

# Appendix A: Research to Inform the CSTA PK–12 Standards Revision

## Executive Summary

The revision to the CSTA PK–12 Standards was a collaborative and research-driven process designed to ensure that the resulting standards reflect the latest insights and best practices in computer science education. This report documents the extensive research that informed the revision, resulting in updated standards that reflect the “grounded in research” value that underpins the process.

WestEd led a detailed literature review and analysis of related standards and frameworks, as well as a comparison with 12 other sets of instructional guidelines. The research was guided by key questions about alignment with learning progressions, the influence of emerging technologies such as generative AI, pedagogical practices promoting equity, and coverage across existing computer science curricula. WestEd developed design briefs and literature reviews for each standard concept, ensuring that writers had access to the most relevant and timely research as they drafted new standards. Additionally, the *Amplifying Social Impacts of Computing Standards* (ASICS) project provided recommendations related to impacts and ethics of computing, and the *Identifying AI Priorities for All K-12 Students* project, co-led by CSTA and AI4K12, developed recommendations related to artificial intelligence.

This report outlines key recommendations pulled from this research as well as specific examples of how the research is reflected in the updated standards. Table 1 presents a preview of the findings, highlighting one recommendation and one example for each topic in the report. The full report includes several examples per concept.

**Table 1. Examples of Recommendations and Their Reflection in the Standards**

Concept	Research Provided	Sample Recommendation	Example in the Standards
Structure	<a href="#">Comparison of CSTA Standards to Other Standards and Frameworks</a> <a href="#">Standards Alignment Review</a> <a href="#">Structure Design Brief</a>	Grade bands should be organized in the following way: <ul style="list-style-type: none"> <li>PK standards should be included as part of a grade band (e.g., PK–2), if they are included at all.</li> <li>Elementary school standards (grades K–5) can be written for individual grades or for two grade bands: K–2 and 3–5.</li> <li>Middle school standards (grades 6–8) should be banded together.</li> <li>High school standards (grades 9–12) should be banded together.</li> </ul>	PK/K standards are banded, and grades 1–5 are separated into discrete grade level standards.  Middle school standards (grades 6–8) are banded.  High school standards (grades 9–12) are banded.

Concept	Research Provided	Sample Recommendation	Example in the Standards
Algorithms & Design	<a href="#">Algorithms and Programming Literature Review</a>  <a href="#">Structure Design Brief</a>	Support students in following and writing step-by-step instructions for solving problems.	This recommendation is exemplified in the following standards, as well as in many standards that ask students to design and create algorithms: <ul style="list-style-type: none"> <li>EK-ALG-PS-01: Carry out algorithms in daily activities.</li> <li>E1-ALG-PS-01: Decompose a problem or task into individual parts to develop an algorithm.</li> </ul>
Programming	<a href="#">Algorithms and Programming Literature Review</a>	Program comprehension (i.e., reading, interpreting, and communicating about code) is an important concept that seems absent in the 2017 CSTA K–12 Standards.	The Programming subconcept Reading & Documenting addresses program comprehension.
Data & Analysis	<a href="#">Data and Analysis Literature Review</a>  <a href="#">Data and Analysis Design Brief</a>	At the elementary level, students should ask and answer questions of small datasets collected in familiar contexts.	This recommendation is exemplified in the following standards: <ul style="list-style-type: none"> <li>E2-DAT-DI-09: Develop a question that can be answered with data.</li> <li>E4-DAT-DC-09: Organize collected data into a table using a computational tool, with rows representing records and columns representing attributes.</li> </ul>
Systems & Security	<a href="#">Computing Systems and Security Literature Review</a>  <a href="#">Computing Systems and Security Design Brief</a>	A correct and detailed understanding of the internet as a network of networks with specific servers and connections is rare and typically only seen in children over the age of 10 or 11, so this should not be addressed until middle school standards.	In the updated standards, MS-SYS-NT-35 (“Explain how the resilience of the internet depends on interconnected devices and their roles and functions within the network.”) is a middle school standard, rather than an elementary school standard.
Computing & Society	<a href="#">Computing and Society Literature Review</a>	The History of Computing standards should progress from a small/local scope at lower grades to a larger/global scope at higher grades.	The updated standards include a comprehensive progression demonstrating how computing relates to society as a whole. This recommendation is specifically exemplified in the following standards progression: <ul style="list-style-type: none"> <li>Elementary (EK-SOC-HI-14): Identify computing technologies used in daily life that have changed over time.</li> </ul> <i>(...continued)</i>

Concept	Research Provided	Sample Recommendation	Example in the Standards
Computing & Society (continued)	<a href="#">Computing and Society Literature Review</a>	The History of Computing standards should progress from a small/local scope at lower grades to a larger/global scope at higher grades.	<ul style="list-style-type: none"> <li>Middle school (MS-SOC-HI-38): Compare the roles of individuals, communities, organizations, and governments in shaping computing technologies across major eras in computing history.</li> <li>High school (HS-SOC-HI-38): Analyze the historical trajectory of a specific computing technology and how its development is linked to societal and environmental factors.</li> </ul>
Artificial Intelligence	<a href="#">Artificial Intelligence Design Brief</a>  <a href="#">Identifying AI Priorities for All K-12 Students</a>	Begin introducing AI curriculum in early elementary school.	AI is included in several elementary standards. For example: <ul style="list-style-type: none"> <li>E5-ALG-IM-03: Articulate how human-centered design principles are incorporated into the development of a computing technology.</li> <li>E3-SOC-HU-18: Examine why people design and build computing technologies.</li> </ul>
Impacts & Ethics	<a href="#">Structure Design Brief</a>  <a href="#">Amplifying Social Impacts of Computing Standards Reference Materials</a>  <a href="#">Computing Impacts and Ethics in the CSTA Standards: A Synthesis of Expert Perspectives</a>	Impacts and ethics content is taught inconsistently when it is defined as a separate concept within standards. Embed this content throughout the standards in order to increase the probability that these are taught more consistently.	Impacts and ethics content is embedded across multiple concepts instead of separated as its own concept.

The revised CSTA PK–12 Standards reflect a direct line from research to practice. Recommendations from research, literature reviews, curriculum analyses, and expert partnerships were consistently translated into actionable standard language and structure throughout the update process. This meticulous integration ensures that standards not only respond to current instructional needs and technological advancements, but are also poised to support equitable, rigorous, and relevant computer science education for all students.

## Introduction

*Grounded in research* was one of the core values guiding the revision to the CSTA PK–12 Standards. This report describes how research informed the revision process and foregrounds the ways the updated standards reflect research-based practices alongside our other values.

Research was one of many inputs that writers considered in drafting the updated standards. Writers also drew on public feedback, advisor feedback, community definitions, and their own computer science education experiences. So, although research informs many aspects of the updated standards, it is not always possible to draw a direct line from each research recommendation to a final standard. We provide some examples of some direct connections from research to final standard language in this report.

Given project constraints, the team prioritized research that primarily influenced the Foundational Standards. [Reimagining CS Pathways](#) (CSTA et al., 2024) and related projects influenced standards organization at a high level (including Foundational and Specialty organization) and provided a base layer of content for each of the defined specialty areas. Due to the varied nature of the specialty standards, the team consulted with individuals and organizations that have conducted research related to each specific specialty area. This report focuses primarily on research related to the Foundational Standards.

## Overview of the Research Process

WestEd conducted a literature review and detailed analysis of related standards and frameworks to inform the CSTA K–12 Standards update. The literature review was driven by the following questions:

- How well do 2017 CSTA and state standards align with research on learning progressions for K–12 computer science topics?
- How might the increasing use of generative AI influence learning progressions for K–12 computer science topics, particularly around programming?
- What pedagogical practices have been shown to promote equity for students learning K–12 CS content?
- How well do popular K–12 CS curricula align with 2017 CSTA and state CS standards and practices?
- What learning progressions are suggested or inferred for K–12 computer science education related to:
  - algorithms?
  - programming?
  - data and analysis?
  - computing systems and security?
  - impacts and ethics?
- To what extent do popular K–12 computer science curricula cover 2017 CSTA standards?
- What pedagogical practices promote equity for students learning K–12 computer science content?

WestEd’s initial literature review search resulted in 727 articles. The team narrowed the list down to 54 relevant articles matching an agreed-upon criteria for inclusion. The literature review of these 54 articles led to specific findings and recommendations that writers were able to apply by concept area.

Additionally, WestEd conducted a standards and frameworks comparison to compare the 2017 CSTA standards to 12 other sets of standards, frameworks, and instructional guidelines.

- CS-specific standards and frameworks:
  - [EU Informatics Reference Framework for School](#)
  - [AI4K12 Guidelines](#)
  - [K-12 Cybersecurity Learning Standards](#)
- Other STEM standards and frameworks:
  - [Common Core State Standards for Mathematics \(CCSS-M\)](#)
  - [Guidelines for Assessment and Instruction in Statistics Education II \(GAISE II\)](#)
  - [Next Generation Science Standards \(NGSS\)](#)
  - [Standards for Technological and Engineering Literacy \(STEL\)](#)
- Arts and Humanities standards and frameworks:
  - [Common Core State Standards for English Language Arts \(CCSS-ELA\)](#)
  - [National Curriculum Standards for Social Studies](#)
  - [National Core Arts Standards](#)
  - [The Common Career Technical Core](#)
  - [Social Justice Standards](#)

The goals of the comparisons were to:

- Use the structure of other standards and frameworks to inform the structure of the revised computer science standards;
- Identify enduring content from the 2017 CSTA standards as well as areas where the field has evolved and the standards should be updated accordingly; and
- Make recommendations for standards writers about the structure and content of the revised computer science standards.

WestEd developed design briefs and literature reviews related to each standard concept based on this research. The WestEd team shared the resulting recommendations with the standards writers, who used the analyses to inform their work. Additionally, the ASICS project provided recommendations related to impacts and ethics of computing, and the *Identifying AI Priorities for All K–12 Students* project, co-led by CSTA and AI4K12, developed recommendations related to Artificial Intelligence. Table 2 includes links to the research provided to writers during the standards development process.

Table 2. Research Shared with Writers

Concept or Topic	Research Provided
Structure	<a href="#">Comparison of CSTA Standards to Other Standards and Frameworks</a> <a href="#">Standards Alignment Review</a> <a href="#">Structure Design Brief</a>
Algorithms & Design	<a href="#">Algorithms and Programming Literature Review</a> <a href="#">Structure Design Brief</a>
Programming	<a href="#">Algorithms and Programming Literature Review</a>
Data & Analysis	<a href="#">Data and Analysis Literature Review</a> <a href="#">Data and Analysis Design Brief</a>
Systems & Security	<a href="#">Computing Systems and Security Literature Review</a> <a href="#">Computing Systems and Security Design Brief</a>
Computing & Society	<a href="#">Computing and Society Literature Review</a>
Artificial Intelligence	<a href="#">Artificial Intelligence Design Brief</a> <a href="#">Identifying AI Priorities for All K–12 Students</a>
Impacts & Ethics	<a href="#">Structure Design Brief</a> <a href="#">Amplifying Social Impacts of Computing Standards Reference Materials</a> <a href="#">Computing Impacts and Ethics in the CSTA Standards: A Synthesis of Expert Perspectives</a>
Other Resources	<a href="#">Reimagining CS Pathways: Every Student Prepared for a World Powered by Computing</a> <a href="#">State K–12 Computer Science Standards Comparison Report</a> <a href="#">International Computer Science Standards Comparison Report</a> <a href="#">The 2025 Computer Science Teacher Landscape: Insights Into Teacher Preparedness for a World Powered by Computing</a>

## Examples of Research Recommendations and Their Influence on the Standards

The writers incorporated the research into their writing process as they made decisions about how to update the standards. This research was one of many inputs that writers considered in drafting the updated standards. They also drew on public feedback, advisor feedback, the [Reimagining CS Pathways report](#), and their own computer science education experiences. Although it is not always possible to draw a direct line from each research recommendation to each standard, we can highlight specific examples of how the research is directly reflected in the updated CSTA PK–12 Standards. Included below are some select examples of recommendations from the research that were shared with standards writers as well as samples of the influence of these recommendations on the final standards. These examples do not represent a comprehensive list of all the ways in which research informed the standards development. They instead serve as an exemplification of the direct connections between the research and the final standards. Examples are provided for all five standards concepts (Algorithms & Design, Programming, Data & Analysis, Systems & Security, and Computing & Society), the overall structure of the standards, and how AI and impacts & ethics content was incorporated throughout the standards.

### Structure

Writers used the [Standards Alignment Review](#), the [Comparison of CSTA Standards to Other Standards and Frameworks](#), and the [Structure Design Brief](#) to inform decisions around the structure of the updated CSTA PK–12 Standards. Table 3 outlines some example recommendations from the research and the resulting structural decisions reflected in the final standards.

**Table 3. Examples of Structure Recommendations and Resulting Standards Structure**

Recommendation	Example(s) in the Standards
Adopt clear descriptions of the content and practices. Explicitly integrate practices and content within the standards.	The standards include clear descriptions of both concepts and practices. Practices are organized into four categories (of two to four practices each): Ethics & Social Responsibility, Inclusive Collaboration, Computational Thinking, and Human-Centered Design. Each standard integrates a subconcept with one or two specific practices.
Standards should describe what students should know and be able to do after instruction. They should be accompanied by supplementary material that defines the concepts, practices, and their respective learning progressions, as well as identifies interdisciplinary connections.	The standards themselves are limited to describing what students should know and be able to do after instruction. Each standard is accompanied by implementation examples and interdisciplinary connections. The introduction to the standards contains definitions of the concepts and practices.

Recommendation	Example(s) in the Standards
<p>Grade bands should be organized in the following way:</p> <ul style="list-style-type: none"> <li>PK standards should be included as part of a grade band (e.g., PK–2), if they are included at all.</li> <li>Elementary school standards (grades K–5) can be written for individual grades or for two grade bands: K–2 and 3–5.</li> <li>Middle school standards (grades 6–8) should be banded together.</li> <li>High school standards (grades 9–12) should be banded together.</li> </ul>	<p>PK/K standards are banded, and grades 1–5 are separated into discrete grade level standards.</p> <p>Middle school standards (grades 6–8) are banded.</p> <p>High school standards (grades 9–12) are banded.</p>
<p>The length of standards should follow these guidelines:</p> <ul style="list-style-type: none"> <li>Standards should generally be one sentence of around 20 words, with one verb.</li> <li>Write 10–15 standards per grade level and aim for a total of 150–200 standards.</li> </ul>	<p>Each standard is one sentence of about 15 words and begins with a single, measurable verb from <i>Bloom’s for Computing</i>.<sup>1</sup></p> <p>There are about 15 foundational standards per grade level and about 200 foundational standards total.</p>
<p>Impacts and ethics are taught inconsistently when they are defined separately from other concepts within the standards. Embed this content throughout the standards in order to increase the probability that these are taught more consistently.</p>	<p>Impacts and ethics content is embedded across concepts instead of separated as its own concept.</p>
<p>In a review of eight widely used K–12 computer science curricula, the Algorithms &amp; Programming topic area received the most coverage across all reviewed curricula except for one.</p>	<p>Algorithms and Programming are two distinct concepts rather than one combined concept.</p>
<p>In a review of eight widely used K–12 computer science curricula, standards for Computing Systems and for Networks &amp; the Internet are covered less than standards for Algorithms and for Programming.</p>	<p>Computing Systems and Networks &amp; the Internet are combined into one concept (Systems &amp; Security) rather than two distinct concepts.</p>

<sup>1</sup> Association for Computing Machinery (ACM) Committee for Computing Education in Community Colleges (CCECC). (2023). *Bloom’s for computing: Enhancing Bloom’s revised taxonomy with verbs for computing disciplines*. <https://ccecc.acm.org/files/publications/Blooms-for-Computing-20240814.pdf>

## Algorithms & Design

Writers used the information presented in the [Algorithms and Programming Literature Review](#) and the [Structure Design Brief](#) to inform decisions about Algorithms & Design standards. This research informed the decision to separate Algorithms and Programming into two distinct concepts. Table 4 outlines some example recommendations from the research and how these recommendations are reflected in the final Algorithms & Design standards.

**Table 4. Examples of Recommendations and Algorithms & Design Standards**

Recommendation	Example(s) in the Standards
<p>Due to increasing use of AI, there should be a greater emphasis on algorithms in curricula and teachers' instruction than the 2017 standards reflect. Splitting Algorithms and Programming into two distinct concepts allows for greater emphasis on algorithms and AI use.</p>	<p>Algorithms &amp; Design and Programming are two distinct concepts. While there is a similar number of Programming standards as compared to the number of 2017 standards, there are far more Algorithms &amp; Design standards.</p> <p>AI is integrated across all five concepts and most significantly included in the Algorithms &amp; Design and Computing &amp; Society standards.</p>
<p>Support students in following and writing step-by-step instructions for solving problems.</p>	<p>This recommendation is exemplified in the following standards, as well as in many standards that ask students to design and create algorithms:</p> <ul style="list-style-type: none"> <li>• EK-ALG-PS-01: Carry out algorithms in daily activities.</li> <li>• E1-ALG-PS-01: Decompose a problem or task into individual parts to develop an algorithm.</li> </ul>
<p>Support students in understanding how to make algorithms more efficient and scalable.</p>	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• HS-ALG-PS-02: Optimize the design of an algorithm using procedural abstraction and control structures.</li> <li>• HS-ALG-PS-03: Evaluate algorithms for efficiency, correctness, and clarity, using metrics or test cases.</li> </ul>
<p>Incorporate key ideas about human-centered design, “an approach to interactive systems that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility, and sustainability and counteracts possible adverse effects of use on human health, safety, and performance” (NIST, 2021).</p>	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E3-ALG-IM-03: Compare how different algorithms may affect outcomes, situations, and people with a wide range of needs.</li> <li>• E4-ALG-IM-03: Evaluate how different algorithms for solving the same problem produce outcomes that may benefit or disadvantage different groups of people.</li> <li>• E5-ALG-IM-03: Articulate how human-centered design principles are incorporated into the development of a computing technology.</li> </ul>

## Programming

Research related to the Programming concept revealed that most of the 2017 Programming standards maintained alignment with current research. The resulting recommendations emphasized the importance of preserving this alignment in the updated standards. Writers used information presented in the [Algorithms and Programming Literature Review](#) to inform their decisions related to the Programming concept. Table 5 outlines some example recommendations from the research and how these recommendations are reflected in the final Programming standards.

**Table 5. Examples of Recommendations and Programming Standards**

Recommendation	Example(s) in the Standards
<p>Due to increasing use of AI, there is a greater emphasis on algorithms in current curricula and teachers' instruction than the 2017 standards reflect. Splitting Algorithms and Programming into two distinct concepts would allow for greater emphasis on algorithms and AI use.</p>	<p>Algorithms &amp; Design and Programming are two distinct concepts.</p> <p>AI is integrated across all five concepts and most significantly included in the Algorithms &amp; Design and Computing &amp; Society standards.</p>
<p>The literature reviewed is in accord with many of the 2017 CSTA K–12 Standards. So, the existing standards provide a solid starting ground for the 2026 revision. Keep most of the Programming learning progressions intact, as they are the most aligned to evidence.</p>	<p>The Programming learning progressions from the literature and 2017 CSTA K–12 Standards are maintained.</p>
<p>Program comprehension (i.e., reading, interpreting, and communicating about code) is an important concept that seems absent in the 2017 CSTA K–12 Standards.</p>	<p>The Programming subconcept Reading &amp; Documenting addresses program comprehension.</p>
<p>Instead of making these standalone standards, integrate these topics as practices within other standards:</p> <ul style="list-style-type: none"> <li>• Attribution and intellectual property</li> <li>• Project roles or project timelines</li> </ul>	<p>"Attribution and intellectual property" appears in the second practice in Ethics &amp; Social Responsibility: <i>Respect other creators of computational technologies. Only use others' work with permission and give appropriate attribution.</i></p> <p>"Project roles or project timelines" appears in the second practice of Inclusive Collaboration: <i>Establish shared goals, break the work into discrete tasks, and set development milestones.</i></p>

## Data & Analysis

Writers used the [Data and Analysis Literature Review](#) and the [Data and Analysis Design Brief](#) to inform decisions related to the Data & Analysis standards. Table 6 outlines some example recommendations from the research and how these recommendations are reflected in the final Data & Analysis standards.

**Table 6. Examples of Recommendations and Data & Analysis Standards**

Recommendation	Example(s) in the Standards
<p>Consider using or adapting the four-step statistical problem-solving process from the GAISE II: (1) formulate statistical investigative questions, (2) collect/consider the data, (3) analyze the data, and (4) interpret the results.</p> <p>Data collection should progress in the following way in the standards:</p> <ul style="list-style-type: none"> <li>• <i>Elementary school</i>: Students can collect the data by hand, through counting, categorizing, and measuring objects, or use data that has already been collected.</li> <li>• <i>Middle school</i>: Students should use computational tools to collect and store data (e.g., through online surveys or sensors). Students should begin developing understanding of spreadsheets and how computational tools can assist with transforming, summarizing, and representing/visualizing data (especially using tables, bar charts, line graphs, and scatterplots).</li> <li>• <i>High school</i>: Students should use spreadsheets and other computational tools to transform, analyze, and visualize data and create simulations. Students should develop test cases to ensure that computations and simulations perform as intended. Advanced students may begin using statistical software that requires programming to clean data, conduct descriptive and inferential statistical analysis, and create/modify simulations.</li> </ul>	<p>The Data Investigation and Data Collection &amp; Preparation subconcepts reflect this recommended progression of data collection.</p> <p>This is specifically exemplified in the following Data Collection and Preparation standards progression:</p> <ul style="list-style-type: none"> <li>• <i>Elementary school</i> (E1-DAT-DC-08): Use multiple methods to collect both numeric and non-numeric data to help answer questions.</li> <li>• <i>Middle school</i> (MS-DAT-DC-23): Use a computational tool to sort, filter, group, and summarize structured data.</li> <li>• <i>High school</i> (HS-DAT-DC-21): Use a computational tool to generate simulated data that fits certain parameters for use in a simulation.</li> </ul> <p>This is specifically exemplified in the following Data Investigation standards progression:</p> <ul style="list-style-type: none"> <li>• <i>Elementary school</i> (EK-DAT-DI-09): Investigate a question that can be answered by collecting data in students' everyday environments.</li> <li>• <i>Middle school</i> (MS-DAT-DI-27): Summarize a data investigation process, including potential biases, limitations, and supporting evidence.</li> <li>• <i>High school</i> (HS-DAT-DI-25): Create a data visualization of a multivariate dataset to answer a question or make a classification or prediction.</li> </ul>

Recommendation	Example(s) in the Standards
At the elementary level, students should ask and answer questions of small datasets collected in familiar contexts.	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E2-DAT-DI-09: Develop a question that can be answered with data.</li> <li>• E4-DAT-DC-09: Organize collected data into a table using a computational tool, with rows representing records and columns representing attributes.</li> </ul>
At the elementary level, students should begin using simple computational tools to make basic data tables, picture graphs, bar graphs, and line graphs.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• E4-DAT-DC-09: Organize collected data into a table using a computational tool, with rows representing records and columns representing attributes.</li> </ul>
At the middle school level, students should ask and answer questions of large datasets (hundreds or thousands of cases) that cannot be easily summarized manually and that are collected from a variety of contexts, including science, social science, and humanities.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• MS-DAT-DC-22: Explain how data and its associated metadata can be used to answer questions.</li> </ul>
At the middle school level, students should use computational tools to collect and store data (e.g., online surveys, sensors). Students should begin developing an understanding of spreadsheets and how computational tools can assist with transforming, summarizing, and representing/visualizing data (especially by using tables, bar charts, line graphs, and scatterplots).	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• MS-DAT-DC-23: Use a computational tool to sort, filter, group, and summarize structured data.</li> </ul>
At the high school level, students should ask and answer complex questions involving large datasets collected from a variety of contexts, including science, social science, and humanities.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• HS-DAT-DI-26: Evaluate a data simulation or visualization to answer a data question, inform decision-making, and identify potential limitations.</li> </ul>
At the high school level, students should use spreadsheets and other computational tools to transform, analyze, and visualize data and create simulations. Students should develop test cases to ensure computations and simulations perform as intended. Advanced students may begin using statistical software that requires programming to clean data, conduct descriptive and inferential statistical analysis, and create/modify simulations.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• HS-DAT-DI-25: Create a data visualization of a multivariate dataset to answer a question or make a classification or prediction.</li> </ul>

## Systems & Security

Writers used the information found in the [Computing Systems and Security Literature Review](#) and the [Computing Systems and Security Design Brief](#) to inform their work on the Systems & Security Standards. Table 7 outlines some example recommendations from the research and how these recommendations are reflected in the final Systems & Security standards.

**Table 7. Examples of Recommendations and Systems & Security Standards**

Recommendation	Example(s) in the Standards
There is a lot of content related to Networks and Security that was not addressed in the 2017 standards and should be included in the revised standards.	Writers expanded these standards greatly in the updated Systems & Security concept.
<p>In general, security should be more comprehensively addressed in the standards. For example:</p> <ul style="list-style-type: none"> <li>• Students should know what a good password is and understand the importance of strong passwords. They should also understand what personal information is and how to protect it.</li> <li>• Students should be knowledgeable about ways to physically and digitally keep devices and information secure. Digital security knowledge should include methods of cryptography to securely transmit data.</li> <li>• Students should have knowledge of the roles of software and software developers in keeping devices and information secure. They should also be knowledgeable about different security measures (including encryption), understand the strengths and weaknesses of the measures, and understand potential security threats.</li> </ul>	<p>The Security subconcept is included within the Systems &amp; Security concept in response to this recommendation.</p> <p>This recommendation is specifically exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E1-SYS-SE-12: Describe how to keep devices and online accounts safe from unauthorized access.</li> <li>• E3-SYS-SE-13: Evaluate how sharing information online might reveal personally identifiable information and other details.</li> <li>• HS-SYS-SE-31: Identify different types of cybersecurity and physical security measures and the trade-offs for users, data, and devices.</li> </ul>
A correct and detailed understanding of the internet as a network of networks with specific servers and connections is rare and typically only seen in children over the age of 10 or 11, so this should not be addressed until middle school standards.	MS-SYS-NT-35: Explain how the resilience of the internet depends on interconnected devices and their roles and functions within the network. This is a middle school standard in the updated standards, rather than an elementary school standard.
At the elementary level, students should know the components or parts of computing devices.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• E5-SYS-HW-12: Explain how hardware and software components of a computing system work together to perform input and output operations, processing, and storage.</li> </ul>

Recommendation	Example(s) in the Standards
At the elementary level, students should know that the internet is different from the devices used to access it and from the activities it facilitates. They should also be able to distinguish online activities from offline activities.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>E3-SYS-NT-14: Explain how people access the internet to gain information and communicate with each other.</li> </ul>
At the middle school level, students should understand that the internet is a network of networks with specific servers and connections.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>MS-SYS-NT-35: Explain how the resilience of the internet depends on interconnected devices and their roles and functions within the network.</li> </ul>
At the middle school level, students should (a) be able to form a comprehensive view of the computing systems they work with and (b) know how to navigate various representations of computing systems (e.g., the physical computing artifact, paper-based representations, code).	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>MS-SYS-NT-34: Model how information in a network is broken down into packets, transmitted between devices, and reassembled.</li> </ul>
At the high school level, students should have knowledge about threats and vulnerabilities, including attacks that affect the security of sensitive data.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>HS-SYS-SE-31: Identify different types of cybersecurity and physical security measures and the trade-offs for users, data, and devices.</li> </ul>

## Computing & Society

Writers used the recommendations and research found in the [Computing and Society Literature Review](#) to inform their work on the Computing & Society standards. The literature review specifically focused on the history of computing because it is not commonly part of computer science standards, and one of the goals of the literature review was to learn how historical information was represented and incorporated into standards in other disciplines. Table 8 outlines some example recommendations from the research and how these recommendations are reflected in the final Computing & Society standards.

**Table 8. Examples of Recommendations and Computing & Society Standards**

Recommendation	Example(s) in the Standards
<p>The History of Computing standards should progress from a small/local scope at lower grades to a larger/global scope at higher grades.</p>	<p>The updated standards include a comprehensive progression demonstrating how computing relates to society as a whole. This recommendation is specifically exemplified in the following standards progression:</p> <ul style="list-style-type: none"> <li>• <i>Elementary school</i> (EK-SOC-HI-14): Identify computing technologies used in daily life that have changed over time.</li> <li>• <i>Middle school</i> (MS-SOC-HI-38): Compare the roles of individuals, communities, organizations, and governments in shaping computing technologies across major eras in computing history.</li> <li>• <i>High school</i> (HS-SOC-HI-38): Analyze the historical trajectory of a specific computing technology and how its development is linked to societal and environmental factors.</li> </ul>
<p>CS standards should prioritize historical content over historical thinking, and history standards should focus on historical topics and not specific facts.</p>	<p>The History of Computing subconcept is included within the Computing &amp; Society concept, which highlights computer science–specific historical content without being overly prescriptive about which content to cover.</p>
<p>At the elementary level, focal topics for computing history standards should include comparison of daily life with computing today and in the past.</p>	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• EK-SOC-HI-14: Identify computing technologies used in daily life that have changed over time.</li> <li>• E1-SOC-HI-14: Compare how an everyday activity changed after a specific computing technology was introduced.</li> <li>• E3-SOC-HI-16: Examine how computing innovations have changed the ways people live, work, or communicate over time.</li> </ul>
<p>At the elementary level, focal topics for computing history standards should include computing and computer scientists in students’ daily life and community.</p>	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• E1-SOC-CE-16: Describe how computing is used by people at home, at school, and in the community.</li> </ul>

Recommendation	Example(s) in the Standards
At the elementary level, focal topics for computing history standards should include notable computer scientists from a range of backgrounds, eras, industries, and areas of computing.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>E4-SOC-HI-16: Investigate the contributions of diverse individuals and communities in the history of computing.</li> </ul>
At the middle school level, focal topics for computing history standards should include notable computer scientists and organizations related to each generation of computing.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>MS-SOC-HI-38: Compare the roles of individuals, communities, organizations, and governments in shaping computing technologies across major eras in computing history.</li> </ul>
At the middle school level, focal topics for computing history standards should include notable impacts of computing on social, cultural, political, and economic spheres.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>MS-SOC-HI-39: Analyze intended and unintended impacts of a historical computing technology on society and the environment.</li> </ul>
At the high school level, focal topics for computing history standards should include beneficial and harmful consequences of past advances in computing on social, cultural, political, and economic spheres.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>HS-SOC-HI-38: Analyze the historical trajectory of a specific computing technology and how its development is linked to societal and environmental factors.</li> </ul>
At the high school level, focal topics for computing history standards should include ethical and socially responsible computing for the present, based on lessons learned from computing's influence on the past.	This recommendation is exemplified in the following standard: <ul style="list-style-type: none"> <li>HS-SOC-ET-41: Evaluate the societal and environmental impacts of an emerging technology, including those that lead to inequities in access and outcomes.</li> </ul>

## Artificial Intelligence

Writers used the information in the [Artificial Intelligence Design Brief](#) and in [Identifying AI Priorities for All K–12 Students](#) to inform how they incorporated impacts and ethics content throughout the standards. Table 9 outlines some example recommendations from the research and how these recommendations impacted the way AI content is reflected in the final standards.

**Table 9. Examples of Recommendations and Resulting Incorporation of Artificial Intelligence in the Standards**

Recommendation	Example(s) in the Standards
<p>Due to increasing use of AI, there should be a greater emphasis on algorithms in curricula and in teachers' instruction than the 2017 standards reflect. Splitting Algorithms and Programming into two distinct concepts would allow for greater emphasis on algorithms and AI use.</p>	<p>Algorithms &amp; Design and Programming are two distinct concepts. Although there is a similar number of Programming standards as compared to the number of 2017 standards, there are far more Algorithms &amp; Design standards.</p> <p>AI is integrated across all five concepts and most significantly included in the Algorithms &amp; Design and Computing &amp; Society standards.</p>
<p>Minimally, include all prioritized learning outcomes within each of the following five categories identified in the <a href="#">Identifying AI Priorities for All K–12 Students</a> report:</p> <ul style="list-style-type: none"> <li>• Humans and AI</li> <li>• Representation and Reasoning</li> <li>• Machine Learning</li> <li>• Ethical AI System Design and Programming</li> <li>• Societal Impacts of AI</li> </ul>	<p>All prioritized learning outcomes plus some additional learning outcomes from the AI Priorities project were incorporated into the standards.</p> <ul style="list-style-type: none"> <li>• Humans and AI learning outcomes are incorporated into             <ul style="list-style-type: none"> <li>▪ Computing &amp; Society: Humans &amp; Computing standards</li> </ul> </li> <li>• Representation and Reasoning learning outcomes are incorporated into             <ul style="list-style-type: none"> <li>▪ Algorithms &amp; Design: Machine Learning standards</li> </ul> </li> <li>• Machine Learning learning outcomes are incorporated into             <ul style="list-style-type: none"> <li>▪ Algorithms &amp; Design: Machine Learning standards</li> <li>▪ Computing &amp; Society: Humans &amp; Computing standards</li> </ul> </li> <li>• Ethical AI System Design and Programming learning outcomes are incorporated into             <ul style="list-style-type: none"> <li>▪ Algorithms &amp; Design: Machine Learning and Impacts of Algorithms &amp; Design standards</li> <li>▪ Data &amp; Analysis: Impacts of Data Science standards</li> <li>▪ Computing &amp; Society: History of Computing standards</li> </ul> </li> <li>• Societal Impacts of AI learning outcomes are incorporated into             <ul style="list-style-type: none"> <li>▪ Algorithms &amp; Design: Impacts of Algorithms &amp; Design standards</li> <li>▪ Systems &amp; Security: Impacts of Computing Systems standards</li> <li>▪ Computing &amp; Society: Emerging Technologies standards</li> <li>▪ Computing &amp; Society: Career Exploration standards</li> </ul> </li> </ul>

Recommendation	Example(s) in the Standards
Begin introducing AI curriculum in early elementary school.	<p>AI is included in several elementary standards. For example:</p> <ul style="list-style-type: none"> <li>• E5-ALG-IM-03: Articulate how human-centered design principles are incorporated into the development of a computing technology.</li> <li>• E3-SOC-HU-18: Examine why people design and build computing technologies.</li> </ul>
In middle school, students should explain how people’s goals and values can influence the design of AI, how the design process can incorporate those goals and values, and how AI can show biases toward different cultures.	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• MS-DAT-IM-29: Analyze how decisions made at different stages of working with data can lead to biased data, misleading conclusions, and compromised AI models.</li> <li>• MS-SOC-ET-40: Evaluate when it is appropriate to use AI and other emerging technologies to solve a problem based on their capabilities, limitations, and environmental impacts.</li> </ul>
In middle school, students should use generative AI to aid their programming of novel applications.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• MS-PRO-RD-18: Analyze AI-generated code for accuracy and usability in a programming project.</li> </ul>
In high school, students should evaluate the design of AI systems to ensure that those systems include a plan for accountability and a respect for privacy. Students should use an ethical design process to design AI, explain ethical dilemmas that might arise due to AI, and predict how AI can change society.	<p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• HS-DAT-IM-27: Evaluate the societal, environmental, and ethical implications of large-scale data collection and processing, including within AI applications.</li> </ul>
Prepare students to be critical consumers, responsible creators, and informed citizens.	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E5-ALG-ML-02: Train a machine learning model to make a classification or prediction.</li> <li>• HS-ALG-PS-05: Evaluate AI-generated output to assess bias, accuracy, and potential harms.</li> <li>• HS-ALG-ML-08: Develop a machine learning model for a chosen task using appropriate data and tools.</li> </ul>

## Impacts & Ethics

Writers used the information in the [Structure Design Brief, Amplifying Social Impacts of Computing Standards Reference Materials](#), and [Computing Impacts and Ethics in the CSTA Standards: A Synthesis of Expert Perspectives](#) to inform how they incorporated impacts and ethics content throughout the standards. Table 10 outlines some example recommendations from the research and how these recommendations impacted the way impacts and ethics content is reflected in the final standards.

**Table 10. Examples of Recommendations and Resulting Incorporation of Impacts & Ethics in the Standards**

Recommendation	Example(s) in the Standards
Impacts and ethics are taught inconsistently when they are defined separately from other concepts within the standards. Embed this content throughout the standards in order to increase the probability that these are taught more consistently.	Impacts and ethics content is embedded across concepts instead of separated as its own concept.
Impacts and ethics should also be embedded within practices to encourage students to use computing for positive social impact and to respect others' rights and dignity when creating computational technologies.	<p>Impacts and ethics content is contained within these Ethics &amp; Social Responsibility practices:</p> <ul style="list-style-type: none"> <li>• 1. Use computing for positive social impact.</li> <li>• 2. Respect others' rights and dignity when creating computing technologies.</li> </ul> <p>Impacts and ethics content is also contained within these Human-Centered Design practices:</p> <ul style="list-style-type: none"> <li>• 10. Understand and involve diverse users in design decisions.</li> <li>• 12. Design computing technologies that empower and inform users.</li> </ul>
Elevate responsible design practices.	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E5-ALG-IM-03: Articulate how human-centered design principles are incorporated into the development of a computing technology.</li> <li>• MS-ALG-IM-10: Examine evidence of beneficial and harmful impacts, ethical issues, and biases of algorithms encountered in daily life.</li> <li>• HS-PRO-TR-20: Refine a computing technology based on user feedback, testing results, and responsible design values to improve its effectiveness and impact.</li> </ul>

Recommendation	Example(s) in the Standards
Identify values and specifically focus on harms and benefits of computational decisions.	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E4-DAT-IM-11: Investigate how data collected about people may affect individuals and groups.</li> <li>• HS-ALG-IM-11: Articulate the values embedded in the design of an algorithmic system.</li> <li>• HS-SOC-ET-42: Design a conceptual solution to a real-world problem using an emerging technology, analyzing its potential benefits and harms.</li> </ul>
Avoid harm caused by computing technologies, including physical or mental injury, unjustified destruction or disclosure of information, and unjustified damage to property, reputation, or the environment.	<p>This recommendation is exemplified in the following standards:</p> <ul style="list-style-type: none"> <li>• E2-SYS-IM-13: Describe the benefits and harms that arise from an individual’s use of computing systems and digital tools.</li> <li>• MS-ALG-IM-10: Examine evidence of beneficial and harmful impacts, ethical issues, and biases of algorithms encountered in daily life.</li> </ul>
Respect the work required to produce new ideas, inventions, creative works, and computing artifacts.	<p>This recommendation is exemplified in the following Ethics &amp; Social Responsibility practice:</p> <ul style="list-style-type: none"> <li>• 2. Respect others’ rights and dignity when creating computing technologies.</li> </ul> <p>This recommendation is exemplified in the following standard:</p> <ul style="list-style-type: none"> <li>• HS-PRO-PD-14: Apply appropriate attribution of intellectual property when developing a computing technology.</li> </ul>

## Conclusion

As this report exemplifies, the updated CSTA PK–12 Standards are grounded in extensive research, ensuring both their relevance and their rigor for contemporary computer science education. The revision process thoughtfully integrated a wide range of research, literature reviews, analyses of standards and frameworks, and expert recommendations, with findings and design briefs directly informing the content and structure of the standards. The examples provided show clear connections between research and the resulting language and topics of the updated standards. This direct alignment reinforces the credibility and adaptability of the standards, supporting equitable, future-oriented, and research-based practices for all learners and ensuring that the standards reflect the evolving needs and insights of the computer science education community.