LEC 04

CSE 122

Stacks & Queues

BEFORE WE START

Talk to your neighbors:

Dogs or cats?

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Questions during Class?

Raise hand or send here

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Lecture Outline

- Announcements ◀
- Review: ADTs, Stacks & Queues
- Queue Manipulation
- Stack Manipulation
- Problem Solving

Announcements

- Quiz 0 next Monday (July 10th)
- Resub 0 (R0) due tonight
  - P0 grades will be released today, so you technically can resubmit
- Creative Project (C0) due tomorrow
- Programming Assignment 1 (P1) will be released Friday
  - It will be due next Thursday (July 13)

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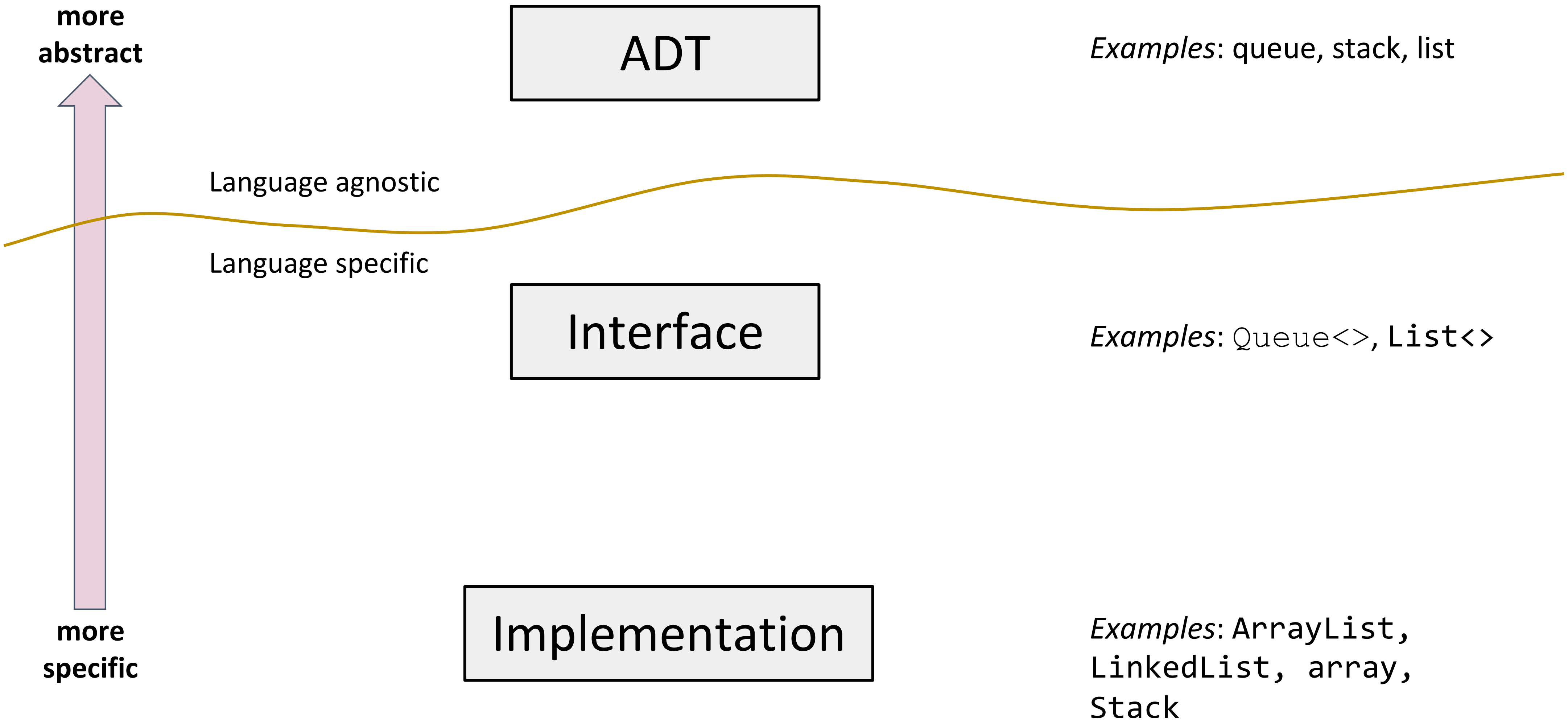
(PCM) Abstract Data Types

- **Abstract Data Type (ADT)**: A specification of a collection of data and the operations that can be performed on it.
  - Describes *what* a collection does, not *how* it does it

- We don't know exactly how a stack or queue is implemented, and we don't need to!
  - Only need to understand high-level idea of what a collection does and its operations in order to use them

  - **Stack:** retrieves elements in reverse order as added.
    Operations: push, pop, peek, …
  - **Queue:** retrieves elements in same order as added.
    Operations: add, remove, peek, …

(PCM) Abstract Data Types



more abstract

ADT

Examples: queue, stack, list

Language agnostic

Language specific

Interface

Examples: `Queue<>`, `List<>`

more specific

Implementation

Examples: `ArrayList`, `LinkedList`, `array`, `Stack`

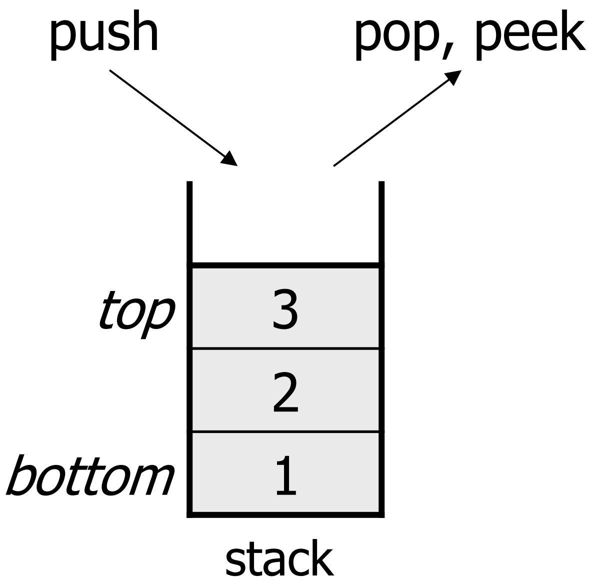
Stack - What is it good for?

What is it?

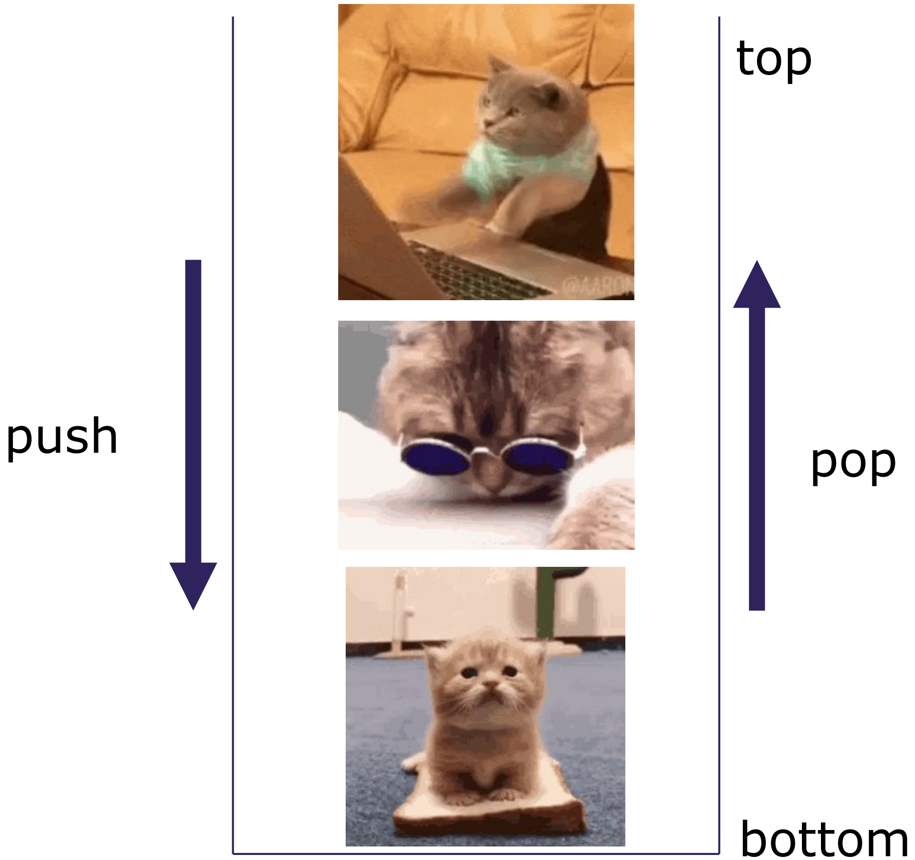
- A **Last**-in-First-out (LIFO) data structure
    - Elements are removed in the **reverse order** to how they were added
- All elements must be of same type*
- Dynamically sized

What is Stack particularly good at?

- `push` - add element to top
- `pop` - remove element from top
- Supported operations are few but *very efficient*



(PCM) Stacks



top

push

pop

bottom

Stacks in Computer Science

- Programming languages and compilers:
  - method calls are placed onto a stack (*call=push, return=pop*)
  - compilers use stacks to evaluate expressions
- Matching up related pairs of things:
  - find out whether a string is a palindrome
  - examine a file to see if its braces { } match
  - convert "infix" expressions to pre/postfix
- Sophisticated algorithms:
  - searching through a maze with "backtracking”
  - many programs use an "undo stack" of previous operations

(PCM) Programming with Stacks

`Stack<`**E**`>()`	constructs a new stack with elements of type **E**
`push(`**value**`)`	places given value on top of stack
`pop()`	removes top value from stack and returns it; throws `EmptyStackException` if stack is empty
`peek()`	returns top value from stack without removing it; throws `EmptyStackException` if stack is empty
`size()`	returns number of elements in stack
`isEmpty()`	returns `true` if stack has no elements

```
Stack<String> s = new Stack<String>();
s.push("a");
s.push("b");
s.push("c");                  // bottom ["a", "b", "c"] top
System.out.println(s.pop()); // "c"
```

- `Stack` has other methods that we will ask you not to use

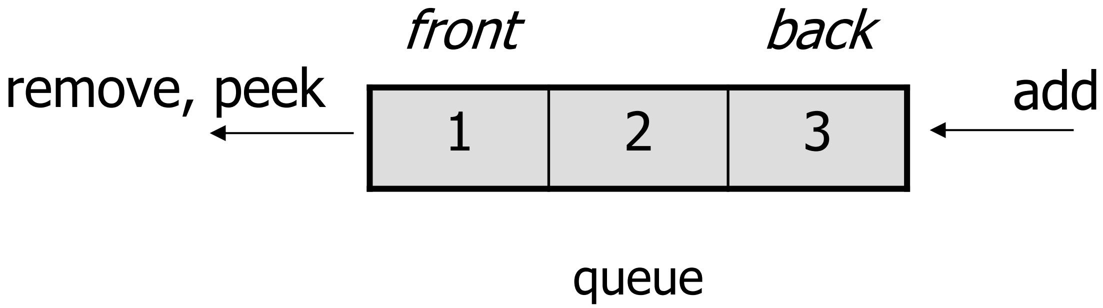
Queue - What is it good for?

What is it?

- A **First**-in-First-out (FIFO) data structure
  - Elements are removed in the **same order** to how they were added
- All elements must be of same type*
- Dynamically sized

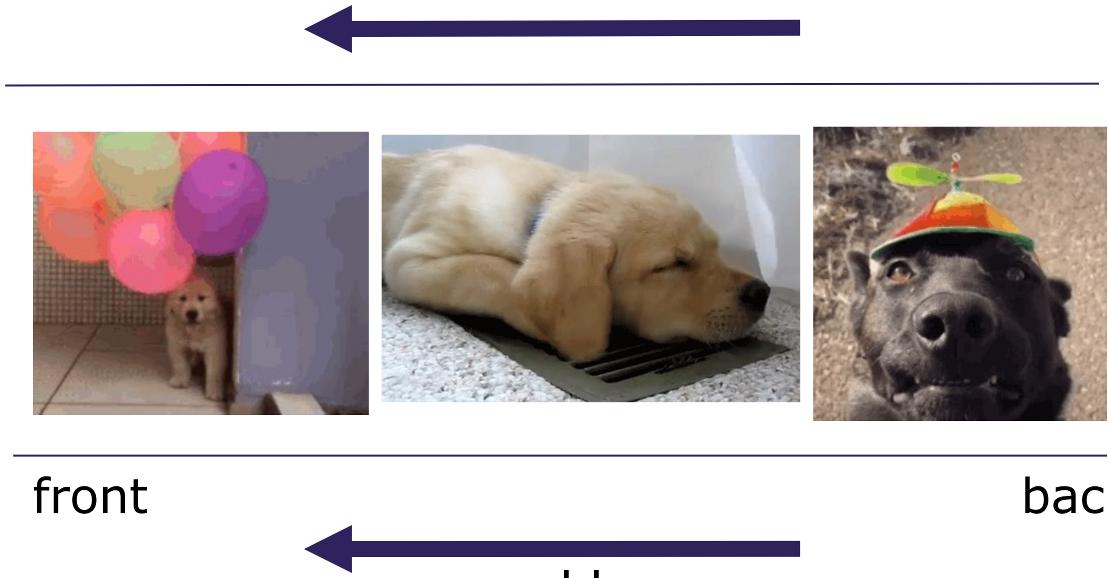
What is Queue particularly good at?

- `add` - add element to back
- `remove` - remove element from front
- Supported operations are few but *very efficient*



(PCM) Queue

remove



front

back

add

Queues in Computer Science

- Operating systems:
  - queue of print jobs to send to the printer
  - queue of programs / processes to be run
  - queue of network data packets to send

- Programming:
  - modeling a line of customers or clients
  - storing a queue of computations to be performed in order

- Real world examples:
  - people on an escalator or waiting in a line
  - cars at a gas station (or on an assembly line)

(PCM) Programming with Queues

`add(`**`value`**`)`	places given value at back of queue
`remove()`	removes value from front of queue and returns it; throws a `NoSuchElementException` if queue is empty
`peek()`	returns front value from queue without removing it; returns `null` if queue is empty
`size()`	returns number of elements in queue
`isEmpty()`	returns `true` if queue has no elements

```
Queue<Integer> q = new LinkedList<Integer>();
q.add(42);
q.add(-3);
q.add(17);          // front [42, -3, 17] back

System.out.println(q.remove());    // 42
```

- **IMPORTANT**: When constructing a queue you must use a new `LinkedList` object instead of a new `Queue` object.

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- **Queue Manipulation** ◀
- Stack Manipulation
- Problem Solving

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Practice : Think

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What is the return of this method?

```
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;
        numbers.push(number);
    }

    return total;
}
```

A) 0

B) 1

C) 5

D)15

E) 25

F) Throws an error

Practice : Pair

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What is the return of this method?

```java
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;
        numbers.push(number);
    }

    return total;
}
```

A) 0

B) 1

C) 5

D)15

E) 25

F) Throws an error

Practice : Think

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What is the return of this method?

```
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    Queue<Integer> q = new LinkedList<>();

    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;

        q.add(number);
    }

    return total;
}
```

A) 0
B) 1
C) 5
D) 12
E) 15
F) Throws an error

Practice : Pair

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What is the return of this method?

```
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    Queue<Integer> q = new LinkedList<>();

    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;

        q.add(number);
    }

    return total;
}
```

A) 0
B) 1
C) 5
D) 12
E) 15
F) Throws an error

Stack Sum bug

```java
// numbers: bottom [1, 2, 3, 4, 5] top
public static int sum(Stack<Integer> numbers) {
    Queue<Integer> q = new LinkedList<>();

    int total = 0;
    for (int i = 0; i < numbers.size(); i++) {
        int number = numbers.pop();
        total += number;

        q.add(number);
    }

    // Still need to move back to the stack!
    return total;
}
```

Loop Table

i	total	numbers	numbers.size()
0	5	[4, 3, 2, 1]	
1	9	[3, 2, 1]	4
2	12	[2, 1]	3
3			2

Exit the loop!!

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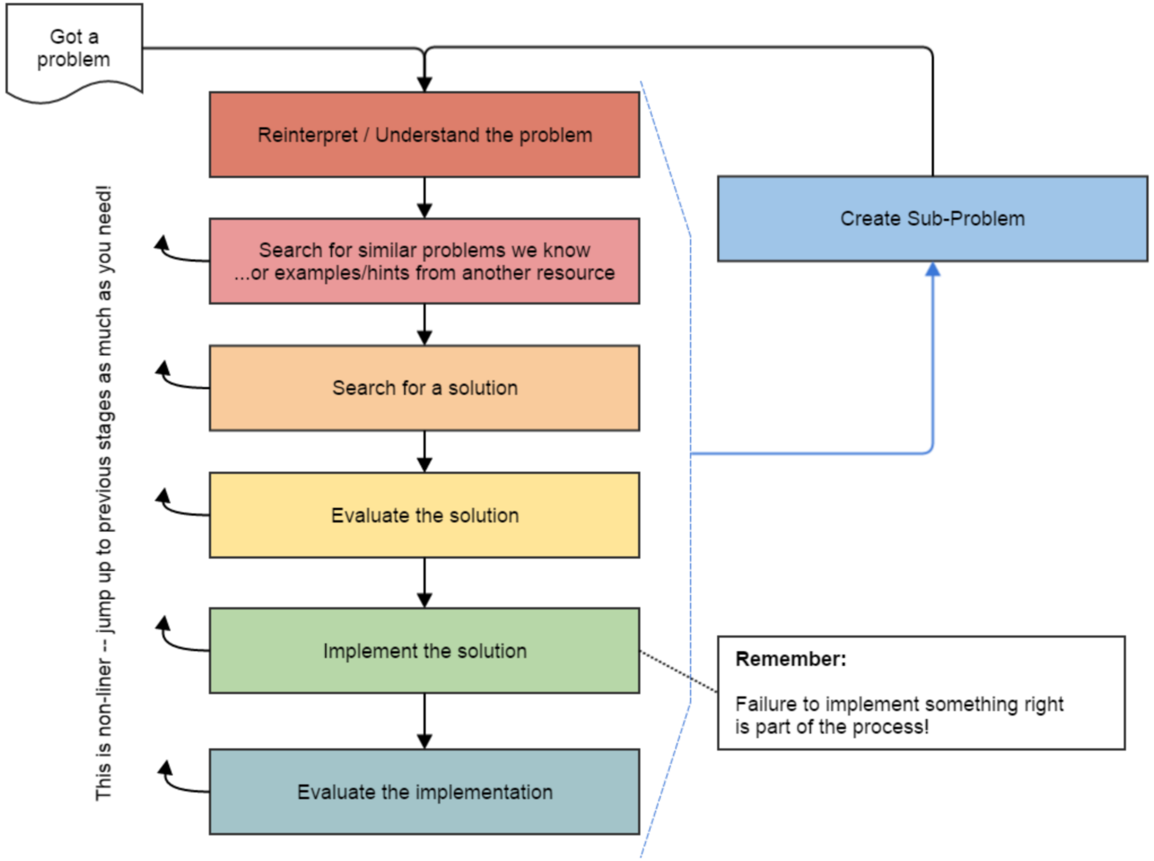
- **Problem Solving** ◀

Problem Solving

- On their own, Stacks & Queues are quite simple with practice (few methods, simple model)
- Some of the problems we ask are complex *because* the tools you have to solve them are restrictive
  - sum(Stack) is hard with a Queue as the auxiliary structure
- We challenge you on purpose here to practice **problem solving**


Got a problem
Reinterpret / Understand the problem
Search for similar problems we know ...or examples/hints from another resource
Search for a solution
Evaluate the solution
Implement the solution
Evaluate the implementation
Create Sub-Problem
This is non-liner -- jump up to previous stages as much as you need!
Remember:
Failure to implement something right is part of the process!

Source: Oleson, Ko (2016) - Programming, Problem Solving, and Self-Awareness: Effects of Explicit Guidance

Common Problem-Solving Strategies

- **Analogy** – Is this similar to a problem you've seen?
  - sum(Stack) is probably a lot like sum(Queue), start there!
- **Brainstorming** – Consider steps to solve problem before writing code
  - Try to do an example "by hand" → outline steps
- **Solve Sub-Problems** – Is there a smaller part of the problem to solve?
  - Move to queue first
- **Debugging** – Does your solution behave correctly on the example input.
  - Test on input from specification
  - Test edge cases ("What if the Stack is empty?")
- **Iterative Development** – Can we start by solving a different problem that is easier?
  - Just looping over a queue and printing elements

Common Stack & Queue Patterns

- Stack → Queue and Queue → Stack
  - We give you helper methods for this on problems
- Reverse a Stack with a S→Q + Q→S
- “Cycling” a queue: Inspect each element by repeatedly removing and adding to back `size` times
  - Careful: Watch your loop bounds when queue’s size changes
- A ”splitting” loop that moves some values to the Stack and others to the Queue

See you Friday!

- Practice with Stacks & Queues in Section
- Quiz on Monday (July 10th)
- Challenge problem in lecture on Friday
- P1, released Friday, will use Stacks & Queues
- Remember to do the PCM for Friday!