

MATH COUNTS

Peter B.
Henderson

Programming and Mathematical Thinking

Editor's Note:
Peter B. Henderson and
Allan M. Stavely
co-authored this column.

OUR GUEST CONTRIBUTOR for this Math Counts column is Allan Stavely, who recently wrote *Programming and Mathematical Thinking: A Gentle Introduction Featuring Python* [2], which will be available in early 2014. In this column, Allan gives his motivation for writing this book, shares his insights on the role mathematics can play in the curricula, and provides some guidelines for achieving these goals.

I'd like to second a statement that the editor of this column made previously, but push it farther, in his September 2013 column Dr. Henderson, speaking of the current state of mathematics in undergraduate computer science, said:

The mathematical foundation concepts are not used or reinforced effectively in most computer science courses, the relevant connections between these mathematical concepts and the fundamental concepts of computer science are not made, and the importance of mathematics as a tool for reasoning, problem solving and analysis, and solution verification are lost for many students.

To the last point, I would add: the importance of discrete-mathematics struc-

tures in day-to-day programming is lost for many students.

The courses in my department have long followed a familiar pattern: introductory programming in the first semester, data structures and algorithms in the second semester, and a discrete mathematics course in the second year as a prerequisite to several courses in the third and fourth year. Many of my students never saw the point of the discrete math course at the time they were taking it; students call the course "Weird Math." Courses like the third-year analysis-of-algorithms and formal-languages-and-automata courses would use discrete-math structures, of course, so that when the students hit my fourth-year compiler-writing course they could cope with the sets and trees and directed graphs used in compiler writing. However, I suspect that many of the students left the course thinking that discrete structures are used only in such advanced and exotic computer science topics.

On the contrary, I claim that concepts of discrete mathematics are enormously useful in even the most basic kinds of programming. Let me quote from a forthcoming textbook of mine. The example is adapted from my book *Toward Zero-Defect Programming* [3].

Many experienced programmers approach the design of a program by describing its input, output, and internal data objects in the vocabulary of discrete mathematics: sets, sequences, mappings, relations, and so on. This is a useful habit

for us, as programmers, to cultivate. It can help to clarify our thinking about design problems; in fact, solutions often become obvious. And we inherit a well-understood vocabulary for specifying and documenting our programs and for discussing them with other programmers.

For example, consider this simple programming problem. Suppose that we are writing software to analyze web pages, and we want some code that will read two web pages and find all of the URLs that appear in both. Some programmers might approach the problem like this:

First I'll read the first web page and store all the URLs I find in a list.
Then I'll read the second web page and, every time I find a URL, search the list for it. But wait: I don't want to include the same URL in my result more than once. I'll keep a second list of the URLs that I've already found in both web pages, and search that before I search the list of URLs from the first web page.

But a programmer who is accustomed to thinking in terms of discrete-mathematical structures might immediately think of a different approach:

The URLs in a web page are a set. I'll read each web page and build up the set of URLs in each using set insertion. Then I can get the URLs common to both web pages by using set intersection.

Either approach will work, but the second is conceptually simpler and it will probably be more straightforward to implement. In fact, once the problem is described in mathematical terms, most of the design work is already done.

Programmers can exploit the properties of sets and relations and other discrete structures in their work even before they study those structures formally and learn how to construct proofs using them. Beginning computer science students can often do their work more skillfully and professionally, as in the example above, if they think in terms of the discrete structures when formulating designs. So can programming students who aren't computer science majors.

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Table of Contents Programming And Mathematical Thinking

1. Understanding the eBook Programming And Mathematical Thinking
 - The Rise of Digital Reading Programming And Mathematical Thinking
 - Advantages of eBooks Over Traditional Books
2. Identifying Programming And Mathematical Thinking
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Programming And Mathematical Thinking
 - User-Friendly Interface
4. Exploring eBook Recommendations from Programming And Mathematical Thinking
 - Personalized Recommendations
 - Programming And Mathematical Thinking User Reviews and Ratings
 - Programming And Mathematical Thinking and Bestseller Lists
5. Accessing Programming And Mathematical Thinking Free and Paid eBooks
 - Programming And Mathematical Thinking Public Domain eBooks
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 - Programming And Mathematical Thinking Budget-Friendly Options
6. Navigating Programming And Mathematical Thinking eBook Formats
 - ePub, PDF, MOBI, and More
 - Programming And Mathematical Thinking Compatibility with Devices
 - Programming And Mathematical Thinking Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Programming And Mathematical Thinking
 - Highlighting and Note-Taking Programming And Mathematical Thinking
 - Interactive Elements Programming And Mathematical Thinking

8. Staying Engaged with Programming And Mathematical Thinking
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Programming And Mathematical Thinking
9. Balancing eBooks and Physical Books Programming And Mathematical Thinking
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Programming And Mathematical Thinking
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Programming And Mathematical Thinking
 - Setting Reading Goals Programming And Mathematical Thinking
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Programming And Mathematical Thinking
 - Fact-Checking eBook Content of Programming And Mathematical Thinking
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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