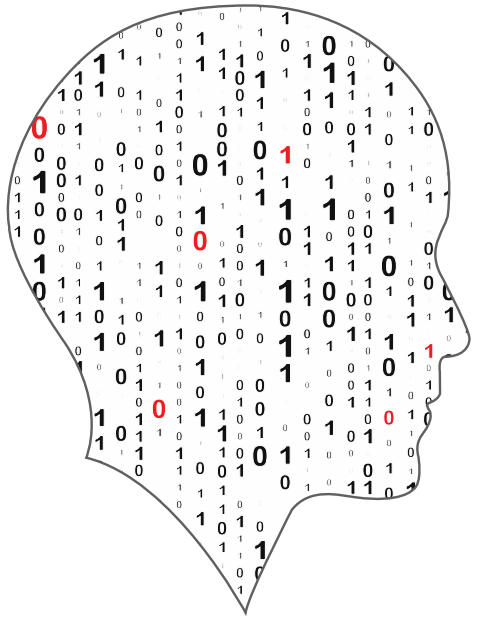
PDST
Professional Development Service for Teachers
An tSeirbhís um Fhorbairt Ghairmiúil do Mhúinteoirí

An Roinn Oideachais agus Scileanna
Department of Education and Skills

National Workshop 5



LEAVING CERTIFICATE
COMPUTER SCIENCE

Session Schedule

Section 1	*Critical Reflection: Who am I to teach?*
Section 2	*Introduction to Algorithms*
Section 3	*Searching and Sorting Algorithms*
Section 4	*Analysis of Algorithms*
Section 5	*Final Reflection*

By the end of this session participants will have:

- participated in an interactive dialogue on critical reflection and algorithmic bias.
- developed their understanding of rule-based algorithms and explored the ubiquitious nature of algorithms in today's society.
- explained, through demonstration, the opertation of a variety of searching and sorting algorithms.
- used an analysis framework to compare the time complexity of the aforementioned algorithms and in doing so deepened their understanding of these algorithms.
- reflected on ideas to facilitate the effective learning of algorithms in their own classrooms.

Section I
Critial Reflection: *Who am I to teach?*

IMPROVING GENDER BALANCE

Girls

according to 15 and 16 Year old girls

CASTeL | DCU | IOP Institute of Physics In Ireland | Science Foundation Ireland sfi For what's next

IMPROVING GENDER BALANCE

Boys

according to 15 and 16 year old girls

CASTeL | DCU | IOP Institute of Physics In Ireland | Science Foundation Ireland sfi For what's next

A builder, leaning out of the van, shouts “nice legs” to a nurse passing by. The same nurse arrives at work, and casually mentions this to a senior doctor. The doctor said,” I’d never say that”. The doctor has two grown up children who are 22 and 30. They get on very well. One is a Sergeant in the Army; the other is training to be a beauty therapist. The doctor divorced last year and is currently dating someone else.

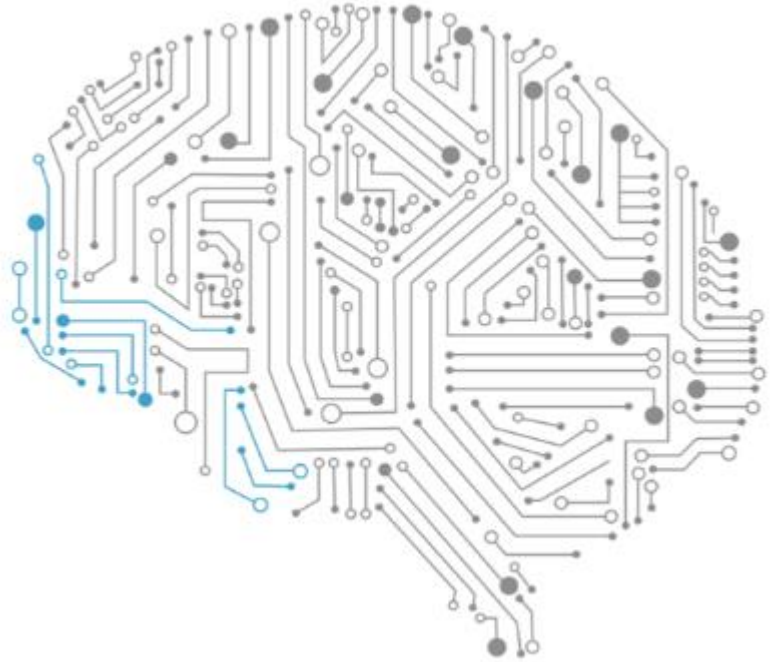
Complete the quiz

	True	False	Don't know
The builder was driving a van			✓
The van was travelling quicker than the nurse			✓
There was at least one man in the van			✓
Not every man mentioned would shout "nice legs"			✓
The doctor is no longer living with his wife			✓
The doctor has a new girlfriend			✓
The doctor's son is in the army			✓
The youngest child is training to be a beauty therapist			✓
At some point a man spoke to a woman			✓
At least two of the people mentioned are men			✓
A woman was shouted at			✓

What is Unconscious Bias?

- Natural
- Rapid categorization of people
- Created by social influence
- Unintentional
- Used by everyone
- Most likely to be acted on when we are stressed or tired
- A bad thinking habit

What does Unconscious Bias have to do with Algorithms?



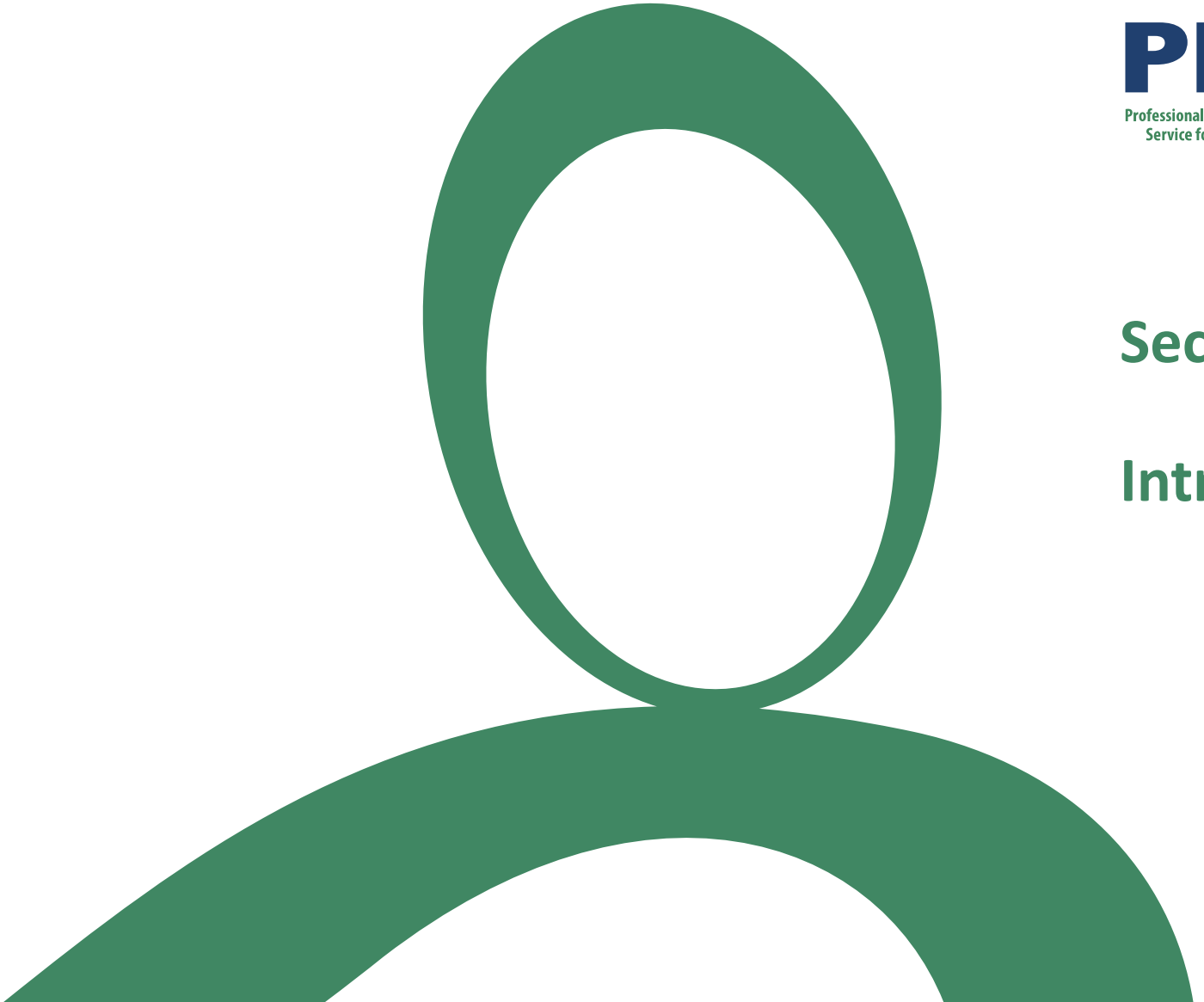
"some of the biggest problems in the industry aren't technical – they're people (egos etc.) …. diversity creates better solutions and opportunities because of wider experience set, perspectives and **less bias …**

James Whelton, CoderDojo Co-Founder

What does Unconscious Bias have to do with YOU?

Personal Reflection

What are my values as a teacher?



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Section II

Introduction to Algorithms

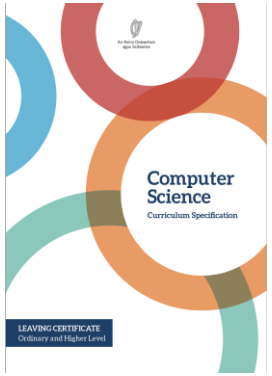
Algorithms and the Specification

"The core concepts are developed theoretically and applied practically. In this way, conceptual classroom-based learning is intertwined with experimental computer lab-based learning throughout the two years of the course."

NCCA Curriculum specification, Page 20

Strand 1: Practices and principles	Strand 2: Core concepts	Strand 3: Computer science in practice
▸ Computers and society ▸ Computational thinking ▸ Design and development	▸ Abstraction ▸ Algorithms ▸ Computer systems ▸ Data ▸ Evaluation/Testing	▸ Applied learning task 1 - Interactive information systems ▸ Applied learning task 2 - Analytics ▸ Applied learning task 3 - Modelling and simulation ▸ Applied learning task 4 - Embedded systems

LCCS Learning Outcomes



2.5 use pseudo code to outline the functionality of an algorithm

2.6 construct algorithms using appropriate sequences, selections/conditionals, loops and operators to solve a range of problems, to fulfil a specific requirement

2.7 implement algorithms using a programming language to solve a range of problems

2.8 apply basic search and sorting algorithms and describe the limitations and advantages of each algorithm

2.9 assemble existing algorithms or create new ones that use functions (**including recursive**), procedures, and modules

2.10 explain the common measures of algorithmic efficiency using any algorithms studied

What is an algorithm?

"An algorithm is a set of rules for getting a specific output from a specific input. Each step must be so precisely defined that it can be translated into computer language and executed by machine"

Donald Knuth (1977)

According to Knuth, an algorithm has five important features:

- **Finiteness**
- **Input**
- **Effectiveness**
- **Definiteness**
- **Output**

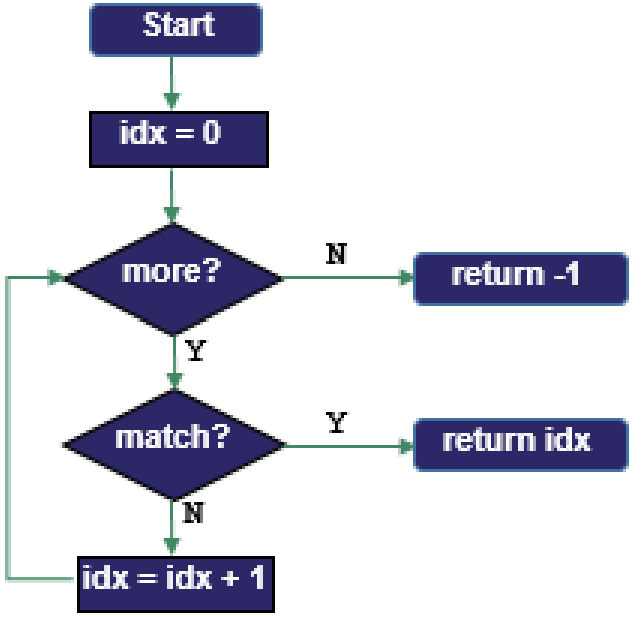
Source: Knuth, D The Art of Computer Programming (Vol. 1, Fundamental Algorithms, 3rd ed.)

Some Examples …

Chocolate Cream Pie

1. Heat milk, marshmallows and chocolate in 3-quart saucepan over low heat, stirring constantly, until chocolate and marshmallows are melted and blended. Refrigerate about 20 minutes, stirring occasionally until mixture mounds slightly when dropped from a spoon.

2. Beat whipping cream in chilled small bowl with electric mixer on high speed until soft peaks form. Fold chocolate mixture into whipped cream. Pour into pie shell. Refrigerate uncovered about 8 hours or until set. Garnish with milk chocolate curls and whipped cream.




```
1. Set low = 0
2. Set high = length of list - 1
3. Set index = (low+high)/2, rounded down to an integer
4. If the value at the index position is the same as the target value
      Return index
   Else If the value at the index position is less than the target value
      Set low = index + 1
   Else If the value at the index position is less than the target value
      Set high = index - 1
5. Go back to step 3 above
6. Return -1
```

```
p = 1029
q = 462

r = p%q # step 1
while (r != 0): # step 2
    p = q # step 3
    q = r # step 3
    r = p%q # step 1 (again)

print("GCD is", q)
```

What is an algorithm?

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A step-by-step procedure for solving a problem or accomplishing some end especially by a computer

Merriam-Webster

- ✓ A sequence of instructions
- ✓ A way of capturing intelligence and sharing it with others
- ✓ Provide general solutions to problems
- ✓ Some problems are so hard that they cannot be solved by algorithms (Computability)
- ✓ Can be expressed in a variety of different ways
- ✓ Common elements include input, processing, output
- ✓ Close relationship between algorithms and data structures
- ✓ Essential features are correctness and effectiveness
- ✓ Rule-based algorithms vs. Machine learning algorithms (AI)

Activity #1: Introduction to Algorithms

Instructions :

1. Read the Stable Marriage Problem statement

2. Watch Video (*The Secret Rules of Modern Living, Marcus Du Sautoy*)

https://www.youtube.com/watch?v=kiFfp-HAu64 (23:44 – 23:53)

3. In what other contexts do you think the Gale-Shapley algorithm could be used?

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Section III

Searching and Sorting

Introduction

Sorting and Searching?

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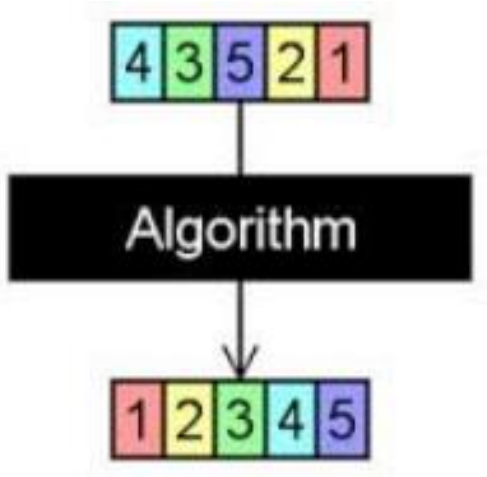
An algorithm that maps the following input/output pair is called a sorting algorithm:



Input: A list or array, A, that contains n orderable elements: $A[0, 1, \ldots, n-1]$.

Output: A sorted permutation of A, called B, such that $B[0] \leq B[1] \leq \cdots \leq B[n-1]$.

An algorithm that maps the following input/output pair is called a search algorithm:

Input: An array, A, that contains n orderable elements: $A[0, 1, \ldots, n-1]$ and some target value commonly referred to as an *argument*.

Output: If the argument is found in A it is conventional to return its zero-based positional offset (i.e. the index) and if the argument is not found some implementations return the length of the list while others return -1.

List Traversal

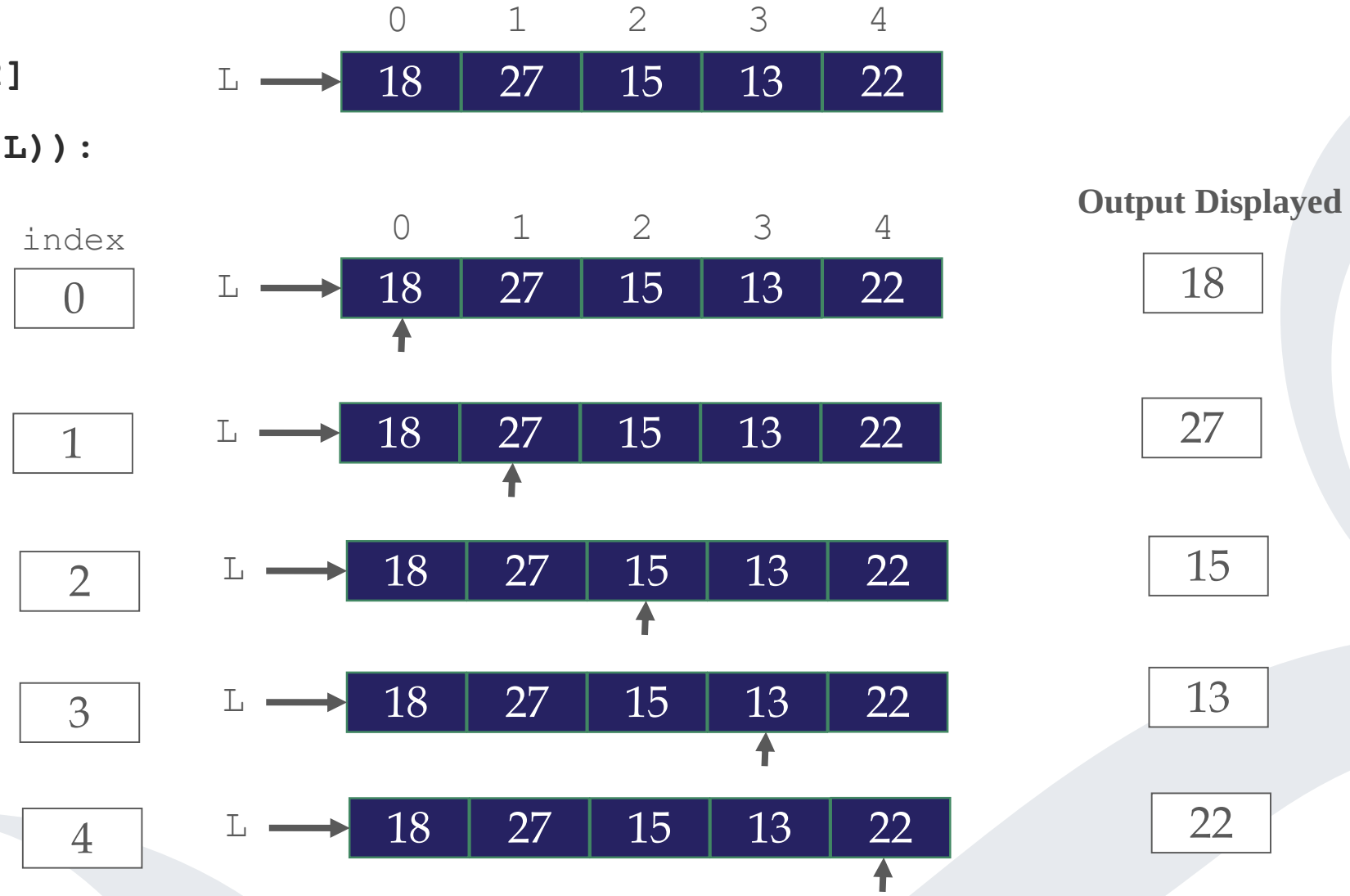
Pass over each element in the list one at a time

```
L = [18, 27, 15, 13, 22]

for index in range(len(L)):
    print(L[index])
```

Equivalent to …

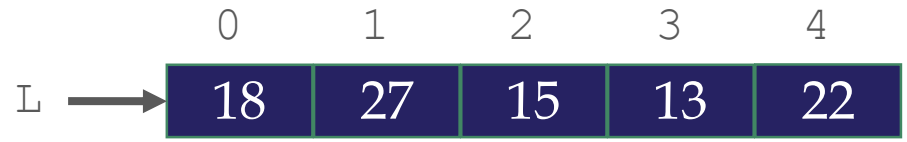
```
print(L[0])
print(L[1])
print(L[2])
print(L[3])
print(L[4])
```



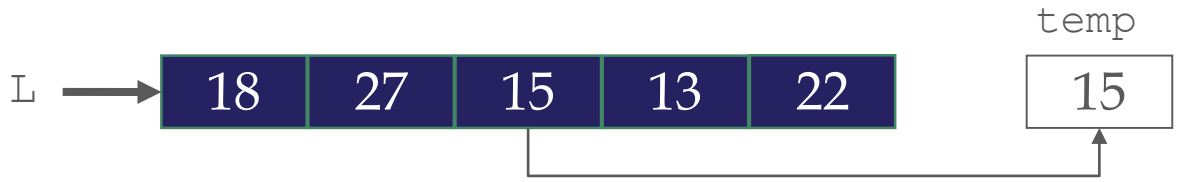
The Swap Operation

Let's say we wanted to exchange `L[2]` and `L[1]`

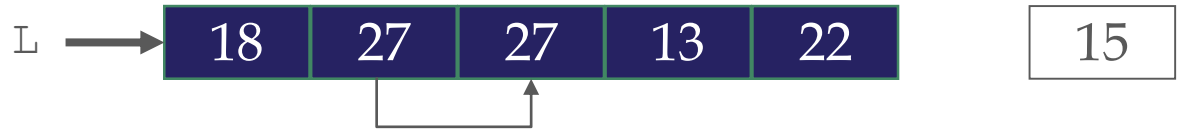
```
L = [18, 27, 15, 13, 22]
```




```
temp = L[2]
```



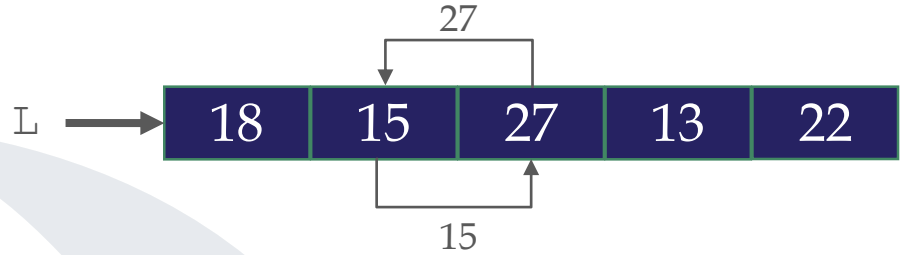

```
L[2] = L[1]
```




```
L[1] = temp
```

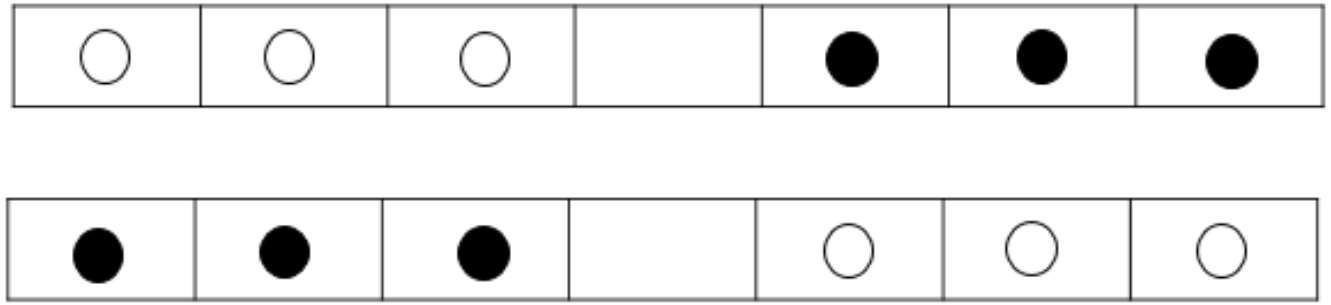
Python supports a single statement swap:

```
L[2], L[1] = L[1], L[2]
```



Application of The Swap Operation

The aim is swap the positions of the black and white pieces.

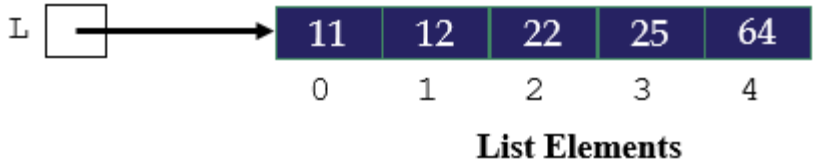


Pieces can move either by sliding into an adjacent empty square, or by jumping a single adjacent piece into the empty square immediately beyond.

Correctness

Before implemention begins it is a good idea to know what we want!

Question: What does the function shown below do?




```
1  def isSorted(L):
2      for i in range(1, len(L)):
3          if L[i] < L[i-1]:
4              return False
5
6      return True
```

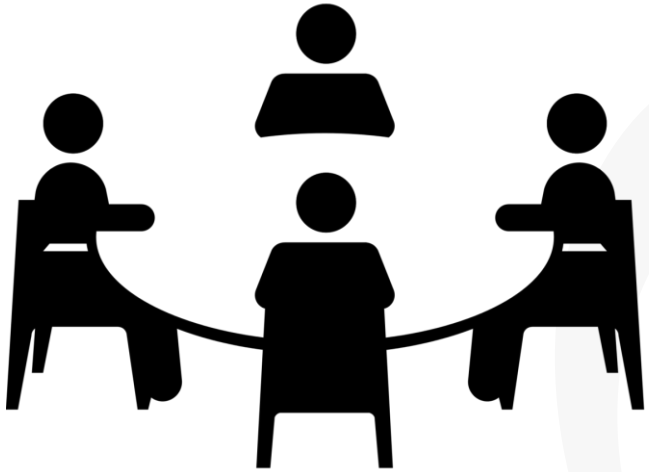
Activity #2: Developing our understanding

Instructions :

1. Read the algorithm provided and make notes in your workbook

2. Each table to agree common understanding of their assigned algorithm and prepare a demonstration which they will use to teach others

3. Participants move around the room (in teams of 2) explaining and demonstrating the algorithm they have learned to others



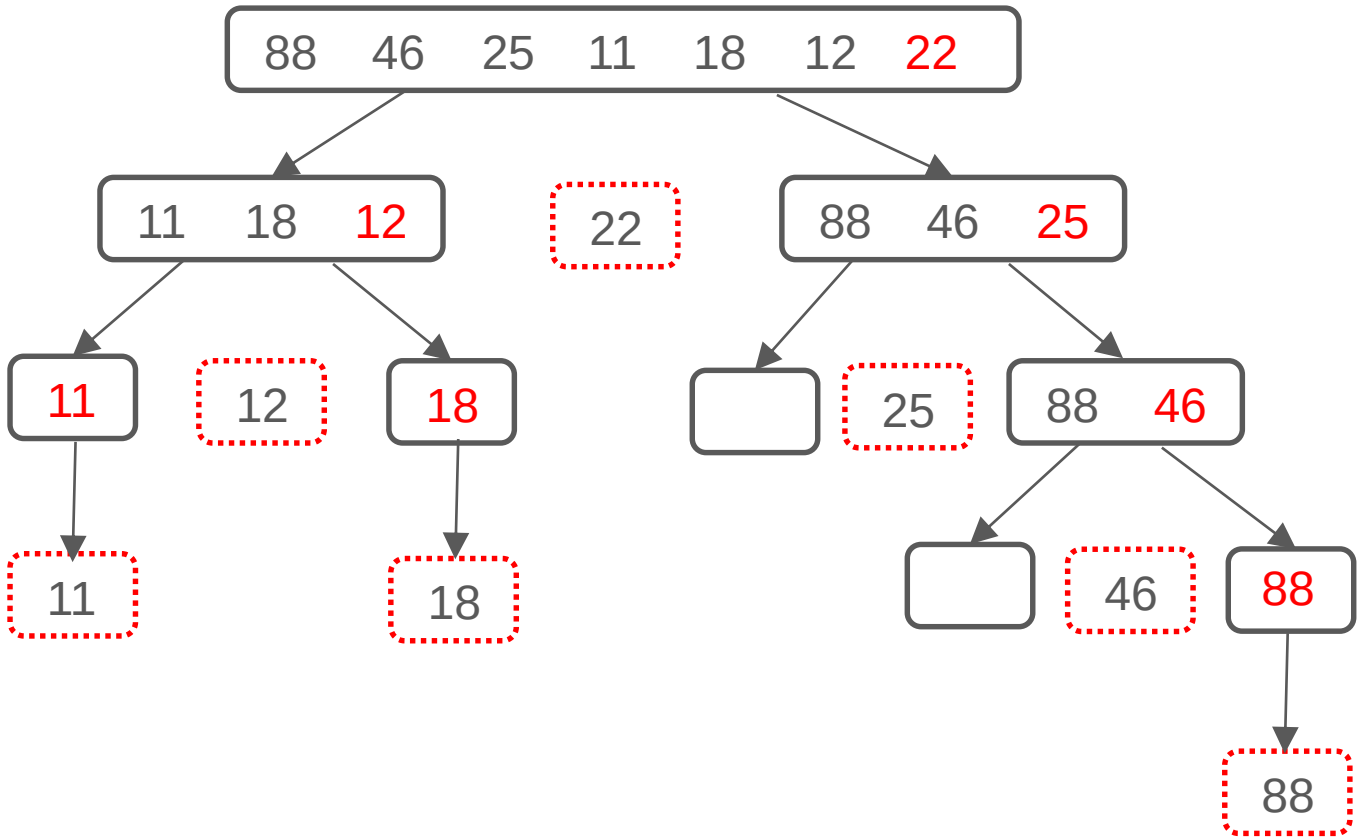
Simple (selection) Sort

Insertion Sort

Bubble Sort

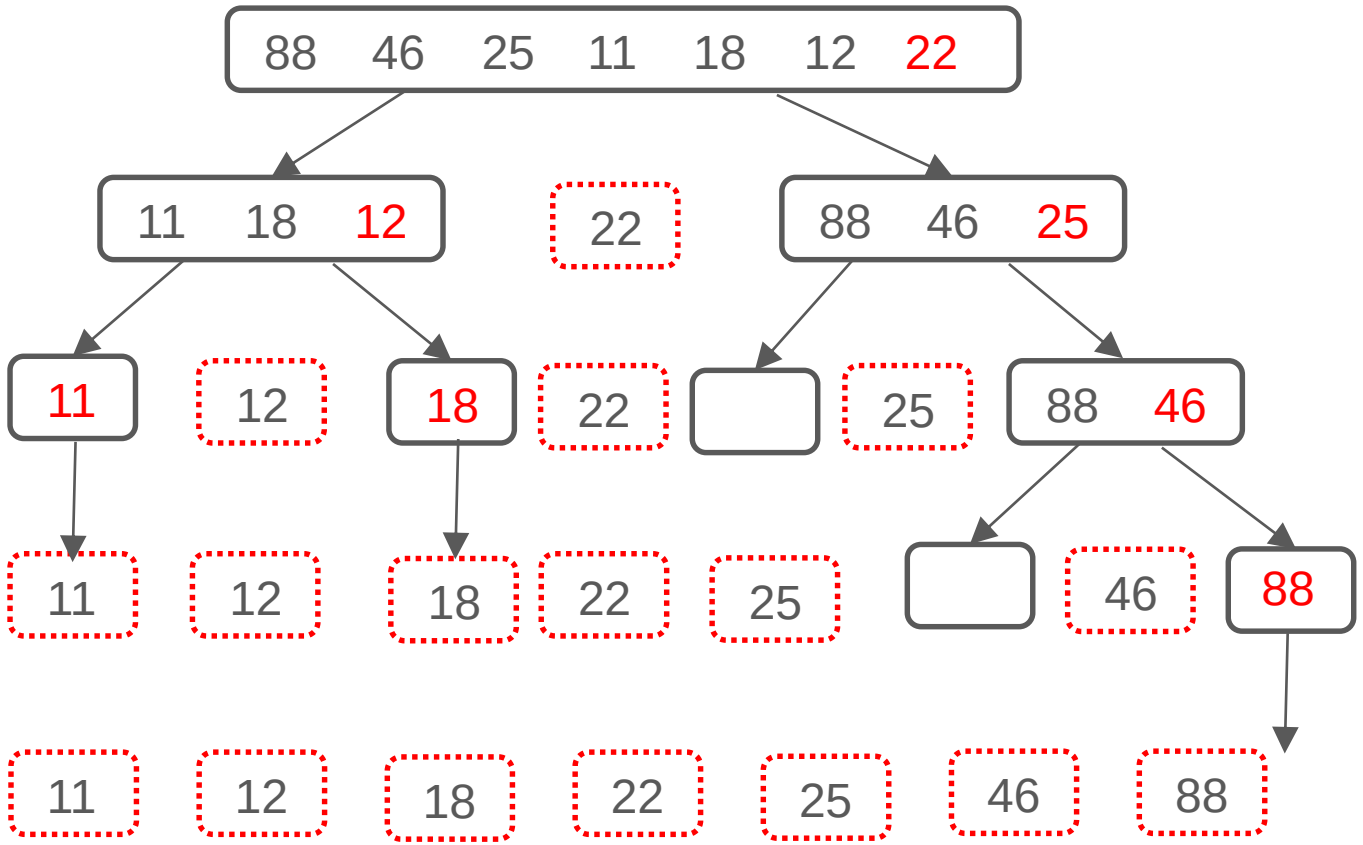
Activity to be followed by a short discussion at the end.

Quicksort (1 of 2)



denotes empty list

Quicksort (2 of 2)



denotes empty list

Section IV
Analysis of Algorithms

Efficiency

```python
import time

def selection_sort(aList):
    # Traverse through all array elements
    for i in range(len(aList)):
        # Swap the minimum element with the current element
        min_val = min(aList[i:])
        min_idx = aList.index(min_val)
        aList[i], aList[min_idx] = aList[min_idx], aList[i]


print("%s \t %s" %("Size", "Time(ms)"))
for list_size in [10, 1000, 2000, 4000, 8000]:
    L = list(range(list_size))
    L.reverse()
    t1 = time.time()
    selection_sort(L)
    t2 = time.time()
    print("%d \t %.1f" %(len(L), ((t2-t1) * 1000)))
```

```
Size    Time(ms)
10      0.0
1000    54.8
2000    224.4
4000    660.2
8000    2628.0
```

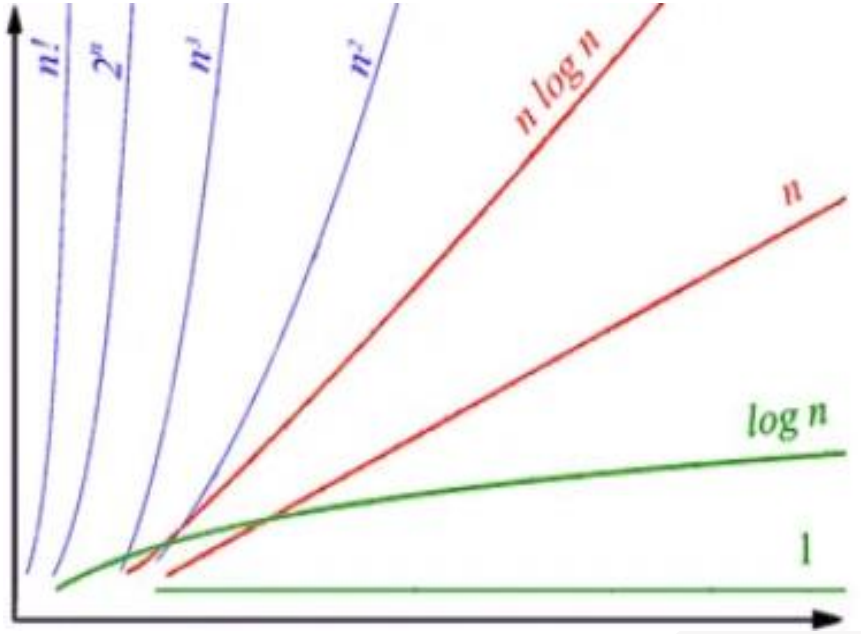
Measures of Algorithmic Efficiency (Complexity)

Question: If an algorithm works how can we be sure it will work well?

Answer: Big O notation

Big O is a notation used in Computer Science to describe the worst case running time (or space requirements) of an algorithm in terms of the size of its input usually denoted by n.

O(1)	*Constant Complexity*
O(n)	*Linear Complexity*
O(n^2)	*Quadratic Complexity*
O($\log_2 n$)	*Logarithmic Complexity*
O($n \log_2 n$)	*Linearithmic Complexity*
O(2^n)	*Exponential Complexity*
O(n!)	*Factorial Complexity*



The number of operations (*y-axis)* versus input size *n*

Summary: Algorithmic Time Complexity

Always consider the running time and the expected format of the input list before choosing a search or sorting algorithm for a particular problem.

	Best Case	Average Case	Worst Case
Linear Search	$O(1)$	$O(n)$	$O(n)$
Binary Search	$O(1)$	$O(log_2 n)$	$O(log_2 n)$
Simple (selection) Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$
Bubble Sort	$O(n)$	$O(n^2)$	$O(n^2)$
Insertion Sort	$O(n)$	$O(n^2)$	$O(n^2)$
Quicksort	$O(n\ log_2 n)$	$O(n\ log_2 n)$	$O(n^2)$

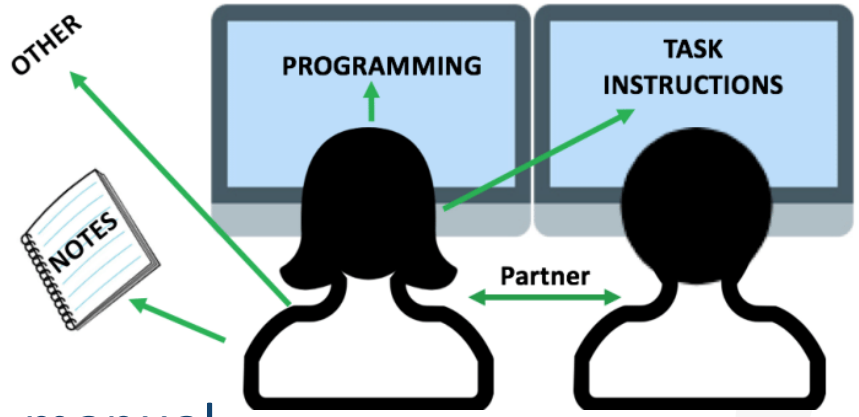
Activity #3: Analysis of Search Algorithms

Instructions :

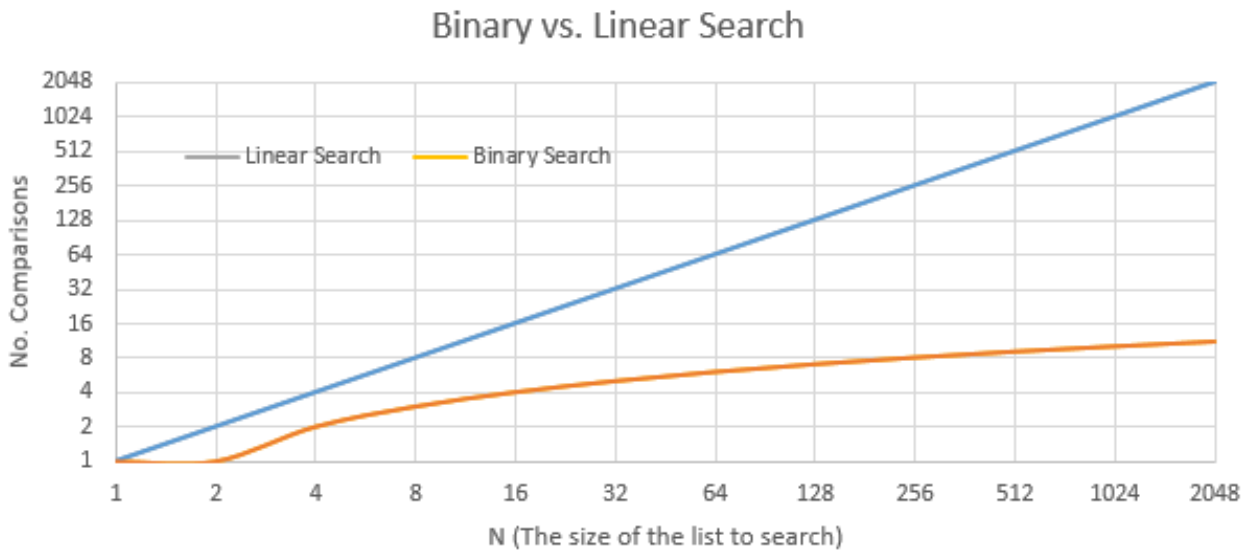
1. Participants work in pairs (pair programming)

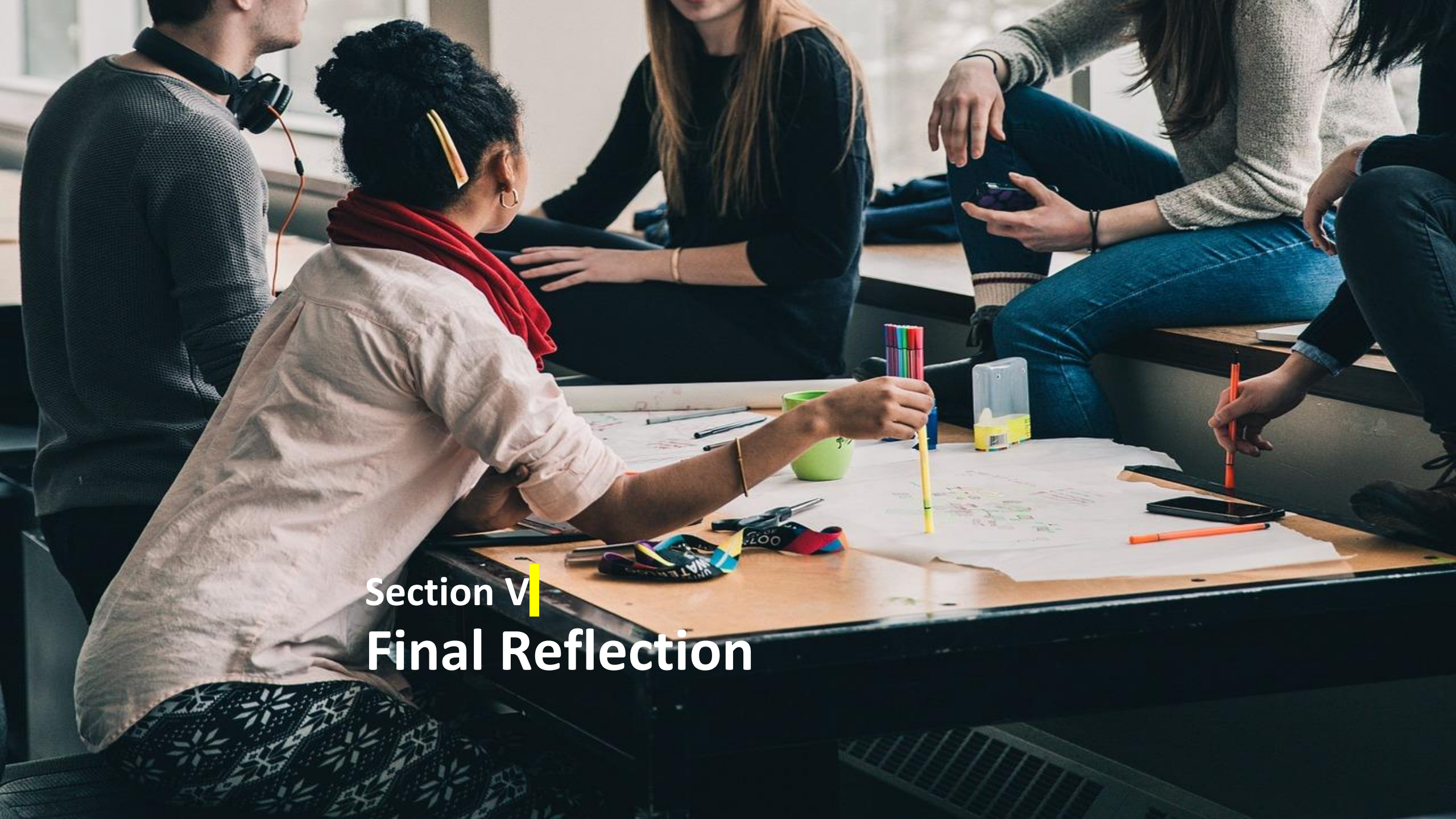
2. Each pair opens the Python programs provided

3. The code is modified according to the instructions in the manual



TASK:
Use the analysis framework provided to test the assertion that the binary search exponentially faster than the linear search (see graph)

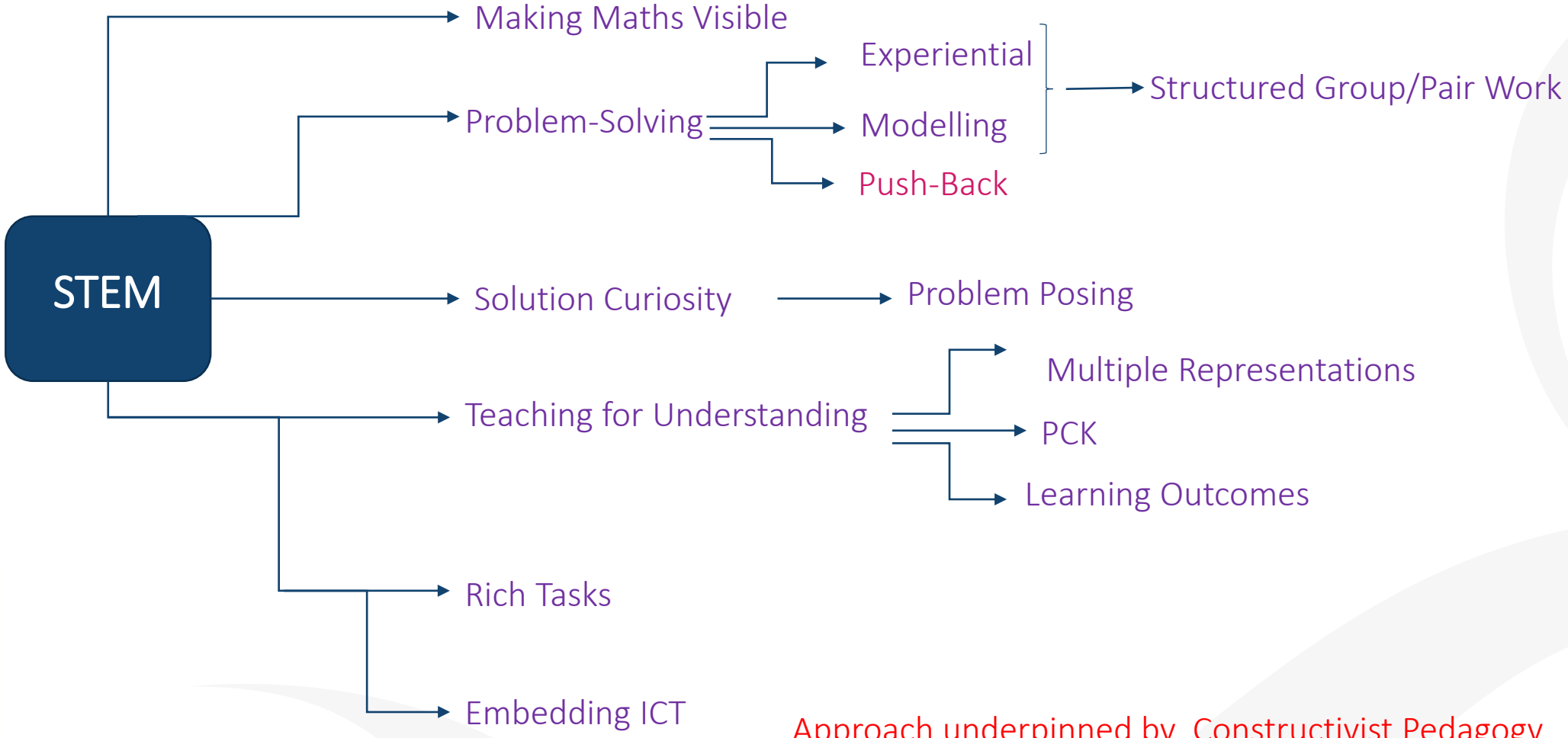




Section V

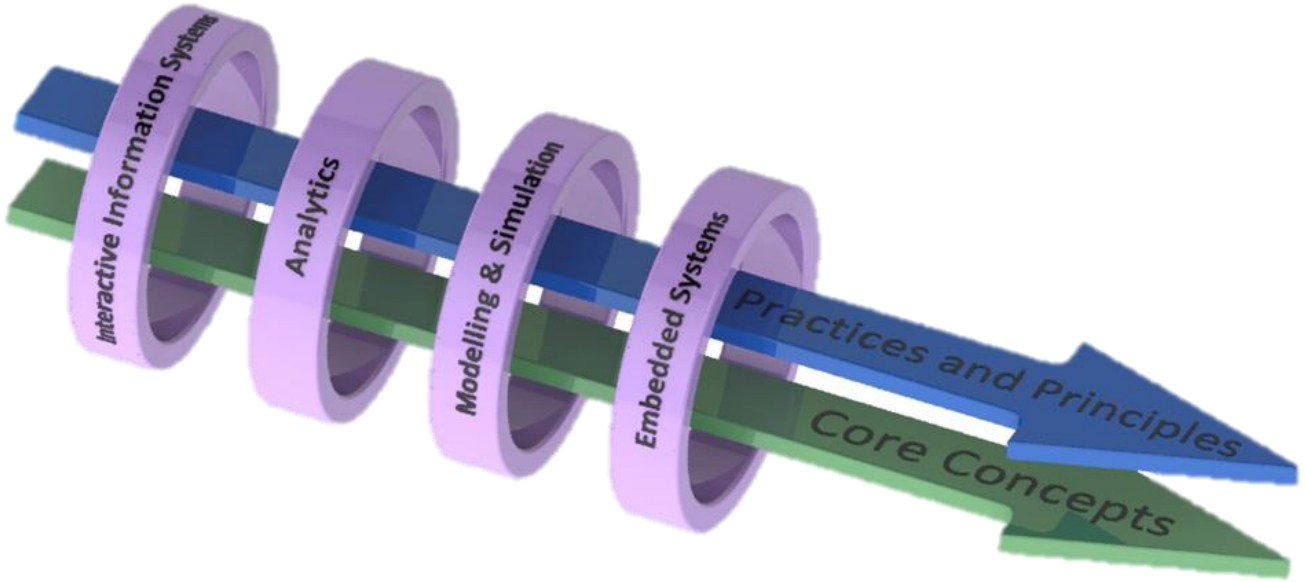
Final Reflection

STEM As a Connected Discipline



Approach underpinned by Constructivist Pedagogy

Interwoven Approach



Points to remember

The specification offer a variety of opportunities to discuss, explore and learn about algorithms

Whatever way I facilitate my students to learn algorithms should be consistent with my values as a teacher?

Snowball Reflection (Wider Group Reflection)

Instructions :

Individually reflect on the question posed and write your thoughts on the paper provided

Scrunch up the page of paper and walk to the closest wall

On “GO” throw the piece of paper towards the centre of the room

Carefully, collect a “snowball” different from your own, read it, reflect upon it and discuss it with a colleague from a different table

Snowball Reflection

How will I provide students with opportunities to learn more about algorithms?

References on Unconscious Bias

Jennifer Spratt and Lani Florian (2015) Inclusive pedagogy: From learning to action. Supporting each individual in the context of 'everybody' http://dx.doi.org/10.1016/j.tate.2015.03.006

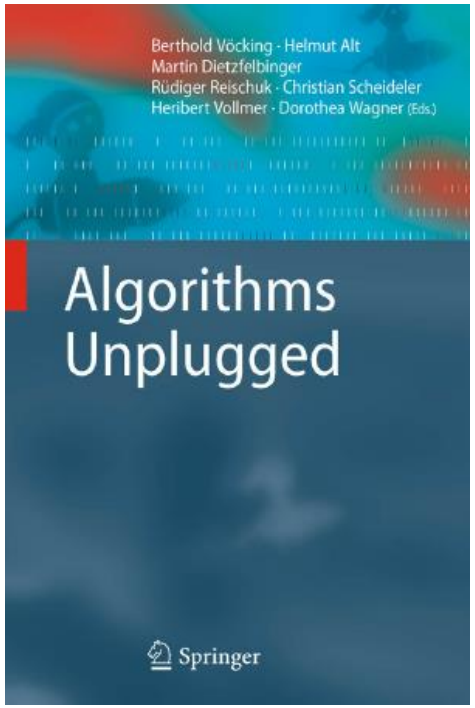
Wonch Hill P, McQuillan J, Talbert E, Spiegel A, Gauthier GR, Diamond J. Science Possible Selves and the Desire to be a Scientist: Mindsets, Gender Bias, and Confidence during Early Adolescence. *Social Sciences.*2017;**6**(2):55. doi:10.3390/socsci6020055

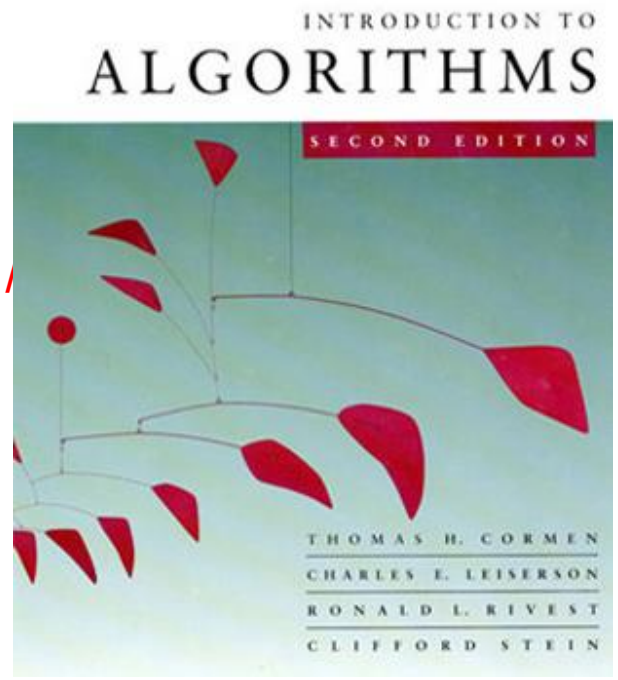
Ito T, McPherson E. Factors Influencing High School Students' Interest in pSTEM.Frontiers in psychology. 2018;9:1535. https://doi.org/10.3389/fpsyg.2018.01535

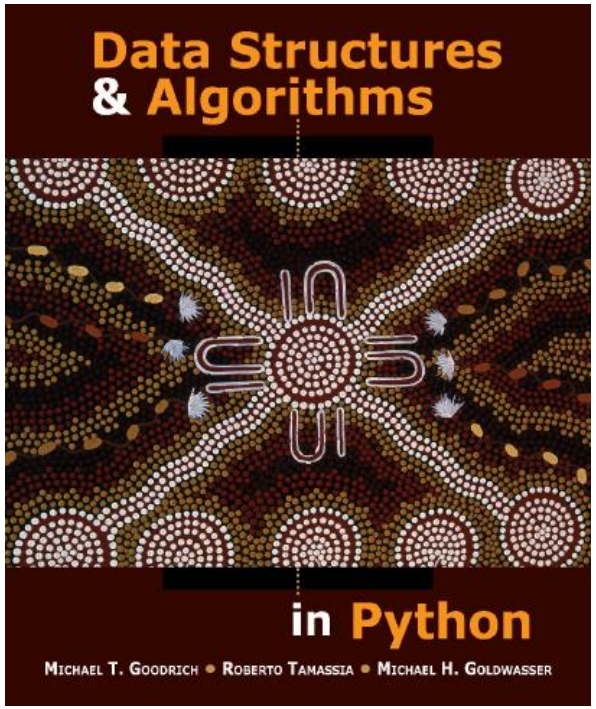
Sheelagh Drudy (2008) Gender balance/gender bias: the teaching profession and the impact of feminisation, Gender and Education, 20:4, 309-323, https://doi.org/10.1080/09540250802190156

Accenture (2017) Girls in STEM. Powering Economic Growth: Attracting more young women into Science and Technology 3.0

Resources







http://courses.cs.vt.edu/~csonline/Algorithms/Lessons/index.html

https://www.khanacademy.org/computing/computer-science/algorithms

http:/algs4.cs.princeton.edu/home

http://csunplugged.org/

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