Introduction

The Ohio Department of Education’s Office of Learning and Instructional Strategies is in the process of revising Ohio’s Learning Standards for Computer Science.

The State Board of Education adopted Ohio’s Learning Standards and Model Curriculum for Computer Science in December 2018. Implemented in the 2019-2020 (FY2020) school year, the purpose of Ohio’s Learning Standards and Model Curriculum for Computer Science is to provide guidance to schools and districts. Ohio educators, many of whom engage daily with Ohio students, led the process to create Ohio’s Learning Standards and Model Curriculum for Computer Science.

The review and revision process presents an opportunity for families, computer science professionals, community members and other educators, to provide suggestions for improving the model curriculum through a public comment survey, open March 2 through March 18.

In the Fall of 2021, the public was invited to provide comments on the current standards and model curriculum. Advisory group members, who have an educational background or professional experience in computer science, met several times to discuss the public comment and make suggestions for revisions. The advisory group then provided direction and guidance to the working groups of Ohio educators, who worked to write the revisions.

The following is a draft of the revised model curriculum available for viewing and public comment. This document contains the revisions to the model curriculum for this strand, revised content is highlighted in yellow. If the model curriculum for a specific standard did not need to be edited it was not included in this document.

In your review, please focus on the content of the statements. All materials will be going through additional technical edits, but because of the timeline outlined in HB110, the Department wanted to make these drafts available for public comment at this time.

To see the model curriculum adopted by the Ohio State Board of Education in 2018, please visit the Model Curriculum for Computer Science.
Ohio’s Computer Science Standards are organized by strands, topics and content statements.

Kindergarten through Grade 8 - Content statements are organized by grade level. Below is an example of a content statement for kindergarten and its corresponding content statement code. This content statement addresses the topic of Devices within the Computing Systems strand.
# Computer Science Model Curriculum: Quantum Computing DRAFT

Additions / Revisions are noted in yellow.

<table>
<thead>
<tr>
<th>Strand</th>
<th>Networks and the Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
<td><strong>Cybersecurity</strong></td>
</tr>
</tbody>
</table>

**NI.C.9-12.F.a** Examine and employ principles of cybersecurity.

**NI.C.9-12.F.b** Identify physical, social and digital security risks to address possible attacks from both existing and emergent technologies including cluster computing and quantum key distribution.

## Expectations for Learning

### LEARNING PROGRESSION

By the end of grade 8:
Students understand physical measures to protect devices and software measures to protect electronic information. Students understand general practices used to identify malware infections. Students can describe how malware can affect information.

In the 9-12 Foundational Level:
Students will be able to understand the cybersecurity impact on business and the economy. Students will be able to employ principles of cybersecurity and emergent technologies including cluster computing and quantum key distribution.

In the 9-12 Advanced Level:
Students will be able to find the cybersecurity threat and provide a plan of action to remove the threat.

### IMPORTANT CONCEPTS
- All endpoints must be protected
- Physical security is the protection from physical actions and events that could cause loss or damage
- Humans are the weakest point in cybersecurity
  - As emerging technologies evolve, so do the threats of cybersecurity attacks

### KEY SKILL/PROCEDURES
- Identify the goals, objectives and purposes of cybersecurity
- Identify common risks, alerts and warning signs
- Describe the concepts of malware attacks
- Identify types of controls to eliminate malware from occurring
- Demonstrate understanding of authentication, authorization and verification

### Content Elaborations

**CLARIFICATIONS**

Know a response plan to understand why it is needed.
<table>
<thead>
<tr>
<th>Strand</th>
<th>Networks and the Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Cybersecurity</td>
</tr>
</tbody>
</table>

Know the cybersecurity cycle to be able to create a response plan.
Apply authentication, authorization and verification to be able to control network usage.
Know common types of cybersecurity attacks to recognize and implement countermeasures.
Physical security is necessary to limit access to important hardware, making it more difficult to add malicious code to computers and network devices. Examples of physical security could include how and when to limit computer access to certain individuals, how to secure computers, and where to store backups and external hard drives.

Quantum Key Distribution (QKD) is a quantum cryptography protocol for the secure sharing of information. It produces a shared secure key for encryption and decryption of messages.

**CONTENT FOCUS**
- Understanding the cybersecurity cycle
- Response plans (i.e., plan & prepare, identify, containment, investigation, remediation, follow-up)
- Common types of cybersecurity attacks

**COMPUTER SCIENCE PRACTICES**

*Practice 3. Recognizing and Defining Computational Problems*  
2. Decompose complex real-world problems into manageable subproblems that could integrate existing solutions or procedures.

*Practice 5. Creating Computational Artifacts*  
1. Plan the development of a computational artifact using an iterative process that includes reflection on and modification of the plan, taking into account key features, time and resource constraints, and user expectations.

*Practice 6. Testing and Refining Computational Artifacts*  
3. Evaluate and refine a computational artifact multiple times to enhance its performance, reliability, usability and accessibility.
<table>
<thead>
<tr>
<th>Strand</th>
<th>Networks and the Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
<td><strong>Networking</strong></td>
</tr>
</tbody>
</table>

**Expectations for Learning**

**LEARNING PROGRESSION**

By the end of grade 8, students will be able to develop a model representing networking hardware to understand the flow of information. Students will be able to generally identify a wide range of protocols and how they are utilized to transfer data across the internet. Students will understand that information that is lost via transmission will be retransmitted.

In the 9-12 Foundational Level, students will be able to gather information to be able to create simple LANs and WANs with the understanding of how devices connect.

In the 9-12 Advanced Level, students will be able to develop and connect a working network model from given criteria.

**IMPORTANT CONCEPTS**

- Network devices have connectivity
- Protocols are used for network communications
- Network topologies have limitations
- Different network topologies can be interconnected
- Devices have both a physical and logical address

**KEY SKILL/PROCEDURES**

- Demonstrate how to connect to a network device
- Identify the tools to trace data through a network
- Explain how to trace data through a network
- Compare and contrast network topologies
- Compare and contrast network devices
- Identify the network to which a device is connected
- Define the common network protocols
Strand | Networks and the Internet
--- | ---
Topic | Networking

Content Elaborations

CLARIFICATIONS
Examples of network devices could be:
- hubs
- switches
- routers
- firewalls
- virtual servers

This should include the network differences between classical, clustered and quantum computing.

The scalability and reliability of networks can be evaluated by describing the relationship between routers, switches, servers, topology and addressing.

CONTENT FOCUS
Internet Protocol addresses and how they relate to devices and the network

COMPUTER SCIENCE PRACTICES
Practice 6. Testing and Refining Computational Artifacts
1. Systematically test computational artifacts by considering all scenarios and using test cases.
2. Identify and fix errors using a systematic process.
## Expectations for Learning

### LEARNING PROGRESSION

By the end of grade 8:
Students will be able to identify improvements to possibly make a computing device for better interaction with users.

In the 9-12 Foundational Level:
Students will extract technological information about computing systems and their limitations to determine effective solutions for given situations. Students will understand the troubleshooting process to evaluate a predetermined situation.

In the 9-12 Advanced Level:
Students will extract technological information about computing systems to determine and integrate the best practices for complex situations.

### IMPORTANT CONCEPTS
- Different devices interact with each other
- Everyday devices have computers in them
- Criteria can be used to evaluate computing systems
- There are multiple methods to evaluate computing systems
- Computing systems can consist of both virtual and physical components

### KEY SKILL/PROCEDURES
- Communicate/explain how different devices interact to determine the proper device for usage
- Identify the different devices and their purpose to evaluate the proper device for usage
- Create criteria to effectively evaluate a computing system
- Apply a method of evaluation to verify functionality

---

<table>
<thead>
<tr>
<th>Strand</th>
<th>Computing Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
<td><strong>Devices</strong></td>
</tr>
<tr>
<td>CS.D.9-12.F.a</td>
<td>Identify different multifunctional computing devices and connection technologies, both virtual and physical, to describe their purpose.</td>
</tr>
<tr>
<td>CS.D.9-12.F.b</td>
<td>Develop and apply criteria to evaluate computing systems for a given purpose and existing limitations.</td>
</tr>
<tr>
<td>CS.D.9-12.F.c</td>
<td>Create an artifact to demonstrate the roles and interactions of computing systems embedded in everyday objects.</td>
</tr>
<tr>
<td>CS.D.9-12.F.d</td>
<td>Evaluate alternative computing architectures for emerging technologies including cluster and quantum computing to understand the troubleshooting process.</td>
</tr>
</tbody>
</table>
## Computing Systems

### Devices

<table>
<thead>
<tr>
<th><strong>Content Elaborations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLARIFICATIONS</strong></td>
</tr>
<tr>
<td>Examples of simple devices could be:</td>
</tr>
<tr>
<td>- a garage door opened</td>
</tr>
<tr>
<td>- a toaster</td>
</tr>
<tr>
<td>- a microwave</td>
</tr>
<tr>
<td>Examples of complex devices could be:</td>
</tr>
<tr>
<td>- tablet on a refrigerator</td>
</tr>
<tr>
<td>- an alarm system</td>
</tr>
<tr>
<td>- a multi-functional printer</td>
</tr>
<tr>
<td>Examples of virtual devices could be:</td>
</tr>
<tr>
<td>- a cloud server</td>
</tr>
<tr>
<td>- a remote server</td>
</tr>
<tr>
<td>- a software driver emulating hardware</td>
</tr>
<tr>
<td>- a virtual hard drive</td>
</tr>
<tr>
<td>Examples of connecting technologies could be:</td>
</tr>
<tr>
<td>- wired networks and components</td>
</tr>
<tr>
<td>- routers and switches</td>
</tr>
<tr>
<td>- wireless network technologies</td>
</tr>
<tr>
<td>- Bluetooth</td>
</tr>
</tbody>
</table>

### CONTENT FOCUS

- Understand that everyday devices have computers
- Understand how different devices communicate with each other
- Understand the difference between virtual and physical

### COMPUTER SCIENCE PRACTICES

- Practice 4. Developing and Using Abstractions
  1. Extract common features from a set of interrelated processes or complex phenomena
### Strand: Impacts of Computing

#### Topic: Safety, Law and Ethics

| IC.SLE.9-12.F.a | Interpret and analyze breaches in privacy and security to investigate the legal and ethical impact in classical and emerging technologies. |
| IC.SLE.9-12.F.b | Analyze the concepts of usability and security to explain typical tradeoffs between them. |
| IC.SLE.9-12.F.c | Analyze the collection and generation of data through automated processes to explain the legal concerns that are not always evident to users. |
| IC.SLE.9-12.F.d | Explain the beneficial and harmful effects of intellectual property laws to determine the impacts on innovation. |

### Expectations for Learning

#### LEARNING PROGRESSION

**By the end of grade 8:**
- Students understand and can explain the difference between public and personal information, the necessity of not sharing personal information and the implications of misinformation.

**In the 9-12 Foundational Level:**
- Students will investigate security concerns, data breaches, privacy policies, intellectual property laws, the inverse relationship of usability versus security, a user's legal rights and the Creative Commons license. All these investigations will focus on both the legal and ethical impacts on our complex society.

**In the 9-12 Advanced Level:**
- Students will further investigate the inverse relationship of usability versus security as well as all aspects of copyright law. This will also include creating, solving and implementing solutions to a variety of real-world situations.

#### IMPORTANT CONCEPTS

- There are legal ramifications when individuals or groups break security or privacy laws
- There are many practices involving privacy and security that, while technically legal, are not ethical
- It is difficult to increase security in a system without decreasing usability
- It is difficult to increase usability in a system without decreasing security
- Automated collection of data can have legal implications depending on how it is done
- Users have legal rights that they often are not aware of
- Intellectual property laws impact how data can be used and what attribution is required
- There are multiple types of licenses that can be applied to information and processes
- Intellectual property laws can both protect creators and stifle innovation
- Software "Terms of Use" and privacy policies can affect your legal rights
- Current law and legislation may not be current due to emerging technologies’ rapid advancement
- Challenges identified with classical technologies can guide how we prepare for future technologies

#### KEY SKILL/PROCEDURES

- Describe what constitutes a breach of security or a breach of privacy
- Analyze security and privacy breaches
- Summarize the legal and ethical impact of security breaches
<table>
<thead>
<tr>
<th>Strand</th>
<th>Impacts of Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Safety, Law and Ethics</td>
</tr>
<tr>
<td></td>
<td>• Explain the difference between law and ethics</td>
</tr>
<tr>
<td></td>
<td>• Analyze the tradeoffs between security and usability</td>
</tr>
<tr>
<td></td>
<td>• Describe the legal protections people have under current laws</td>
</tr>
<tr>
<td></td>
<td>• Compare how different companies use automatic processes of data collection</td>
</tr>
<tr>
<td></td>
<td>• Define intellectual property</td>
</tr>
<tr>
<td></td>
<td>• Explain the beneficial and harmful effects of intellectual property laws</td>
</tr>
<tr>
<td></td>
<td>• Describe the different types of licenses that exist to protect content creators</td>
</tr>
<tr>
<td></td>
<td>• Explain what a Creative Commons license is and how it is used</td>
</tr>
</tbody>
</table>

**Content Elaborations**

**CLARIFICATIONS**
Analyzing security and privacy breaches could include looking at how they happened and why. Additionally, you could examine what the company could have done to minimize or avoid the breach.

Students should understand software "Terms of Use" and privacy policies.

Your legal rights include the rights to your personal data and your intellectual property rights.

**CONTENT FOCUS**
Focus on tradeoffs, both security versus usability and free software versus commercial software. You do not need to go deeply into legal understanding. A basic understanding should be sufficient to discuss the impact of the laws.

**COMPUTER SCIENCE PRACTICES**

*Practice 7. Communicating About Computing*
1. Select, organize, and interpret large data sets from multiple sources to support a claim.
2. Describe, justify and document computational processes and solutions using appropriate terminology consistent with the intended audience and purpose.
3. Articulate ideas responsibly by observing intellectual property rights and giving appropriate attribution.
### Strand | Algorithmic Thinking and Programming
---|---
**Topic** | Algorithms
ATP.A.9-12.A.a | Define and explain recursive algorithms to understand how and when to apply them.
ATP.A.9-12.A.b | Use recursion to effectively solve problems.
ATP.A.9-12.A.c | Define and explain sorting and searching algorithms to understand how and when to apply them.
ATP.A.9-12.A.d | Use sorting and searching to analyze and organize data.
ATP.A.9-12.A.e | Compare and contrast classical, cluster, and quantum computing algorithms to understand their similarities and differences.

### Expectations for Learning

**LEARNING PROGRESSION**

By the end of the 9-12 Foundational Level:
Students can break a problem into steps, and then, in addition to pseudocode, represent the algorithm using process and data flow diagrams. Students can explain the steps of the problem and be able to communicate why they broke the problem down the way they did. Finally, they can implement their created algorithm in an appropriate programming language and refine it using best practices.

In the 9-12 Advanced Level:
Students will use complex list algorithms such as sorting and searching. They will also understand, explain and use the concept of recursion, where a method calls itself until an exit condition is met. Students will further explain the need for cluster computing algorithms, where the need for improved performance and availability over a single computer exists. Students will explain the need for quantum computing algorithms, cryptography: where the existence of hidden problem structures can exploit in ways that classical computers cannot.

**IMPORTANT CONCEPTS**

- A recursive method must simplify a problem and have an exit condition
- Data can be analyzed and sorted by sorting and searching
- Different sorting and searching algorithms work more efficiently with different sets of data

**KEY SKILL/PROCEDURES**

- Describe how recursive algorithms can be more or less effective than iterative algorithms
- Demonstrate how to rewrite simple algorithms from iterative to recursive
- Explain Recursive Sorting algorithms
- Explain Simple Sorting algorithms
- Explain simple and binary searches

### Content Elaborations

**CLARIFICATIONS**

Use a visualization to show the various searches, efficiency of access times and completion times

Demonstrate the construction and logic behind a decimal to binary recursive function
<table>
<thead>
<tr>
<th>Strand</th>
<th>Algorithmic Thinking and Programming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Algorithms</td>
</tr>
<tr>
<td></td>
<td>A simple sort does not utilize recursion</td>
</tr>
</tbody>
</table>

**CONTENT FOCUS**

Focus on using already optimized algorithms for determining which should be used. Recursion should be understood and utilized, not necessarily created from scratch.

**COMPUTER SCIENCE PRACTICES**

*Practice 4. Developing and Using Abstractions*

3. Create modules and develop points of interaction that can apply to multiple situations and reduce complexity.

4. Model phenomena and processes and simulate systems to understand and evaluate potential outcomes.

*Practice 5. Creating Computational Artifacts*

2. Create a computational artifact for practical intent, personal expression, or to address a societal issue.

*Practice 6. Testing and Refining Computational Artifacts*

3. Evaluate and refine a computational artifact multiple times to enhance its performance, reliability, usability and accessibility.
<table>
<thead>
<tr>
<th>Strand</th>
<th>Impacts of Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
<td><strong>Culture</strong></td>
</tr>
<tr>
<td>IC.Cu.9-12.A.a</td>
<td>Evaluate an alternative solution where a current tool does not exist due to limited resources.</td>
</tr>
<tr>
<td>IC.Cu.9-12.A.b</td>
<td>Analyze the global impact of the distribution of computing resources in terms of equity, access, and influence.</td>
</tr>
<tr>
<td>IC.Cu.9-12.A.c</td>
<td>Design a study of the potential impacts of classical computers, clustered computing, and quantum computing in different fields.</td>
</tr>
<tr>
<td>IC.Cu.9-12.A.d</td>
<td>Evaluate and explore how research and commercial entities are using clustered and quantum computing as alternative solutions due to limitations of classical computers.</td>
</tr>
</tbody>
</table>

**Expectations for Learning**

**LEARNING PROGRESSION**

By the end of the 9-12 Foundational Level:
Students practiced analyzing new technologies and professions, using appropriate criteria to be able to predict and recognize the true measurable impact on each part of our complex society.

In the 9-12 Advanced Level:
Students will be able to evaluate, analyze, adapt and make predictions about new technologies and professions to solve real-world situations. These real-world situations will include a wide variety of economic, scarcity, social and geopolitical factors. Students will focus on individual, local and global interactions to solve these higher-level real-world situations.

Beyond High School:
Students will continue to investigate the impacts of technology and computing resources on all aspects of our society and culture at the collegiate level.

**IMPORTANT CONCEPTS**

- Technology is not equally used or available around the world
- There are often free and different alternatives to modern computing tools
- It is important to account for scarcity when evaluating tools to solve a problem
- Economic, social and geopolitical factors have influenced the computer's impact on the world
- Computers have had a dramatic impact on our culture
- Identify how emerging computer technologies are impacting how we imagine the future in both current research and cultural society
- Identify how emerging computer technologies are impacting how we imagine the future in both current research and cultural society

**KEY SKILL/PROCEDURES**

- Evaluate a current computing tool's appropriateness for a specific problem
- Compare and contrast computing tools based on appropriateness and scarcity
- Describe some of the difficulties in distributing computing resources around the world
- Explain how economic, social and geopolitical factors influence computing
- Identify ways computation has revolutionized our culture
- Predict how computers may impact our culture in the future
## Impacts of Computing

<table>
<thead>
<tr>
<th>Topic</th>
<th>Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Evaluate an emerging computing tool’s (e.g., cluster & quantum computing) appropriateness for a specific problem

### Content Elaborations

**CLARIFICATIONS**

Computer distribution differs by network availability, such as whether broadband is available, as well as hardware availability such as the number of households that have computers.

An example of an alternative solution would be a person who does not have international phone service, but wants to talk with people from home, using a free phone app to make an online video call when both ends are connected to wifi.

**CONTENT FOCUS**

Focus on how computer distribution is different across the world, and how people then need to solve computing problems differently depending on their available resources.

**COMPUTER SCIENCE PRACTICES**

**Practice 1. Fostering an Inclusive Computing Culture**

1. Include the unique perspectives of others and reflect on one’s own perspectives when designing and developing computational products.
2. Address the needs of diverse end users during the design process to produce artifacts with broad accessibility and usability.

**Practice 2. Collaborating Around Computing**

4. Evaluate and select technological tools that can be used to collaborate on a project.

**Practice 7. Communicating About Computing**

1. Select, organize and interpret large data sets from multiple sources to support a claim.
<table>
<thead>
<tr>
<th>Strand</th>
<th>Impacts of Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
<td>Safety, Law and Ethics</td>
</tr>
</tbody>
</table>

**IC.SLE.9-12.A.a** Create a scenario to demonstrate typical tradeoffs between usability and security and recommend security measures based on these or other tradeoffs.

**IC.SLE.9-12.A.b** Evaluate and explore how research and commercial entities use intellectual property laws including copyright, trademarks, and patents to identify practical, business and ethical impacts.

### Expectations for Learning

**LEARNING PROGRESSION**

By the end of the 9-12 Foundational Level:

Students investigated security concerns, data breaches, privacy policies, intellectual property laws, the inverse relationship of usability versus security, a user's legal rights and the Creative Commons license. All these investigations focused on both the legal and ethical impacts on our complex society.

In the 9-12 Advanced Level:

Students will further investigate the inverse relationship of usability versus security as well as all aspects of intellectual property laws. This will also include creating, solving and implementing solutions to a variety of real-world situations.

**IMPORTANT CONCEPTS**

- Security measures must account for usability concerns to be successful
- Security requires tradeoffs, both of usability and of other concepts, such as speed, size
- Intellectual property laws include copyright, patent and trademark
- Intellectual property laws have significant impact on the computing world
- Intellectual property laws have ethical and legal implications for businesses, people, and society
- Intellectual property laws have significant impacts on the development of new technologies

**KEY SKILL/PROCEDURES**

- Create a realistic scenario that requires computer security
- Explain what security tradeoffs are and how they work
- Defend the tradeoffs of security and other concepts the student use
- Define copyright and explain how it is protected
- Explain what "free," "open-source" and "commercial" software types are and the differences between them
- Argue the positive and negative impacts of copyrights
- Describe how to research for existing intellectual property holdings
- Evaluate and explore Terms of Use and Privacy Policies
<table>
<thead>
<tr>
<th>Strand</th>
<th>Impacts of Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Safety, Law and Ethics</td>
</tr>
<tr>
<td><strong>Content Elaborations</strong></td>
<td></td>
</tr>
<tr>
<td><strong>CLARIFICATIONS</strong></td>
<td>Any time personally identifiable information is being shared on a computer there should be security involved, so any scenario that the students create that includes this would be acceptable.</td>
</tr>
<tr>
<td><strong>CONTENT FOCUS</strong></td>
<td>Focus on using the understanding of security and usability tradeoffs to solve a problem</td>
</tr>
<tr>
<td><strong>COMPUTER SCIENCE PRACTICES</strong></td>
<td></td>
</tr>
<tr>
<td><em>Practice 7. Communicating About Computing</em></td>
<td></td>
</tr>
<tr>
<td>1. Select, organize, and interpret large data sets from multiple sources to support a claim.</td>
<td></td>
</tr>
<tr>
<td>2. Describe, justify, and document computational processes and solutions using appropriate terminology consistent with the intended audience and purpose.</td>
<td></td>
</tr>
<tr>
<td>3. Articulate ideas responsibly by observing intellectual property rights and giving appropriate attribution.</td>
<td></td>
</tr>
</tbody>
</table>