

Computer Mathematics *Standards of Learning* - 2023 Overview of Revisions

This overview includes a summary of the content embedded in four content strands.

Data Representation and Storage

- Represent data and convert data between different number systems
- Differentiate between variable data types based upon their characteristics
- Represent data using appropriate data structures

Components of Programming

- Design a step-by-step plan to perform a task or solve a problem, including those arising from mathematical and interdisciplinary contexts
- Construct Boolean expressions and implement conditional statements
- Perform interaction with loops
- Write and implement the output and input phases of a computer program
- Implement library functions to process data
- Write and implement user-defined functions
- Implement pre-defined algorithms, including search routines and sort routines

Applications of Programming

- Write and implement programs using sequencing, selection, and iteration to perform a specific task or solve a problem, including those arising from mathematical and interdisciplinary contexts
- Create documentation using written comments to annotate the intended purpose of the components of a user-created program
- Verify how programs access and process variables
- Translate a mathematical expression or statement into computer code
- Trace existing code to interpret the intended purpose

Evaluation of Programming

- Test a program to match a sample output, using a set of data
- Debug a program using appropriate techniques
- Compare and contrast the efficiency of computer programs

Comparison of Computer Mathematics *Standards of Learning* – 2016 to 2023

2016 <i>Standards of Learning</i> Essential Knowledge and Skills (EKS) Problem Solving	2023 <i>Standards of Learning</i> Knowledge and Skills (KS) Data Representation and Storage (DRS)
<p>COM.1 The student will design and apply computer programs to solve practical problems in mathematics arising from business and applications in mathematics.</p> <ul style="list-style-type: none"> ● Design and implement computer programs to solve practical problems. ● Analyze and interpret graphs, charts, and tables in the design and implementation of a computer program. ● Design and implement computer programs to <ul style="list-style-type: none"> ○ solve practical problems arising from business; and ○ solve mathematical problems, using formulas, equations, and functions. 	<p>[Moved to CM.CP.1 and CM.AP.1]</p>
<p>[Moved from COM.6 and COM.15]</p>	<p>CM.DRS.1 The student will represent data and convert data between different number systems.</p> <ul style="list-style-type: none"> a) Represent data in different number systems, including binary, decimal, and hexadecimal. b) Convert data between number systems (e.g., binary to decimal, decimal to hexadecimal).

<p align="center">2016 <i>Standards of Learning</i> Essential Knowledge and Skills (EKS) Problem Solving</p>	<p align="center">2023 <i>Standards of Learning</i> Knowledge and Skills (KS) Data Representation and Storage (DRS)</p>
<p>[Moved from COM.14]</p>	<p>CM.DRS.2 The student will differentiate between variable data types based upon their characteristics.</p> <ul style="list-style-type: none"> a) Describe the characteristics of different variable data types, including <ul style="list-style-type: none"> i) Boolean; ii) character; iii) integer; iv) decimal (double/float); and v) string. b) Differentiate between variable data types to determine the data type needed based upon intended use (e.g., character versus string, integer versus double/float).
<p>[Moved from COM.16]</p>	<p>CM.DRS.3 The student will represent data using appropriate data structures.</p> <ul style="list-style-type: none"> a) Given a specific task or problem, determine the appropriate data structure (e.g., lists, arrays, objects) to represent data. b) Perform tasks related to lists or arrays (one-dimensional or two-dimensional), including <ul style="list-style-type: none"> i) declare a list or array (one-dimensional or two-dimensional); ii) choose an appropriate data type for a list or an array; and iii) fill the list or array with data. c) Access and manipulate a particular element of a list or an array. d) Implement predefined objects to consolidate related information of different data types.

<p style="text-align: center;">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Design</p>	<p style="text-align: center;">2023 Standards of Learning Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>COM.2 The student will design, write, document, test, and debug a computer program.</p> <ul style="list-style-type: none"> ● Describe a computer program. ● Design, write, document, test, and debug a complete computer program. ● List and describe the processes involved in writing a computer program. ● Describe the function of an algorithm. ● Provide required documentation for a program. ● Determine what a given output statement will print. ● Debug a program. 	<p>[Moved to CM.CP.1; CM.AP.1; CM.AP.2; CM.EP.1; and CM.EP.2]</p>
<p>COM.3 The student will write program specifications that define the constraints of a given problem.</p> <ul style="list-style-type: none"> ● Write program specifications that define the constraints of a given problem. ● Describe the preconditions, postconditions, and desired input and output of a given problem. ● Determine whether or not a given problem is solvable using a computer program. 	<p>[Moved to CM.CP.1]</p>
<p>COM.4 The student will design an algorithm to solve a given problem.</p> <ul style="list-style-type: none"> ● Design a step-by-step algorithm to solve a problem. 	<p>[Moved to CM.CP.1]</p>

<p style="text-align: center;">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Design</p>	<p style="text-align: center;">2023 Standards of Learning Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>COM.5 The student will divide a given problem into modules by task and implement the solution.</p> <ul style="list-style-type: none"> ● Divide a problem into modules by task. ● Write task-oriented modules, which may include <ul style="list-style-type: none"> ○ a user-defined function; ○ subroutines; or ○ procedures. ● Determine the need for a subroutine or user-defined function. ● Determine the difference between and the need for internal and external subroutines and functions. ● Implement the solution of the problem. 	<p>CM.CP.1 The student will design a step-by-step plan to perform a task or solve a problem, including those arising from mathematical or interdisciplinary contexts.</p> <ol style="list-style-type: none"> a) Design a step-by-step plan to perform a task or solve a problem using a flowchart or pseudocode that outlines the subtasks needed. b) Define the variables needed to perform a task or solve a problem. c) Define the constraints of a task or problem (e.g., pre-conditions, post-conditions) to determine the desired input and output.
<p>COM.6 The student will translate mathematical expressions into programming expressions by declaring variables, writing assignment statements, and using the order of operations.</p> <ul style="list-style-type: none"> ● Translate mathematical expressions into a programming expression. ● Declare appropriately named variables to store values used in computations. ● Write variable assignment statements. ● Use the order of operations to simplify expressions. ● Construct and evaluate expressions that include multiple arithmetic operations. 	<p>[Moved to CM.DRS.1; CM.AP.4]</p>

<p style="text-align: center;">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Design</p>	<p style="text-align: center;">2023 Standards of Learning Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>COM.7 The student will select and call library functions to process data, as appropriate.</p> <ul style="list-style-type: none"> ● Use library functions in designing programs to process data. ● Use library functions that are arithmetic or string operations. ● Invoke a value-returning library function. 	<p>[Moved to CM.CP.7]</p>
<p>COM.8 The student will implement conditional statements that include “if/then” statements, “if/then/else” statements, case statements, and Boolean logic.</p> <ul style="list-style-type: none"> ● Construct a simple logical (Boolean) expression to evaluate a given condition. ● Construct an “if/then” statement to perform a specific task. ● Construct an “if/then/else” statement to perform a specific task. ● Construct a case statement to perform a specific task. ● Use conditional statements to incorporate decision making into programs. 	<p>CM.CP.2 The student will construct Boolean expressions and implement conditional statements.</p> <ol style="list-style-type: none"> a) Write and implement Boolean expressions using logical and relational operators (e.g., !, &&, , ==, <, >, >=, <=, !=). b) Write and implement “if” conditional statements. c) Write and implement “if/else” conditional statements. d) Write and implement compound conditional statements (e.g., nested conditionals, chained conditional statements). e) Determine which parts of an algorithm are executed based on a condition being true or false.
<p>COM.9 The student will implement pre-defined algorithms, including sort routines, search routines, and simple animation routines.</p> <ul style="list-style-type: none"> ● Implement pre-defined algorithms into a program. ● Implement a sort routine on a one-dimensional array. ● Implement a sequential search routine on a one-dimensional array. ● Implement a binary search routine on a one-dimensional array. ● Implement a simple animation routine. 	<p>[Moved to CM.CP.8]</p>

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Design</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>[Moved from COM.13]</p>	<p>CM.CP.3 The student will perform iteration with loops.</p> <ul style="list-style-type: none"> a) Write and implement “while” and “for” loops. b) Differentiate between loops that run a fixed number of times and loops that run an indefinite number of times (e.g., stopping dependent on variable conditions). c) Identify conditions that cause infinite loops. d) Determine the outcome of code segments that include loops.

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Implementation</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>COM.10 The student will design and implement the input phase of a program, which will include designing screen layout, getting information into the program by way of user interaction and/or file input, and validating input.</p> <ul style="list-style-type: none"> ● Design a screen layout to facilitate input. ● Design program information input by user interaction and file input. ● Validate data, using a variety of methods. ● Construct input statements to read values into a program. ● Determine the contents of variables that have been assigned values by input statements. 	<p>CM.CP.4 The student will write and implement the output phase of a computer program.</p> <ul style="list-style-type: none"> a) Write and implement the output phase of a computer program, which may include: <ul style="list-style-type: none"> i) formatting output in text-based environments; ii) displaying output through a graphical user interface; and iii) sending output to a physical device (e.g., speakers, robots, LED lights). b) Write output to a file.

<p align="center">2016 <i>Standards of Learning</i> Essential Knowledge and Skills (EKS) Program Implementation</p>	<p align="center">2023 <i>Standards of Learning</i> Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>COM.11 The student will design and implement the output phase of a computer program, which will include designing output layout, accessing available output devices, using output statements, and labeling results.</p> <ul style="list-style-type: none"> ● Design an output layout. ● Access available output devices. ● Use output statements. ● Label results. 	<p>CM.CP.5 The student will write and implement the input phase of a computer program.</p> <ul style="list-style-type: none"> a) Write and implement input statements to store user given values into a program. b) Validate input data using exception coding (e.g., using a “while” loop to control valid input by a user). c) Determine what output a program will produce given a specific input.
<p>[New Expectation]</p>	<p>CM.CP.6 The student will implement library functions.</p> <ul style="list-style-type: none"> a) Implement library functions to process data. b) Implement library functions to perform mathematical operations (e.g., random, absolute value, square root, power). c) Implement void library functions and return library functions. d) Implement overloaded library functions.
<p>COM.12 The student will design and implement computer graphics to enhance output.</p> <ul style="list-style-type: none"> ● Design and implement computer graphics using various techniques such as <ul style="list-style-type: none"> ○ plotting points or shapes; ○ determining and setting window or screen dimensions; ○ determining and setting screen or background colors; and ○ using box commands. ● Describe the role of graphics in the computer environment. 	<p>[Embedded in CM.CP.4; CM.CP.5]</p>

<p align="center">2016 <i>Standards of Learning</i> Essential Knowledge and Skills (EKS) Program Implementation</p>	<p align="center">2023 <i>Standards of Learning</i> Knowledge and Skills (KS) Components of Programming (CP)</p>
<p>[Moved from COM.7]</p>	<p>CM.CP.7 The student will write and implement user-defined functions.</p> <ul style="list-style-type: none"> a) Write and implement a user-defined function to complete a task or sub-task. b) Write and implement void functions and return functions. c) Write and implement functions that accept parameters.
<p>[Moved from COM.9]</p>	<p>CM.CP.8 The student will implement pre-defined algorithms, including search routines and sort routines.</p> <ul style="list-style-type: none"> a) Differentiate between types of search routines. b) Differentiate between types of sort routines. c) Implement pre-defined algorithms. d) Implement a search routine on a one-dimensional list or an array, including sequential search and binary search. e) Implement a sort routine on a one-dimensional list or an array (e.g., selection sort, insertion sort, merge sort).
<p>COM.13 The student will implement various mechanisms for performing iteration with an algorithm.</p> <ul style="list-style-type: none"> ● Determine when an iterative algorithm is needed in a computer program. ● Incorporate single entry point, single exit point, preconditions, and postconditions into iterative algorithms. 	<p>[Moved to CM.CP.3]</p>
<p>COM.14 The student will select and implement appropriate data structures, including arrays (one- and/or two-dimensional) and objects.</p>	<p>[Moved to CM.DRS.2; CM.DRS.3]</p>

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Implementation</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Components of Programming (CP)</p>
<ul style="list-style-type: none"> ● Implement a one-dimensional or two-dimensional array for a given problem: <ul style="list-style-type: none"> ○ choose an appropriate data type for an array; ○ assign a value to an array element; ○ fill an array with data, and process the data in the array; ○ access a particular element of a two-dimensional array; ○ process a two-dimensional array by rows and by columns; and ○ retrieve data from an array. ● Use data files in computer programs, both as a source of input data and as a way to save data for the next program execution. ● Implement objects to consolidate related information of different data types. 	

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Data Manipulation</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Applications of Programming (AP)</p>
<p>COM.15 The student will define and use appropriate variable data types that include integer, real (fixed and scientific notation), character, string, Boolean, and object.</p> <ul style="list-style-type: none"> ● Define variables using data types, including <ul style="list-style-type: none"> ○ integer; ○ real (fixed and scientific notation); ○ character; ○ string; ○ Boolean; and 	<p>[Moved to CM.DRS.2]</p>

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Data Manipulation</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Applications of Programming (AP)</p>
<ul style="list-style-type: none"> o object. ● Use standard naming conventions to create variable names. 	
<p>COM.16 The student will describe the way the computer stores, accesses, and processes variables, including the following topics: the use of variables versus constants, parameter passing, scope of variables, and local versus global variables.</p> <ul style="list-style-type: none"> ● Determine when the use of a variable is appropriate. ● Describe how a computer stores, accesses, and processes variables. ● Incorporate parameter passing into programs. ● Differentiate between local and global variables and describe their appropriate use. ● Compare and contrast variables and constants. ● Describe the basic interplay between hardware and software in program execution. 	<p>[Moved to CM.AP.3]</p>
<p>[Moved from COM.1, COM.4]</p>	<p>CM.AP.1 The student will write and implement programs using sequencing, selection, and iteration to perform a specific task or solve a problem, including those arising from mathematical and interdisciplinary contexts.</p> <ul style="list-style-type: none"> a) Determine what components of programming are needed to implement a step-by-step plan to perform a specific task or solve a problem.

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Data Manipulation</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Applications of Programming (AP)</p>
	<ul style="list-style-type: none"> b) Write a computer program that includes sequencing, selection (conditionals), and iteration (loops). c) Write and implement computer programs to solve mathematical problems using <ul style="list-style-type: none"> i) formulas and equations; ii) functions; iii) probability and statistics; and iv) data-analysis.
<p>[Moved from COM.2]</p>	<p>CM.AP.2 The student will create documentation using written comments to annotate the intended purpose of the components of a user-created program.</p> <ul style="list-style-type: none"> a) Create documentation using written comments to: <ul style="list-style-type: none"> i) describe the overall purpose of a program; ii) align a previously created step-by-step plan to a written program; iii) describe pre-conditions and post-conditions; and iv) improve the readability of a program.
<p>[New Expectation]</p>	<p>CM.AP.3 The student will verify how programs access and process variables.</p> <ul style="list-style-type: none"> a) Verify that the variable types are aligned to the purpose of the algorithm. b) Verify that global variables are set to constant values before run time. c) Differentiate between the scopes of variables (e.g., global scope versus local scope) and verify the intended use.

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Data Manipulation</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Applications of Programming (AP)</p>
<p>[Moved from COM.6]</p>	<p>CM.AP.4 The student will translate a mathematical expression or statement into computer code.</p> <ul style="list-style-type: none"> a) Declare, initialize, and assign variables to represent mathematical expressions or statements. b) Implement order of operations, including logical and relational operators. c) Translate a mathematical expression or statement into a programming statement(s).
<p>[New Expectation]</p>	<p>CM.AP.5 The student will trace existing code to interpret the intended purpose.</p> <ul style="list-style-type: none"> a) Trace existing code of an algorithm to <ul style="list-style-type: none"> i) identify values at each stage of an algorithm; and ii) predict return values of functions given specific arguments. b) Use tracing to describe the intended purpose of existing code for an algorithm.

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Testing</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Evaluation of Programming (EP)</p>
<p>COM.17 The student will test a program using an appropriate set of data. The test data should include boundary cases and test all branches of a program.</p> <ul style="list-style-type: none"> ● Test a program, using an appropriate and complete set of data. ● Demonstrate that a set of data tests all branches of a program. 	<p>CM.EP.1 The student will test a program to match a sample output, using a set of data.</p> <ul style="list-style-type: none"> a) Produce a given output by entering a data set. b) Test a program including boundary cases and inaccurate data types to verify the intended outcomes.

<p align="center">2016 Standards of Learning Essential Knowledge and Skills (EKS) Program Testing</p>	<p align="center">2023 Standards of Learning Knowledge and Skills (KS) Evaluation of Programming (EP)</p>
<p>COM.18 The student will debug a program using appropriate techniques (e.g., appropriately placed controlled breaks, the printing of intermediate results, and other debugging tools available in the programming environment), and identify the difference among syntax errors, runtime errors, and logic errors.</p> <ul style="list-style-type: none"> ● Debug a program, using controlled breaks, the printing of intermediate results, and other debugging tools. ● Identify the differences among syntax errors, runtime errors, and logic errors. 	<p>CM.EP.2 The student will identify errors and debug a program using various techniques.</p> <ol style="list-style-type: none"> a) Differentiate among syntax errors, runtime errors, and logic errors. b) Debug a program using various techniques: <ol style="list-style-type: none"> i) interpret syntax and runtime error messages; ii) place controlled breaks; iii) output intermediate results; iv) disable a section of code by converting it into a comment; v) trace code to identify logic errors; and vi) use debugging tools available in the programming environment.
<p>[New Expectation]</p>	<p>CM.EP.3 The student will compare and contrast the efficiency of computer programs.</p> <ol style="list-style-type: none"> a) Compare and contrast the efficiency of computer programs in terms of <ol style="list-style-type: none"> i) complexity of algorithms with the same intended outcomes; ii) memory space used; and iii) run time.

2023 Computer Mathematics SOL – Summary of Changes

Computer Mathematics (2016 SOL to 2023 SOL Numbering)	Parameter Changes/Clarifications (2023 SOL)
<ul style="list-style-type: none"> ● COM.1 → CM.CP.1; CM.AP.1 ● COM.2 → CM.CP.1; CM.AP.1; CM.AP.2; CM.EP.1; CM.EP.2 ● COM.3 → CM.CP.1; CM.AP.1 ● COM.4 → CM.CP.1 ● COM.5 → CM.CP.1 ● COM.6 → CM.DRS.1; CM.AP.4 ● COM.7 → CM.CP.7 ● COM.8 → CM.CP.2 ● COM.9 → CM.CP.8 ● COM.10 → CM.CP.4 ● COM.11 → CM.CP.5 ● New Expectation → CM.CP.6 ● COM.12 → CM.CP.4; CM.CP.5 ● COM.13 → CM.CP.3 ● COM.14 → CM.DRS.2, CM.DRS.3 ● COM.15 → CM.DRS.2 ● COM.16 → CM.AP.3 ● COM.17 → CM.EP.1 ● COM.18 → CM.EP.2 ● New Expectation → CM.EP.3 	<ul style="list-style-type: none"> ● CM.AP.2 - Improve the readability of a program ● CM.EP.2 - Trace code to identify logic errors ● CM.CP.3 - Perform iteration with loops

Deletions from Computer Mathematics (2016 SOL)	Additions to Computer Mathematics (2023 SOL)
<ul style="list-style-type: none"> COM.12 - The student will design and implement computer graphics to enhance output (not explicitly included but may be embedded in CM.CP.4 and CM.CP.5) 	<ul style="list-style-type: none"> CM.CP.6 - Implement library functions to process data CM.AP.5 - Trace existing code to interpret the intended purpose

KEY: DRS = Data Representation and Storage (2023); CP = Components of Programming (2023); AP = Applications of Programming (2023); EP = Evaluation of Programming (2023); EKS = Essential Knowledge and Skills (2016); KS = Knowledge and Skills (2023); US = Understanding the Standard