers, it is important to critically think about the possible responses we might have for students who encounter difficulty in understanding a graph. Recent educational research has focused on the practice of teachers' professional noticing of students' thinking. Professional noticing is "a high-leverage teaching practice that consists of three related skills: (1) attending to a student's strategies as they reason mathematically or statistically; (2) interpreting the student's strategies; and (3) deciding how to respond to the student based on their understanding (Jacobs, Lamb, & Philipp, 2010)." In this activity, teachers will analyze a segmented bar graph, consider how sixth- and seventh-grade students interpreted this graph, and craft responses to each student as if they were their teacher.

Example: Learning About Students' Statistical Thinking Through Interviews

Author: Randall Groth

Citation

Groth, Randall E. Developing statistical knowledge for teaching during design-based research. *Statistics Education Research Journal* 16, no. 2 (2017): 376–396. doi.org/10.52041/serj.v16i2.197.

Form

- Audience: Prospective middle school teachers.
- Type: Clinical experience activity of approximately six one-hour class sessions.

Function: Prospective teachers decide if the mean or median best describes the center of a given dataset. They elicit middle school students' thinking about summarizing the same dataset. Finally, teachers construct a lesson for the middle school students.

Features

- Reflection
- Research-based activity
- Student artifacts
- Video

Description: Prospective teachers solve and discuss a task from the National Assessment of Educational Progress that involves deciding between mean and median to describe typical values in datasets. Then, they pose the NAEP task to middle school students during an interview and ask them to think aloud as they solve it. The interview is video recorded and students' written work on it is retained. Prospective teachers analyze the video and written work, then collaborate with one another and a teacher educator to design a lesson for the students they interviewed.

Example: Engaging in the Statistical Problem-Solving Process

Author: Pip Arnold

Citations

Arnold, Pip, and Christine Franklin. What makes a good statistical question? *Journal of Statistics and Data Science Education* (2021): 1–11. tinyurl.com/ysudyrw4

Arnold, Pip. Statistical investigative questions: An enquiry into posing and answering investigative questions from existing data. Doctoral thesis, University of Auckland, 2013. <https://hdl.handle.net/2292/21305>

Tāhūrangi - New Zealand Curriculum. (n.d.). *Get real - Variation in data*. tinyurl.com/ms8n36vk

Form: Ongoing professional learning or prospective teacher-learning methods course aimed at middle school teachers. The series of three activities are about 1.5 hours each. They could be delivered as a day-long workshop or as a series of stand-alone shorter sessions.

Function: Engaging in student-level activities to deepen teacher understanding of SKT around the Statistical Problem-Solving Process.

Features

- Article review
- Collaborative group work
- Real data
- Reflection

- Research-based
- Technology

Description: Teacher educators engage prospective or practicing teachers in a series of tested student-level activities in New Zealand classrooms that collectively address different elements of the Statistical Problem-Solving Process. While the activities target students in grades 6–8 (ages 11–14 years), teachers working at earlier grade levels could benefit from engaging in the activities to build their pedagogical and subject content knowledge.

Level C Example Descriptions

Example: Simulation of Practice of Interpreting and Responding to Student Thinking—Informal Line of Best Fit

Authors: Stephanie Casey; Andrew Ross; Samantha Maddox; Melody Wilson

Citations

Casey, Stephanie, Andrew Ross, Samantha Maddox, and Melody Wilson. MODULE(S2): Statistics for Secondary Mathematics Teaching. 2nd ed. Mathematics of Doing, Understanding, Learning, and Educating for Secondary Schools. Association of Public and Land-Grant Universities, 2023. modules2dotcom.wordpress.com/statistics

Casey, Stephanie A. Examining student conceptions of covariation: A focus on the line of best fit. *Journal of Statistics Education* 23, no. 1 (2015). doi.org/10.1080/10691898.2015.11889722

Form

- Audience: Prospective or practicing middle or high school teachers
- Type: Activity (approximately 90 minutes) to be implemented within a teacher preparation course or professional development session. Note that teachers will be asked to make video recordings, so this has usually been implemented outside of synchronous group sessions.

Function: Teachers interpret approaches that students commonly use when asked to place an informal line of best fit on a scatterplot. Teachers also develop pedagogical moves to make in response to different student approaches.

Features

- Student artifacts
- Reflection
- Research-based activity

Description: Teachers are presented with a scenario in which they are teaching an eighth-grade math class about the informal line of best fit (i.e., modeling data with a linear association through a line placed by eye). In this scenario, they have presented students with data exhibiting linear association in a scatterplot and asked students to come up with their own

approaches for finding the informal line of best fit, using a piece of spaghetti as the line. The activity then presents images of how two students placed their lines and the accompanying student explanations. Teachers are asked to record videos of themselves in which they interpret each student's thinking, then they present their response to each student as if they were speaking to the student in real time.

Example: From German Tank to Chickpeas: Estimating the Size of a Population

Authors: Laura Morera; Marcel Algueró; Bernat Portell; Learning Team at Innovamat

Citation

Scheaffer, Richard, Indra Gnanadesikan, Ann Watkins, and Jeffrey A. Witmer. *Activity-based statistics*. New York: Springer-Verlag, 1996.

Form

- Audience: Practicing high school teachers
- Type: Three activities (~45 minutes each) for an advanced workshop

Function: Teachers work through constructing simulations to estimate population size. Motivating the first problem through the historical German Tank Problem, teachers estimate the population size using slips of paper in a bag. Then, teachers estimate the number of

chickpeas in a bag. They compare the estimation methods used for the population size with those typically used when estimating the population mean or the population proportion.

Features

- Article review
- Media review
- Technology
- Traditional and non-traditional statistical measures
- Videos

Description: The aim of this workshop activity is to make an estimate of the population size in two scenarios. On one hand, we propose a case where elements are identifiable because they are numbered (the German Tank Problem). On the other hand, we propose a situation where initially we cannot distinguish population elements (mark and recapture). We challenge teachers to reflect on strategies to infer population size in both cases, while also raising questions about refining these strategies.

Example: A Lesson Study Using ESTARS

Authors: Beth Chance; Soma Roy

Citation

NSF Discovery Research K-12, Award #2201121)

Form

- Audience: Practicing high school teachers
- Type: Professional development experience of approximately 4–6 hours broken up into five sessions and one direct teaching activity

Function: Teachers are provided an orientation to *GAISE II* and engage in a module that incorporates the *GAISE II* recommendations. They co-develop similar lessons for their students, implement the lesson with their students, and reconvene to share their reflections.

Features

- Student artifacts
- Collaborative group work
- Lesson study
- Microteaching
- Research-based
- Reflection
- Technology

Description: This lesson study takes teachers through a module, Foot Length and Height: A CSI-type investigation, developed through the ESTARS project that aligned with the *GAISE II* recommendations. Teachers complete the module themselves, adjust the module for classroom use, microteach the model for other teachers, implement the module in their own classrooms, and reconvene to reflect on the implementation. Adjustments to the classroom

module are made through group feedback and reflection.

Example: American Time Use Survey

Authors: Anna Bargagliotti; Rob Gould; Christine Franklin; Pip Arnold

Citation

Arnold, P., Bargagliotti, A., Franklin, C., & Gould, R. (2022). Bringing complex data into the classroom. *Harvard Data Science Review*, 4(3). doi.org/10.1162/99608f92.4ec90534

This example was used in Stats&DataNet Professional Development: www.amstat.org/education/sdn/home

Form

- Audience: Practicing high school teachers
- Type: Project for teachers that requires approximately 8 hours

Function: The purpose of this project is for teachers to develop practices for complex datasets, namely data interrogation, data moves, and data consideration. After the data are understood, teachers conduct a statistical investigation following the Statistical Problem-Solving Process. Teachers make pedagogical connections to develop a similar investigation that can be done with students.

Features

- Collaborative group work
- Media review
- Real data
- Research-based
- Reflection
- Teacher artifacts
- Technology

Description: This project allows teachers to connect a data visualization seen in the news to a deep statistical study of the dataset used to make the visualization. A main focus is on the *GAISE* component of Collect/Consider Data. After teachers interrogate the secondary data, they carry out a statistical investigation using the dataset. The culmination of the activity is to have teachers connect to their own classrooms by developing a similar data collection plan for their students and leading students to conduct an investigation on the data they collected.

Chapter 6

Summary, Next Steps, and Future Directions

To ensure long-term impact and keep up with the pace of change, statistics and data education for teachers must be continuous, collaborative, and practice-centered.

Summary

This Statistical Education of Teachers II document (update of the 2015 *SET* document) outlines what is needed for statistics and data education for teachers. Although the foundational statistics content, concepts, and practices have remained relatively stable, the rapidly evolving landscape of data, technology, and AI necessitates revisiting what and how we teach students to become sound statistical thinkers capable of reasoning with data. Teacher educators must therefore balance timeless principles with adaptive practices that prepare teachers to thrive with uncertainty.

Chapter 1 conceptualizes the effective preparation of teachers for teaching of statistics and data education as the interplay of three important foundational pillars: (1) *Pre-K–12 GAISE II* framework to describe essential content for student learning, (2) Statistical Knowledge for Teaching to characterize the subject-matter expertise teachers need, and (3) the Effective Teaching Practices needed to support student learning. These foundational pillars do not stand alone but instead work together to support teachers' development of statistics and data education for teaching. Chapters 2 and 3 identify seven cross-cutting big ideas of statistics and data education and present a framework

of teacher learning objectives. The intention of *SET II* is to provide guidance for teacher educators to assist new and experienced teachers in the big ideas and the framework in teacher preparation. While the seven big ideas hold relatively constant across time, the framework tables should be viewed as a “living document” that will require revision to incorporate new learning outcomes as data practices, computational tools, and societal demands evolve and advance (Lee et al., 2024).

Next Steps

AI technologies are reshaping the workings of society today. Generative artificial intelligence has rapidly been integrated into the workforce and daily life, for better or worse. Educators have the burden of weighing the benefits of using a widely used tool with the potential risks of adopting a tool that hasn't yet been well-researched in classroom settings and for learning. Teachers of statistics are uniquely positioned to understand and teach the basic principles underlying these technologies to help prepare the next generation of students. However, while genAI and other emerging tools offer opportunities to personalize instruction, enhance feedback, and increase efficiency, they also bring large potential risks around cognitive development (Tau et al., 2026), dependency (Ahmad et al., 2023; Bai et al., 2023; Kasneci et al., 2023; Pedró et al., 2019),

algorithmic bias (Shieh, et al. 2026; Cirillo & Rementia 2022; Speer 2017), and privacy (Kumar & Vavekanand 2025). More research is needed to understand the risks and benefits and the appropriate uses of AI technologies for teaching and learning. However, we can potentially draw lessons from past rapid technological shifts. Social media's integration into schools preceded robust research on its developmental impacts, and only later did evidence about the possibility for negative effects on mental health emerge (Agyapong-Opoku 2025), possibly illustrating how the negatives of implementation of social media in our daily lives outweighed the positives. A teacher educator's attention should focus on whether the tool assists students and teachers in meeting learning outcomes and objectives, aside from any special convenience the tool may offer. Therefore, responsible teacher educators at this time should:

Urge extreme caution in the adoption of genAI as a teaching and learning tool and its use with teachers, pending further research from emerging studies on the potential risks and benefits for student learning of implementation of genAI within learning environments. This entails thinking critically about piloting AI technologies to assess their impact on student learning, and documenting instructional decisions rather than adopting tools uncritically. It also

entails exploring student data privacy, algorithmic bias, and responsible use of AI technologies in educational settings. Emphasizing understanding of GAI's workings helps teachers remain informed consumers rather than passive users of technology.

Encourage teachers to be aware of the connections between statistics/data content and GAI, with the understanding that this connection will change over time. This entails possibly developing modules on machine learning fundamentals, difference between mathematical deterministic models and statistical probabilistic models, and ethical considerations in using AI technologies. Using such modules, teachers can critically evaluate AI technologies and explain them to students.

Teacher educators, administrators, and policy makers must stay current on what research-based adaptations are needed in the education of teachers to address these advancements. They need to help teachers develop an integrated skill set that combines the foundational pillars, cross-cutting themes, and frameworks of teacher learning outcomes. Evidence from systematic reviews shows that teacher data literacy is multidimensional—encompassing knowledge, skills, dispositions, and behaviors related to interpreting and using data for instructional purposes (Lee et al., 2024; Schreiter, 2024).

Recognizing the evolving needs of teachers education requires the view that teacher education is ongoing and continues throughout a teacher's career. Teacher educators must continue to provide professional learning opportunities at all stages of a teacher's career path. Different ways of preparing teachers should be embraced adhering to the cross-cutting big ideas and frameworks presented in this report. Research on teacher and student learning on statistics and data education should continue and be used to inform best practices at all times. In addition, policy makers should prioritize professional learning for teachers. Teacher educators should transmit enthusiasm to teachers about the possibilities and power of working with data. Helping teachers and students to learn how to work with data and make informed decisions not only empowers an individual teacher or students but also illustrates how statistics and data education are the way we learn things in a world of uncertainty.

Future Directions

To ensure long-term impact and keep up with the pace of change, statistics and data education for teachers must be continuous, collaborative, and practice-centered. The report promotes all types of professional development (e.g., models with coaching and communities of practice (Zhou

et al, 2023), one-off sessions, etc.)—the more the better! Teacher educators should build teachers’ capacity to “learn how to learn” new tools by teaching them to read documentation, evaluate claims, and practice reproducibility habits. Such dispositions reduce obsolescence as tools evolve. To align with *SET II*’s vision and using the guidance from this document, we recommend the following key practices for teacher educators:

- **Maintain the three important foundational pillars as the structure for teacher statistics and data education:** Use *Pre-K–12 GAISE II Framework* to describe essential content for student learning; Statistical Knowledge for Teaching to characterize the subject-matter expertise teachers need; and the Effective Teaching Practices needed to support student learning
- **Maintain timeless the cross-cutting big ideas:** Focus on statistics and data reasoning and data habits of mind using best practices.
- **Revisit the framework regularly:** Revisit learning objectives to reflect evidence from research, emerging technologies, ethical concerns, and societal shifts.
- **Understand the connection between genAI and statistics and data:** Help teachers understand the connection

between genAI models and statistics and data to better comprehend its mechanisms, limitations, and implications for use and consider which of these connections are also important for students. Use research evidence to inform and meet evolving needs.

- **Support sustained professional learning:** Build structures for ongoing inquiry, collaboration, and critical reflection.

SET II offers both timeless guidance and timely direction. By embracing the pillars for teacher preparation, the cross-cutting ideas and adopting the framework, teacher educators can ensure that teachers develop a critical skepticism of genAI and other tools/technologies that may be developed to thrive in a data-rich, technology-driven society. This report began by presenting the following seven big ideas:

1. Engaging with the statistical problem-solving process
2. Understanding the role of questioning
3. Understanding the difference and application of probabilistic and deterministic thinking
4. Engaging with modeling in all facets of working with data
5. Using technology as a tool for learning and doing statistics
6. Developing Statistical Habits of Mind
7. Adhering to humanistic practices

Looking to the future, we believe these big ideas will continue to be essential for preparing teachers, and in turn students, to live, work, and play in society where technology is rapidly changing. We invite readers to engage in scholarship, contribute to professional learning communities, and share the excitement and desire to educate teachers as they hold the key to impacting our future and society.

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Chapter 7

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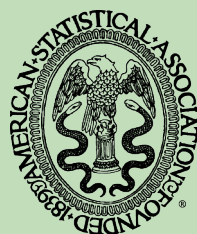
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Statistical Education of Teachers II (SET II) connects a compelling vision for statistics and data education with concrete guidance for teacher preparation and professional learning. Extending across subjects and pre-K–12 grade levels, it describes what teachers need to know and how they can help students question, explore, analyze, and interpret the world through data.

Seven cross-cutting big ideas anchor the report, supported by clear teacher learning outcomes, targeted preparation recommendations, and 17 examples of teacher learning experiences. Together, these resources help educators design courses, strengthen professional development, and connect statistical content with effective teaching.

Whether you prepare future teachers, support practicing educators, or shape educational policy, SET II offers direction for helping students become thoughtful consumers and producers of statistical information.



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