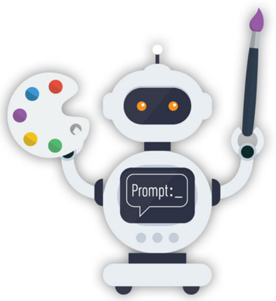


Preface

"Today, we're at the cusp of a major shift in computing. The intersection of AI and accelerated computing is set to redefine the future."—Jensen Huang, NVIDIA CEO[1]

Welcome to ***Java How to Program: An Objects-Natural Approach, Twelfth Edition***. In this Preface, we present the "soul of the book." This edition's key theme is **leverage**. You'll learn Java programming faster, broader and more deeply with a trio of the latest complementary pedagogic methodologies. You'll do more powerful things than with previous learning approaches and be better prepared to meet the programming and software development challenges you'll face in upper-level courses and your professional career:

- **Powerful: We use code to teach code.** You'll learn with our traditional **live-code approach**. Along with a thorough study of Java fundamentals and algorithm development, you'll **leverage your learning experience**, mastering Java's basics by immersing yourself in hundreds of complete working code examples with meaningful outputs.
- **More powerful: We use objects to teach objects.** New in this edition, you'll use our **objects-natural approach** to learn Java object-oriented programming. Even as a novice programmer, you'll **leverage your ability to write more significant programs** by using richly functional, preexisting classes from Java's extensive libraries and other open-source libraries on repository sites like `github.com`.
- **Most powerful: We use generative AI to teach generative AI.** Also new in this edition, you'll master **genAI**—the key set of artificial-intelligence technologies that **leverage your creative capabilities.** In the examples and exercises, you'll use prompts and build programs that produce original text, Java code, images, audio, speech, music and even video!

A Personal Anecdote from Co-Author Harvey Deitel

In the 1970s, a friend suggested I teach an intro-to-computing course at a local college. In the segment on the hierarchy of programming-language types from **low-level machine languages** to **intermediate-level assembly languages** to **high-level languages**, I explained that programming becomes more productive as you move up this hierarchy. You get further from the raw computer-hardware details and closer to the application domain, where you think in terms of the real-world problems you're trying to solve. Individual statements in these languages become more powerful up the hierarchy, **leveraging your ability to solve more challenging problems faster while producing better-engineered solutions.**

1. Jensen Huang, NVIDIA COMPUTEX 2024 Keynote, June 2, 2024. Accessed March 2, 2025. `https://www.youtube.com/watch?v=pKXDVsWZmUU`.

The students were curious, asking where all this was headed. I said, "It seems reasonable to predict that even higher-level programming technologies will appear, which will help people solve ever more challenging real-world problems faster and better. As the programming statements you write become more powerful, someday you'll be programming so close to the application domain that you'll **tell the computer *what* you need rather than providing the increasingly complex details of *how* to build it—and the computer will produce the software for you!**"

That was in the 1970s. Then, in the 1980s and 1990s, object-oriented programming—Java's key programming model—exploded onto the scene. Objects come from "blueprints" called classes. Almost any noun or concept can be represented by a class. There are, of course, vast numbers of those in the real world. Programmers began building extensive class libraries, **further leveraging the software-development process**. When the early versions of Java appeared in the mid-1990s, notably, they were free and accompanied by hundreds of powerful pre-built classes, making it easier for programmers to quickly build significant applications in key domains like graphics, GUI, concurrency, Internet networking, data structures, database and much more. Many of these classes had hundreds or thousands of lines of code, but to create an object of a class, a novice programmer typically had to write only one straightforward line of code, then use a few brief statements to make that object "strut its stuff." This represented a **very-high-level programming capability** even closer to the problem domain.

All the while, the field of AI was evolving quickly from its roots in the 1950s. However, it wasn't until Google's 2017 research paper "Attention is All You Need"[2] defined the transformer model that the current AI boom took off. This is the root of today's large language models, which power the genAI chatbots and tools you'll use throughout this book.

In November 2022, OpenAI released ChatGPT, reaching a million users in five days and 100 million in two months. **No other application had ever become so widely used that quickly while profoundly enhancing users' productivity and leveraging their ability to make computers do really interesting and powerful things**.

We have integrated genAI throughout this book. Most importantly for Java programming students, genAIs remarkably can write, document, explain, debug, correct, critique, tune and enhance the performance of Java code. GenAIs are not perfect—they make mistakes and sometimes "hallucinate"—so you must monitor them carefully. We'll demonstrate these coding capabilities in the approximately 600 genAI exercises and examples throughout the book. GenAI has created an **ultra-high-level programming capability** that will **leverage your Java learning experience and ability to produce robust, top-quality Java software quickly, conveniently and economically**.

An Extraordinary Range of Real-World Java Applications

In this book, we provide a friendly, contemporary, code-intensive, case-study-oriented introduction to Java, one of the world's most popular programming languages.[3,4] Java is

2. Ashish Vaswani et al., "Attention Is All You Need." arXiv preprint, arXiv:1706.03762, 2017. Accessed January 31, 2025. `https://arxiv.org/abs/1706.03762`.
3. PYPL PopularitY of Programming Language Index for January 2025. Accessed January 18, 2025. `https://pypl.github.io/PYPL.html`.
4. Tiobe Index for January 2025. Accessed January 18, 2025. `https://www.tiobe.com/tiobe-index/`.

popular for a wide range of applications because it's platform-independent, robust and has extensive standard and third-party class library support. It's used to build software for everything from the smallest Internet of Things (IoT) devices (like sensors connected to the Internet worldwide) to the largest cloud-based enterprise computing platforms. Some interesting uses of Java include:[5]

- Minecraft (one of the all-time most popular video games),[6]
- financial trading platforms (e.g., the LSEG Real-Time SDK[7])
- Federal Aviation Administration (FAA) APIs for flight and airport information,[8]
- Android mobile app development[9]—Android is the leading mobile device operating system, with a 73.5% market share worldwide,[10]
- NASA Mars rover software[11] and
- tools for analyzing genetic DNA and RNA sequencing data.[12]

Other Java uses listed by the popular genAI chatbots ChatGPT,[13] Gemini,[14] Claude[15] and Perplexity that you'll use (among others) throughout this book[16] include:

- desktop GUI applications (as we do beginning with JavaFX in Chapters 15–17),
- cross-platform 2D and 3D game-development libraries (such as FXGL),
- embedded systems (such as smart cards, Blu-ray players, cable set-top boxes, printers and automotive infotainment systems),
- scientific and educational software,
- web-based applications (such as the Spring and Spring Boot frameworks),

5. *ChatGPT* response to "List interesting things Java has been used for, like the Mars rover." January 15, 2025. `https://chatgpt.com`. We edited the response.
6. "Minecraft," Wikipedia. Last modified January 20, 2025. Accessed January 20, 2025. `https://en.wikipedia.org/wiki/Minecraft`.
7. LSEG Developers. "Real-Time SDK for Java." Accessed January 20, 2025. `https://developers.lseg.com/en/api-catalog/real-time-opnsrc/rt-sdk-java`.
8. Federal Aviation Administration, GitHub Repository. Accessed January 20, 2025, `https://github.com/Federal-Aviation-Administration`.
9. "Welcome to Android Developers." Accessed January 15, 2025. `https://developer.android.com/`.
10. "Mobile Operating System Market Share Worldwide." StatCounter. Accessed January 20, 2025, `https://gs.statcounter.com/os-market-share/mobile/worldwide`.
11. Ross, Philip. "Java Runs Remote-Controlled Mars Rover." CNET. Java 16, 2004. Accessed January 20, 2025. `https://www.cnet.com/tech/tech-industry/java-runs-remote-controlled-mars-rover/`.
12. Broad Institute. "Getting Started with GATK4." GATK Documentation. Updated July 20, 2024. Accessed January 20, 2025. `https://gatk.broadinstitute.org/hc/en-us/articles/360036194592-Getting-started-with-GATK4`.
13. *ChatGPT* response to "Give me 100 words on what kinds of apps Java is popular for." January 16, 2025. `https://chatgpt.com`. We edited the response.
14. *Gemini* response to "Give me 100 words on what kinds of apps Java is popular for." January 16, 2025. `https://gemini.google.com/app`. We edited the response.
15. *Claude* response to "Give me 100 words on what kinds of apps Java is popular for." January 16, 2025. `https://claude.ai`. We edited the response.
16. *Perplexity* response to "Give me 100 words on what kinds of apps Java is popular for." January 16, 2025. `https://perplexity.ai`. We edited the response.

- high-performance server-side software,
- enterprise solutions for banking and finance,
- large-scale distributed systems,
- robotics, and
- big data technologies (like Hadoop that store and process vast amounts of data).

Target Audiences

The book is appropriate for introductory- through intermediate-level academic and professional courses based on the curriculum recommendations of the **ACM** and **IEEE** professional societies[17] and for ***Advanced Placement (AP) Computer Science*** **exam preparation.**[18] It also will help you prepare for most topics covered by the **Oracle Java SE (Standard Edition) Developer Professional certification.**[19]

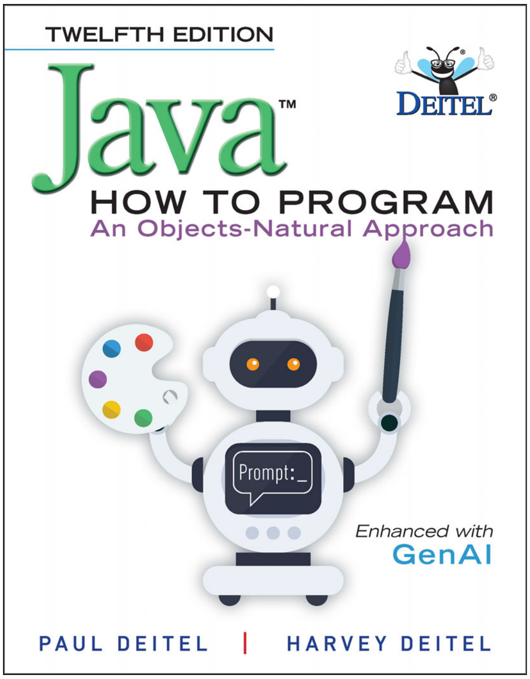
The book's modular architecture (see the "Java How to Program: An Objects-Natural Approach, 12/e: High-Level Overview" on the following two pages) makes it appropriate for several audiences:

- Introductory and intermediate college programming courses in computer science, computer engineering, information systems, information technology, software engineering and related disciplines.
- Science, technology, engineering and math (STEM) college courses with a programming component.
- Professional industry training courses.
- Programmers experienced in other languages who must learn Java for use in upcoming projects.
- Programmers who know some Java and need to learn the latest Java features and idioms to prepare for upcoming projects.
- Professional Java programmers preparing to take the Oracle Java certification exam.[20]

17. ACM/IEEE (Assoc. Comput. Mach./Inst. Electr. Electron. Eng.). 2023. *Computer Science Curricula 2023* (New York: ACM). Accessed January 18, 2025. `https://csed.acm.org/wp-content/uploads/2023/03/Version-Beta-v2.pdf`.
18. "AP Computer Science A." Accessed January 1, 2025. `https://apstudents.collegeboard.org/courses/ap-computer-science-a/assessment`.
19. "Exam: Java SE 21 Developer Professional (1Z0-830)." Accessed January 18, 2025. `https://mylearn.oracle.com/ou/exam/java-se-21-developer-professional-1z0-830/40805/139080/220555`.
20. Jeanne Boyarsky and Scott Selikoff, *OCP Oracle Certified Professional Java SE 21 Developer Study Guide* (New York: Wiley, 2024). [Jeanne Boyarsky was a technical reviewer on *Java How to Program: An Objects-Natural Approach, 12/e.*]

Java How to Program: An Objects-Natural Approach, 12/e

High-Level Overview



Programming Paradigms

Procedural (Chapters 2–7), **object-oriented** (Chapters 8–10), **generic** (Chapters 12 and 13), **functional** (Chapter 14), **concurrent** (Chapter 18) and **genAI-enhanced** (Chapter 19).

Part 1: Introduction

Chapter 1, Intro to Computers, the Internet, Java and Generative AI—Hardware/software concepts. Data hierarchy. Internet and Web. "Cloud." Internet of Things (IoT). Metaverse. Intro to AI/genAI. Test-driving the Java Development Kit (JDK). **27 genAI prompt exercises**.

Chapter 2, Intro to Java Programming—Java fundamentals. Input/output. Primitive types. Arithmetic. Decision making. **Objects-natural (ON) case study: `String` class**. **12 genAI prompt exercises.**

Part 2: Additional Programming Fundamentals

Chapter 3, Algorithm Development and Control Statements: Part 1—Problem-solving/algorithm development. `if`, `if`/`else`, `while` statements. Counter-controlled/sentinel-controlled iteration. Nested control statements. **ON case study: `BigInteger` for supersized integers**. **17 genAI prompt exercises.**

Chapter 4, Control Statements: Part 2—`for`, `do`/`while`, `switch`, `break`, `continue` statements. Logical operators. Structured-programming summary. **ON case study: `BigDecimal` for precise monetary calculations**. **13 genAI prompts.**

Chapter 5, Methods—Custom methods. Random numbers. Simulation. **ON case study: Date/Time API**. Featured exercise: Tortoise-and-hare race simulation. **16 genAI prompt exercises.**

Chapter 6, Arrays and `ArrayList`s—Data structures. Built-in arrays. **ON case study: `ArrayList` for dynamically resizable arrays**. Featured exercises: Knight's Tour and the heuristic programming AI strategy, (optional) Simpletron: Building your own virtual machine. **28 genAI prompt exercises.**

Chapter 7, Strings, NLP and Regex: Generative AI Foundations—`String`, `Character`, `StringBuilder` classes. Intro to natural language processing (NLP). **ON case studies: 1. Regular expressions for pattern matching in text**, **2. Securing data with AES private-key cryptography**. **22 genAI prompt exercises.**

Part 3: Object-Oriented Programming

Chapter 8, Real-World Modeling with Custom Classes—Crafting valuable classes. `Account` class case study. Card-shuffling-and-dealing simulation. `Time` class case study. Controlling class-member access. Constructors. *Set*/*get* methods. Data validation. Throwing exceptions. `static` and `final` class members. `record` classes. Featured exercise: Enhancing the card-shuffling-and-dealing simulation. **33 genAI prompt exercises.**

Chapter 9, Real-World Modeling with Inheritance, Polymorphism & Interfaces—Inheritance hierarchies. Runtime polymorphism. Inheritance *is-a* relationship vs. composition *has-a* relationship. Interfaces. Programming to an interface, not an implementation. Dependency injection. `sealed` classes and interfaces. Featured exercises: Programming-to-an-interface modifications. **31 genAI prompt exercises.**

Chapter 10, Exception Handling: A Deeper Look—`try` statement to catch and handle exceptions. `Throwable` hierarchy. Checked vs. unchecked exceptions. `try`-with-resources statement. **30 genAI prompt exercises.**

Chapter 11, Files, I/O Streams, JSON Serialization & CSV Files—Data persistence. Text vs. binary files. NIO classes. Retrieving file/directory info. `Formatter` class. JSON (JavaScript Object Notation) serialization. Invoke an OpenWeatherMap web service with `java.net.http` features. CSV (comma-separated values) file format. Titanic disaster CSV dataset and basic data analytics. **ON case study: Securing data and protecting user privacy with RSA public-key cryptography**. Featured exercises: Enhancing the OpenWeatherMap web service example, Data analytics with the `diamonds.csv` Dataset. **38 genAI prompt exercises.**

Part 4: Data Structures, Generic Collections, Lambdas and Streams

Chapter 12, Generic Collections—Prepackaged data structures from the Java collections framework. Pre-built generic data structures. Featured exercise: (optional) Building your own compiler that compiles programs to execute on Chapter 7's optional Simpletron virtual machine exercise solution. **30 genAI prompt exercises.**

Chapter 13, Generic Classes and Methods: A Deeper Look—Implement a custom generic method and a custom generic class. Compile-time type safety. **24 genAI prompt exercises.**

Chapter 14, Functional Programming with Lambdas & Streams—Use lambdas and stream pipelines to write certain kinds of programs faster, simpler, more concisely and hopefully with fewer bugs than previous techniques. Focus on immutability. Chapter 18, Concurrency: Platform Threads to Virtual Threads, demonstrates parallelizing stream pipelines to enhance performance on multi-core architectures. **36 genAI prompt exercises.** [Chapter 22 can be covered here.]

Part 5: JavaFX Graphical User Interfaces, Graphics and Multimedia

Chapter 15, JavaFX Graphical User Interfaces: Part 1 —Scene Builder for simple drag-and-drop GUI design. Layouts. Controls. Event handling. Welcome app. Tip Calculator app. **13 genAI prompt exercises.**

Chapter 16, JavaFX GUI: Part 2—Additional layouts and controls. Mouse, `RadioButton` and property-change events. Data binding. Customizing a control's appearance. `FileChooser` and `DirectoryChooser` dialogs. **21 genAI prompt exercises.**

Chapter 17, JavaFX Graphics and Multimedia—Cascading Style Sheets (CSS) for customizing JavaFX nodes' appearance and text fonts. 2D and 3D shapes. Move, rotate and scale node transformations. Display, play and pause video. Incrementally change properties with `Transition` and `Timeline` animations. Frame-by-frame animations with `AnimationTimer`. CSS transitions for simplified animation effects. `Canvas` for drawing with the mouse. **31 genAI prompt exercises.**

Part 6: Advanced Topics

Chapter 18, Concurrency: Platform Threads to Virtual Threads—Multi-core programming. Create and manage multiple tasks. Performance case studies. Profile sequential vs. parallel sorting with Date/Time APIs. Prepackaged parallel algorithms. Classic producer–consumer relationship. Easier-to-use, less error-prone, higher-level concurrency features. Project Loom: Lightweight virtual threads, structured concurrency, scoped values. **51 genAI prompt exercises**.

Chapter 19, Building API-Based Java Generative AI Applications—Multimodal genAIs that understand text, code, image, speech and video inputs and generate text, code, images, speech and video. Work with OpenAI APIs to create apps that summarize text, analyze text for sentiment, create accessible descriptions of images, detect a text's language and translate text among languages, generate Java code, perform named entity recognition on text and obtain structured JSON outputs, transcribe speech to text, synthesize speech from text, generate closed captions for a video and more. **21 genAI prompt exercises and 73 API-based programming projects.**

Chapter 20, Accessing Databases with JDBC and SQLite—Storing persistent data in databases. SQLite database management system. Structured Query Language (SQL) CRUD (create, read, update, delete) operations. JDBC API. Connecting to a database. Retrieve data from a database. JavaFX `TableView`. JDBC `PreparedStatements`. **19 genAI prompt exercises**.

Chapter 21, Java Platform Module System—Create custom packages and modules. Declare module dependencies. Specify which packages a module exports. Define the services a module offers or consumes. Reflection and enabling reflective access. Bundling resources with modules. **31 genAI prompt exercises**.

Chapter 22, Computer Science Thinking: Recursion, Searching, Sorting, Big O—Key classic computer science concepts. Recursive and iterative factorial calculations. Recursive Fibonacci calculations. (Optional) JavaFX app that recursively creates a "feather fractal." Array searching and sorting algorithms. Text-based algorithm visualizations. Rich selection of recursion, searching and sorting exercises. **14 genAI prompt exercises.** [Can be covered at the end of Part 4: Data Structures.]

Appendices

Appendix A, Introduction to JShell for Interactive Java—Java's friendly, command-line REPL (read-evaluate-print-loop) for exploration, discovery and experimentation. Like having Python's interactivity in Java. Many sections can be covered in conjunction with the book's early chapters.

Appendix B, Formatted Output—formatting features for output and for `Strings` in memory. Summarizes the formatting features we discuss throughout the book and introduces additional capabilities.

Appendix C, Number Systems—Introduces binary (base 2), octal (base 8), decimal (base 10) and hexadecimal (base 16) number systems.

Possible Topics on the Deitel.com Blog

Sequenced collections. Flexible constructor bodies. Bit manipulation. Labeled `break` and `continue` statements. JavaFX `Subscription` API. Intro to basic JavaFX game development with FXGL (FX Game Library), animation, collision detection, particle effects and more. We'll link our Java-related blog posts to the book's webpage at `https://deitel.com/jhtp12`

Live-Code Approach

At the heart of the book is the Deitel signature **live-code approach**. Rather than code snippets, you'll learn Java hands-on from a broad selection of 200+ fully coded, real-world examples and case studies with live outputs and hundreds of additional exercises and projects drawn from computer science, data science, AI and other fields. Read the Before You Begin section that follows this Preface to learn how to download the code examples and set up your Windows or macOS computer to run them.

Chapter 1's Test-Drive (Section 1.12) shows how to compile and run the code examples with the free, open-source OpenJDK version of the Java Development Kit. **Executing each program in parallel with reading the text will make your Java programming learning experience "come alive,"** leveraging your learning experience. We also provide test-drives of the following popular Java developer tools at `https://deitel.com/jhtp12`:

- JetBrains IntelliJ IDEA Community Edition
- The Eclipse IDE for Java Developers
- Microsoft Visual Studio Code

"Objects-Natural" Approach

Object-oriented programming textbooks have traditionally used a "late objects" or an "early objects" teaching approach. What's really "late" or "early" in these textbooks is not "objects." It's teaching how to develop custom classes—the "blueprints" from which objects are built. We've written textbooks using both approaches in popular object-oriented programming languages.

What Is "Objects Natural?"

As we wrote our textbook *Intro to Python for Computer Science and Data Science: Learning to Program with AI, Big Data and the Cloud*,[21] we noticed that although our presentation fits the "late objects" model, it is actually something more—and that something is special. We call it the **"objects-natural approach,"** and we're now using it in each object-oriented programming language textbook and professional book we write.

Like "late objects," our objects-natural approach begins with programming fundamentals such as problem-solving, algorithm development, data types, variables, operators, control statements, methods, arrays and strings in the early chapters—all before you develop your own *custom* classes. However, with the objects-natural approach, you'll get lots of practice using powerful *existing* classes that do significant things, quickly creating objects of those classes (typically with one line of code) and telling them to "strut their stuff" with a minimal number of simple Java statements. This is one of the most compelling aspects of working with a mature object-oriented language like Java. And you'll do this long before you create and use custom Java classes in Chapter 8 and inheritance, polymorphism and interfaces in Chapter 9.

21. Deitel, Paul, and Harvey Deitel. *Intro to Python for Computer Science and Data Science: Learning to Program with AI, Big Data and the Cloud*. Upper Saddle River, NJ: Pearson, 2020.

An Abundance of Free Classes

We emphasize using the massive number of valuable free classes in the Java ecosystem. These typically come from:

- the **Java Application Programming Interface** (API)—**Java's standard library**—and
- free third-party Java libraries, often created by the open-source community.

We encourage you to view lots of Java code on sites like GitHub. Reading other programmers' code is a great way to learn.

Generative AI (GenAI) Approach[22]

Leveraging genAI was integral in developing *Java How to Program: An Objects-Natural Approach, 12/e*. It will also be essential to how you interact with the material. Here, we outline our approach to integrating genAI throughout the book, its potential to profoundly enhance Java education, and **how to leverage these tools effectively while maintaining a cautious and critical mindset.**

While writing the book, we integrated genAI not as a replacement for our work as authors but as a powerful enhancement tool. Similarly, you should use genAI to augment your learning and problem-solving skills, not to replace them. **Our experience with genAI has been both enlightening and entertaining—it's like having a diverse team of experts available to assist you 24/7, though one that requires careful supervision.**

Two Approaches to Using genAI

We integrate genAI using two approaches:

- **Prompt engineering:** Outside Chapter 19, we focused on prompt engineering to optimize the interaction with genAI tools. Think of this as learning a new and different type of programming language. With prompt engineering, you craft precise instructions or queries to guide genAIs in producing the required responses. You can also iteratively tune your prompts, refining and adjusting them to help the genAIs produce more accurate and relevant results—**the better your prompts, the better the results**. It takes lots of experience to learn how to create great prompts—you'll get that experience in this book.
- **Java code using AI APIs plus prompt engineering:** Chapter 19 combines prompt engineering and API-based code development, emphasizing how genAI can help you build and tune complete Java applications. We use the OpenAI APIs.

Chapter 19's examples and exercises dive deeper into using **genAI for code generation and analysis** as we build API-based Java genAI applications. You'll learn to craft effective

22. *ChatGPT* (`https://chatgpt.com`), *Gemini* (`https://gemini.google.com`), *Claude* (`https://claude.ai`) and *Perplexity* (`https://perplexity.ai`) responses to the prompt, "The following is a list of miscellaneous notes on how we used genAIs when working on our new Java programming textbook geared toward programming novices and how our readers will use genAI while reading the book. Turn these notes into useful flowing text, reorganizing the points as necessary and removing redundancy." January 1, 2025. To demonstrate the power of genAIs, we followed the preceding prompt with a lengthy (and sometimes repetitive) list of our raw author notes for this section, asking the genAIs to organize our notes into smooth, flowing paragraphs. We then edited the final presentation.

prompts to produce code snippets, debug and tune your programs, and create complete Java applications.

Generative AI Tools We Used

Our work relied on many genAIs, including four primary genAI chatbots:

- OpenAI ChatGPT
- Google Gemini
- Anthropic Claude
- Perplexity AI

We used them all for each task because they produced some overlapping and some different results—each had insights to contribute. In fact, the same genAI often yielded different results when we gave it the same prompt, even if only moments later. Each has unique strengths and weaknesses. GenAIs constantly evolve, so capabilities and limitations will change over time, most likely improving dramatically.

We also used **OpenAI's Dall-E** for **image generation** (Dall-E is now integrated into ChatGPT) and **Sora** for **video generation**. Many genAIs offer free trials or tiers, which can give you good results but might be less capable than their paid counterparts.

Role of GenAIs in Education

GenAIs will play a crucial role in education in general and especially in programming-language education. They serve as an always-available team of virtual experts, accessible at little or no cost, to assist students, instructors and professionals.

Educational institutions remain divided on whether to allow genAI usage. Some embrace it as we do in this book. Some have banned it. Others permit it, with safeguards like offline exams. We encourage students to become familiar with these tools, which are likely to be indispensable throughout their education and professional careers. However, they should comply carefully with the policies of their educational institutions and instructors, noting that their instructors' policies might vary significantly.

GenAIs for Enhancing Learning Experiences

GenAIs can enhance learning experiences by:

- Providing multiple perspectives on complex concepts.
- Offering interactive debugging assistance.
- Helping identify areas for review when concepts are unclear.
- Supporting various learning styles through different explanatory approaches.
- Offering personalized feedback on the code you write.

When solving exercises, we encourage you to do the work, using genAIs to enhance your learning experience. Our Generative AI exercise sections help you:

- Learn prompt engineering—crafting and refining prompts to achieve optimal results.
- Learn what genAIs can do by trying lots of prompts.
- Learn the level of detail with which each genAI responds to prompts.

- Discover new ways to solve problems.
- Compare the strengths and weaknesses of different genAIs.
- Understand that genAIs make mistakes and how to detect and address those errors.
- Be aware that genAIs can produce inaccurate results.
- Get clarification on points raised in the book.
- Enhance your knowledge when you want more detail.

GenAIs for Enhancing Teaching Experiences

In the mid-to-late-2020s, the key to successful genAI integration in education lies in using it as a **supplement to, rather than a replacement for**, traditional learning methods. GenAIs can enhance teaching experiences by:

- Suggesting how to present concepts most effectively, such as by giving real-world analogies.
- Generating exercises at various levels and the corresponding solutions.
- Generating quiz and test questions and solutions.
- Generating customized lecture slides.
- Assisting with grading assignments and exams.

How We Used GenAIs

We integrated genAI into our authoring efforts—not to write the manuscript (except by design in cited instances) or code examples but to enhance research, development, tuning the writing and proofreading. We used genAIs to:

- Refine our genAI prompting skills to get better results.
- Brainstorm.
- Extract key points from this book's content and use them to draft PowerPoint slides for instructors to prepare and deliver their classes.
- Verify our content.
- Check that we used current Java programming idioms and clean code[23] guidelines appropriate for a book at this level.
- Check our grammar and writing clarity.
- Generate multiple-choice question drafts from our content.
- Draft exercise solutions using only the techniques we presented to a given point in the book.
- Draft marketing text directly from our content.
- Draft blog posts directly from our content.
- Convert pseudocode to Java and vice versa.

23. Martin, Robert C. *Clean Code: A Handbook of Agile Software Craftsmanship*. Upper Saddle River, NJ: Addison Wesley, 2009.

- Refactor our code to conform to our coding conventions, such as code indentation and comment relevance and density.
- Refactor code (e.g., renaming variables, methods and classes, extracting repetitive code into separate functions, etc.).

Effective prompt engineering was key in most cases, and revisiting an ongoing chat with a carefully tuned prompt often led to dramatically improved results.

Guidelines for Students and Instructors

We encourage you to use genAIs as a learning tool rather than just an answer generator. Just as programming mastery requires understanding language and library capabilities, effective genAI use requires developing skills with different prompts. You should:

- Keep track of your prompts and the quality of their results. This is crucial for learning what works and what doesn't. This will also help you identify the nuances of different genAI platforms. You'll build a repertoire of valuable prompts and anticipated results that will leverage future programming efforts.
- Experiment with multiple genAIs—including new ones as they appear—and compare the results to understand their diverse capabilities.
- Experiment with different prompting strategies to see which ones help you achieve your desired outcomes. Different programming challenges can require different prompting strategies.
- **If genAI results are unsatisfactory, tune your prompt and try again**. For example, you'll see that some genAIs emphasize producing smooth, professional quality writing, while others dig deeper into the subject matter.
- Use genAIs for **discovery**—finding new ideas, insights and patterns that might not initially be apparent. GenAIs offer wide-ranging perspectives, analyzing vast amounts of data and synthesizing information into actionable outputs that can enhance creativity or inform decisions. GenAI discovery can enhance your creativity and uncover possibilities beyond your expertise, helping you grow your knowledge and wisdom.[24]

Hallucinations and Errors

GenAIs have limitations. They've been known to "hallucinate," confidently providing fabricated answers. When you ask them to perform tasks, sometimes the results contain errors, such as Java code that does not work. We've included successful and unsuccessful genAI interactions in the book. For instance, while genAIs helped us enhance our Number Systems Appendix with innovative applications of hexadecimal, we also encountered situations where they struggled with seemingly straightforward tasks. As early as Chapter 2, we encountered genAI failures when asking them to write simple Java statements. We deliberately included some of these failure cases as valuable teaching moments, demonstrating that genAIs are fallible, so you must use them cautiously. This underscores the importance of maintaining human oversight and verification, especially in business-critical and mission-critical situations.

24. *ChatGPT* response to "What does it mean to use generative AIs for discovery?" January 18, 2025. `https://chatgpt.com`. We edited the response.

Why We Use Paid Services

While free or free-tier genAIs are valuable, paid services often offer more robust capabilities, availability and reliability. Many genAIs are paid services due to the sheer cost of training the large language models that provide the genAIs' powerful capabilities. For example, training OpenAI's GPT-4 and Google's Gemini cost $78 million and $191 million, respectively—not including the salaries of the people developing the large language models and other overhead costs.[25] We encourage you to use free or low-cost tools when available. You can even ask genAIs to suggest the best free versions. Professionals will often choose paid tools to get the best results.

What We're Trying to Accomplish

We aim to prepare you for a future in which genAIs will be indispensable in your personal life and professional career. By integrating genAI examples and exercises throughout the book, we aim to help you become comfortable using these tools and understand their advantages and pitfalls. Developing a healthy sense of caution while exploring genAI capabilities will empower you to use them effectively.

Chapter 19's API-Based Complete, Live-Code Java GenAI App Case Studies

Chapter 19 presents the following fully implemented code examples that programmatically interact with OpenAI's APIs:

- **Text Summarization** (Section 19.4.1): Asks the OpenAI chat API for a summary abstract paragraph of a Deitel video transcript and a list of the transcript's key points. Text responses like these are known as **chat completions**.
- **Sentiment Analysis** (Section 19.4.2): Asks the OpenAI chat API for the sentiment of a transcript and an explanation of how the genAI came to its conclusion.
- **Accessible Image Descriptions** (Section 19.4.3): This multimodal application uploads images and asks the OpenAI chat API for detailed descriptions of the `for`-loop UML diagram in Section 4.3 and a scenic Aruba beach photo.
- **Language Detection and Translation** (Section 19.4.4): Asks the OpenAI chat API to translate text to a specified target language—it **autodetects the source language**. We translate text from English to Spanish and Japanese, then from Spanish and Japanese back to English. Many of today's genAIs can translate among scores of languages.
- **Java Code Generation** (Section 19.4.5): Asks the OpenAI chat API to generate Java code for a simulation summarizing 600 million six-sided die rolls and displaying the results.
- **Named-Entity Recognition and Structured Outputs** (Section 19.4.6): Demonstrates producing a structured JSON response in your specified format. This app performs a natural language processing (NLP) task called named entity recognition (NER), which attempts to locate and categorize text mentions like dates, times, quantities, places, people, things, organizations, etc. To make the results

25. Stanford Institute for Human-Centered Artificial Intelligence (HAI), AI Index Report 2024, May 2024. Accessed March 8, 2025. `https://hai-production.s3.amazonaws.com/files/hai_ai-index-report-2024-smaller2.pdf`.

easier to process, we provide the API with the exact JSON response format we wish to receive, then use the **Jackson open-source library** (Chapter 11) to process the results.

- **Speech-to-Text** (Section 19.5.1): This multimodal application (speech audio and text) uploads a speech audio file to the **OpenAI Whisper model**, which transcribes it to text and returns the text transcription.
- **Text-to-speech** (Section 19.5.2): This multimodal application (text and speech audio) uploads text to the **OpenAI TTS-1 model** to synthesize speech from the text. This example converts English, Spanish and Japanese text samples into speech using the same voice.
- **Image Generation** (Section 19.6): Demonstrates code that asks the **Dall-E APIs** to generate images of a Havanese dog in the styles of a Japanese anime character in neon colors against a black background, Vincent Van Gogh and Leonardo DaVinci.
- **Creating closed captions for a video** (Section 19.7.1): This multimodal accessibility application (speech audio, text and video playback) uploads an audio track from a video and transcribes it into a JSON format containing timestamps and corresponding transcribed text. Then, the app requests a chat completion that generates **closed captions in VTT format.**[26] We show VTT-formatted text and screen captures displaying captions over the corresponding video.
- **Moderation** (Section 19.8): Asks the **OpenAI moderation API** to evaluate text prompts for harmful or inappropriate text, such as harassment, hate speech, violence, self-harm and sexually explicit content.

Generative AI Prompt Exercises

We fed the complete list of all the book's approximately 600 genAI exercises (a 100+ page PDF) to ChatGPT, Gemini, Claude and Perplexity, asking them to categorize the kinds of things we do in those exercises. Next, we fed all their categorized lists to the four genAIs, asking them to summarize the summaries, and we chose the best one—Claude in this case:

- **Code Generation and Implementation**—Writing new Java programs from specifications or pseudocode. Implementing specific features, algorithms and APIs. Creating test programs and practical applications. Generating solutions for both basic and advanced programming tasks.
- **Code Refactoring and Enhancement**—Modernizing code with current Java features (streams, enhanced loops). Improving code structure, readability, and maintainability. Converting between different approaches while maintaining functionality. Improving performance.
- **Educational Content**—Creating tutorials, exercises, and learning materials. Explaining complex concepts (polymorphism, immutability, etc.). Developing beginner-friendly programming exercises. Writing comprehensive documentation and guides.

26. "WebVTT." Wikipedia. Last modified December 31, 2024. Accessed March 1, 2025. `https://en.wikipedia.org/wiki/WebVTT`.

- **Technical Analysis**—Analyzing code behavior and feature implementations. Comparing different approaches, tools, and frameworks. Evaluating trade-offs in design decisions. Breaking down complex technical concepts.
- **Best Practices and Standards**—Implementing coding standards and design patterns. Addressing security considerations. Optimizing performance. Following Java development best practices.
- **Technology Evaluation**—Comparing libraries, tools, and frameworks. Assessing the pros and cons of different approaches. Making informed technology choices. Exploring new features and updates.
- **Debugging and Error Handling**—Finding and fixing syntax and logical errors. Implementing exception handling. Improving fault tolerance. Preventing common pitfalls.
- **API and Library Integration**—Working with Java APIs and external libraries. Understanding API features and capabilities. Implementing integration techniques. Creating API documentation and tutorials.
- **Real-world Applications**—Developing practical use cases and industry applications. Creating interactive applications (GUIs, games, multimedia). Implementing real-world scenarios. Building sample projects.
- **Performance Optimization**—Analyzing and improving performance. Optimizing resource usage. Conducting benchmarks. Implementing efficiency improvements.
- **Creative Development**—Building multimodal applications. Creating visualizations. Generating test scenarios and sample data. Developing unique use cases.

Generative AI API-Based Java Programming Exercises

Chapter 19, Building API-Based Java Generative AI Applications, suggests challenging project exercises like creating genAI multimedia apps that can debate one another and using genAI to build and solve crossword puzzles. We fed Chapter 19's 90+ exercises into the genAIs, asking for a categorized summary of them, then summarized the summaries. Here's what they produced:

- **Multimodal Applications**—Combining text, image, audio, and video capabilities. Creating integrated experiences like interactive books. Developing multimedia educational content. Building comprehensive tools that leverage multiple AI modalities.
- **Text-Based Applications**—Document processing (indexing, summarization, exploration). Creative writing (story generation, poetry, debates). Language tools (translation, tone rewriting). Professional document creation (resumes, presentations). Structured outputs.
- **Image Processing Applications**—Generative art and design (logos, fashion, floor plans). Technical visualization (UML diagrams). Image analysis and recognition.
- **Audio and Music Applications**—Speech processing (transcription, voice cloning). Music generation (MIDI, Magenta AI). Multilingual audio applications. Podcast and audio content analysis.

- **Educational Tools**—Programming tutors (Java, coding exercises). Subject-specific learning aids (math, arithmetic). Course content creation. Interactive educational experiences.
- **Gaming and Puzzle Applications**—Puzzle generators and solvers (Crosswords, Word Search). Interactive game development.
- **Video**—Investigating and experimenting with generative AI video creation tools.
- **Chatbot Development**—Character-based chat experiences. Specialized domain experts.
- **Research and Analysis Tools**—Medical applications (drug discovery, personalized medicine). AI capability exploration. Text detection and analysis. Educational research.
- **Creative Applications**—Children's book creation. Interactive storytelling. Artistic content generation. Creative writing tools.
- **Practical Tools and Utilities**—Document generators. Translation services. Content summarizers. Professional tools (resume filters, presentation creators).

Key Takeaways

- **Try multiple genAIs**: Compare their strengths and weaknesses.
- **Master prompt engineering**: Craft effective prompts for optimal results. Build a catalog of your best prompts.
- **Be cautious of hallucinations**: Always review genAI output critically.
- **Embrace the power of genAI**: Use it to enhance your Java learning experience, not to replace it.
- **Adhere to your college's or university's genAI policies** and note that your instructors may each feel differently about acceptable uses of genAI.

New and Updated Features

In the following sections, we discuss the 26 key new features and updates we've made for *Java How to Program: An Objects-Natural Approach, 12/e*, including:

1. **Objects-Natural Case Studies.** Chapter 1 presents a friendly introduction to object technology's basic concepts and terminology. In the early chapters, you'll create and use powerful objects of preexisting Java API classes to do significant things without knowing how to write classes in general or how those particular classes are implemented—and you'll do this long before you create and use objects of your own custom classes in Chapter 8. We've added objects-natural case studies on class `String` (Chapter 2), class `BigInteger` for supersized integers (Chapter 3), class `BigDecimal` for the precise monetary calculations required in business applications (Chapter 4), the Date/Time API (Chapter 5), class `ArrayList` (Chapter 6) for dynamically resizable arrays, regular expressions for locating patterns in text (Chapter 7), secret-key AES cryptography (Chapter 7) and public-key RSA cryptography (Chapter 11). Throughout the rest of the book, many other case studies use objects of Java API and open-source library classes extensively.

2. **Approximately 600 integrated generative AI (genAI) prompt exercises.** Most sections end with genAI prompt exercises (approximately 450) in which you'll interact with genAIs using prompt engineering. In addition, many chapters include end-of-chapter genAI prompt exercises (approximately 150). You'll feel like you have lots of Java experts at your side 7-by-24 (some receiving modest pay and some free) to answer your questions about the book's Java content, help you probe more deeply into topics of interest, and even help you write and debug Java code. Better yet, they're competing among themselves and a steady flow of new entries to offer you the best results while each rapidly improves.
3. **Chapter 19, Building API-Based Java Generative AI Applications**, demonstrates programmatically interacting with OpenAI's APIs for text summarization, sentiment analysis, describing images for accessibility, translating text among languages, generating Java code, named-entity recognition, transcribing speech to text, synthesizing speech from text, creating closed captions for video, image generation and much more in the chapter's 94 exercises.
4. **Approximately 400 Checkpoint exercises and answers.** Most sections in the core computer science Chapters 1–10 end with **Checkpoint exercises for self-study**. Each is immediately followed by its answer. Chapter sections are intentionally small. We use a "read-a-little, code-a-little, test-a-little" approach. In the core computer science Chapters 1–10, you read about a new concept, study and execute the corresponding code examples, then test your understanding via the integrated fill-in-the-blank, true/false, discussion and code-based Checkpoint exercises and answers. This will help you keep a brisk learning pace.
5. Covers the **latest Java language features, library features and programming idioms**. To keep the book up to date as new versions of Java are released, we'll place new code examples and explanations on **our blog** at **`https://deitel.com/blog`** and link them to the book's webpage at `https://deitel.com/jhtp12`.
6. **Streamlined contemporary treatment of object-oriented programming**, including `record` classes, `sealed` classes and interfaces, and a new case study on programming to an interface, not an implementation, focusing on composition and dependency injection.
7. **Enhanced file-processing** coverage, including using the **Jackson open-source library** to input and output data in the **JSON** and **CSV** formats that are so popular in today's data-science applications.
8. **Invoking popular web services** (such as **OpenWeatherMap**) with web networking capabilities provided by the **`java.net.http` package**.
9. **Special feature introducing data analytics with the CSV-format Titanic disaster dataset** and a corresponding data-analytics exercise using the `diamonds.csv` dataset.
10. **Special feature on cryptography**, including **secret-key AES cryptography** and **public-key RSA cryptography**. Cryptography is crucial for the rapidly growing interest in **computer privacy and security**.
11. **Special feature on simple data wrangling** steps used to prepare text for training natural language processing (NLP) and genAI models. Data wrangling is a key **data science** technology.

12. New Chapter 1 sections briefly discuss the **metaverse** and its related technologies—virtual reality (VR), augmented reality (AR), mixed reality, blockchain, cryptocurrency, nonfungible tokens (NFTs) and Web3—and **software development technologies**, **big data**, and **AI's intersection with computer science and data science**.
13. Enhanced treatment of **JavaFX GUI, graphics, animation and video—**technologies that will be core to the emerging metaverse.[27] The presentation includes an intro to JavaFX's new CSS transitions for simplified animation effects.
14. An intro to **JavaFX game development** with the **open-source FXGL (FX Game Library**) in Chapter 17.
15. In a new Chapter 16 exercise, students can rework Chapter 8's **card-shuffling-and-dealing simulation** using JavaFX and attractive free Wikimedia Commons card images.
16. Flexible coverage of **JShell**, Java's friendly, command-line REPL (read-evaluate-print-loop) environment for quickly exploring, discovering and experimenting with Java's language features and libraries—**it's like having Python's interactivity in Java**.
17. **Concurrency**, **Parallelism** and **Multi-Core Performance** updates for key **Project Loom** technologies like **virtual threads** and the emerging **structured concurrency** and **scoped values**.
18. **Enhanced database treatment** that interactively introduces **Structured Query Language** (SQL) using the popular **SQLite database management system's command-line tools**. The examples now use **SQLite databases**. We replaced the older Swing `JTable` with **JavaFX's `TableView`**, which offers a nicer look-and-feel, better performance and more customization than `JTable`.
19. Hundreds of new and updated **contemporary examples, exercises and projects**.
20. We recast our **Building Your Own Computer** Simpletron case study exercise to the more topical **Building Your Own Virtual Machine**.
21. We now use `RandomGenerator` (from Java 17), which provides enhanced random-number generation capabilities and is preferred for simulations. We use `SecureRandom` in security scenarios, such as our cryptography examples.
22. Our **hundreds of programming tips** gleaned from our combined ten decades of programming, teaching and industry experience have been fully integrated into the regular text flow in this edition.
23. We added various application programming case studies. Some are chapter examples that present and walk through the complete source code, some are exercises and projects with detailed specifications from which you should be able to develop the code solution on your own, and some are projects that require additional research. Project exercises ask you to go deeper into what you've learned and explore other technologies. Some might require many hours, days or weeks of implementation effort. Many are appropriate for class projects, term projects, directed-study courses, capstone-course projects and even thesis research.

27. We anticipate that the next edition of *Java How to Program* will begin to employ metaverse technologies like augmented reality and virtual reality.

24. We enhanced existing case studies and added new ones focusing on AI and data science, including simulations with random-number generation, natural language processing (NLP) and artificial intelligence via generative AI and heuristic programming.
25. In the book's Pearson+ eText and Revel interactive multimedia versions, we've tuned and enhanced the hundreds of glossary items for the core computer science Chapters 1–10.
26. We've tuned and enhanced the hundreds of auto-graded assessment questions in the book's Revel interactive multimedia version based on Pearson's new, more robust assessment engine.

Teaching Approach and Pedagogy Features

Syntax Coloring

We syntax color all the Java code, similar to how most Java integrated development environments (IDEs) and code editors syntax color code.

Using Fonts for Emphasis

We emphasize on-screen components in **bold** (e.g., the **File** menu) and Java program text in a `fixed-width` font (e.g., `int x = 5;`).

Objectives

The chapter Objectives sections list the chapter's goals.

Illustrations/Figures

Abundant tables, line drawings, UML diagrams, programs and program outputs are included.

Exercises

The end-of-chapter exercises include:

- Simple recall of important terminology and concepts.
- What's wrong with this code?
- What does this code do?
- Writing individual statements and small portions of methods and classes.
- Writing complete methods, classes and programs.
- Major projects.
- Generative AI exercises that dig deeper into a variety of topics.

Java How to Program, 12/e contains hundreds of live-code examples. We stress program clarity and concentrate on building well-engineered software.

Preparing for Industry

To help students prepare to work in industry, we use the terminology from the latest Java specification document (`https://docs.oracle.com/javase/specs/`) in preference to general programming terms. We also show Java as it's intended to be used with a rich collection of application programming case studies, focusing on computer science, artificial intelligence, data science and many other fields.

Avoid Heavy Math

We avoid heavy math, leaving it to upper-level courses. Optional mathematical exercises and projects are included for science and engineering courses.

KIS (Keep It Simple), KIS (Keep it Small), KIT (Keep it Topical)

- **Keep it simple**—We strive for simplicity and clarity.
- **Keep it small**—Many of the book's examples are small. We use more substantial code examples, exercises and projects when appropriate, particularly in the case studies, which are a core feature of this textbook.
- **Keep it topical**—To "take the pulse" of modern Java, we read, browsed or watched thousands of current articles, research papers, white papers, books, documentation pieces, blog posts, forum posts, webinars and videos. We placed Google Alerts on hundreds of important Java-related, general computing, AI and data science topics.

Hundreds of Contemporary Examples, Exercises and Projects (EEPs)

Our code examples, exercises and projects familiarize students with current topics of interest in computing. Instructors can tailor courses to their unique audiences and vary labs and exam questions each semester.

Extensive VideosNotes

The book's **Pearson+ eText and Revel** interactive multimedia versions contain extensive **VideoNotes** in which co-author Paul Deitel discusses the material in the Before You Begin section, and patiently explains and provides additional insights on most of the programs in the book's core computer science Chapters 1–10.

Glossary Items

The book's **Pearson+ eText and Revel** interactive multimedia versions contain hundreds of glossary items for the core computer science Chapters 1–10. These are also used in student learning tools to create flashcards and matching exercises.

Performance

We focus on techniques and strategies for meeting the extraordinary performance needs of today's applications.

Data Experiences

In Chapter 11, you'll work with real-world text data. You'll read and analyze the Titanic Disaster dataset,[28] which is popular for introducing the field of **data analytics**. This dataset is stored in a **CSV (comma-separated values) file**, a format we introduce in Chapter 11. In the exercises, you'll use what you learned in the Titanic Disaster dataset example to ana-

28. "TitanicSurvival" dataset on `https://vincentarelbundock.github.io/Rdatasets`. Dataset authors: Frank E. Harrell, Jr., and Thomas Cason.

lyze the `diamonds.csv` dataset. Also, see the "Data Science Overlaps with Computer Science" section later in this Preface.

Secure Java Programming

It's challenging to build industrial-strength systems that stand up to attacks from viruses and other forms of "malware." Today, via the Internet, such attacks can be instantaneous and global in scope. Building security into software from the beginning of the development cycle can significantly reduce vulnerabilities.

The CERT® Coordination Center (founded in 1988; `https://cert.org`) was created to analyze and respond promptly to attacks. CERT—the Computer Emergency Response Team—is a government-funded organization within the Carnegie Mellon University Software Engineering Institute. CERT publishes and promotes secure coding standards for various popular programming languages to help software developers implement industrial-strength systems by employing programming practices that prevent system attacks from succeeding.

We audited our book against the SEI CERT Oracle Coding Standard for Java

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https://wiki.sei.cmu.edu/confluence/display/java/
   SEI+CERT+Oracle+Coding+Standard+for+Java
```

and the newer Oracle Secure Coding Guidelines for Java SE

```
https://www.oracle.com/java/technologies/javase/seccodeguide.html
```

and adhere to secure coding practices appropriate for a textbook at this level.

Privacy

The ACM/IEEE's curricula recommendations[29] for Computer Science, Information Technology and Cybersecurity mention privacy hundreds of times. Every programming student and professional must consider privacy issues and concerns. Several exercises in Chapter 1 ask you to investigate privacy issues. We also discuss secret-key and public-key cryptography, which is critical to privacy and security, in Chapters 7 and 11.

In Chapter 1's exercises, you'll start thinking about these issues by researching ever-stricter privacy laws such as HIPAA (Health Insurance Portability and Accountability Act) and the California Consumer Privacy Act (CCPA) in the United States, and GDPR (General Data Protection Regulation) for the European Union.

Ethics

The ACM/IEEE's curricula recommendations[30] for Computer Science, Information Technology and Cybersecurity mention ethics more than 100 times. In several Chapter 1 exercises, you'll focus on ethics issues via Internet search and generative AI research. You'll investigate privacy and ethical issues surrounding intelligent assistants, like Amazon Alexa, Apple Siri and generative AIs' voice capabilities. We'll also examine the excitement and controversies surrounding genAIs such as OpenAI's ChatGPT,[31] Dall-E[32] and many more.

29. "Curricula Recommendations." Accessed January 18, 2025. `https://www.acm.org/education/curricula-recommendations`.
30. "Curricula Recommendations." Accessed January 18, 2025. `https://www.acm.org/education/curricula-recommendations`.
31. "Introducing ChatGPT." Accessed January 18, 2025. `https://openai.com/blog/chatgpt`.
32. "Dall-E 2." Accessed January 18, 2025. `https://openai.com/product/dall-e-2`.

Programming Wisdom

Hundreds of programming tips are fully integrated into the regular text flow in this edition:

- **Good programming practices** call attention to techniques that help you produce clearer, more understandable and more maintainable programs.
- We point out **common programming errors** to reduce the likelihood you'll make them.
- **Performance tips** highlight opportunities to make your programs run faster or minimize memory use.
- **Software engineering observations** highlight architectural and design issues that affect the construction of software systems, especially large-scale systems.
- **Look-and-feel observations** (Chapters 15–17) highlight graphical user interface (GUI) conventions. These observations help you design attractive, user-friendly graphical user interfaces that conform to industry norms.

Tour of the Book

The two-page "High-Level Overview" early in this Preface shows the book's modular architecture. We recommend that you refer to that diagram as you read this section.

The early chapters establish a solid foundation in Java fundamentals. The mid-to-high-end chapters introduce intermediate and advanced Java programming topics. We discuss six programming paradigms:

- procedural programming (Chapters 2–7)—**enhanced with our objects-natural approach**,
- object-oriented programming (8–10),
- generic programming (Chapters 12 and 13),
- functional programming (Chapter 14),
- concurrent programming (Chapter 18),
- and new in this edition—**genAI-enhanced programming** (Chapter 19)

Whether you're a student getting a sense of the textbook you'll be using, an instructor planning your course syllabus, or a professional software developer deciding which chapters to read as you prepare for a project, this Tour of the Book will help you make the best decisions.

Part 1: Introduction

Parts 1 and 2 (Chapters 1–7) provide a friendly, example-driven treatment of traditional introductory programming topics.

Chapter 1, Intro to Computers, the Internet, Java and Generative AI, engages programming novices with intriguing facts and figures to excite them about studying computers and computer programming. The chapter includes technology trends, hardware, software and Internet concepts, and a sample data hierarchy from bits to bytes, fields, records and databases. It lays the groundwork for the Java programming discussions in Chapters 2–22 and the many case-study examples, exercises and projects.

We discuss the programming-language types and technologies you'll likely use as you develop software. We introduce the Java API—existing, reusable, top-quality, high-performance capabilities that help you avoid "reinventing the wheel."

We introduce the Internet, the World Wide Web, the "Cloud," the Internet of Things (IoT), the emerging metaverse, and exciting new developments in generative AI. We briefly mention many other topics of current interest including open-source software, virtualization, simulation, web services, multi-core hardware architecture, multithreading, systems programming, natural language processing, data science, robust secure programming, cryptography, GitHub, StackOverflow, forums, blockchain, NFTs (nonfungible tokens), cryptocurrencies (like Bitcoin and Ethereum), artificial general intelligence (AGI) and more, laying the groundwork for modern application development.

This chapter's test-drive demonstrates compiling and executing Java code with the OpenJDK version of the Java Development Kit. You'll learn just how big "big data" is and how quickly it's getting even bigger. The chapter closes with an introduction to artificial intelligence (AI)—a key overlap between computer science and data science. AI and data science will likely play significant roles in your computing career. **Includes 27 genAI prompt exercises.**

Chapter 2, Intro to Java Programming, presents Java fundamentals and illustrates key language features, including input, output, primitive data types, arithmetic operators and their precedence, and decision-making. As part of our objects-natural approach, Section 2.9's **objects-natural case study** demonstrates **creating and using objects of the Java API's class `String`**—without you having to know how to develop custom classes in general or how class `String` is implemented in particular). `String`s represent names, places, course titles, locations of files, website addresses and more. **Includes 12 genAI prompt exercises.**

Part 2: Additional Programming Fundamentals

Chapter 3, Algorithm Development and Control Statements: Part 1, is one of the most important chapters for programming novices. It focuses on problem-solving and algorithm development with Java's control statements. You'll develop algorithms through the disciplined process of top-down, stepwise refinement, using the `if` and `if...else` selection statements, the `while` iteration statement for counter-controlled and sentinel-controlled iteration, and the increment, decrement and assignment operators. The chapter presents three **algorithm-development case studies—Counter-Controlled Iteration**, **Sentinel-Controlled Iteration** and **Nested Control Statements**. Section 3.14's **objects-natural case study** demonstrates using the **Java API's `BigInteger` class to create supersized integers** much larger than computer hardware can natively represent. **Includes 17 genAI prompt exercises.**

Chapter 4, Control Statements: Part 2, presents additional Java control statements—`for`, `do...while`, `switch`, `break` and `continue`—and the logical operators. A key feature of this chapter is its **structured programming summary**. Section 4.12's **objects-natural case study** demonstrates **using the Java API's `BigDecimal` class for precise monetary calculations. Includes 13 genAI prompt exercises.**

Chapter 5, Methods, introduces custom methods. We discuss random-number generation and simulation techniques and use them in our first of several **random-number simulation**

case studies throughout the book to **implement a popular casino dice game**. We introduce the Java API's random-number generation capabilities. In Chapters 7 and 11, we use the Java API's features for producing "nondeterministic" random numbers that cannot be predicted—which is desirable in security applications, such as cryptography. We also discuss how the method-call stack and activation records support the method call/return mechanism.

Section 5.12's **objects-natural case study** introduces features of the Java Date/Time API, which provides robust capabilities for conveniently managing date and time information, performing date and time calculations and presenting dates and times using locale-specific formatting that considers the user's spoken (or written) language, country and time zone (that is, the user's locale). We'll build a program that inputs a user's birth date and time (or approximations if they wish), then determines the day of the week the user was born and calculates how long the user has been alive. In a **Random-Number Simulation case study exercise**, you'll implement a simple but fun version of the **classical race between the tortoise and the hare**. **Includes 16 genAI prompt exercises.**

Chapter 6, Arrays and `ArrayList`s, begins our early coverage of data structures. We present built-in arrays that store lists and tables of values. You'll define and initialize arrays and access their elements. We discuss passing arrays to methods, sorting and searching arrays and manipulating multidimensional arrays. We introduce class `Arrays`, which contains methods for performing common array manipulations. Section 6.20's **objects-natural case study** discusses creating and manipulating objects of the **Java Collection Framework's `ArrayList<E>` collection class**. The Java API provides many predefined collections (that is, data structures) that store groups of related objects in memory. These classes offer efficient, proven methods that organize, store and retrieve your data portably without requiring knowledge of how the data is being stored. This reduces program development time and helps create more robust applications. This chapter's exercises include a case study on the famous **Knight's Tour problem**, which we approach in various ways, including an AI strategy called **heuristic programming**.

This chapter also contains the first of our two optional **systems programming case study exercises—Building Your Own Virtual Machine**. In the context of several **case study exercises**, you'll "peel open" a hypothetical computer and study its internal structure. We introduce simple machine-language programming and write several small machine-language programs for this computer, which we call the Simpletron. As its name implies, it's a simple machine, but as you'll see, a powerful one as well. The Simpletron runs programs written in the only language it directly understands—Simpletron Machine Language (SML). To make this an especially valuable experience, you'll then build a computer (using software-based simulation) on which you can run your SML programs! The Simpletron experience will give you a basic introduction to **virtual machines—one of the most important systems-architecture concepts in modern computing**. Chapter 12, Generic Collections, contains our optional **systems programming case study exercise** on **Building Your Own Compiler**, which can compile high-level language programs into SML code that executes on your Simpletron virtual machine. Students enjoy these challenges! **Includes 28 genAI prompt exercises.**

Chapter 7, Strings, NLP and Regex: Generative AI Foundations, presents many of the `String`, `Character` and `StringBuilder` class' features. We present an intro to natural language processing (NLP), which is at the root of powerful generative AIs like OpenAI's ChatGPT, Google's Gemini, Anthropic's Claude, Perplexity and many others. This chapter presents two **objects-natural case studies**:

- Section 7.8 introduces **regular-expression pattern matching and text replacement** using built-in features of class `String` and features from the `java.util.regex` package. After demonstrating regular expression fundamentals, we use them to perform simple data-wrangling steps to prepare text for training NLP and generative AI models.
- Section 7.9's title—pMa5tfEKwk59dTvC04Ft1IFQz9mEXnkfYXZwxk4ujGE=—looks like gibberish. This is not a mistake! This case study continues our emphasis on security and privacy by introducing **cryptography**, which is critically important in today's connected world. Every day, cryptography is used behind the scenes to ensure your Internet-based communications and stored data are private and secure. This case study introduces **private-key cryptography** with the AES (Advanced Encryption Standard) algorithm. In Chapter 11, our final objects-natural case study presents **public-key cryptography with the enormously popular RSA algorithm.**

Includes 22 genAI prompt exercises.

Part 3: Object-Oriented Programming

Chapter 8, Real-World Modeling with Custom Classes, begins our upgraded object-oriented programming treatment. Java is extensible—each class you create becomes a new type you can use to create objects. In Chapters 8 and 9, you'll learn Java's features for crafting valuable classes and manipulating objects of those classes, starting with a case study on creating and using a simple bank account class. Next, in the context of a **Random-Number Simulation case study and corresponding exercises**, you'll use collections of `String`s, random-number generation and simulation techniques to implement a **text-based, card-shuffling-and-dealing program**. Students can rework this case study using JavaFX and attractive free Wikimedia Commons card images in a Chapter 16 exercise.

Using a `Time` class case study and several additional classes, we continue with a deeper look at building classes, controlling access to class members and creating constructors to initialize class objects. We validate data and throw exceptions to indicate that problems have occurred. We design classes with *set* and *get* methods for changing and retrieving an object's instance variable values and discuss composition in which a class has references to objects of other classes as members. We discuss `enum`, `static` and `final` in more depth. We also discuss how Java reclaims unused objects (a process called garbage collection) and show a special relationship among classes in the same package. We introduce **record classes** for creating immutable objects that conveniently store related data items then use them to introduce pattern matching with `switch` expressions. **Includes 33 genAI prompt exercises.**

Chapter 9, Real-World Modeling with Inheritance, Polymorphism & Interfaces, focuses on the relationships among classes in an inheritance hierarchy and the powerful runtime polymorphic processing capabilities (for conveniently "programming in the general") that these relationships enable. In this chapter's polymorphism case study, you'll implement an `Employee` class hierarchy in an application that performs polymorphic payroll calculations.

We distinguish between the **inheritance *is-a* relationship** and **composition's *has-a* relationship**. Inheritance tends to create tightly coupled classes. We introduce interfaces, which are particularly useful for assigning common functionality to possibly unrelated classes, enabling objects of these classes to be processed polymorphically. We use a `Payable` interface implemented in disparate `Employee` and `Invoice` classes to demonstrate that objects of classes implementing the same interface can respond polymorphically to that interface's method calls.

We also explain current idioms, such as "**programming to an interface, not an implementation**" and "**preferring composition to inheritance**." We reimplement the `Employee` hierarchy using **composition and dependency-injection techniques** to create loosely coupled classes, which makes systems easier to maintain. We also introduce `sealed` classes and interfaces, which enable a class's or interface's designer to control which classes can extend a superclass or implement an interface. **Includes 31 genAI prompt exercises.**

Chapter 10, Exception Handling: A Deeper Look, continues our exception-handling discussion that began in Chapter 6. Exception handling is important for building **business-critical** applications in which a failure could disrupt company operations and cause financial losses, like

- E-commerce platforms (e.g., online stores), such as Amazon, eBay, Etsy and Shopify
- Customer Relationship Management (CRM) software, such as SalesForce, HubSpot and Zoho

and for building **mission-critical** applications in which failure could lead to significant financial loss, injury or even loss of life, like

- air traffic control systems,
- hospital life-support systems,
- emergency response systems used to dispatch police, firefighters and emergency medical technicians (EMTs), and
- military systems.

To use a Java component, you need to know not only how that component behaves when "things go well" but also what exceptions that component "throws" when "things go poorly."

We discuss when to use exceptions and demonstrate Java's `try` statement for catching and handling exceptions. We introduce Java's `Throwable` hierarchy and checked vs. unchecked exceptions, chained exceptions, creating custom exceptions, preconditions, postconditions, assertions and catching multiple exceptions with one `catch` handler. We also discuss the **`try`-with-resources statement** for automatically releasing resources like files, network connections and database connections when a `try`-with-resources statement's `try` block terminates. This version of the `try` statement is used extensively in subsequent chapters to ensure resources like files and database connections are promptly returned to the system when no longer needed. **Includes 30 genAI prompt exercises.**

Chapter 11, Files, I/O Streams, JSON Serialization & CSV Files, demonstrates using files for data persistence and is a significant update in this edition. We begin with Java's architecture for handling files programmatically and discuss the differences between text and binary files. We demonstrate using NIO classes and interfaces to retrieve information about files and directories. Then, we create and manipulate sequential text files using `Formatter` objects to write to and `Scanner` objects to read from them.

Next, we present several case studies that demonstrate transforming objects to and from popular data formats. The first introduces **JavaScript Object Notation** (**JSON**)—a human-and-computer-readable text format. We use the popular **Jackson open-source library** to write objects' JSON representations to a file (a process known as serialization), then read the JSON and recreate (deserialize) the objects. The second JSON case study uses Java API networking features from the **`java.net.http` package** to invoke an `OpenWeatherMap.org` web service that returns a city's weather report in JSON format then uses Jackson to process the response and display the weather report.

Next, we introduce the **CSV** (**comma-separated values**) **file format** and how to write and read CSV files using the Jackson open-source library. CSV is popular for datasets used in **big data**, **data analytics**, and **data science**, as well as **artificial intelligence applications** like **natural language processing**, **machine learning**, and **deep learning**—all key technologies that enable genAI. We use the Jackson library to read the **Titanic disaster dataset**, which lists information about the passengers and whether they survived when the ship struck an iceberg and sank during its maiden voyage in 1912. Then, we view some of the data and use it to introduce **basic data analytics**—a core **data science** technology.

In our final **objects-natural case study**, we continue emphasizing security by enhancing our private-key cryptography example from Section 7.9, using **RSA public-key cryptography** to encrypt and decrypt the AES secret key. This enables secure transmission of the private key to an encrypted message's recipient. Such techniques are critical for securing data and protecting user privacy. **Includes 38 genAI prompt exercises.**

Part 4: Data Structures, Generic Collections, Lambdas and Streams

Chapter 12, Generic Collections, presents our broader and deeper treatment of the Java generic collections framework that began with the **generic `ArrayList` collection** in Chapter 6. The Java collections framework contains many other **pre-built generic data structures**. We discuss the interfaces that declare the capabilities of each collection type, various classes that implement these interfaces, methods that process collection objects, and iterators that traverse collections. You'll see that **the Java API provides commonly used data structures, so you do not need to create your own**—the vast majority of your data structure needs can be fulfilled by reusing these Java API capabilities.

We introduce convenience factory methods that help you create small immutable collections. After reading **Chapter 14, Functional Programming with Lambdas & Streams**, you'll be able to reimplement many of this chapter's examples more concisely and elegantly, and in a way that makes them easier to parallelize to improve performance on multi-core systems. In Chapter 18, Concurrency: Platform Threads to Virtual Threads, you'll learn how to improve multi-core performance using Java's **concurrent collections** and **parallel stream operations**.

This chapter presents the second of our two optional systems programming case study exercises—**Building Your Own Compiler**. In the context of several projects, you'll build a simple compiler that translates programs written in a small high-level programming language into our Simpletron Machine Language (SML). You'll write programs in this concise high-level language, compile them on the compiler you build, then run them on the Simpletron virtual machine you might have built in Chapter 6's optional systems programming case study exercise—**Building Your Own Virtual Machine**. And with Chapter 11's file-processing techniques, your compiler can write the generated machine-language code into a file from which your Simpletron virtual machine can then read your SML program, load it into the Simpletron's memory and execute it! This is a nice end-to-end introduction to systems programming for novice computing students. **Includes 30 genAI prompt exercises.**

Chapter 13, Generic Classes and Methods: A Deeper Look, shows how to write custom generic classes and methods similar to those presented in **Chapter 12, Generic Collections**. We discuss how generics enable the compiler to detect type mismatches at compile time—known as **compile-time type safety**. We implement a generic method and a generic class. **Includes 24 genAI prompt exercises.**

Chapter 14, Functional Programming with Lambdas & Streams, introduces functional programming. We use lambdas and streams to write certain kinds of programs faster, simpler, more concisely and hopefully with fewer bugs than previous techniques. We architected the chapter as a series of easy-to-include-or-omit sections keyed to the book's earlier sections and chapters. We integrate lambdas and streams into several key examples after Chapter 14, because their capabilities are so convenient and compelling. Many of this chapter's sections are written so they can be covered earlier in the book. We suggest students begin with Sections 14.1–14.7 after Chapter 6 and professionals begin with Sections 14.1–14.5 after Chapter 4. We demonstrate improved ways to implement tasks you programmed in earlier chapters. After reading Chapter 14, you'll be able to cleverly reimplement many examples throughout the book. In **Chapter 18, Concurrency: Platform Threads to Virtual Threads**, you'll parallelize (i.e., perform multiple operations simultaneously) a stream operation so it can take advantage of multi-core architectures to enhance performance—a key goal of lambdas and streams. In Chapter 18, you'll also learn that it's hard to create parallel tasks that operate correctly if those tasks modify a program's state (that is, its variables' values). So, the techniques you'll learn in Chapter 14 focus on immutability—not modifying the data source being processed or any other program state. **Includes 36 genAI prompt exercises.**

Chapter 22, Computer Science Thinking: Recursion, Searching, Sorting, Big O, can be covered here.

Part 5: JavaFX Graphical User Interfaces, Graphics and Multimedia

Chapter 15, JavaFX Graphical User Interfaces: Part 1, begins our multiple-chapter feature on JavaFX graphical user interfaces (GUIs), graphics, multimedia and game-playing. Chapter 15 focuses on developing GUIs, which provide a user-friendly mechanism for interacting with applications. A GUI (pronounced "GOO-ee") gives an application a distinctive "look-and-feel." Providing apps with consistent, intuitive user-interface components gives users a sense of familiarity with a new application so they can learn it faster and use it more productively. This chapter introduces JavaFX GUI basics, including layout, controls and event handlers, which we'll implement using lambdas. You'll use the free

Scene Builder tool to quickly create two GUIs with simple drag-and-drop design techniques. **Includes 13 genAI prompt exercises.**

Chapter 16, JavaFX GUI: Part 2, continues our JavaFX presentation with additional GUI layouts and controls. We show how to handle mouse and `RadioButton` events, set up event handlers that respond to property changes on controls (such as the value of a `Slider`), display shapes, bind variables to controls so the controls update automatically when the variables' data changes, and customize a GUI component's appearance. You'll also use `FileChooser` and `DirectoryChooser` dialogs to conveniently select a file or directory. Chapter 18 shows how to perform long-running tasks in a manner that allows a JavaFX GUI to remain responsive. **Includes 21 genAI prompt exercises.**

Chapter 17, JavaFX Graphics and Multimedia, presents key JavaFX graphics and multimedia capabilities, including:

- Cascading Style Sheets (CSS) for customizing JavaFX nodes' appearance and text fonts—this is based on the same technology used for decades in web development to precisely and elegantly control webpage styling.
- Two-dimensional shapes (lines, rectangles, circles, ellipses, arcs, polylines, polygons and custom paths).
- Transforming JavaFX nodes in various ways, such as translating (moving), rotating and scaling (resizing).
- Displaying videos and controlling their playback (e.g., play and pause).
- Dynamically modifying nodes with `Transition` and `Timeline` animations—these incrementally change property values (such as rotation, size and location) over time.
- Frame-by-frame animations with an `AnimationTimer`.
- CSS transitions for simplifying certain animation effects.
- Canvas for drawing with the mouse.
- Three-dimensional shapes (boxes, cylinders and spheres).

We also introduce **FXGL for JavaFX game development. Includes 31 genAI prompt exercises.**

Part 6: Advanced Topics

Chapter 18, Concurrency: Platform Threads to Virtual Threads, focuses on improving application performance and responsiveness with concurrency and multi-core programming. Chapter 18 is one of the most important chapters in the book, presenting Java's features for building applications that create and manage multiple tasks. We updated the chapter to the latest Java technologies and idioms, especially those of the game-changing Project Loom.

This chapter presents several **multithreading and multi-core systems performance case studies**. In the **Profiling Sequential and Parallel Sorting Algorithms example**, we show how to use prepackaged parallel algorithms to create multithreaded programs that will run faster (often much faster) on today's multi-core computer architectures. For example, we sort 100 million values using a sequential sort then a parallel sort. We use timing operations from Java's Date/Time API to profile the performance improvement we get on today's popular multi-core systems, as we employ more cores. We show that the parallel sort runs 700% faster than the sequential sort on our computer with a 12-CPU-core Apple M2 Max processor. We include a **parallel vs. sequential stream processing** example, again using the Date/Time API to show performance improvements. The **`CompletableFuture`** example demonstrates sequential and parallel execution of long-running calculations.

In the **Producer/Consumer Relationship with `ArrayBlockingQueue` case study**, we discuss the classic producer–consumer relationship and demonstrate how to implement it using the predefined `ArrayBlockingQueue` class. We emphasize that **concurrent programming is difficult to get right, so you should prefer the easier-to-use, less error-prone, higher-level concurrency features**.

We've added coverage of **Project Loom**, which enhances Java's threading model with simpler, lightweight **virtual threads** (finalized in Java 21). These require significantly less memory and processor overhead than Java's traditional platform threads, enabling applications to launch enormous numbers of concurrent virtual threads and helping meet the demands of today's massively parallel applications. Project Loom reduces the complexity of writing concurrent programs, making concurrency easier to use. We also introduce two emerging Project Loom features—structured concurrency and scoped values.[33] **Structured concurrency** enables programmers to treat multiple threads as a single unit of work (a scope), making it easier to manage those threads, handle errors and reclaim resources no longer needed. **Scoped values** simplify data sharing among virtual threads in the same scope, reducing the need for complex thread-synchronization techniques. **Includes 51 genAI prompt exercises.**

Chapter 19, Building API-Based Java Generative AI Applications, includes many cool, fully coded API-based Java generative AI applications—see the Integrated Generative AI section's "Our Chapter 19 API-Based Complete, Live-Code Java GenAI Apps" subsection earlier in this Preface for the complete list. In the preceding chapters, we focused on manually prompting genAIs via their web interfaces and asking you to study, compare and use their results. We did not show the results of our suggested genAI prompts—you observed those in action.

When genAIs were first introduced, they typically received a text prompt and generated a specific type of output, such as text or an image. Many genAIs are now multimodal, enabling them to understand text, images, audio and even video inputs and use them to generate outputs combining text, images, audio and video. For example, you can prompt genAIs with a speech audio file and instructions asking them to transcribe the speech to text, display the transcription, analyze its sentiment (positive, negative or neutral), translate it to another spoken language and synthesize speech in that other language—and even create images and videos from the generated text! These capabilities were out of reach to most developers just a few years ago.

This chapter uses the **Simple-OpenAI open-source library** to enable Java programmers to conveniently interact with OpenAI's APIs to build powerful multimodal Java generative AI applications. You'll observe that prompt engineering is also an essential aspect

33. At the time of this writing, structured concurrency and scoped values were preview features undergoing rapid change. Once they stabilize, we'll present revised live-code examples on our blog at `https://deitel.com/blog`.

of programming with genAI APIs. In the chapter examples and exercises, you'll work with genAIs to build text, speech, code, image and video apps. **Includes 94 genAI prompt and API-based coding exercises.**

Chapter 20, Accessing Databases with JDBC and SQLite, introduces database management systems (DBMSs) for conveniently storing and organizing persistent data. After an overview of database concepts, you'll use the popular open-source **SQLite** database management system's command-line tools to learn **Structured Query Language** (SQL) fundamentals. You'll execute SQL queries live to perform basic CRUD (create, read, update, delete) operations on a SQLite database and immediately see their results. Next, we use **Java's JDBC APIs** to interact programmatically with SQLite databases. JDBC is portable—so the same code we show can manipulate databases in many popular open-source and proprietary database management systems. We demonstrate connecting to databases, executing queries to update databases and retrieve data from them, and displaying query results in JavaFX `TableView`s. The chapter features a JavaFX database-driven address book application demonstrating **prepared statements** for reusable, more secure, parameterized queries. You'll enhance this app with update and delete options in the exercises. Just like genAIs can write Java code for you, they can also write SQL code, as you'll do in this chapter's genAI prompt exercises. **Includes 19 genAI prompt exercises.**

Chapter 21, Java Platform Module System (JPMS), introduces modules, which provide a higher level of aggregation above packages and enable precise organization of your code. By default, modules encapsulate implementation details while allowing you to explicitly control what is exposed to client code. Modules are primarily geared to developers, helping them be more productive as they build, maintain and evolve large software systems. We discuss JPMS's goals then demonstrate creating custom packages and modules, declaring module dependencies, specifying which packages a module explicitly makes available to other modules, and defining the services a module offers or consumes. We also discuss how to control reflective access between modules. Reflection allows programs to inspect and manipulate classes and their members at runtime. For example, JavaFX leverages reflection to bind a program's GUI controls to the Java code that handles user interactions with the controls. **Includes 31 genAI prompt exercises.**

Chapter 22, Computer Science Thinking: Recursion, Searching, Sorting, Big O, introduces some key classic computer science topics. First, we use factorial and Fibonacci calculations to introduce recursive methods that call themselves directly or indirectly. We develop a JavaFX application that creates a custom "feather fractal"—a geometric figure that can be generated from a pattern repeated recursively. Next, we consider several array searching and sorting algorithms and compare their processor demands and memory consumption. We present a friendly introduction to computer science's **Big *O* notation**, which indicates how hard an algorithm may have to work to solve a problem based on the number of items it must process. The chapter includes two **case studies** that **visualize the high-speed binary search and merge sort algorithms** to illustrate how they work. The chapter includes a rich selection of recursion, searching and sorting exercises. You'll attempt some of the classic problems in recursion and implement alternative searching and sorting algorithms. Instructors can present this chapter after Chapter 6 in introductory computer science courses. **Includes 14 genAI prompt exercises.** [Chapter 22 can be covered after Chapter 14.]

Appendices

Appendix A, Introduction to JShell for Interactive Java, provides optional flexible coverage of **JShell**, Java's friendly, command-line REPL (read-evaluate-print-loop) environment that enables you to quickly explore, discover and experiment with Java's language features and libraries—**it's like having Python's interactivity in Java**. Many of this appendix's sections can be covered with the book's early chapters for instructors who'd like to incorporate this capability in their courses from the start.

JShell replaces the cycle of edit-compile-execute cycle with its **read-evaluate-print-loop (REPL)**. Rather than complete programs, you write JShell commands and Java code snippets. When you enter a snippet, JShell immediately

- **reads** it,
- **evaluates** it and
- **prints** (displays) messages that help you see the effects of your code, then it
- **loops** to perform this process again for the next snippet.

The appendix is **example-intensive**—you should do each of the scores of examples and fully solved exercises. You'll see how JShell and its **instant feedback** keep your attention and speed the learning and software-development processes. After you read **Chapter 2** and **Section A.2**, you can do each of the end-of-appendix exercises and immediately check your answers. This will help you master the basics of JShell quickly.

As a student, you'll find JShell easy and fun to use. It will help you learn Java features faster and more deeply and will help you verify that these features work how they're supposed to. As an instructor, you'll appreciate how JShell encourages your students to dig in and how it leverages the learning process. As a professional, you'll appreciate how JShell helps you rapidly prototype key code segments and discover and experiment with new APIs.

Appendix B, Formatted Output, presents formatting features for output and for `Strings` in memory. The appendix summarizes the formatting features discussed throughout the book and introduces additional capabilities.

Appendix C, Number Systems, introduces the binary (base 2), octal (base 8), decimal (base 10) and hexadecimal (base 16) number systems programmers use.

Thinking Like a Developer—GitHub and StackOverflow

The best way to prepare [to be a programmer] is to write programs, and to study great programs that other people have written. In my case, I went to the garbage cans at the Computer Science Center and fished out listings of their operating systems.[34]—William Gates (Microsoft founder)

You'll work with such popular websites as GitHub and StackOverflow and do lots of Internet research.

34. William Gates, quoted in *Programmers at Work: Interviews With 19 Programmers Who Shaped the Computer Industry* by Susan Lammers. Microsoft Press, 1986, p. 83.

- **StackOverflow** is one of the most popular programming question-and-answer sites. Many problems you might encounter have already been discussed here. It's a great place to get your code-oriented questions answered. Many of our Google searches for various, often complex, issues throughout our writing effort returned StackOverflow posts as their first results.
- **GitHub** (now owned by Microsoft[35]) is an excellent venue for finding free, open-source code to explore and incorporate into your projects—and for you to contribute your code to the open-source community if you'd like. Open source is software with source code that anyone can inspect, modify, and enhance."[36] We encourage you to try lots of demos and view free, open-source code examples (available on sites such as GitHub) for inspiration. Over one hundred million developers worldwide use GitHub.[37] The site hosts over 518 million repositories for code in hundreds of programming languages—developers made 5.2 billion contributions to those repositories in 2024.[38] GitHub includes version-control tools that help developers manage public open-source projects and private projects. **There is a massive Java open-source community on GitHub where developers contribute to over 250 thousand Java code repositories.[39] We encourage you to study and execute lots of developers' open-source Java code. This is a great way to learn and is a natural extension of our live-code and objects-natural teaching approaches enhanced with generative AI.[40]**

Computing and Data Science Curricula

This book is designed for courses that adhere to one or more of the following ACM/IEEE CS-and-related curricula, which call for covering security, data science, ethics, privacy and performance concepts and using real-world data:

- Computer Science Curricula 2023,[41]
- Information Systems 2020,[42]

35. Microsoft, "Microsoft to Acquire GitHub for $7.5 Billion," Microsoft News, June 4, 2018. Accessed January 29, 2025. `https://news.microsoft.com/2018/06/04/microsoft-to-acquire-github-for-7-5-billion/`.
36. "What is open source?" Accessed January 18, 2025. `https://opensource.com/resources/what-open-source`.
37. "Let's build from here: The complete developer platform to build, scale, and deliver secure software." Accessed January 18, 2025. `https://github.com/about`.
38. "Octoverse 2024: The state of open source software." Accessed January 18, 2025. `https://octoverse.github.com/`.
39. "Java." Accessed January 18, 2025. `https://github.com/topics/java`.
40. You'll need to become familiar with the variety of open-source licenses for software on GitHub.
41. ACM/IEEE (Assoc. Comput. Mach./Inst. Electr. Electron. Eng.). 2023. *Computer Science Curricula 2023* (New York: ACM). Accessed January 18, 2025. `https://csed.acm.org/wp-content/uploads/2023/03/Version-Beta-v2.pdf`.
42. Association for Computing Machinery (ACM) and Association for Information Systems (AIS), Information Systems 2020 (IS2020): A Competency Model for Undergraduate Programs in Information Systems (2020), `https://www.acm.org/binaries/content/assets/education/curricula-recommendations/is2020.pdf`.

- CC2020: A Vision on Computing Curricula,[43]
- Computing Curricula 2020 recommendations,[44]
- Information Technology Curricula 2017,[45]
- Cybersecurity Curricula 2017,[46]
- the 2016 data science initiative "Curriculum Guidelines for Undergraduate Programs in Data Science"[47] from the faculty group sponsored by the NSF and the Institute for Advanced Study, and
- ACM Data Science Task Force's *Computing Competencies for Undergraduate Data Science Curricula Final Report*.[48]

Computing Curricula

- According to "CC2020: A Vision on Computing Curricula,"[49] the curriculum "needs to be reviewed and updated to include the new and emerging areas of computing such as **cybersecurity** and **data science**."

Data Science Overlaps with Computer Science[50]

The ACM Data Science Task Force's *Computing Competencies for Undergraduate Data Science Curricula*[51] include algorithm development, programming, computational thinking, data structures, database, mathematics, statistical thinking, machine learning, data science and more—a significant overlap with computer science, especially given that the data science courses include key AI topics. We include basic data science concepts in various examples, exercises, projects and case studies throughout the book.

43. A. Clear, A. Parrish, G. van der Veer and M. Zhang "CC2020: A Vision on Computing Curricula." Accessed January 18, 2025. `https://dl.acm.org/doi/10.1145/3017680.3017690`.
44. CC2020 Task Force, *Computing Curricula 2020*. Accessed January 18, 2025. `https://www.acm.org/binaries/content/assets/education/curricula-recommendations/cc2020.pdf`.
45. *Information Technology Curricula 2017*. Accessed January 18, 2025. `https://www.acm.org/binaries/content/assets/education/curricula-recommendations/it2017.pdf`.
46. *Cybersecurity Curricula 2017*. Accessed January 18, 2025. `https://cybered.hosting.acm.org/wp-content/uploads/2018/02/newcover_csec2017.pdf`.
47. *Computing Competencies for Undergraduate Data Science Curricula*, ACM Data Science Task Force, January 2021. Accessed January 20, 2025. `https://www.acm.org/binaries/content/assets/education/curricula-recommendations/dstf_ccdsc2021.pdf`.
48. ACM Data Science Task Force, *Computing Competencies for Undergraduate Data Science Curricula*. January 2021. Accessed January 22, 2025. `https://dstf.acm.org/DSTF_Final_Report.pdf`.
49. A. Clear, A. Parrish, G. van der Veer and M. Zhang, "CC2020: A Vision on Computing Curricula," `https://dl.acm.org/citation.cfm?id=3017690`.
50. This section is intended primarily for data science instructors but also includes important information for computer science instructors.
51. ACM Data Science Task Force, *Computing Competencies for Undergraduate Data Science Curricula*. January 2021. Accessed January 22, 2025. `https://dstf.acm.org/DSTF_Final_Report.pdf`.

Key Points from the Data Science Undergraduate Curriculum Proposal[52]

We cover each of the following:

- Learn programming fundamentals commonly presented in computer science courses, including working with data structures.
- Be able to solve problems by creating algorithms.
- Work with procedural, functional and object-oriented programming.
- Explore concepts via simulations.
- Use development environments.
- Work with real-world data in practical case studies and projects.
- Work with existing software.
- Work with high-performance tools, such as Java's multithreading libraries.
- Focus on data's ethics, security and privacy issues.

We present and use **data science topics** in several examples and exercises. We use **generative AI** extensively via prompt engineering throughout the book and via API-based programming in Chapter 19.

Deitel.com and the Deitel Blog

On the textbook's webpage at `https://deitel.com/jhtp12`, we provide:

- The book's reviewer testimonials.
- A link to the book's GitHub repository, where you can download the example code.
- Book updates.

For more information about downloading the code examples and setting up your Java development environment, see the Before You Begin section that follows this Preface. When we create Java-related blog posts at

```
https://deitel.com/blog
```

we'll also link each to the book's webpage at `https://deitel.com/jhtp12`.

Instructor Supplements

The following supplements are available to qualified instructors:

- **Lecture PowerPoint slides** containing diagrams, tables and bulleted items summarizing key points in the text.
- The **Instructor Solutions Manual** contains solutions to many of the end-of-chapter exercises. Solutions are not provided for "project" exercises.
- A **Test Item File** containing four-part multiple-choice assessment questions and answers.

52. "Appendix—Detailed Courses for a Proposed Data Science Major," Accessed March 7, 2025. `https://www.annualreviews.org/content/journals/10.1146/annurev-statistics-060116-053930#supplementary_data`. (You must now click the **Supplemental Appendix** link at this site.)

If you're teaching from the book's **Pearson+ eText** or **Pearson Revel** versions, the download links for these resources are located in the instructor interface's Resources tab. If you're using one of the book's other e-book formats, you can access the resources at

```
https://pearsonhighered.com
```

Log into your instructor account, then enter the book's title in the search interface to find the book's Pearson webpage containing the download links.

The lecture slides do not include the source code—the files[53] for the hundreds of live-code examples are available to instructors and students in the book's GitHub repository at

```
https://github.com/pdeitel/JavaHowToProgram12e
```

See the Before You Begin section for download and installation instructions.

Please do not write to us requesting access to the Pearson Instructor's Resource Center. Access is restricted to college instructors who have adopted the book for their courses. Instructors may obtain access only through their Pearson representatives. If you're not a registered faculty member, contact your Pearson representative or visit

```
https://pearson.com/replocator
```

Software Used in *Java How to Program, 12/e*

Most of the software you'll need for this book is free for download, though the code examples in **Chapter 19, Building API-Based Java Generative AI Applications**, use paid web services. See the **Before You Begin** section following this Preface for download links. We wrote the Java code examples using the free OpenJDK on macOS and Windows. We developed a utility class used by Chapter 19's examples in the free JetBrains IntelliJ IDEA Community Edition integrated development environment (IDE).

Java Documentation Links

The book includes abundant citations to research papers, articles, white papers, videos, blog posts, online documentation and more that we studied while writing the manuscript. You may want to access some of these resources for additional information and insights. The latest Java versions' documentation are available at:

```
https://docs.oracle.com/en/java/javase/index.html
```

We reference the API documentation frequently so you can get more details about the Java API capabilities we use:

```
https://docs.oracle.com/en/java/javase/23/docs/api/index.html
```

As new Java versions are released, you can access their API documentation by replacing 23 in the preceding link with the new version number (24, 25, etc.).

We also frequently cite the latest Java SE (Standard Edition) Specification, which is available in both HTML and PDF forms at:

```
https://docs.oracle.com/javase/specs/
```

53. We recommend instructors present source code in their favorite Java integrated development environment (IDE) or code-oriented text editor. These typically provide customizable syntax highlighting and adjustable font sizes for presentation purposes.

You can keep track of future changes at:

`https://openjdk.org/projects/jdk/`

Getting Your Questions Answered

Popular Java and general programming online forums include

- `https://stackoverflow.com`
- `https://www.reddit.com/r/java/`
- `https://dev.to/t/java`

Also, vendors often provide forums for their tools and libraries. Many libraries are managed and maintained at `https://github.com`. Some library maintainers offer support through the Issues tab on a given library's GitHub page.

Generative AIs

You can conveniently ask genAIs programming and Java questions and get immediate responses. We recommend that you ask multiple genAIs and compare the results. Keep in mind that genAIs sometimes make mistakes and even hallucinate, so you should verify the results with additional online searches. We experienced these problems many times as we developed this manuscript.

Communicating with the Authors

As you read the book, if you have questions, we're easy to reach at

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We'll respond promptly.

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Java How to Program: An Objects-Natural Approach, 12/e, is available in digital formats:

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Acknowledgments

We’d like to thank Barbara Deitel for the long hours devoted to technical research on this project. We’re fortunate to have worked with Pearson’s dedicated team of publishing professionals. We appreciate the guidance, wisdom and energy of Tracy Johnson, Manager, Commercial Product & Content Strategy Computer Science. Tracy and her team handle all of our academic textbooks. Erin Sullivan and Jackleen Sougrakpam recruited the book’s academic and professional reviewers, respectively, and managed the review process. Bob Engelhardt and Rajinder Singh managed the production of the book’s suite of digital versions. Ashley Santora, Kaitlyn Coddington and Jenell Forschler helped us determine which genAIs in general and which genAI outputs in particular were acceptable to our publisher, Pearson Education, from a permissions perspective. We selected the cover art, and Chuti Prasertsith designed the cover. Jessica Deitel contributed design insights to the cover layout.

Reviewers

We wish to acknowledge the efforts of our recent editions reviewers—distinguished academics, Oracle Java team members, Oracle Java Champions and other industry professionals. They scrutinized the text and the programs and provided countless suggestions for improving the presentation. Any remaining faults in the book are our own.

We appreciate the guidance of JavaFX experts Johan Vos and Carl Dea—and on previous editions, Jim Weaver, Jonathan Giles and Simon Ritter—on the three JavaFX chapters.

Twelfth Edition Academic and Professional Reviewers:

- Brian Canada (Professor of Computational Science, University of South Carolina Beaufort).
- Bob Myers (Computer Science Department, Florida State University).
- Emily Navarro (Continuing Lecturer, Department of Informatics, University of California, Irvine).

- Jeanne Boyarsky (CodeRanch, Java Champion, co-author of the *OCP Oracle Certified Professional Java SE 21 Developer Study Guide*).
- Carl Dea (Lead Software Developer at a global business consulting and services company, co-author *JavaFX 9 by Example*).
- Trisha Gee (Java Champion).
- Simon Roberts (President, Dancing Cloud Services, LLC).
- José Antonio González Seco (Parliament of Andalusia, Spain).
- Ron Veen (Java Developer, Special Agent at Team Rockstars IT) and David Vlijmincx (Senior Software Developer, JPoint), co-authors of *Virtual Threads, Structured Concurrency, and Scoped Values: Explore Java's New Threading Model*, and *Cloud-Native Development and Migration to Jakarta EE*.
- Johan Vos (Co-founder and CTO, Cloud Products at Gluon, Java Champion, co-author *The Definitive Guide to Modern Java Clients with JavaFX: Cross-Platform Mobile and Cloud Development Updated for JavaFX 21 and 23*).

For a list of *Java How to Program*'s previous editions' reviewers, visit

`https://deitel.com/jhtp12`

A Special Thank You to Brian Goetz

Brian Goetz, Oracle's Java Language Architect and co-author of *Java Concurrency in Practice*, did a full-book review of the 10th edition. He provided us with insights and constructive comments. For the 11th edition, he did a detailed review of our new JShell chapter and answered our Java questions throughout the project.

A Special Thank You to Robert Field

Robert Field, Oracle's JShell Architect reviewed the JShell chapter while the tool was under development, responding to our numerous emails in which we asked questions, reported bugs we encountered and suggested improvements. Having our content scrutinized by the person responsible for JShell and seeing some of our suggestions incorporated into the product was a privilege.

Google Search

Thanks to Google, whose search engine answers our constant stream of queries, each in a fraction of a second, at any time—and at no charge. It's one of the best productivity enhancement tools we've added to our research process in the last 20 years.

Grammarly

We use the paid version of Grammarly on all our manuscripts. They describe their tools as an "AI-powered writing partner."[54] Grammarly also provides free tools that you can integrate into several popular web browsers, Microsoft® Office 365™ and Google Docs™.

Generative AIs

Throughout the book-development process we used the paid versions of **OpenAI's ChatGPT**, **Google's Gemini** and **Anthropic's Claude**, and the free version of **Perplexity** to research new Java topics, verify facts, check our code for the latest Java idioms, suggest

54. "Grammarly." Accessed January 18, 2025. `https://grammarly.com`.

enhancements, ensure thorough coverage and more. Much of what we learned as we used them is reflected in the Generative AI prompting exercises integrated throughout the book and the API-based coding exercises in Chapter 19.

Oracle, Gluon and the OpenJFX Community

Thanks to Oracle Corporation, Gluon and the OpenJFX Community, which collaborate on JavaFX's evolution, releasing a new JavaFX version with each new Java version. Also, thanks to Gluon for their friendly and convenient drag-and-drop Scene Builder GUI development tool.

Welcome to the exciting world of Java programming enhanced with generative AI. We've enjoyed writing 12 editions of our academic and professional Java content over the last 30 years. We hope you have an informative, challenging and entertaining learning experience with ***Java How to Program: An Objects-Natural Approach, 12/e*** and enjoy this look at modern Java software development.

As you read the book and work through the code examples, we'd appreciate your comments, criticisms, corrections and suggestions for improvement. Please send all correspondence, including questions, to

`deitel@deitel.com`

We'll respond promptly. Our best wishes for your success,

Paul Deitel
Harvey Deitel

About the Authors

Paul J. Deitel, CEO and Chief Technical Officer of Deitel & Associates, Inc., is a graduate of MIT with over 44 years of experience in computing. He holds the Java Certified Programmer and Java Certified Developer designations and is an Oracle Java Champion. He is one of the world's most experienced programming-languages trainers, having taught professional courses to software developers since 1992. His video courses on platforms like O'Reilly Online Learning have garnered millions of views, with his Java Fundamentals LiveLessons, Python Fundamentals LiveLessons and C# Fundamentals LiveLessons each ranking #1 at various times among thousands of video products. He has delivered hundreds of programming courses to academic, industry, government and military clients of Deitel & Associates, Inc. internationally, including UCLA, SLB (formerly Schlumberger), IBM, Siemens, Sun Microsystems (now Oracle), Dell, Fidelity, NASA at the Kennedy Space Center, the National Severe Storm Laboratory, White Sands Missile Range, Rogue Wave Software, Boeing, Cisco, Puma, iRobot and many more. He and his co-author, Dr. Harvey M. Deitel, are among the world's best-selling programming-language textbook/professional book/video/interactive multimedia authors.

Dr. Harvey M. Deitel, Chairman and Chief Strategy Officer of Deitel & Associates, Inc., has over 64 years of experience in computing. Dr. Deitel earned B.S. and M.S. degrees in Electrical Engineering from MIT and a Ph.D. in Mathematics from Boston University—he studied computing in each of these programs before they spun off Computer Science programs. He has extensive college teaching experience, including earning tenure and serving as the Chairman of the Computer Science Department at Boston College before founding Deitel & Associates in 1991 with his son, Paul. The Deitels' publications have earned international recognition, with more than 100 translations published in Japanese, German, Russian, Spanish, French, Polish, Italian, Simplified Chinese, Traditional Chinese, Korean, Portuguese, Greek, Urdu and Turkish. Dr. Deitel has delivered hundreds of programming courses to academic, corporate, government and military clients.

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