

First Edition

AP Computer Science Principles

Student Edition Sample Chapter



Mc
Graw
Hill



First Edition

AP[®] Computer Science Principles

AP Computer Science Principles

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KEY FEATURES for AP Success

The text begins with an introductory chapter for students to set a foundation for the learning ahead. It provides an overview of the key concepts, explains how the program is structured, and emphasizes the significance of topics in the AP Computer Science Principles course.

WELCOME TO AP Computer Science Principles

As you explore the dynamic world of computing, this program will help you master the essential knowledge and skills to succeed in the AP Computer Science Principles course and on the Exam. Through engagement with the textbook and dynamic digital resources you will:

- Develop a strong understanding of core computer science principles.
- Enhance your programming and data analysis skills.
- Complete programming tasks that demonstrate your problem-solving abilities.

Whether you are completely new to the subject area or have some experience, this program is designed to guide you step-by-step from day 1 through Exam day.

Overview of the Course

AP Computer Science Principles introduces you to the wide and changing world of computer science. Unlike courses that focus only on programming, this course covers both technical details and broader ideas about how computing affects society. You will learn how computers solve problems, analyze data, encourage creativity, and influence the world around us.

The course is built around five "Big Ideas":

Big Idea 1	Topics	Exam Weighting
Creative Development Explore how collaboration and an iterative design process are essential to creating effective computing solutions.	• Working in teams • Program design and development	10%–13% of the total exam content

WELCOME TO AP Computer Science Principles

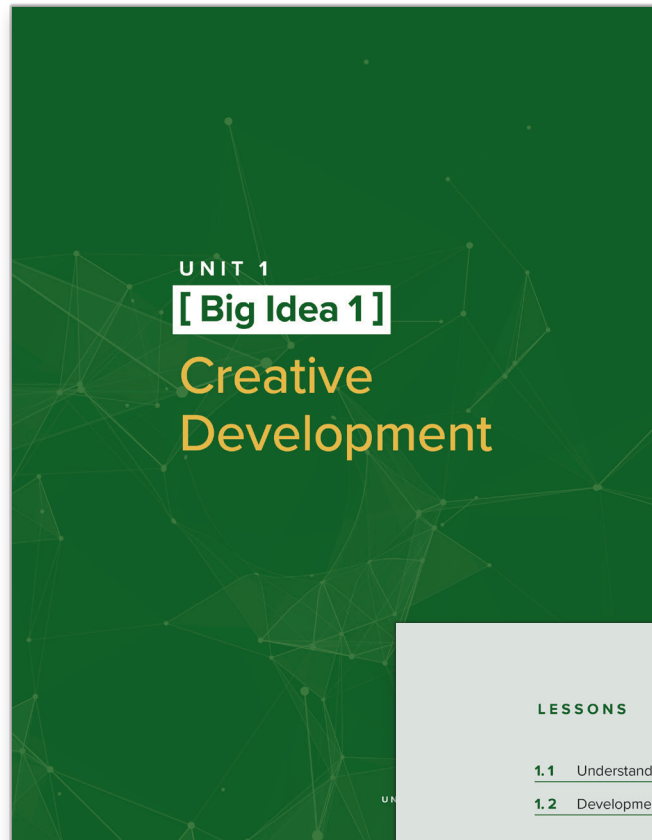
Big Idea 2	Topics	Exam Weighting
Data Understand how computers handle data and how data can be analyzed to discover new insights.	• Data compression • Extracting information from large datasets	17%–22% of the total exam content
Big Idea 3	Topics	Exam Weighting
Algorithms and Programming Learn how to create and use algorithms and abstractions to solve problems or express creativity.	• Developing and refining algorithms • Creating simulations • Understanding algorithmic efficiency	30%–35% of the total exam content
Big Idea 4	Topics	Exam Weighting
Computer Systems and Networks Study how computer systems function and how networks, including the internet, work.	• The structure and functioning of the internet • Parallel and distributed computing systems	11%–15% of the total exam content
Big Idea 5	Topics	Exam Weighting
Impact of Computing Examine the effects of computing on societies, economies, and cultures. You'll also consider ethical responsibilities involved.	• The digital divide and access to technology • Computing bias and its impacts • Safe and secure computing practices	21%–26% of the total exam content

22 WELCOME TO AP Computer Science Principles

AP Computer Science Principles is organized around five core themes.

These five "Big Ideas" frame every unit and exam question.

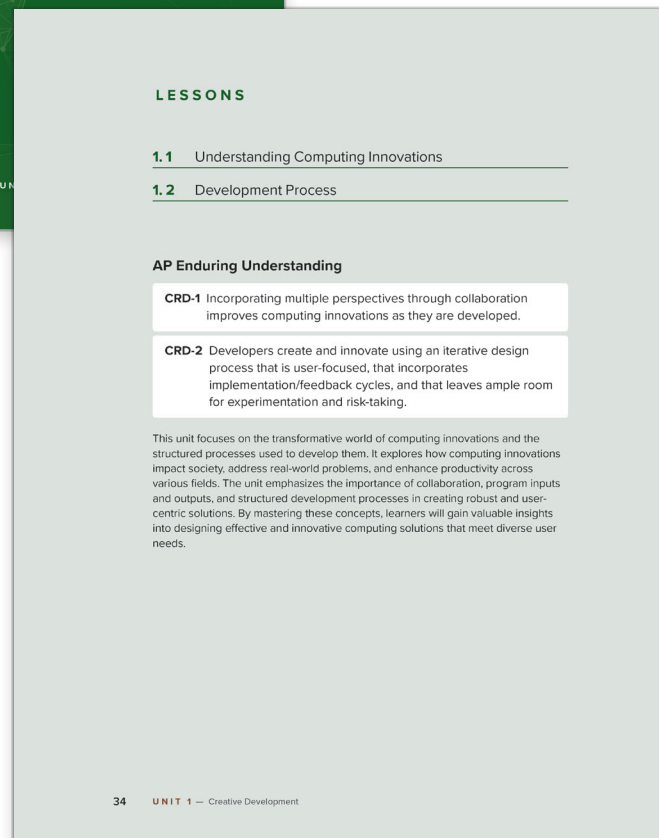
Discrete Unit Focus on Big Ideas



Fully aligned with the AP Computer Science Principles framework, the text is organized into five units, each providing a discrete focus on one of the Big Ideas.

The **lesson overview** provides an at-a-glance look at which topics will be covered in the unit.

The **AP Enduring Understanding** items highlight the deep, lasting concepts students should carry forward. Enduring Understandings connect the classroom work to the AP framework's goals for each unit.



Lesson Introduction and Pages

LESSON 1

Understanding Computing Innovations

AP Learning Objectives

- CRD-1.A** Explain how computing innovations are improved through collaboration.
- CRD-1.B** Explain how computing innovations are developed by groups of people.
- CRD-1.C** Demonstrate effective interpersonal skills during collaboration.
- CRD-2.A** Describe the purpose of a computing innovation.
- CRD-2.B** Explain how a program or code segment functions.
- CRD-2.C** Identify input(s) to a program.
- CRD-2.D** Identify output(s) produced by a program.

The **AP Learning Objectives** link each lesson back to the framework.

Definition

A computing innovation is a new or improved creation that includes a program as an essential part of how it works.

Key terms are highlighted at point of use. These callouts provide definitions of essential concepts, encouraging students to pause to learn or review important terminology.

More about...

Programs consist of multiple code segments that work together to achieve the desired task. They are usually organized into units or modules to make them easier to develop and maintain.

More about... provides extra context or helpful tips to deepen understanding.

Best practice

When converting binary to decimal, or vice versa, write down the powers of 2 for each position to avoid mistakes.

Best Practice tips offer expert advice to help students avoid common mistakes and solve problems more efficiently.

Input

Program **input** is the data received by the program to be processed. It can come from a user or be passed on from another program. Inputs exist in various forms, such as tactile, audio, visual, and text:

Input	Example
Tactile	• Tapping on a touchscreen • Clicking with a mouse
Audio	• Speaking into a microphone • Using voice commands
Visual	• Scanning a QR code with a camera • Recognizing faces using facial recognition software
Text	• Entering data into a form on a website • Writing a text message

Input data is supplied to a program through an event. Events can occur when a key is pressed, a mouse is clicked, a program starts, or any other action influences the program's execution flow. For example, clicking a button on a website might trigger an event that sends user data to a server. Input can also come from a user or other

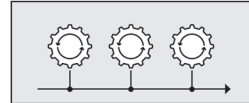
Tables organize detailed examples—like inputs, outputs, or code modules—in a structured format.

Diagrams present complex ideas in an easy-to-follow visual format.

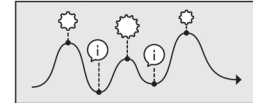
Ordered and Intentional vs. Exploratory Development

Development processes can be categorized as either ordered and intentional or exploratory. In **ordered and intentional** approaches, developers follow a structured methodology with clearly defined phases and objectives, progressing systematically from one stage to the next. On the other hand, **exploratory** development embraces flexibility and adapts to evolving requirements. These processes involve more experimentation and may evolve as new insights or changes arise during development.

Ordered and Intentional

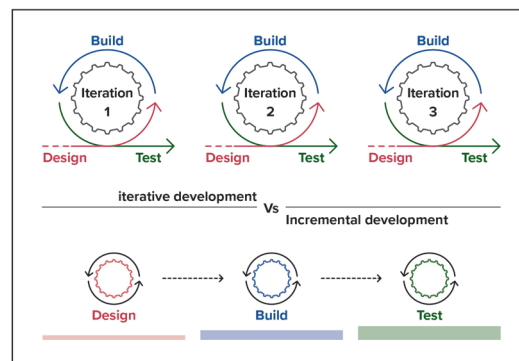


Exploratory



Iterative vs. Incremental Development

Another key distinction is between iterative and incremental processes. In **iterative development**, the focus is on continuous refinement and improvement, revisiting earlier stages based on user feedback, testing, or reflection. This often involves multiple cycles of revision. **Incremental development**, in contrast, breaks the project into smaller pieces, ensuring that each component functions properly before integrating it into the whole. This approach facilitates gradual progress by building the solution in manageable steps.



Example**Python Syntax**

```
x = 0
while x != 3:
    print(x)
    x += 1
```

```
0
1
2
```

The loop executes until x equals 3, printing numbers 0 to 2.

Pseudocode Syntax

```
x ← 0
REPEAT UNTIL x = 3
{
    DISPLAY x
    x ← x + 1
}
```

Infinite Loops

An infinite loop occurs when the loop's exit condition is never satisfied.

Example**Python Syntax**

```
x = 0
while x != -1:
    print(x)
    x += 1
```

```
0
1
2
3
....
```

106 UNIT 3 Algorithms and Programming LESSON 2 Control Flow in Programming

Real, runnable code examples are shown in blue. These snippets use actual Python code so students can copy, paste, and execute them in their programming environment.

Pseudocode Syntax

```
x ← 0
REPEAT UNTIL x = 3
{
    DISPLAY x
    x ← x + 1
}
```

Language-agnostic pseudocode is displayed in black. It removes specific syntax rules and emphasizes the underlying algorithmic steps, making the logic clear without tying students to a particular programming language.

Python Syntax

```
x = 0
while x != -1:
    print(x)
    x += 1
```

```
0
1
2
3
....
```

The green highlighted text shows the exact output students will see when the code runs to confirm that the program is behaving as expected.

End-of-Lesson Review

Key Takeaways

- Computing innovations can be found in physical devices, non-physical software, or computing concepts, all of which transform how we live and work.
- Collaboration is essential in the development of innovations, playing a pivotal role in ensuring diverse perspectives, reducing bias, and enhancing creativity in developing computing innovations.
- Programs, or software, process a variety of inputs and produce outputs. They need a user-friendly interface that makes interactions simple and intuitive, enhancing overall functionality.

Key Terms

computing innovation

A new or improved creation that includes a program as an essential part of how it works.

physical computing innovation

Tangible devices that combine hardware and software to interact with the physical world.

non-physical computing software

Programs that operate on computers or digital devices to perform tasks.

non-physical computing concept

Abstract ideas or systems that utilize computing principles.

collaboration

The process of working with others to design and develop computing innovations by incorporating diverse perspectives.

program

A collection of instructions that accomplish a specific task when executed by a computer.

input

Data received by a program to be processed, such as tactile, audio, visual, or text-based data.

output

Data produced by a program in response to input, such as visual displays, audio notifications, or text reports.

42 UNIT 1 Creative Development LESSON 1 Understanding

Key Takeaways summarizes the most important concepts from the lesson, providing an opportunity to review and reinforce the material before moving on.

Key Terms lists the essential vocabulary from the lesson, promoting mastery of the precise language used in the course and on the exam.

Activities

End-of-lesson activities are designed to reinforce understanding and provide hands-on practice.

These include:

- > **Short answer questions** to review key concepts and terminology.
- > **Discussion prompts** for collaborative reflection on what students have learned.
- > **Mini-coding challenges or debugging exercises** that let students apply ideas immediately in actual code.

These activities help students check their comprehension, sharpen their skills, and prepare for performance tasks and exam questions.

Activities

1. Describe a scenario when binary search is significantly faster than linear search.
2. Explain what is meant by a random value in programming and real life.
3. Describe what a simulation is and why it is used.
4. Explain the difference between decidable and undecidable problems.
5. The following Python code is given:

```
import random
random_value = random.randint(1, 3)
print("Random value:", random_value)
```

- Write the pseudocode for a procedure that generates a random number between 1 and 10.
- Explain why each run of the program might produce a different number.
- In what real-world scenarios could generating random numbers be useful?

156 UNIT 3 Algorithms and Programming LESSON 5 Advanced Algorithms and Efficiency

End-of-Unit Questions

Exam Questions

- Which of the following describes a computing innovation?
 - A machine that operates manually
 - A new or improved creation involving a program as an essential part
 - A software that operates only on mobile devices
 - An improvement in mechanical engineering
- Which of the following is an example of physical computing innovation?
 - Word processor software
 - Virtual reality
 - Smart home devices
 - Cloud storage
- Computing innovations contribute to solving real-world problems by:
 - increasing manual labor.
 - improving efficiency and accessibility.
 - limiting collaboration.
 - making processes more complicated.

The end-of-unit **practice questions** mimic the multiple-choice format students will see on exam day, allowing them to:

- > Apply what they have learned and test their understanding of each Big Idea and lesson objective.
- > Become familiar with single-select, passage-based, and multi-select question formats.
- > Assess their readiness by identifying which topics have been mastered and which need to be reviewed before exam day.

Full-Length Practice Exam

Practice Exam

SECTION I: Multiple Choice

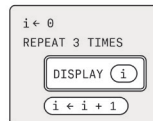
- A hospital is developing an AI-powered diagnostic tool to assist doctors in identifying diseases faster and more accurately. Which of the following best explains how collaboration improves this innovation?
 - Doctors work alone to create the best tool without interference.
 - A diverse team including doctors, engineers, and designers ensures different perspectives and expertise are incorporated.
 - Only programmers are needed to develop the AI tool, as they write the code.
 - Collaboration slows down the innovation process and leads to unnecessary complexity by involving too many people with different ideas that may not align.

A complete AP-style **practice exam** is included at the back of the book. It mirrors the format of the actual test, featuring Section I with single-select, passage-based, and multiple-choice questions, followed by Section II performance task prompts.

There are questions with block-based code mirroring the style of the AP exam.

The appendices also include reference lists with block-based code syntax and examples.

30. What will be the output of this loop?



- 1 2 3
- 0 1 2
- 0 1 2 3
- None

SECTION II

Create Performance Task: Written Responses

You will submit a program of your own design along with written responses to several prompts. Use these prompts along with your PPR to prepare for the AP Exam.

Prompt Category	Sample Prompt
Written Response 1: Program Purpose and Function	- Describe the purpose of your program. What problem does it solve, or what creative task does it perform? - Identify at least one input and one output of the program. - Explain how the input(s) influence what the program does and how the output(s) reflect the program's intended function. - Explain how you came up with the concept for this program. What led you to choose this idea, and how did you decide on the features to include?

Section II includes AP-style prompts students may encounter on the exam. These prompts can be used with the Personalized Project Reference (PPR) to practice explaining the program clearly and thoroughly, and prepare for key response categories like purpose, inputs/outputs, and algorithm development.

Quick Reference

APPENDIX

Performance Task Example

Preparing the Create Performance Task for Submission

Components You Must Upload

In the Create Performance Task, you will develop a program that solves a problem, enables innovation, explores personal interests, or demonstrates a skill. You may collaborate with a partner to develop your program. Your Personalized Project Reference must be complete before you submit your program.

You will have at least 9 hours of class time to complete your program and three components to the AP Digital Portfolio by the end of the course.

Component	Requirements
A. Program Code	Functional program code that includes required programming elements
B. Video	Record a 60-second demonstration of your program running, showing key functions
C. Personalized Project Reference	Selected code segments that be used on the exam

Component A: Program Code (Created Independently)

Submit a single PDF file of your complete program code. Clearly acknowledge any part of the code that was generated by AI (e.g., open-source libraries, AI-generated code). Your program must include:

240 Performance Task Example

The **Performance Task Example** is a step-by-step walkthrough of a Create task, showing exactly what to build, how to format the code/video/reference, and sample exam-style questions.

Example: Fitness Tracker with Step Goal Analysis

The example includes:

1. Program Code (Python)
2. Video Description (Summary of what the video will show)
3. Personalized Project Reference (Includes screen captures)
4. Exam Questions (Written Response 1, 2a, 2b, and 2c) with Answers

1. Program Code (Python)

This program tracks a user's daily steps and analyzes whether they met their fitness goals.

```
# Step Tracker Program
def calculate_streak(steps_list, goal):
    # Find longest streak of days meeting goal
    longest_streak = 0
    current_streak = 0

    # Loop through each day's steps
    for steps in steps_list:
        # Check if goal was met
        if steps >= goal:
            current_streak += 1
            # Update longest streak when needed
            if current_streak > longest_streak:
                longest_streak = current_streak
        else:
            current_streak = 0

    # Create appropriate message based on streak results
    if longest_streak == 0:
        return "No streaks yet. Keep trying!"
    else:
        return "Your longest streak was " + str(longest_streak) + " days in a row!"
```

244 Performance Task Example

Procedures and Procedure Calls	
Python: <pre>def procName(parameter1, parameter2, ...): <Block of statements></pre> Text: <pre>PROCEDURE procName(parameter1, parameter2, ...) { <block of statements> }</pre> Block:	Defines <i>procName</i> as a procedure that takes zero or more arguments. The procedure contains <i>block of statements</i>. The procedure <i>procName</i> can be called using the following notation, where <i>arg1</i> is assigned to <i>parameter1</i>, <i>arg2</i> is assigned to <i>parameter2</i>, etc.: <i>procName</i>(<i>arg1</i>, <i>arg2</i>, ...)
Python: <pre>def procName(parameter1, parameter2, ...): <Block of statements> return expression</pre> Text: <pre>PROCEDURE procName(parameter1, parameter2, ...) { <block of statements> RETURN(expression) }</pre> Block:	Defines <i>procName</i> as a procedure that takes zero or more arguments. The procedure contains <i>block of statements</i> and returns the value of <i>expression</i>. The <i>RETURN</i> statement may appear at any point inside the procedure and causes an immediate return from the procedure back to the calling statement. The value returned by the procedure <i>procName</i> can be assigned to the variable <i>result</i> using the following notation: <i>result</i> ← <i>procName</i>(<i>arg1</i>, <i>arg2</i>, ...)

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Exam Reference Sheet

A quick-lookup **Code Reference list** is available in the back of the book. It lines up three syntaxes: Python code, AP-style pseudocode, and AP-style block-based code for every core construct (variables, loops, conditionals, functions, etc.)

Students can use this table to:

- > Compare syntaxes side-by-side when learning a new concept.
- > Translate between block-based classroom tools and text-based languages.
- > Check work during practice tasks or performance task development.

The **appendix** features a collection of each programming concept in three formats: Python code, AP-style pseudocode, and block-based diagrams. Students can:

- > Practice reading blocks just as they will on the AP exam.
- > Compare visual logic directly with its pseudocode and Python equivalents.
- > Build confidence in tracing and understanding block-based programs before writing their own.

Selection

Example 1

Python Syntax

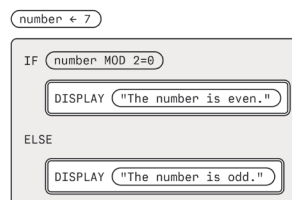
```
number = 7

if number % 2 == 0:
    print("The number is even.")
else:
    print("The number is odd.")
```

Pseudocode Syntax

```
number ← 7
IF (number MOD 2 = 0)
{
    DISPLAY("The number is even.")
}
ELSE
{
    DISPLAY("The number is odd.")
}
```

Block Representation



264

Blocks Reference



BEST-IN-CLASS

Digital Resources

AP Computer Science Principles is enriched with multimedia content that enhances the teaching and learning experience both inside and outside the classroom.

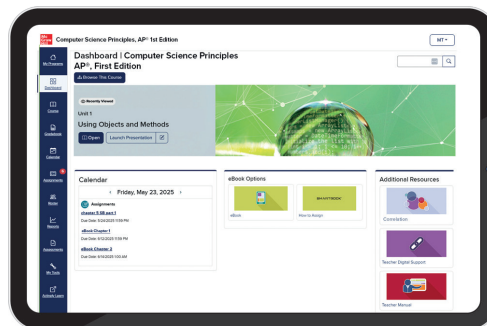
Developed with the world's leading subject matter experts and organized by unit level, the resources provide students with multiple opportunities to contextualize and apply their understanding. Teachers can save time, customize lessons, monitor student progress, and make data-driven decisions in the classroom with the flexible, easy-to-navigate instructional tools.

Student Assignments

Resources are organized at the unit level. To enhance the core content, teachers can add assignments, activities, and instructional aids to any lesson. The course gives students access to:

- an interactive eBook
- Adaptive SmartBook assignments
- two full-length AP Practice Exams
- a calendar of assignments

The course landing dashboard links students to resources that support success.

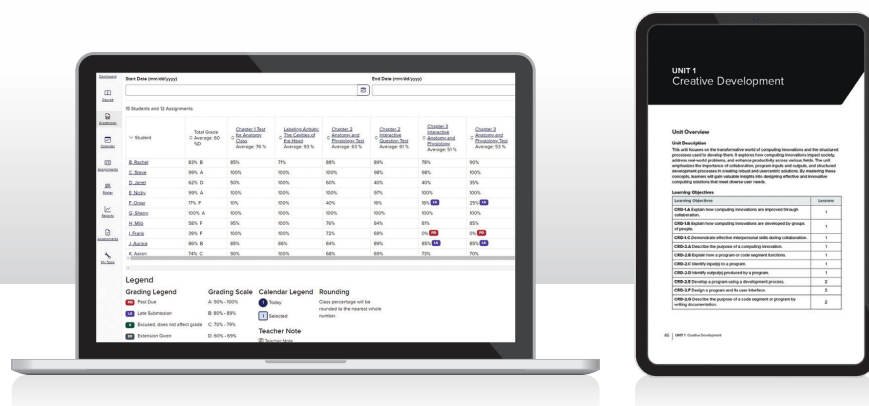


Teacher Resources

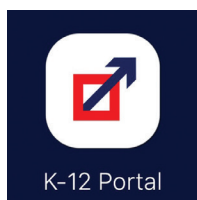
Teachers have access to the interactive eBook, plus a wealth of customizable chapter resources and powerful gradebook tools.

Resources include:

- A digital Teacher Manual with answers to the end-of-chapter questions and the Practice Exam.
- Actionable reporting features that track student progress with data-driven insights.
- A correlation to the College Board course framework, lesson plans, and additional ideas for lecture enrichment.
- On-demand digital support to help teachers navigate through all of the online features.



Powerful Gradebook reports help to inform and adjust in-class instruction.



Mobile Ready

Access to course content on-the-go is easier and more efficient than ever before with the **McGraw Hill K-12 Portal App**.



WELCOME TO

AP Computer Science

Principles

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Computer Systems and Networks Study how computer systems function and how networks, including the internet, work.	• The structure and functioning of the internet • Parallel and distributed computing systems	11%–15% of the total exam content
Big Idea 5	Topics	Exam Weighting
Impact of Computing Examine the effects of computing on societies, economies, and cultures. You'll also consider ethical responsibilities involved.	• The digital divide and access to technology • Computing bias and its impacts • Safe and secure computing practices	21%–26% of the total exam content

Understanding the Exam

Assessment in the AP Computer Science Principles course is comprised of two components: a through-course task and a summative exam. Together these components form your final AP score as follows:

1. **Section I:** End-of-Course Exam
2. **Section II:** Create Performance Task

The **End-of-Course Exam** is administered on a set test date, and the **Create Performance Task** is completed in class over a period of at least 9 hours. Below is an overview of each component.

The End-of-Course Exam

The End-of-Course Exam is a three-hour test broken down as follows:

1. **Multiple-Choice Section (2 Hours)** (70% of your final score)
 - > **Format:** 70 multiple-choice questions
 - Single-select questions (choose one correct answer)
 - Passage-based questions (about a computing innovation)
 - Multi-select questions (choose two correct answers)
 - > **Content:**
 - Covers all five Big Ideas and tests computational thinking skills.
 - Some questions may include code snippets or algorithm analysis.
2. **Written Prompts Section (1 Hour)** (30% of your final score)
 - > **What to Expect:**
 - Four open-ended questions based on your **Personalized Project Reference** from the Create Performance Task.
 - You will explain parts of your program, such as algorithms and abstractions, and discuss your design decisions.

The Create Performance Task

The Create Performance Task, with the written prompts section of the end-of-course exam, accounts for 30% of your final score. You will have at least 9 hours of class time to work on it, and will submit your final materials through the **AP Digital Portfolio**. Students should study the *AP Computer Science Principles Student Handout* and the *AP Digital Portfolio: Student User Guide* carefully for details. Both documents are available on the College Board's website: <https://apcentral.collegeboard.org/courses/ap-computer-science-principles>

Task Requirements

1. **Program Code:** A program that solves a problem or demonstrates an innovation. Upload the program code as a PDF file. Do not mention your name.
2. **Video:** A 60-second video (or less) showing your program receiving input from the user, processing the input to perform its action(s), and producing output to the user. Ensure your video is clear and formatted correctly. Do not narrate the video. If your file size exceeds the 30MB limit provided by College Board, it will not be uploaded. You may need to compress your video before uploading. Make sure that the compressed video is not blurry. Do not mention your name.
3. **Personalized Project Reference:** Four (4) specific code segments submitted to the Digital Portfolio. Do not include comments within the submitted code. Do not mention your name.

Tips for the Code segments

1. Do not include Comments in Code Captures
 - Code with comments will result in zero points on the written response portion.
 - Remove comments before capturing the code or do not include the comment in the segment selected for the code segment snip.
2. Ensure Clear and Readable Font Size
 - Use a minimum of 10-point font (12-point font is preferred).
 - Avoid small font sizes like 8-point, which may not be legible.
3. Prevent Blurry Images
 - Do not zoom out the screen before capturing the code, as enlarging later will blur the image.
 - Capture images at the appropriate size and resolution.

Submission Steps

1. **Log In:** Go to the <https://apstudents.collegeboard.org/digital-portfolios/submit-ap-csp-work> and sign in with your College Board account.
2. **Upload Your Files:**
 - > Your program code file with or without comments.
 - > A video demonstrating your program receiving input, processing the input, and producing output without narration.
 - > Four code segments: Procedure i and ii and List i and ii, without comments.
3. **Verify:** Check that each item is uploaded correctly and meets the guidelines.

Important Dates and Deadlines

- **First half of course:** Join your AP Computer Science Principles class in AP Classroom.
- **Second half of the course:** Complete and submit your Create Performance Task by the official deadline (check the date provided by the College Board and your teacher). Do not wait until the last moment to submit tasks in the AP Digital Portfolio.

Responsible Use of AI Tools

The **Create Performance Task** allows students to use generative AI tools, such as ChatGPT or Claude, as supplementary resources for understanding coding principles, developing code, and debugging according to the latest College Board's Guidance for Artificial Intelligence Tools and Other Services. Students can collaborate with generative AI tools in a manner similar to working with peers on code development. However, students are expected to:

1. Review and Validate AI-Generated Code

AI tools may produce incomplete or inefficient code, as well as code that contains errors or biases. It is your responsibility to test and debug any AI-generated code to ensure its accuracy and functionality.

2. Understand the Code

You must thoroughly understand all code included in your project. This is essential, as you will be required to explain your code during the **written-response section** of the exam. The ability to articulate how your code works, including algorithms, abstraction, and testing methods, is a key part of the evaluation criteria.

3. Avoid Over-Reliance on AI

While AI can assist with coding tasks, your project must reflect your own understanding and creativity. Use AI tools to enhance learning rather than to replace independent problem-solving.

AI Tool Risks

Be aware that AI-generated code can introduce challenges, such as:

- errors and inefficiencies that affect the program's execution,
- complexities that may make it harder to explain or document the code,
- and potential biases in algorithms, which must be identified and mitigated.

Notes

While collaboration with peers is allowed when developing the Program Code, the preparation of assets (program video, program code document, and code segments) must be created independently, without any collaboration.

Teachers and students should frequently review updated policies to ensure compliance.

Scoring and Grading

- The AP Computer Science Principles exam course assessment provides an AP exam score using a scale of 1 to 5, where 5 is "Extremely well-qualified" and 3 is "Qualified."
- There is **no penalty** for guessing on multiple-choice questions.
- Your performance on the multiple-choice section (70%) and the Create Task (30%) combine into a single score.

Best Practices for Preparing Throughout the School Year

Success in the course and on the exam requires steady practice and planning. Follow these guidelines to stay on track.

Setting Up a Study Plan

1. **Organize by Big Ideas:** Study one Big Idea at a time, using textbook chapters and class materials.
2. **Commit to weekly review:**
 - > Go over notes and textbook sections.
 - > Complete practice problems or exercises.
 - > Join study groups or class discussions.
3. **Track Your Progress:** Use quizzes or practice tests to find areas that need future study and review.

Maximizing Collaborative Learning

- **Pair or Group Programming:** Work with classmates to brainstorm ideas, code, and debug.

- **Rotate Roles:** Switch between tasks like coding, testing, and documenting so everyone gains experience in each area.
- **Share Feedback:** Ask questions and offer suggestions to improve each other's understanding.

Practicing Programming Skills Regularly

- **Choose a Language:** Get comfortable with at least one language, like Python.
- **Debug Often:** Practice finding and fixing errors to build strong troubleshooting skills.
- **Build Mini-Projects:** Create small programs that use loops, conditionals, or data structures to reinforce your knowledge.

Completing and Submitting the Performance Task

- **Start Early:** Brainstorm your program idea well before the submission deadline.
- **Document Everything:** Keep notes on your planning, coding, and testing process.
- **Follow the Guidelines:** Make sure your code, video, and written responses meet all College Board requirements.

Taking Practice Tests

- **Full-Length Tests:** Schedule a few practice exams as you get closer to the official test date. A full-length practice exam is included in the textbook, as well as in the digital course.
- **Review Mistakes:** Go through each incorrect or uncertain answer to understand why it was wrong.
- **Focus on Weak Areas:** Spend extra time studying topics you find difficult.

Tips for Taking the Exam

Use the following strategies for both the multiple-choice section and the written prompts linked to your Create Performance Task.

General Test-Taking Strategies

Before the Exam

- > **Know the Question Types:** Be familiar with single-select, passage-based, and multi-select questions.

- > **Practice Timing:** Work on pacing yourself so you can comfortably finish each section.
- > **Familiarize Yourself with Bluebook:** Practice using the Bluebook testing app provided by the College Board, so you feel comfortable navigating its features during the digital exam.

On Exam Day

- > **Read Carefully:** Look for important words like "NOT," "EXCEPT," or "ALL THAT APPLY."
- > **Eliminate Wrong Answers:** Use Bluebook's answer eliminator feature to cross out incorrect choices, helping you narrow down and select the correct answer more efficiently.

Multiple-Choice Questions Section

- **Pace Yourself:** You have two hours for 70 questions. If stuck, mark the question and return later.
- **Look for Clues:** Some questions may link to the same topics; use what you learned from earlier questions.

Common Mistakes to Avoid

- > **Skipping Multi-Select Answers:** For multi-select questions, you must select two correct answers. Leaving out a second response will result in no points for the question.
- > **Overthinking:** Stick to the facts provided in the question. Avoid reading into the scenario more than necessary.

Written Responses for the Create Task

- **Be Specific:** Use examples from your program to explain your decisions.
- **Use Correct Terminology:** Show that you understand key concepts like algorithms and abstraction.
- **Review the Rubric:** Make sure you include all details the College Board wants in your explanation.

Long-Term Benefits

Foundation for Computer Science Studies

AP Computer Science Principles offers a broad introduction to computer science, making higher-level courses—like AP Computer Science A or college-level software engineering—easier to understand.

College Credit and Advanced Placement®

Many colleges give credit or placement for a score of 3 or higher on the AP Computer Science Principles exam. This can help you:

- **Skip Introductory Classes:** Move directly to higher-level courses.
- **Save Time and Money:** Reduce tuition costs by earning credits in high school.
- **Strengthen College Applications:** Show colleges your ability to handle challenging coursework.

Developing Industry-Ready Skills

Businesses in every field need people who can solve problems with technology. This course helps you build:

- **Algorithmic Thinking:** Useful for software development and data science.
- **Data Analysis:** Important in fields like research, marketing, and healthcare.
- **Ethical Computing:** Critical for privacy, security, and responsible AI.

Exploring Career Paths in Technology

AP Computer Science Principles can spark an interest in careers such as:

- Software Development
- Web and Mobile Design
- Data Science and Machine Learning
- Cybersecurity
- Robotics and IoT (Internet of Things)

Frequently Asked Questions

Q: Do I need prior programming experience to take AP Computer Science Principles?

A: No. AP Computer Science Principles is designed to welcome beginners and guide you through essential coding concepts.

Q: Which programming language will I learn?

A: AP Computer Science Principles does not require a specific language. This textbook focuses on Python, but the AP exam uses pseudocode that you can apply to any language.

Q: How much time should I spend on the Create Performance Task?

A: You will be provided at least 9 hours in class, but you may also work outside class for planning, coding, and writing your responses.

Q: How do I submit my performance task?

A: You must submit it through the web page <https://apstudents.collegeboard.org/digital-portfolios/submit-ap-csp-work>. Upload your code, video, and written answers, then mark them as final before the deadline.

Q: What score do I need to earn college credit?

A: Most colleges give credit for a score of 3 or higher, though some may require a 4 or 5. Check specific school policies at <https://apstudent.org/credtpolicies>.

UNIT 1

[Big Idea 1]

Creative Development

LESSONS

1.1 Understanding Computing Innovations

1.2 Development Process

AP Enduring Understanding

CRD-1 Incorporating multiple perspectives through collaboration improves computing innovations as they are developed.

CRD-2 Developers create and innovate using an iterative design process that is user-focused, that incorporates implementation/feedback cycles, and that leaves ample room for experimentation and risk-taking.

This unit focuses on the transformative world of computing innovations and the structured processes used to develop them. It explores how computing innovations impact society, address real-world problems, and enhance productivity across various fields. The unit emphasizes the importance of collaboration, program inputs and outputs, and structured development processes in creating robust and user-centric solutions. By mastering these concepts, learners will gain valuable insights into designing effective and innovative computing solutions that meet diverse user needs.

LESSON 1

Understanding Computing Innovations

AP Learning Objectives

CRD-1.A Explain how computing innovations are improved through collaboration.

CRD-1.B Explain how computing innovations are developed by groups of people.

CRD-1.C Demonstrate effective interpersonal skills during collaboration.

CRD-2.A Describe the purpose of a computing innovation.

CRD-2.B Explain how a program or code segment functions.

CRD-2.C Identify input(s) to a program.

CRD-2.D Identify output(s) produced by a program.

Computing Innovations

Computing innovations are all around us, transforming how we live, work, and entertain ourselves. They aid us in our daily activities and enhance the various aspects of our lives.

Definition

A computing innovation is a new or improved creation that includes a program as an essential part of how it works.

Computing innovations can be categorized into three primary types:

- **Physical computing innovations:** These are tangible devices that we can interact with, such as self-driving cars, wearable fitness trackers, and smart home devices. These innovations rely on both hardware and software to function effectively and interact with users.
- **Non-physical computing software:** These are programs that operate on computers or other digital devices. Examples include picture editing software, video conferencing tools, and other software, such as word processors or spreadsheets. These innovations enable us to perform tasks more efficiently and creatively.
- **Non-physical computing concepts:** These are abstract ideas or systems that leverage computing principles. Examples include e-commerce, artificial intelligence, and virtual reality. These innovations transform how we share, store, and utilize information, revolutionizing modern life.

The main objectives of computing innovations include facilitating the expression of creativity, solving problems, enhancing efficiency, and increasing productivity. For instance, new software might simplify communication with friends, or it might facilitate creative photo-editing. Computing innovations not only provide solutions to complex challenges in fields like healthcare, finance, education, and engineering but also work towards making technology more accessible to a broader audience.

Understanding a computing innovation's purpose and potential societal impact is crucial for developers. This insight guides the development process, ensuring that the resulting solutions address real-world challenges effectively. By comprehending the innovation's purpose, developers can push the boundaries of technological capabilities, to maximize both the desirability of their product and the benefits for society as a whole.

Collaboration

Collaboration plays a pivotal role in successfully developing and implementing new technologies. By bringing together diverse perspectives and skills, collaboration enhances the software development process, leading to a more effective final product. Incorporating multiple perspectives enhances computing innovations during their development while helping avoid biases that might otherwise limit their effectiveness. This results in computing innovations that embody the diverse talents and viewpoints of their designers.

More about...

Collaboration is crucial when developing computing innovations, because having multiple perspectives offers opportunities to improve the design of innovations.

Collaboration among developers can exist both remotely and in person. Online tools support collaboration by enabling programmers to share ideas, provide feedback, and work together in real time, regardless of location. Various models and techniques are also used to increase productivity and meet high standards. One example is pair programming, where two programmers work together at one workstation, allowing for continuous code review and improvement.



Effective collaborative teams practice interpersonal skills, such as communication, consensus building, conflict resolution, and negotiation. These abilities are crucial for preserving a productive and harmonious work environment, resulting in more successful and comprehensive computing innovations.

Another key element is maintaining robust relations with users. The development of computing innovations relies on consultation and communication with users. By collecting information from potential users and staying in touch with their demands and needs, developers can ensure that the final product is aligned with user expectations and practical needs, fully integrating these insights. Additionally, testing throughout the development process—especially with a diverse sample population—helps identify and mitigate biases. This ensures that the computing innovation is more inclusive and effective for a wider range of users.

Software Programs

In computing, **programs** are the essential building blocks that enable computers to perform various tasks, from simple calculations to complex simulations.

Understanding how programs function and interact with various inputs and provide outputs is fundamental to grasping the broader scope of computer science.

Definition

A program is a collection of instructions that accomplish a specific task when executed by a computer. It is also often referred to as software.

A program should be able to work with a variety of inputs and situations. In general, a program's behavior is defined by how it reacts to user inputs, how its statements accomplish tasks, and how its functions operate.

More about...

Programs consist of multiple code segments that work together to achieve the desired task. They are usually organized into units or modules to make them easier to develop and maintain.

Input

Program **input** is the data received by the program to be processed. It can come from a user or be passed on from another program. Inputs exist in various forms, such as tactile, audio, visual, and text:

Input	Example
Tactile	• Tapping on a touchscreen • Clicking with a mouse
Audio	• Speaking into a microphone • Using voice commands
Visual	• Scanning a QR code with a camera • Recognizing faces using facial recognition software
Text	• Entering data into a form on a website • Writing a text message

Input data is supplied to a program through an event. Events can occur when a key is pressed, a mouse is clicked, a program starts, or any other action influences the program's execution flow. For example, clicking a button on a website might trigger an event that sends user data to a server. Input can also come from a user or other

programs. For instance, a Python or Java program might receive input from a user typing into the console or from another program via an API or file. The output generated by a program is usually dependent on the inputs. In event-driven programming, program statements are executed in response to specific events rather than through a sequential control flow.

More about...

Inputs may also originate from files, datasets, or outputs generated by other programs. For example, a Python program might read numeric data from a CSV file, analyze text from a file, or receive data sent by another program over a network. These inputs influence program behavior just as directly as interactive user input or event-driven interactions.

Output

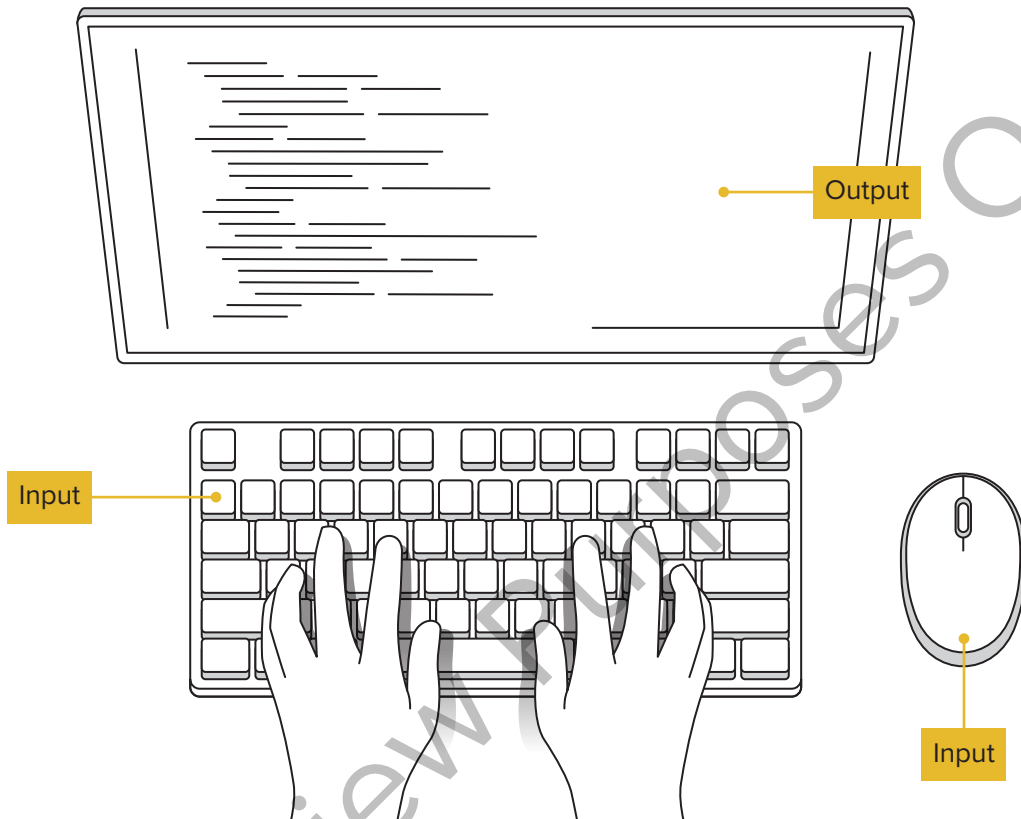
Program **output** is the data sent by a program to a device. Just like program inputs, outputs can take various forms:

Output	Example
Tactile	• Vibrations from a smartphone • Force feedback from a controller
Audio	• Sound notifications/alerts • Sound effects
Visual	• Displaying images on a computer screen • Projecting visuals using a projector
Text	• Printing a document • Generating a text report

The output of a program is usually determined by the input it receives or the program's prior state, such as its internal values or previously stored data. Internal values refer to data stored within the program that influences its behavior and output. These values may include variables or other data structures that update dynamically as the program runs, reflecting past computations, decisions, or system states. This means that what the program produces, as a result, can depend directly on new information provided by the user, or it can be influenced by what the program has already processed or remembered from earlier steps. For instance, a weather app outputs the current weather conditions and forecasts based on the user's location (input), while a game might behave differently depending on the player's progress (prior state).

More about...

When designing a solution to a problem, programmers consider both the program itself and the way the user will interact with the program: the user interface. A well-designed user interface makes it easy for the user to understand what data are required as input for the program to complete its tasks.



Activities

1. Identify the vital component required of a computing innovation.
2. What are the categories of computing innovations?
3. Describe an example of how computing innovations contribute to solving real-world problems and enhancing society.
4. Explain how collaboration when designing computing innovations benefits developers and potential users.
5. Imagine you are designing a voice assistant for elderly users. Based on the lesson, identify three key considerations for input, output, and collaboration to ensure your innovation is user-friendly and effective. Justify your choices.
6. You are designing a mobile app for a smart home system. Write a response explaining:
 - a. What types of input the app might use (e.g., tactile, voice, or visual).
 - b. What types of output the app might provide to the user (e.g., text, audio, or visual). Justify your choices with reasons why they are appropriate for a smart home system.

Key Takeaways

- Computing innovations can be found in physical devices, non-physical software, or computing concepts, all of which transform how we live and work.
- Collaboration is essential in the development of innovations, playing a pivotal role in ensuring diverse perspectives, reducing bias, and enhancing creativity in developing computing innovations.
- Programs, or software, process a variety of inputs and produce outputs. They need a user-friendly interface that makes interactions simple and intuitive, enhancing overall functionality.

Key Terms

computing innovation

A new or improved creation that includes a program as an essential part of how it works.

physical computing innovation

Tangible devices that combine hardware and software to interact with the physical world.

non-physical computing software

Programs that operate on computers or digital devices to perform tasks.

non-physical computing concept

Abstract ideas or systems that utilize computing principles.

collaboration

The process of working with others to design and develop computing innovations by incorporating diverse perspectives.

program

A collection of instructions that accomplish a specific task when executed by a computer.

input

Data received by a program to be processed, such as tactile, audio, visual, or text-based data.

output

Data produced by a program in response to input, such as visual displays, audio notifications, or text reports.

LESSON 2

Development Process

AP Learning Objectives

CRD-2.E Develop a program using a development process.

CRD-2.F Design a program and its user interface.

CRD-2.G Describe the purpose of a code segment or program by writing documentation.

CRD-2.H Acknowledge code segments used from other sources.

CRD-2.I Identify and correct errors in an algorithm or program.

CRD-2.J Identify inputs and corresponding expected outputs or behaviors that can be used to check the correctness of an algorithm or program.

The **development process** refers to a structured set of steps or phases used to design, build, and deliver a product, system, or service. It serves as a framework that helps teams organize, plan, execute, and manage tasks efficiently to achieve their goals. In the context of software or application development, it outlines the lifecycle of creating a product, from understanding user needs to maintaining the final product.

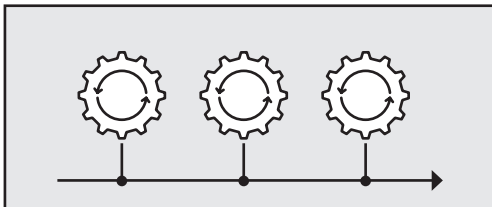
Key Characteristics of the Development Process

Developers utilize a user-focused design process that emphasizes continuous feedback and improvement. There are several distinct development approaches that vary based on how developers manage flexibility and structure:

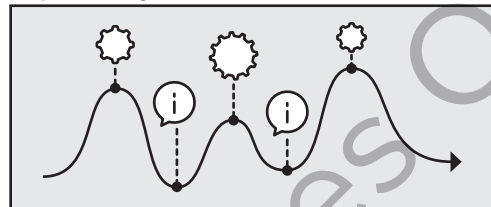
Ordered and Intentional vs. Exploratory Development

Development processes can be categorized as either ordered and intentional or exploratory. In **ordered and intentional** approaches, developers follow a structured methodology with clearly defined phases and objectives, progressing systematically from one stage to the next. On the other hand, **exploratory** development embraces flexibility and adapts to evolving requirements. These processes involve more experimentation and may evolve as new insights or changes arise during development.

Ordered and Intentional

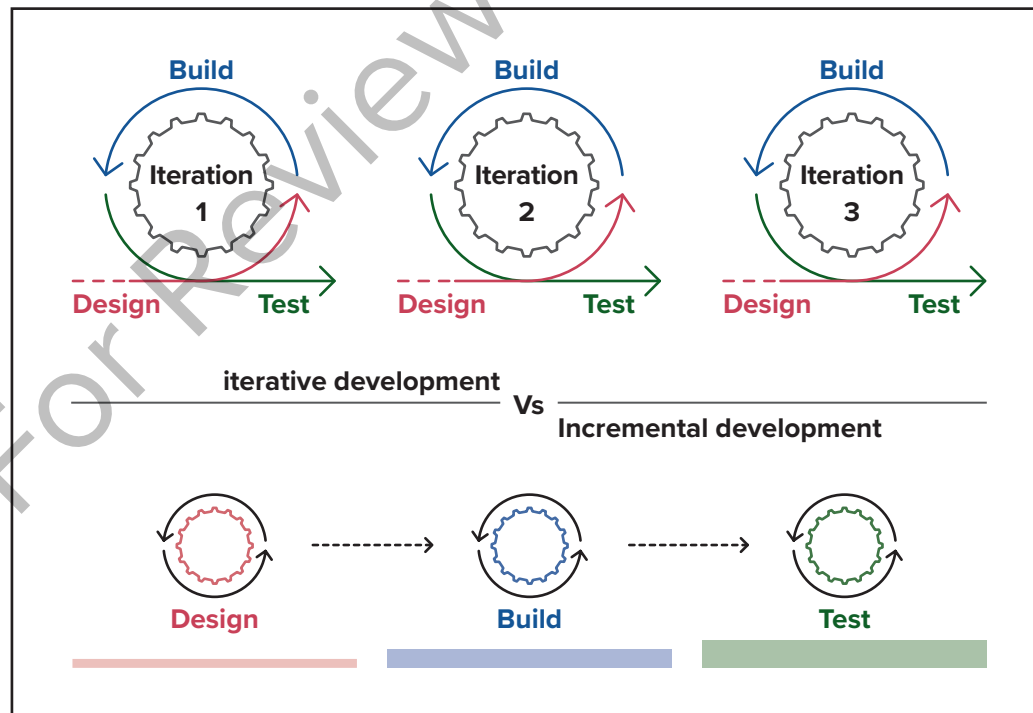


Exploratory



Iterative vs. Incremental Development

Another key distinction is between iterative and incremental processes. In **iterative development**, the focus is on continuous refinement and improvement, revisiting earlier stages based on user feedback, testing, or reflection. This often involves multiple cycles of revision. **Incremental development**, in contrast, breaks the project into smaller pieces, ensuring that each component functions properly before integrating it into the whole. This approach facilitates gradual progress by building the solution in manageable steps.



Phases of the Development Process

The development process can be divided into phases: investigation, reflection, design, prototyping, testing, and documentation.

Investigation

The design of a program begins with a thorough **investigation** to determine its requirements. This phase is crucial for comprehending and recognizing the program's constraints, such as technical limitations (e.g., hardware compatibility or processing power), budgetary constraints, time restrictions, and legal considerations (e.g., accessibility requirements like ADA compliance or data protection laws). Additionally, this phase helps identify the interests and concerns of the end users. Methods of investigation include collecting data through surveys, conducting user testing, interviewing potential users, and making direct observations. This phase sets a solid foundation for the development process by ensuring that the developers have a clear understanding of what needs to be achieved. Proper investigation helps anticipate potential challenges and address user needs more effectively.

Reflection

Reflection is an integral part of the development process, allowing developers to evaluate their progress, identify what works well, and recognize areas for improvement. Reflecting on feedback and testing results enables developers to make informed decisions about necessary changes and enhancements, thus ensuring the program evolves to meet user needs effectively. Regular reflection sessions, typically held periodically or after completing a milestone, help the team stay aligned with project goals and adapt to new insights or challenges during development.

Design

Program requirements describe how a program functions and may include a detailed description of user interactions. A program's specification defines these requirements, providing a clear blueprint for development. During the **design** phase, developers outline how to accomplish the program specification. This phase may involve:

- Developing a thorough testing strategy for the program
- Organizing the program into modules and functional components
- Creating diagrams representing the user interface layouts
- Conducting brainstorming sessions

The design phase translates user needs and technical requirements into a structured plan, ensuring that all aspects of the program are well thought out before implementation begins.

Prototyping

Prototyping involves creating an early, simplified version of a program to explore the design and core functionality. This process can focus on both user interface (UI) and user experience (UX), which serve distinct purposes. UI refers to the visual design and layout of the program, such as buttons, menus, and color schemes, while UX focuses on the overall experience of using the program, including ease of navigation and user satisfaction. Prototyping helps gather feedback on how users interact with the system and allows developers to test essential features to ensure they work as intended. Prototyping allows for early detection of usability issues and technical challenges, making it possible to improve the product based on user feedback iteratively. By doing this, developers can refine key aspects of the program before committing to full-scale development, ensuring that the final product aligns with user needs while also reducing time and costs. To further enhance accessibility and minimize bias, it is important to test prototypes with a diverse group of users, including individuals with different backgrounds, abilities, and levels of technical expertise. This approach helps identify potential barriers and ensures that the program is more inclusive and usable for a wider audience.

Testing

During the development process, **testing** involves using specific inputs to verify that a program generates the expected results. Programmers use the outcomes from these tests to refine their programs. Test cases should cover a range of expected scenarios, particularly those at or beyond the input data's minimum and maximum limits. Identifying suitable testing inputs requires precise program requirements. Practical techniques for detecting and fixing errors include test cases, which involve running the program with predefined inputs and comparing the results to expected outputs; hand tracing, where developers manually follow the program's execution step by step to track variable changes and logic flow; and visualizations, such as flowcharts or graphical debugging tools, which help illustrate how data moves through the program. Additionally, developers can use debuggers, software tools that allow them to pause execution, inspect variable values, and identify issues in real-time, or add extra output statements, which print key values or messages at specific points in the code to monitor execution and diagnose errors. Rigorous testing ensures the program functions correctly under various conditions and meets its specifications, reducing the risk of errors in the final product.

When testing a system or application, various types of errors can occur, each affecting functionality and user experience.

Types of errors

- **Logic Error:** An error leading to incorrect or unexpected behavior. Logic errors can be particularly challenging to identify because the program runs without crashing but produces erroneous results.

Example

Calculating the average of three test scores but dividing them by 2 instead of 3:

```
score1 = 84
score2 = 91
score3 = 87
average = (score1 + score2 + score3) / 2
# Logic error: should divide by 3
DISPLAY(average)
```

- **Syntax Error:** A programming mistake that violates the language's syntax rules. These errors prevent the program from running and are typically easier to fix because the programming environment usually highlights them.

Example

Missing a parenthesis in a function call:

```
PROCEDURE calculate_area(length, width:
# Syntax error: missing closing parenthesis
    DISPLAY(length * width)
```

- **Run-time Error:** An error that arises while the program is running, which may cause it to crash or yield unintended results. Programming languages define their own run-time errors, and handling these errors often involves debugging and refining the code.

Example

Dividing by zero in a program:

```
number = 10
divisor = 0
DISPLAY(number / divisor)
# Run-time error: division by zero
```

- **Overflow Error:** An error that occurs when a computer processes a number outside its allowable range of values. This can lead to unexpected behavior or crashes, especially in programs dealing with large numerical computations.

Example

Calculating the factorial of a large number in a language with fixed-precision integers:

```
PROCEDURE compute_factorial(n):  
    result = 1  
    FOR i IN RANGE(2, n + 1):  
        result = result * i  
    RETURN(result)  
  
DISPLAY(compute_factorial(1000))  
# Overflow error: result is too large to handle
```

Documentation

Program **documentation** involves creating a written record that explains the purpose, functionality, and development process of a code segment, event, procedure, or entire program. Comments, a specific type of documentation embedded within the code, enhance readability without altering the program's execution. Programmers must document their work consistently throughout development to facilitate understanding, maintenance, and collaboration. Documentation serves as a crucial reference for future maintenance and updates, ensuring that any developer working on the program can easily understand its structure and functionality. Not all programming environments support comments, making other documentation methods, such as external documentation files, even more important.

Best practice

When designing a program, you will benefit from considering how you want your program to behave based on different inputs. Identifying key inputs—such as user actions, data from sensors, or other external factors—will guide how you structure your program's logic and behavior. Planning ahead may help you determine what abstractions can be developed and can help identify logic errors early in development.

By thoroughly understanding and implementing these phases, developers can create user-centric programs that effectively meet their users' needs and expectations. This structured approach to development not only enhances the quality of the final product but also fosters a collaborative and innovative environment that is essential for successful software development.

Best practice

Documenting smaller code segments as you work on them is easier than trying to describe larger segments or entire programs all at once.

More about...

Recognizing the developers of code segments worked collaboratively or sourced from others is essential. This can be done in the program documentation by including the origin or original authors, ensuring proper credit and transparency. Acknowledging external contributions respects intellectual property and maintains the integrity of the development process.

Activities

1. What are the phases of the development process?
2. Describe the difference between Iterative and Incremental development.
3. Split into teams and discuss how the phases of the development process (investigation, reflection, design, prototyping, testing, and documentation) would be applied in creating an app tailored to the needs of older adults.
4. Describe how documentation is an essential phase of the development process?
5. What type of error is present in the following code? How can you fix it?

```
subtotal = 50
tax = 0.10 # 10%
tip = 0.15 # 15%

total = subtotal + tax + tip # final cost
DISPLAY("Total cost: ")
DISPLAY(total)
```

Key Takeaways

- The development process can follow structured methodologies or be more exploratory and adapt as the project evolves.
- Developers may choose between iterative development, which focuses on continuous improvement through feedback cycles, and incremental development, where components are built and integrated gradually.
- The development process involves phases like investigation, design, and testing, to ensure the final product meets user needs.
- Effective testing and debugging are crucial for identifying and fixing logic, syntax, run-time, and overflow errors, ensuring that programs function correctly and remain stable under various conditions.

Key Terms

development process

A structured sequence of steps to design, build, and deliver a product.

ordered and intentional development

Developers follow a structured methodology with predefined phases and objectives.

exploratory development

Developers adapt flexibly to evolving requirements, prioritizing experimentation.

iterative development

A process that revisits and refines earlier stages based on feedback.

incremental development

Building the program in small, functional components.

investigation

Research phase to gather requirements and understand user needs.

reflection

Phase to evaluate progress and identify improvements.

prototyping

Creating an early, simplified versions of the program to explore ideas.

testing

Verifying the program works as intended through various test cases.

documentation

Written record of the program's purpose, functionality, and structure.

logic error

An error in the program's algorithm leading to incorrect behavior.

syntax error

A violation of the programming language's syntax rules.

run-time error

An error that occurs while the program is running.

overflow error

An error that occurs when a computer processes a number that is outside of its permitted range.

Exam Questions

1. Which of the following describes a computing innovation?
 - (A) A machine that operates manually
 - (B) A new or improved creation involving a program as an essential part
 - (C) A software that operates only on mobile devices
 - (D) An improvement in mechanical engineering
2. Which of the following is an example of physical computing innovation?
 - (A) Word processor software
 - (B) Virtual reality
 - (C) Smart home devices
 - (D) Cloud storage
3. Computing innovations contribute to solving real-world problems by:
 - (A) increasing manual labor.
 - (B) improving efficiency and accessibility.
 - (C) limiting collaboration.
 - (D) making processes more complicated.
4. Collaboration is crucial in developing computing innovations because it:
 - (A) provides input from diverse perspectives.
 - (B) ensures faster coding.
 - (C) limits the number of developers.
 - (D) replaces the need for testing.

5. What is the primary role of program inputs?

- (A) To produce data outputs.
- (B) To receive and process data.
- (C) To ensure syntax is correct.
- (D) To debug the program.

6. Which of the following is NOT an example of program input?

- (A) Clicking a mouse.
- (B) Speaking into a microphone.
- (C) Scanning a QR code.
- (D) Printing a document.

7. Which phase in the development process focuses on user requirements?

- (A) Prototyping
- (B) Testing
- (C) Investigation
- (D) Documentation

8. What is the primary goal of prototyping in development?

- (A) To finalize the program and launch the product.
- (B) To test usability and gather feedback.
- (C) To review program comments and write the documentation.
- (D) To troubleshoot the program and debug the code.

9. What type of error occurs when dividing by zero in a program?

- (A) Runtime error
- (B) Syntax error
- (C) Logic error
- (D) Overflow error

10. Which error is caused by incorrect syntax rules in a program?

- (A) Logic error
- (B) Runtime error
- (C) Syntax error
- (D) Overflow error

11. What is an example of program output?

- (A) Generating a weather report.
- (B) Tapping on a touchscreen.
- (C) Entering data into a form.
- (D) Clicking a button.

12. What is a benefit of iterative development?

- (A) Avoids user feedback.
- (B) Focuses on continuous refinement and improvement.
- (C) Eliminates the need for documentation.
- (D) Guarantees a faster completion time.

13. What role can reflection play in the development process?

- (A) Debugging the code.
- (B) Evaluating progress and identifying improvements.
- (C) Designing the user interface.
- (D) Gathering initial user requirements.

14. Which describes a logic error in a program?

- (A) Incorrect syntax.
- (B) A calculation that yields incorrect results.
- (C) Dividing a large number beyond capacity.
- (D) Missing a closing bracket.

15. Which statement provides the purpose of program documentation?

- (A) To remove errors in the program.
- (B) To incorporate changes based on user feedback during testing.
- (C) To speed up program execution.
- (D) To explain the program's functionality and purpose.

16. Which statement describes the critical role of user feedback critical during the testing phase?

- (A) It ensures the program aligns with user needs.
- (B) It speeds up the coding process.
- (C) It eliminates the need for documentation.
- (D) It guarantees no errors in the code.

UNIT 2

[Big Idea 2]

Data

For Review Purposes Only

LESSONS

2.1 Representation of Data

2.2 Data Processing and Insights

AP Enduring Understanding

DAT-1 The way a computer represents data internally is different from the way the data are interpreted and displayed for the user. Programs are used to translate data into a representation more easily understood by people.

DAT-2 Programs can be used to process data, which allows users to discover information and create new knowledge.

This unit explains how computers handle and process data. It starts by showing how data is represented in binary, the language of computers, and how it differs from analog data. It also teaches how to convert between binary and decimal numbers. The lessons highlight the benefits of digital data for accuracy and storage.

It explores how data is processed using simplifications, or abstractions, to make complex tasks easier. Data compression is explained, with examples of lossless (no data lost) and lossy (some data lost) methods, showing where each is useful. The unit also discusses how errors can happen when storing numbers and how metadata helps organize and manage information.

Finally, this unit covers ways to process data, like filtering, combining, and visualizing it, to turn raw information into useful insights. This helps explain how computers make sense of large amounts of data to solve problems and discover patterns.

LESSON 1

Representation of Data

AP Learning Objectives

DAT-1.A Explain how data can be represented using bits.

DAT-1.B Explain the consequences of using bits to represent data.

DAT-1.C Calculate the binary (base 2) equivalent of a positive integer (base 10) and vice versa, and compare and order binary numbers.

Introduction to Data

Data is all around us, generated by nearly every action we take. Although we interact with data in a way that's easy to understand, such as reading text on a screen or listening to music, computers handle data very differently. Computers, internally, represent data in a digital form, using a different system from the language we humans use, the binary number system.

At the core of this digital representation are **bits**, or **binary digits**. Bits are represented using either 0 or 1 and are the smallest units of data, forming the foundation for all digital information. Eight bits together make up a **byte**, and bytes are used to represent more complex values, like numbers, letters, or even entire images. Every piece of data, from a single letter to the pixels in a video, is ultimately broken down into 0s and 1s.

Since computers store and process data differently, programs play a crucial role in translating raw binary data into representations that people can understand, like text, images, or sounds. These programs take input, process the data, and provide output in forms that are meaningful to us.

More about...

Data values are stored in various ways inside programs. They can be held in variables, lists of items, or standalone constants. These data structures can be passed between different parts of a program as inputs to procedures or as outputs.

Analog and Digital Data

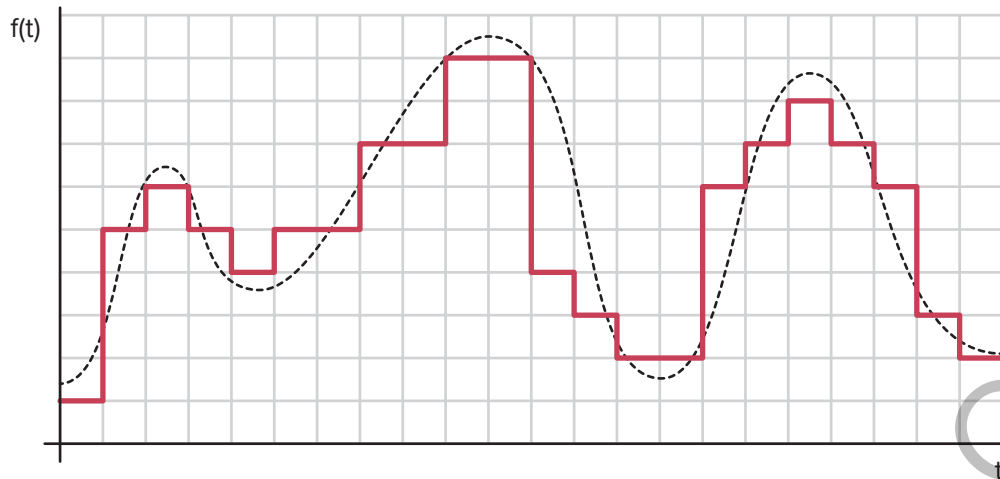
Data can be classified as either analog or digital. **Analog data** represents information as a continuous flow, with values that change smoothly over time. There are no breaks or steps in analog data, which means there is an infinite range of possible values. Examples of analog data include the pitch and volume of music and the temperature changes throughout the day. These values shift naturally, capturing the fine details of real-world phenomena. However, computers, which rely on binary systems, cannot easily process analog data in its raw form.

Digital data, unlike analog, is represented in discrete intervals. It breaks information into bits, allowing computers to store and process it. This shift from continuous to discrete simplifies data handling for computers, but the continuous nature of analog data is lost in translation.

analog clock vs. digital clock



To convert analog data into digital form, the process of **sampling** is used. It involves taking measurements of the analog signal at regular intervals (called samples) and assigning them values that can be stored as digital data. The more frequently these samples are taken, the closer the digital version will resemble the original analog signal. For instance, when recording live music, the sound wave is captured at regular points, allowing the music to be stored and played back in digital formats. However, no matter how high the sampling rate is, some detail from the original analog signal will always be lost due to the transition from a continuous to a discrete form.



The Binary System

Different number bases are used to represent data, the most common being binary and decimal. While we are familiar with the **decimal system** (base 10) that uses digits 0 through 9 to represent numbers, computers rely on the **binary system** (base 2), which uses only two digits: 0 and 1. This system might seem simplistic at first glance, but it forms the backbone of all digital computing.

Binary operates similarly to decimal, but instead of each position representing a power of 10, each position in a binary number represents a power of 2. Just like in decimal, the values of digits are determined by their position.

Consider how we interpret decimal numbers. For example, in the number 834, the rightmost digit (4) represents 4 ones (10^0), the next digit (3) represents 3 tens (10^1), and the leftmost digit (8) represents 8 hundreds (10^2), or:

$$\begin{aligned} &8 \times 10^2 + 3 \times 10^1 + 4 \times 10^0 \\ &= 8 \times 100 + 3 \times 10 + 4 \times 1 \\ &= 800 + 30 + 4 \\ &= 834 \end{aligned}$$

The same logic applies in binary, but we multiply by powers of 2 instead of multiplying by powers of 10. For instance, in the binary number 1011, the rightmost bit (1) represents 1 one (2^0), the next bit (1) represents 1 two (2^1), the third bit (0) represents 0 fours (2^2), and the leftmost bit (1) represents 1 eight (2^3). Added together, this gives us the decimal value of 11:

$$\begin{aligned}
 &1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 \\
 &= 1 \times 8 + 0 \times 4 + 1 \times 2 + 1 \times 1 \\
 &= 8 + 2 + 1 \\
 &= 11
 \end{aligned}$$

The value of each position in binary increases exponentially as you move from right to left, starting at 2^0 for the rightmost bit. Each successive bit is a power of 2 greater than the one before it. The place value for each bit is calculated as 2 raised to the power of the bit's position, with positions starting at 0 from the right.

Example 1: Binary to Decimal Conversion

Let's **convert** the binary number 11010010 to decimal:

First, working from right to left, or starting with the 2^0 place, match each bit to its corresponding power of 2:

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	0	1	0	0	1	0

Next, multiply each bit by its corresponding power of 2:

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	0	1	0	0	1	0
128	64	0	16	0	0	2	0

$$128 + 64 + 16 + 2 = 210$$

Thus, the binary number 11010010 represents 210 in decimal.

Example 2: Decimal to Binary Conversion

Let's **convert** the decimal number 179 to its binary sequence representation..

First, we find the largest power of 2, smaller than or equal to 179. The largest power of 2 that fits is 128 (2^7). We subtract 128 from 179 and note the position of the power, which is 7:

$$179 - 128 = 51 \quad (\text{position } 7)$$

Next, we continue the process by finding the largest power of 2 that fits into the remaining value, 51, which is 32 (2^5):

$$51 - 32 = 19 \quad (\text{position } 5)$$

Then, the largest power of 2 that fits into 19 is 16 (2^4):

$$19 - 16 = 3 \quad (\text{position } 4)$$

For 3, the largest power of 2 that fits is 2 (2^1):

$$3 - 2 = 1 \quad (\text{position } 1)$$

Finally, we subtract 1 (2^0) from 1:

$$1 - 1 = 0 \quad (\text{position } 0)$$

Best practice

When converting binary to decimal, or vice versa, write down the powers of 2 for each position to avoid mistakes.

Now, we form the binary sequence by placing a 1 in the positions we subtracted from and a 0 in the others:

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	0	1	0	0	1	0

Thus, the decimal number 179 equals 11010010 in binary.

You might wonder why computers use binary rather than the more familiar decimal system. The reason lies in the physical nature of computing devices. Binary works perfectly with the two-state electrical systems that computers are built on. In binary, 1 can represent an "on" state (presence of electrical charge), and 0 can represent an "off" state (absence of electrical charge). This simplicity allows faster and more reliable data processing, making binary the most efficient way for computers to operate.

Activities

1. Describe what is represented by each binary digit.
2. How does binary representation of data enable computers to process and store different types of information like text, images, and sounds?
3. List three examples of analog data and three examples of digital data in daily life.
4. Explain how sampling impacts the quality of a digital representation of an analog signal (e.g., in music or video).
5. Why is the binary system more suitable for computers compared to the decimal system?
6. Convert the following binary sequences to decimal:
 - a. 101101
 - b. 1100100
 - c. 1111111
7. Convert the following decimal numbers to binary sequences:
 - a. 29
 - b. 123
 - c. 255

Key Takeaways

- Data is represented digitally in computers using the binary number system, which allows computers to process and store information efficiently.
- Analog data, which represents continuous information, differs from digital data, which is stored in discrete bits.
- The binary system operates with base 2, where each position represents a power of 2, forming the foundation of digital computing.

Key Terms

binary digit (bit)

The smallest unit of data in a computer, representing either 0 or 1.

byte

A group of 8 bits, commonly used to represent larger units of data.

analog data

Continuous data with values that change smoothly over time (e.g., sound, temperature).

digital data

Data represented in discrete intervals, typically in binary form.

sampling

The process of converting analog signals to digital by measuring at regular intervals.

binary system (base 2)

A numeral system using only two digits, 0 and 1.

decimal system (base 10)

A numeral system using ten digits, 0 through 9.

data conversion

The process of translating numbers between different bases.

LESSON 2

Data Processing and Insights

AP Learning Objectives

DAT-1.D Compare data compression algorithms to determine which is best in a particular context.

DAT-2.A Describe what information can be extracted from data.

DAT-2.B Describe what information can be extracted from metadata.

DAT-2.C Identify the challenges associated with processing data.

DAT-2.D Extract information from data using a program.

DAT-2.E Explain how programs can be used to gain insight and knowledge from data.

Data Abstraction

Abstraction allow us to manage intricate information by concentrating on the important aspects and de-emphasizing the complex elements. In computing, bits are the basis for data abstraction, which, when grouped, can represent different forms of data, such as numbers, letters, or even colors.

Definition

Data abstraction is the process of simplifying complexity by concentrating on the core idea while hiding details that are not relevant to the current focus.

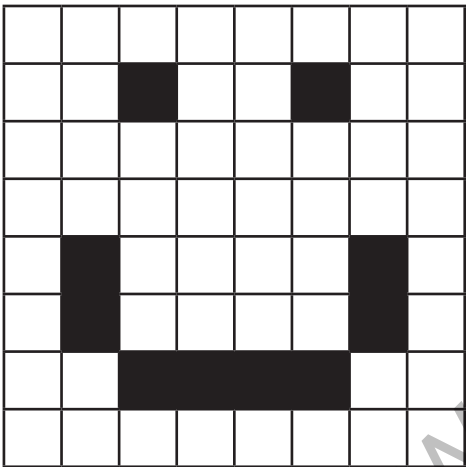
By using data abstraction, we can simplify how we understand and process data and make it possible to build more complex systems without getting overwhelmed by the underlying binary structure. For example, we can work with text instead of individual

bits when we treat a sequence of bits as a character. This makes programming and data manipulation significantly more accessible and more efficient. This approach allows us to focus on solving higher-level problems while the computer handles the low-level details, improving productivity and clarity in software development and data analysis.

More about...

The same sequence of bits may represent different types of data in different contexts, depending on how the program is designed to interpret them, such as numbers, characters, or even instructions for operations.

Picture



Bitmap

☐ =0 ☒ =1

0	0	0	0	0	0	0	0
0	0	1	0	0	1	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	0
0	1	0	0	0	0	1	0
0	0	1	1	1	1	0	0
0	0	0	0	0	0	0	0

Errors in Data Representation

In many programming languages, integers are represented by a fixed number of bits, limiting the range of values that can be stored. An **overflow error** occurs when a calculation produces a value outside this range, causing the number to reset to the smallest possible value. Some languages avoid this by allowing integer sizes to be limited only by the available memory, providing greater flexibility for handling large numbers.

For real numbers, bit limitations lead to **round-off errors**. Since real numbers are often stored in floating-point format with a fixed number of bits, certain values cannot be stored precisely. For example, one-third, or $1/3$, has an infinite decimal and must be approximated in binary. This approximation can cause minor inaccuracies to accumulate in calculations, affecting results.

These limitations in number representation—whether overflow for integers or round-off for real numbers—are important for programmers to consider, especially when working on applications requiring high precision.

More about...

In industries like finance, errors such as overflow can lead to catastrophic outcomes. Proper error handling and awareness of number limits are critical to preventing serious malfunctions.

Data Compression

Data compression plays a critical role in modern computing, allowing us to store and transmit data more efficiently. By reducing the amount of data that needs to be processed, we can save storage space and improve the speed of data transfer.

Definition

Data compression reduces the size (or number of bits) required to store or transmit data by removing redundancy or representing the data more efficiently.

Compression does not always mean losing information; in some cases, the reduction in data size retains all the original content. How effective compression is depends on the amount of redundancy in the data and the algorithm used to compress it.

Lossless vs. Lossy Data Compression

There are two main approaches to data compression: lossless and lossy, each suited to different needs. **Lossless compression** reduces the number of bits used to store or transmit data while ensuring that the original data can be perfectly reconstructed. It is widely used in cases where data integrity is essential, such as with text files, executable programs, and high-precision scientific data. Algorithms like ZIP, FLAC (for audio), and PNG (for images) are examples of lossless compression techniques. These algorithms work by identifying and eliminating redundancy, such as repeating patterns, but without any loss of the original information.

Lossy compression, on the other hand, achieves a much greater reduction in data size by discarding some of the original data. The result approximates the original, where minor details may be lost, but the overall quality remains acceptable for most users. This approach is most used for multimedia files like images, video, and audio, where slight differences from the original are often imperceptible. The JPEG (for images), MP3 (for audio), and MPEG (for video) formats are well-known examples of lossy compression. These algorithms allow for dramatic reductions in file sizes, enabling faster downloads and more efficient storage.

Best practice

Choose lossless compression when accuracy is critical and lossy compression when file size or speed is more important, such as in multimedia.

The choice between lossless and lossy compression relies on the specific needs of the task at hand. Lossless compression is preferred when accuracy and precision are crucial, such as in legal documents, medical imaging, or archival of important files where even small data losses could be problematic. Lossy compression is ideal when file size and transmission speed take priority over perfect fidelity, as in streaming music, sharing videos, or storing large image collections where small quality losses are acceptable for efficiency.



Processing the Data

The ability to process data effectively depends not only on the tools used but also on the skills and expertise of the users. One common challenge is the need to clean data, as raw data sets often contain errors, missing values, or inconsistencies. A data set from a survey might include variations in how respondents input information—such as "NY" versus "New York" for a location, which, if left unprocessed, the computer will interpret as different locations. **Data cleaning** involves making the entries uniform without changing their meaning, which can involve standardizing abbreviations, correcting misspellings, or filling in missing values. This step is critical for ensuring accurate analysis.

Definition

Scalability is the ability of a system or process to handle increased workload or demand by adding resources without sacrificing performance or efficiency.

Large data sets, particularly those involving millions or billions of data points, pose additional challenges. They often require powerful computing resources and parallel systems to process efficiently. **Scalability** is important in these situations, as it determines how well a system can handle increasing amounts of data over time. Scalable systems can expand their capacity to accommodate growth while maintaining the same level of service. Without scalable solutions, processing enormous data sets would be slow and inefficient.

More about...

Companies like Google and Amazon, which handle massive volumes of data daily, rely on distributed computing systems to manage these tasks.

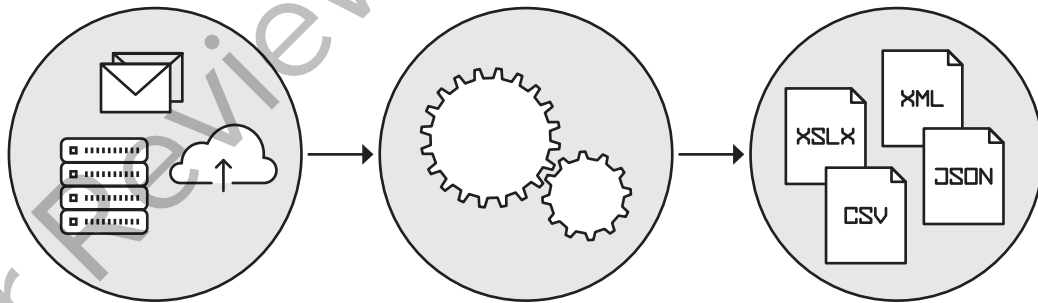
Extracting Information from Data

Programs are essential tools for processing data, enabling users to extract meaningful information and generate new knowledge. Information is created by identifying patterns and facts within data, transforming raw numbers into usable insights. This process opens doors to recognizing trends, establishing connections, and solving complex problems. For instance, digitally processed data may reveal correlations between variables, such as a link between temperature changes and energy consumption.

Definition

Information is a collection of organized data or facts that provide context and meaning, allowing us to understand specific events or situations.

It is crucial, however, to remember that correlation does not equate to causation; a deeper investigation is required to establish whether a causal relationship exists. In some cases, a single source of data might not provide sufficient information to draw accurate conclusions. Combining data from multiple sources offers a more comprehensive view and leads to stronger insight.



Metadata

Metadata, or "data about data," serves as the underlying structure that helps manage and organize information. Images, for example, may have metadata details like the date it was created, the device used to capture it, and the file size. While changes made to metadata does not affect the primary data, it can enhance how the data is cataloged and accessed.

Metadata plays a critical role in improving the usability of data, especially when dealing with large or complex data sets. For music files, for example, metadata can include song's title, artists, album name, or genre, allowing users to sort and filter their music collections easily. In more technical fields, such as scientific research, metadata ensures that experiments are documented properly, providing additional context like methods used, location, or instruments involved. The added layer of information provided by metadata helps make the data more accessible and meaningful for future analysis.

More about...

In cloud storage services, metadata helps organize files by automatically tagging them with creation date, file type, or location, making it easier for users to search and retrieve documents.

Using Programs with Data

Programs are invaluable when it comes to processing data and transforming it into usable information. Tools like spreadsheets or specialized data analysis software enable users to visualize data through graphs, charts, and diagrams, making it easier to extract insights. For example, a marketing team might use a program to analyze customer data, identifying which demographics are most likely to purchase a product. This analysis can lead to more targeted advertising and increased sales.

Definition

Knowledge is the result of interpreting and applying information, where understanding is gained through experience, study, or analysis.

Definition

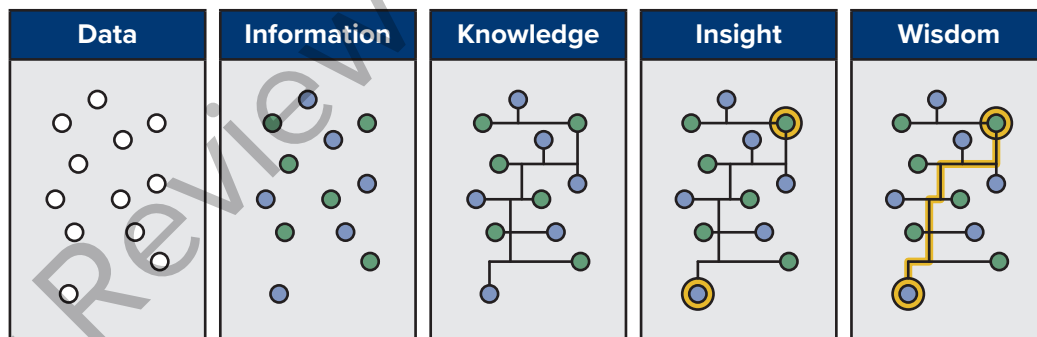
Insight is a deeper comprehension that emerges from analyzing knowledge, often revealing hidden patterns or providing new ways of thinking about complex issues.

Data filtering systems help narrow down large data sets by removing irrelevant or extraneous information, allowing users to focus on the most meaningful data. A company might filter a data set of customer transactions to find those over a certain value or during a specific time period. Similarly, search tools streamline the process of locating specific pieces of information, helping users quickly retrieve what they need from vast data collections.

Several methods can be employed to make working with data more efficient:

- **Transforming:** The process of applying a consistent change to every element in a data set. Examples include a company's payroll system that might need to add a bonus to every salary figure or the conversion of a list of prices from one currency to another by multiplying each price by the exchange rate.
- **Filtering:** Filtering isolates only the data points that meet specific criteria. In student databases, you might filter records to only show students who scored above 90% on their exams. This allows for targeted analysis without sifting through unnecessary data.
- **Combining/Comparing:** This technique aggregates or compares data from different sources or fields. An example would be adding up all the purchases made by a customer to find their total spending or comparing sales figures across different regions to identify trends.
- **Visualizing:** Turning data into visual formats such as pie charts, bar graphs, or scatter plots allows users to quickly grasp trends or patterns not immediately apparent from raw numbers. Visual tools are commonly used in business reports, scientific research, and media presentations to communicate findings in an accessible way.

Programs are used interactively to process information, enabling users to gain insights and knowledge from data. A weather forecasting program may cluster and classify data from multiple sources—such as temperature, humidity, and wind patterns—to predict future weather conditions. Programmers often use a combination of techniques, such as filtering, cleaning, clustering, and classifying the data, to extract valuable insights.



The process of gaining insights from data involves more than just processing numbers—it's about discovering hidden patterns or making connections that lead to new ways of understanding complex issues. Translating raw weather data into patterns that indicate the potential for extreme weather that can be used to inform the public. Similarly, a company may use data analytics programs to find patterns in customer behavior that lead to more personalized marketing strategies, improving customer engagement.

As data are transformed, patterns emerge that allow users to make better decisions, solve problems, and gain deeper insights into the world around them.

Activities

1. Identify ways that data abstraction can be used to simplify complex systems, and why is it crucial in data processing?
2. Describe how can errors such as overflow and rounding-off in number representation affect computations in real-world application?
3. Compare and contrast lossless and lossy compression, including examples of when each type is typically used.
4. Explain the concept of scalability in the context of data processing and provide an example of a scenario where scalability is critical.
5. Describe how can metadata assist in organizing and extracting insights from large data sets? Use a practical example to illustrate its importance.

Key Takeaways

- Data compression, whether lossless or lossy, reduces file size for easier storage and faster transmission.
- Common errors, such as overflow and round-off, occur due to limitations in number representation, affecting the accuracy of results.
- Programs play a key role in processing data, enabling the extraction of useful information, the recognition of patterns, and the generation of insights.
- Techniques like filtering, transforming, and visualizing data are essential for making sense of large data sets.
- Scalability is crucial when handling large volumes of data, ensuring that systems can maintain performance as data demands increase.

Key Terms

abstraction

The process of simplifying complexity by focusing on the main idea and removing irrelevant details.

overflow error

Error occurring when a value exceeds the maximum limit a system can handle.

round-off error

Error occurring when a value cannot be stored precisely.

lossless compression

A type of data compression that retains all original data after decompression.

lossy compression

Compression that reduces file size by discarding less important data.

data cleaning

The process of identifying and correcting errors in data to ensure its quality.

scalability

The ability of a system to handle increased workloads efficiently.

metadata

Data about data, used for organizing and managing information.

Exam Questions

1. What is the fundamental unit of data in a computer?
 - (A) Bit
 - (B) Byte
 - (C) Digit
 - (D) Pixel
2. Identify the lowest level used to represent digital data internally?
 - (A) Decimal System
 - (B) Hexadecimal System
 - (C) Binary System
 - (D) ASCII Code
3. Which type of data is represented as a continuous flow with infinite possible values?
 - (A) Digital Data
 - (B) Binary Data
 - (C) Compressed Data
 - (D) Analog Data
4. What is the process of simplifying complexity by focusing on essential details called?
 - (A) Metadata
 - (B) Data compression
 - (C) Data abstraction
 - (D) Scalability

5. Which of the following statements about digital data is true?

- (A) Digital data is continuous and infinitely precise.
- (B) Digital data is stored as discrete values.
- (C) Digital data is better for representing real-world phenomena than analog data.
- (D) Digital data cannot be converted from analog data.

6. Which of the following provides the main advantage of using binary data representation in computers?

- (A) It allows for more accurate number representation.
- (B) It makes programming easier.
- (C) It is compatible with the two-state electrical systems in computers.
- (D) It is closer to human language.

7. Which process is used to convert analog data into digital data?

- (A) Compression
- (B) Sampling
- (C) Filtering
- (D) Scaling

8. What is the binary sequence used to represent the decimal number 11?

- (A) 1010
- (B) 1101
- (C) 1011
- (D) 1001

9. Which type of error is the result experienced when a number exceeds the fixed range allowed by the system?
- (A) Round-off
 - (B) Overflow
 - (C) Logic
 - (D) Syntax
10. Which compression method reduces file size without losing any original data?
- (A) Lossy Compression
 - (B) Lossless Compression
 - (C) Bit Reduction
 - (D) Sampling
11. Identify the file type that provides lossless compression?
- (A) JPEG
 - (B) MP3
 - (C) MPEG
 - (D) PNG
12. Programmers use abstraction in computing:
- (A) To make data storage more complex.
 - (B) To make programming and data manipulation easier.
 - (C) To ensure data is cleaned before using.
 - (D) To remove redundancy from data.

13. Which of the following is a key difference between lossless and lossy compression?

- (A) Lossy compression results in no data loss, while lossless does.
- (B) Lossy compression removes some data permanently, while lossless retains all data.
- (C) Lossless compression is only used for images.
- (D) Lossy compression is faster than lossless compression.

14. Identify a primary benefit gained from the use of metadata.

- (A) Storing data in a compressed form
- (B) Providing additional context and details about data
- (C) Converting analog data into digital format
- (D) Identifying errors in number representation

15. Select the correct binary representation for the decimal number 179.

- (A) 10110011
- (B) 10101111
- (C) 11010011
- (D) 10111011

16. Identify the error that occurs due to the limitation of representing real numbers in binary?

- (A) Overflow Error
- (B) Round-off Error
- (C) Sampling Error
- (D) Bit Shift Error

17. Which of the following techniques is NOT used for data analysis?

- (A) Filtering
- (B) Visualizing
- (C) Coding
- (D) Transforming

18. Which statement describes scalability in computing?

- (A) The ability of a system to increase workload without losing efficiency
- (B) The process of converting analog data into digital form
- (C) The ability to compress large files efficiently
- (D) The study of binary number systems

19. Select the statement that identifies the purpose of visualizing data?

- (A) To reduce storage space
- (B) To help identify patterns and insights easily
- (C) To convert analog signals into digital format
- (D) To reduce processing time

20. Which of the following is NOT an example of how programs process data?

- (A) Searching for patterns
- (B) Recognizing trends
- (C) Filtering out unnecessary data
- (D) Randomly modifying values