

From Procedural Programming to Object-Oriented Programming (OOP)

A preliminary step by step approach

ISEP/LEI/ESOF

Adapted from Paulo Maio's original version

Content Overview

- Procedural Programming
 - Revision
- Systematization
- **Raising the need for OOP**
 - **Classes as Data Structures**
- Towards OOP
 - Primary Concepts and Principles
- While practicing
 - Main Software Engineering Activities
 - Promoted Working Method

Systematization

User Stories

User Story – What is it?

- A way to express functional requirements of an application
 - Although, it can be used to express non-functional requirements too
- Written from the perspective of an application user (end-users)
 - Roles and/or personas
- Using informal natural language and domain/business jargon
- Follows a common and well-known template:
 - As a <user role>, I <something to do>.
 - As a <user role>, I <something to do>, so that <benefit>.
- Desirably, some acceptance criteria must exist

User Story – What is it?



New artifact introduced!

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Raising the need for OOP

Classes as Data Structures

Problem III

Requirements

- Context:
 - An application to manage the students (number and name) of a course unit and their grades is required. Intended functionalities comprehends adding, updating, removing and listing students sorted and/or filtered by some criteria, among others.
- User Stories (US):
 - US01 – As a user, I want to list students sorted by their number (ascendent).
 - US02 – As a user, I want to list students sorted by their grades (descendent).
- Remarks and Acceptance Criteria (common to all US):
 - No User Interface (UI) is required
 - Solution must have a testing coverage and mutation coverage of, at least, 90%

Analysis

- Data to be managed (example)

Number	Name	Grade
1200001	Ana Maria Sousa	16
1200032	André Pinto da Silva	12
....
1190432	Martim Gomes Costa	17
1181208	Mariana Gonçalves Mendes	14

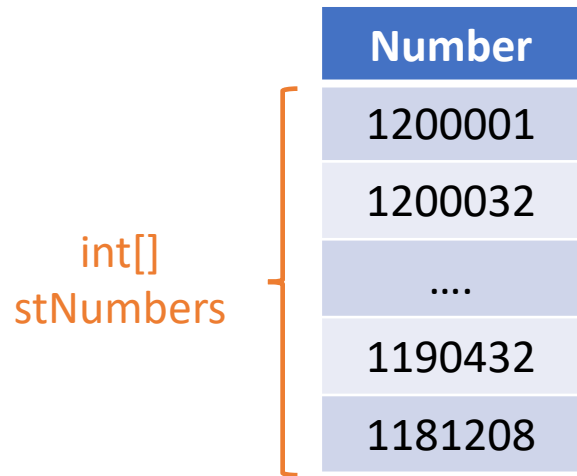
- Used as input on US01 and US02
- Used as output on US01 and US02

Design – How to represent the students data? (using known knowledge, so far)

- Through a matrix?
 - Is it possible?
 - Of which data type? Integers? Strings? Other?

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- Through 3 arrays:

int[] stNumbers	{	Number
		1200001
		1200032
		...
		1190432
		1181208

String[] stNames	{	Name
		Ana Maria Sousa
		André Pinto da Silva
		...
		Martim Gomes Costa
		Mariana Gonçalves Mendes

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- Through a matrix?
 - Is it possible?
 - Of which data type? Integers? Strings? Other?
- Through 3 arrays:

`int[]`
`stNumbers`

Number
1200001
1200032
...
1190432
1181208

`String[]`
`stNames`

Name
Ana Maria Sousa
André Pinto da Silva
...
Martim Gomes Costa
Mariana Gonçalves Mendes

`int[]`
`stGrades`

Grade
16
12
...
17
14

Design – How to represent the students data? (using known knowledge, so far)

- Through a matrix?
 - Is it possible?
 - Of which data type? Integers? Strings? Other?
- Through 3 arrays:

Number	Name	Grade
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int[]
stNumbers

String[]
stNames

int[]
stGrades

Information of a single student is splitted by 3 distinct data structures

Design – (cont.)

- Can we apply the method “*sortArrayAscending*” to each array to accomplish US01?

Number	Name	Grade
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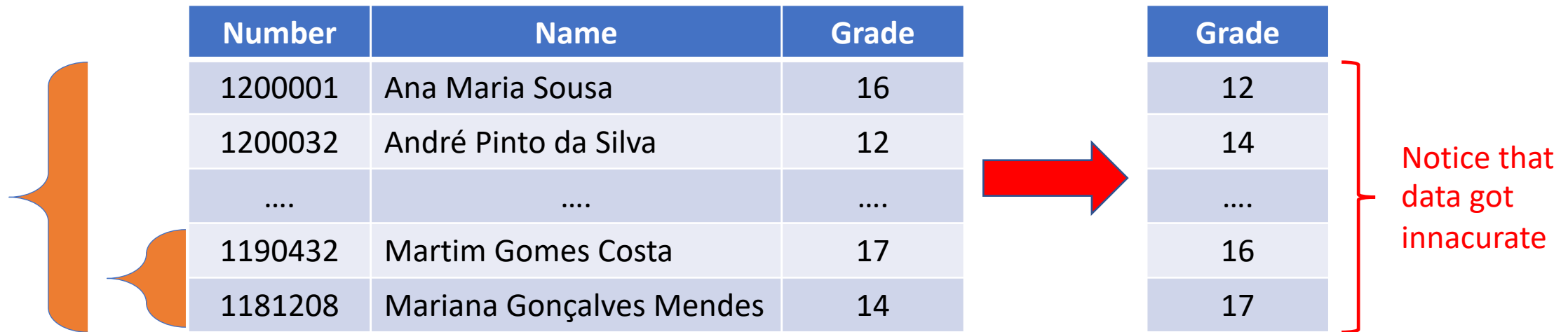
Design – (cont.)

- Can we apply the method “*sortArrayAscending*” to each array to accomplish US01?
 - No! Why? What would happen?

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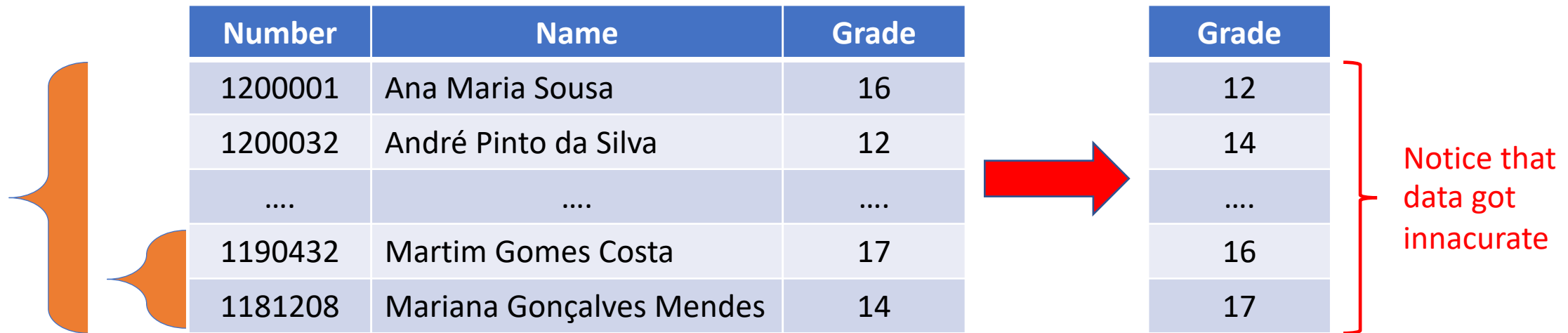
Design – (cont.)

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Design – (cont.)

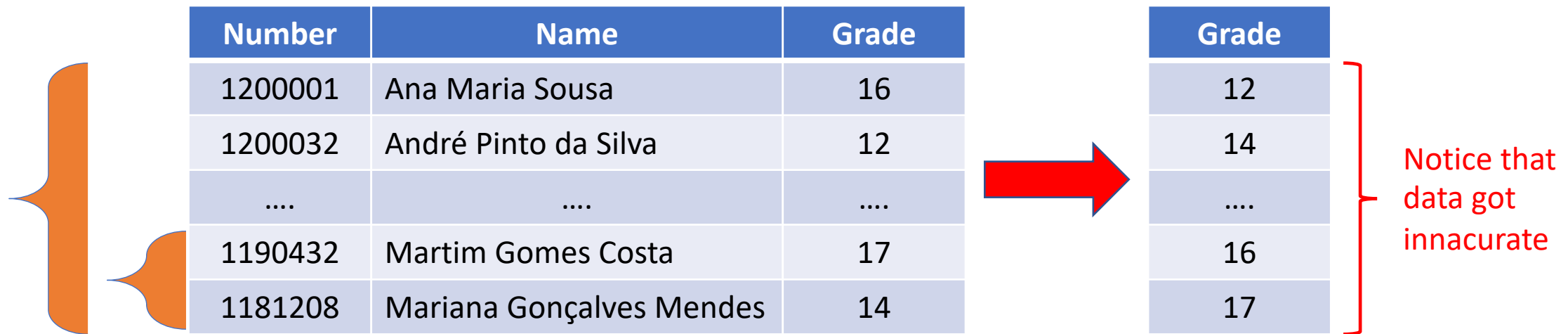
- Can we apply the method “*sortArrayAscending*” to each array to accomplish US01?
 - No! Why? What would happen?



- What “links” the student number to its name and/or grade? Or vice-versa?

Design – (cont.)

- Can we apply the method “*sortArrayAscending*” to each array to accomplish US01?
 - No! Why? What would happen?



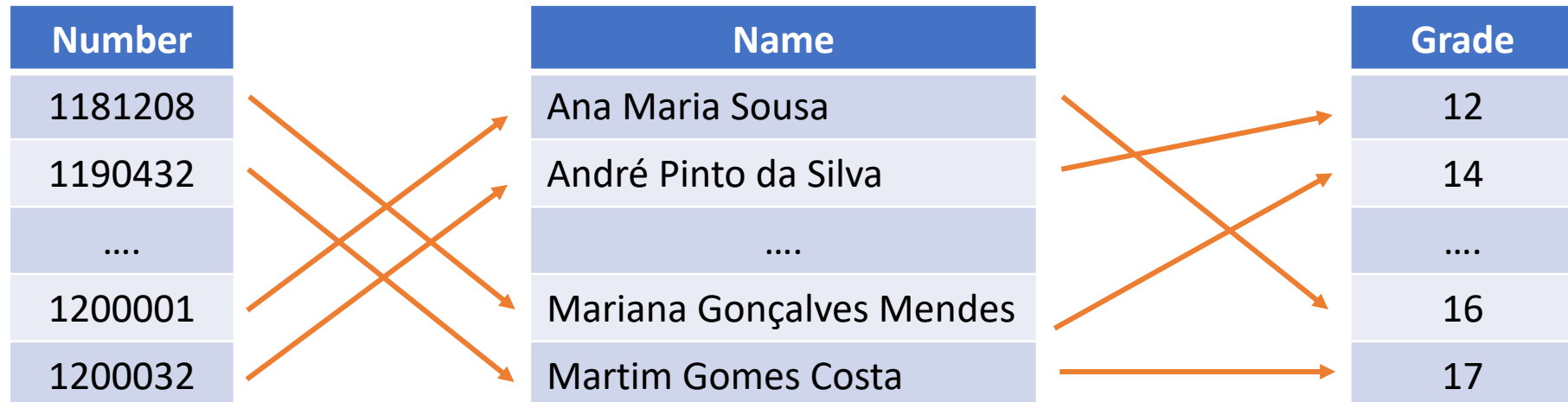
- What “links” the student number to its name and/or grade? Or vice-versa?
 - Having the **same position** into the arrays used to represent students data. **Is it a reliable approach?**

Design – This would result in the following

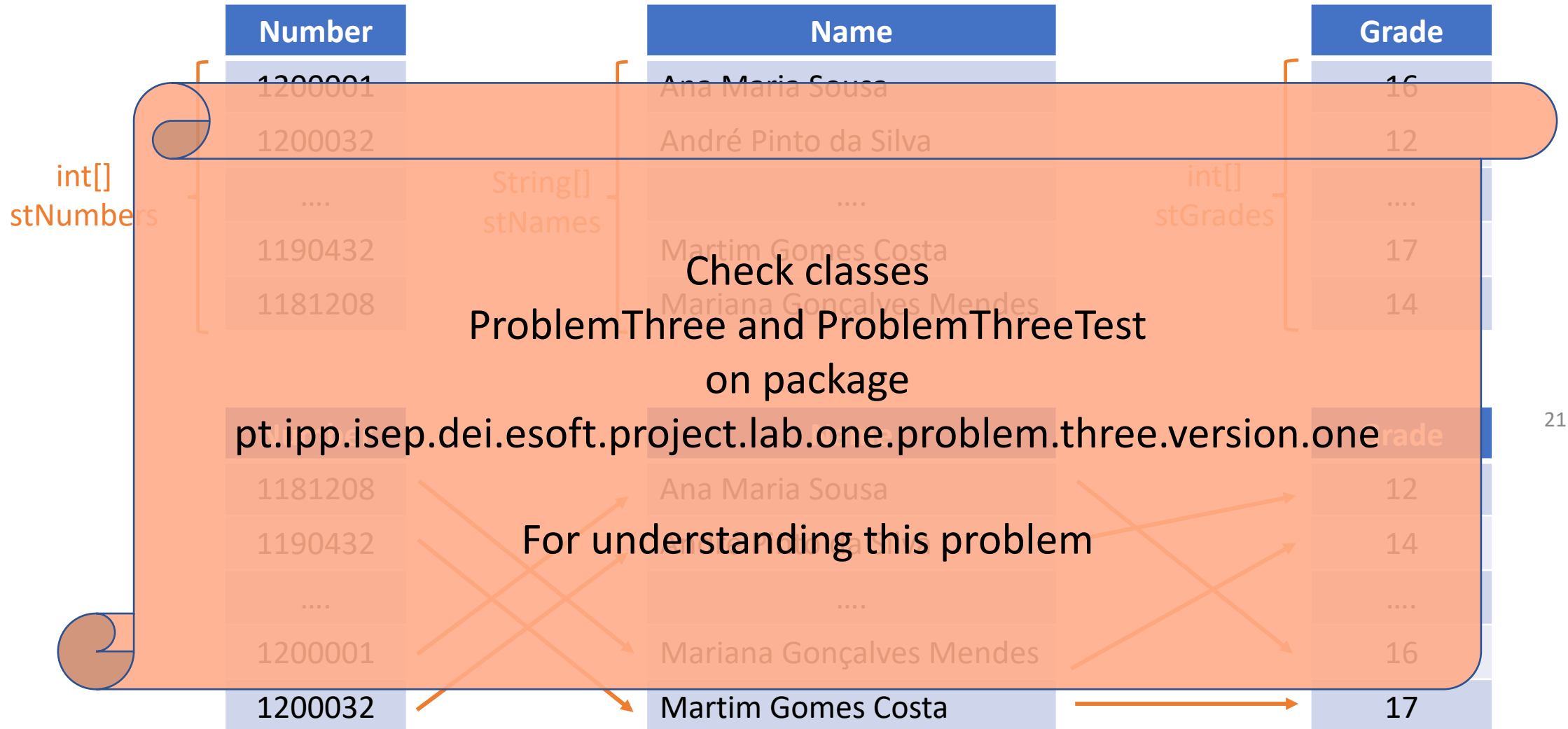
int[] stNumbers	Number	String[] stNames	Name	int[] stGrades	Grade
	1200001		Ana Maria Sousa		16
	1200032		André Pinto da Silva		12

	1190432		Martim Gomes Costa		17
	1181208		Mariana Gonçalves Mendes		14

Design – This would result in the following



Design – This would result in the following



Design Alternatives (Method Signature)

- Alternative I:

```
void sortStudentsByAscendingNumber(int[] studentNumbers, String[] studentNames, int[] studentGrades)
```

- Alternative II:

```
boolean sortStudentsByAscendingNumber(int[] studentNumbers, String[] studentNames, int[] studentGrades)
```

- In both, all arrays are required and passed by reference as so changes made inside the method are visible from the outside
- Return value might be used to signal that something went wrong while sorting

Instructions on how to proceed

- Run the tests on class **ProblemThreeTest**
 - **on package pt.ipp.isep.dei.esoft.project.lab.one.problem.three.version.two;**
 - All tests have been disabled using the @Disabled annotation
 - All will be skipped
- Go one test at a time
 - Delete the @Disabled annotating from the first test and run your tests
 - Implement class ProblemThree with enough code for the test to pass
 - **on package pt.ipp.isep.dei.esoft.project.lab.one.problem.three.version.two;**
 - Once you have implemented, proceed to the next test
- Don't forget, always run all your class tests, to ensure you don't break any previous tests

Possible Implementation for version two

```
public static boolean sortStudentsByAscendingNumber(int[] studentNumbers, String[] studentNames,
                                                    int[] studentGrades) {
    if ((studentNumbers == null) || (studentNames == null) || (studentGrades == null)) {
        return false;
    }

    int arraySize = studentNumbers.length;
    //Sort the studentNumbers in ascending order using two for loops
    for (int i = 0; i < arraySize; i++) {
        for (int j = 0; j < arraySize - i - 1; j++) {
            if (studentNumbers[j] > studentNumbers[j + 1]) {
                //swap elements if not in order - in studentNumbers
                swapIntArrayElements(studentNumbers, j, j + 1);
                //swap elements if not in order - in studentNames
                swapStringArrayElements(studentNames, j, j + 1);
                //swap elements if not in order - in studentGrades
                swapIntArrayElements(studentGrades, j, j + 1);
            }
        }
    }
    return true;
}
```


Possible Implementation for version two

```
public static boolean sortStudentsByAscendingNumber(int[] studentNumbers, String[] studentNames,  
                                                    int[] studentGrades) {  
    if ((studentNumbers == null) || (studentNames == null) || (studentGrades == null)) {  
        return false;  
    }  
  
    int arraySize = studentNumbers.length;  
    //Sort the studentNumbers in ascending order using two for loops  
    for (int i = 0; i < arraySize; i++) {  
        for (int j = 0; j < arraySize - i - 1; j++) {  
            if (studentNumbers[j] > studentNumbers[j + 1]) {  
                //swap elements if not in order - in studentNumbers  
                swapIntArrayElements(studentNumbers, j, j + 1);  
                //swap elements if not in order - in studentNames  
                swapStringArrayElements(studentNames, j, j + 1);  
                //swap elements if not in order - in studentGrades  
                swapIntArrayElements(studentGrades, j, j + 1);  
            }  
        }  
    }  
    return true;  
}
```

Swapping elements is
required for all arrays

Reflection about this approach (1/4)

- Is it error prone?
 - A lot!
 - Arrays may have different sizes!
 - We are considering three individual arrays as a unit or work
 - All arrays are couples to each other
 - Adding one element to an array requires adding an element to all the other
 - Syncing this operation is really hard this way

Reflection about this approach (2/4)

- Is it easy to maintain and evolve?
 - Not really!
 - Tests are difficult to achieve, they seem to have a lot of duplicate code!
 - If we need an array of a different type (i.e., Names) makes this really difficult

Reflection about this approach (3/4)

- How would it be if one need to store several other student attributes (e.g. birthdate, address, email, id card)?
 - Very repetitive!
 - Hard to manage.
 - Sorting method keeps increasing.

Reflection about this approach (4/4)

- Is it close to the human-beings conceptual level?
 - No!
- A more natural approach, closer to human-beings conceptual level, would be better? And, would that be expectable?
 - Yes! Yes!

So, what if we...

- Could **define novel data types** to represent the things (e.g. students, course units) that one observe in the (business) domain we are dealing with?
- Could **manage those data types** (e.g. Student) similarly to the “*built-in*” data types (e.g. int, char, boolean)?
- Could **express and operate closer to the human-beings** conceptual level?

Object Oriented (OO)

Object-Oriented (OO)

- More than a programming style, it is a paradigm
- Probably the most adopted paradigm for software development
 - Up-to-date development processes rely and promote OO
 - Architectural styles and patterns apply and share OO fundamental principals
- Transversal to several software engineering activities
 - Analysis → Analysis OO
 - Design → Design OO
 - Coding → Coding OO
 - Testing → Testing OO

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Consume and produce OO artifacts

OO – Class Definition

- Groups things that show some common characteristics as attributes and behaviours
- It might be thought as a category to which these existing things in our (business) domain belong to
- It provides the blueprint/template to individually represent each of those things
 - e.g., a “Student” class can be used as a template to represent each student in the classroom

OO – Object (or Instance) Definition

- It represents/refers to a concrete thing (physical or conceptual or (in)tangible) of our (business) domain in accordance to one class
 - e.g., each student in the room can be represented as an object of class “Student”
- Each object has a state determining the value of its attributes (e.g. the student name) and exhibit behaviours (or operations) that when executed might change (or not) its internal state
 - e.g. a method called isApproved() stating its approval status

Using Classes as Data Structures: A rudimentary approach

- All attributes are public
- Constructor with no arguments (default)
- No operations

```
public class Student {  
  
    // Attributes  
    public int number;  
    public String name;  
    public int grade;  
  
    // Constructor  
    public Student(String name) {  
        this.name = name;  
        //used to initialize attributes that identify the student  
    }  
}
```

Class Structure – Through example

```
public class Student {  
  
    // Attributes  
    public int number;  
    public String name;  
    public int grade;  
  
    // Constructor  
    public Student() {  
  
    }  
  
    // Operations (Behaviour)  
    public boolean isApproved() {  
        return (this.grade >= 10);  
    }  
}
```

Class Structure – Through example

```
public class Student {
```

The name of the class. Further, can be used as a data type.

```
// Attributes
```

```
public int number;  
public String name;  
public int grade;
```

```
// Constructor
```

```
public Student() {
```

```
}
```

```
// Operations (Behaviour)
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public boolean isApproved() {  
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public class Student {
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The name of the class. Further, can be used as a data type.

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// Attributes
```

```
public int number;  
public String name;  
public int grade;
```

List of the attributes that all objects of this class has. Each attribute has an accessor (*public* or *protected* or *private*), a **data type** and a *designation*.

```
// Constructor
```

```
public Student() {
```

```
}
```

```
// Operations (Behaviour)
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public boolean isApproved() {
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    return (this.grade >= 10);
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The constructor. Invoked to create every object of the class. At least one *public* constructor is usually provided, but several might exist and with other accessors.

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Several methods might be defined to exhibit and capture object behaviours. Accessors constraint method accessibility.

```
}
```

Class Structure – Through example

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public class Student {
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The name of the class. Further, can be used as a data type.

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// Attributes
```

```
public int number;  
public String name;  
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// Operations (Behaviour)
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public boolean isApproved() {  
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Several methods might be defined to exhibit and capture object behaviours. Accessors constraint method accessibility.

Reserved word used to refer to this object's attributes and operations.

Evolving Design – Applying Classes

- Classes
 - Student (cf. defined previously)
- US01 Method
`boolean sortStudentsByAscendingNumber(Student[] students)`
- US02 Method
`boolean sortStudentsByDescendingGrade(Student[] students)`

Evolving Design – Applying Classes

- Classes
 - Student (cf. defined previously)

- US01 Method

`boolean sortStudentsByAscendingNumber(Student[] students)`

Student being used as a novel data type.
Each methods requires, as input, an array of students.

- US02 Method

`boolean sortStudentsByDescendingGrade(Student[] students)`

Instructions on how to proceed

- Check the test cases on the following slides

Testing example

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange  
  
    Student studentOne = new Student();  
    studentOne.number = 1200001;    studentOne.name = "Ana Maria Sousa";    studentOne.grade = 16;  
  
    Student studentTwo = new Student();  
    studentTwo.number = 1200032;    studentTwo.name = "André Pinto da Silva";    studentTwo.grade = 12;  
  
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};  
  
    // Act  
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);  
  
    //Assert  
    assertTrue(result);  
    //check dimension  
    assertEquals(expectedStudents.length, students.length);  
    // check array content  
    assertEquals(expectedStudents, students);  
}
```

Testing example

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange
```

One student object {

```
    Student studentOne = new Student();  
    studentOne.number = 1200001;  studentOne.name = "Ana Maria Sousa";  studentOne.grade = 16;
```

```
    Student studentTwo = new Student();  
    studentTwo.number = 1200032;  studentTwo.name = "André Pinto da Silva";  studentTwo.grade = 12;
```

```
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};
```

```
    // Act
```

```
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
```

```
    //Assert
```

```
    assertTrue(result);
```

```
    //check dimension
```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

```
}
```

Testing example

Creates a new object of the Student class by invoking the constructor

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange
```

```
    Student studentOne = new Student();  
    studentOne.number = 1200001;  studentOne.name = "Ana Maria Sousa";  studentOne.grade = 16;
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    Student studentTwo = new Student();  
    studentTwo.number = 1200032;  studentTwo.name = "André Pinto da Silva";  studentTwo.grade = 12;
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```
    Student[] students = {studentTwo, studentOne};  
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```
    // Act
```

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    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
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    assertTrue(result);
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```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

```
}
```


Testing example

Creates a new object of the Student class by invoking the constructor

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange
```

Sets the value of attribute number on object studentOne

```
    Student studentOne = new Student();  
    studentOne.number = 1200001; studentOne.name = "Ana Maria Sousa"; studentOne.grade = 16;
```

```
    Student studentTwo = new Student();  
    studentTwo.number = 1200032; studentTwo.name = "André Pinto da Silva"; studentTwo.grade = 12;
```

```
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};
```

```
    // Act
```

```
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
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```
    //Assert
```

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    assertTrue(result);
```

```
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```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

```
}
```

Testing example

Creates a new object of the Student class by invoking the constructor

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public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
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```

Sets the value of attribute number on object studentOne

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    Student studentOne = new Student();  
    studentOne.number = 1200001; studentOne.name = "Ana Maria Sousa"; studentOne.grade = 16;
```

```
    Student studentTwo = new Student();  
    studentTwo.number = 1200032; studentTwo.name = "André Pinto da Silva"; studentTwo.grade = 12;
```

```
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};
```

```
    // Act
```

```
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
```

```
    //Assert
```

```
    assertTrue(result);
```

```
    //check dimension
```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

```
}
```

Another
student
object

Testing example

Creates a new object of the Student class by invoking the constructor

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange
```

One
student
object

```
    Student studentOne = new Student();  
    studentOne.number = 1200001; studentOne.name = "Ana Maria Sousa"; studentOne.grade = 16;
```

Sets the value of attribute number on object studentOne

```
    Student studentTwo = new Student();  
    studentTwo.number = 1200032; studentTwo.name = "André Pinto da Silva"; studentTwo.grade = 12;
```

Another
student
object

```
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};
```

*Sets the value of attribute grade
on object studentTwo*

```
    // Act
```

```
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
```

```
    //Assert
```

```
    assertTrue(result);
```

```
    //check dimension
```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

```
}
```

Testing example

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange
```

Creates a new object of the Student class by invoking the constructor

One
student
object

```
    Student studentOne = new Student();  
    studentOne.number = 1200001; studentOne.name = "Ana Maria Sousa"; studentOne.grade = 16;
```

Sets the value of attribute number on object studentOne

```
    Student studentTwo = new Student();  
    studentTwo.number = 1200032; studentTwo.name = "André Pinto da Silva"; studentTwo.grade = 12;
```

Another
student
object

*Sets the value of attribute grade
on object studentTwo*

```
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};
```

```
    // Act
```

```
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
```

```
    //Assert
```

```
    assertTrue(result);
```

```
    //check dimension
```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

*Sets the value of attribute name
on object studentTwo*

```
}
```

Testing example

```
public void ensureSortingTwoUnsortedElementArraysByNumberWorks() {  
    //Arrange
```

Creates a new object of the Student class by invoking the constructor

One
student
object

```
    Student studentOne = new Student();  
    studentOne.number = 1200001; studentOne.name = "Ana Maria Sousa"; studentOne.grade = 16;
```

Sets the value of attribute number on object studentOne

```
    Student studentTwo = new Student();  
    studentTwo.number = 1200032; studentTwo.name = "André Pinto da Silva"; studentTwo.grade = 12;
```

Another
student
object

*Sets the value of attribute grade
on object studentTwo*

Create
Arrays

```
    Student[] students = {studentTwo, studentOne};  
    Student[] expectedStudents = {studentOne, studentTwo};
```

```
    // Act
```

```
    boolean result = ProblemThree.sortStudentsByAscendingNumber(students);
```

```
    //Assert
```

```
    assertTrue(result);
```

```
    //check dimension
```

```
    assertEquals(expectedStudents.length, students.length);
```

```
    // check array content
```

```
    assertEquals(expectedStudents, students);
```

*Sets the value of attribute name
on object studentTwo*

```
}
```

Instructions on how to proceed

- Run the tests on class **ProblemThreeTest**
 - on package **pt.ipp.isep.dei.esoft.project.lab.one.problem.three.version.three;**
 - All tests have been disabled using the @Disabled annotation
 - All will be skipped
- Go one test at a time
 - Delete the @Disabled annotating from the first test and run your tests
 - Implement class ProblemThree with enough code for the test to pass
 - on package **pt.ipp.isep.dei.esoft.project.lab.one.problem.three.version.three;**
 - Once you have implemented, proceed to the next test
- Don't forget, always run all your class tests, to ensure you don't break any previous tests

Implementation

```
public static boolean sortStudentsByAscendingNumber(Student[] students) {  
    if (students == null) {  
        return false;  
    }  
  
    int arraySize = students.length;  
    //Sort the students in ascending order using two for loops  
    for (int i = 0; i < arraySize; i++) {  
        for (int j = 0; j < arraySize - i - 1; j++) {  
            if (students[j].number > students[j + 1].number) {  
                //swap elements if not in order - in students  
                swapStudentArrayElements(students, j, j + 1);  
            }  
        }  
    }  
    return true;  
}
```

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Now the comparison is between the number attribute

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```

Now the comparison is between the number attribute

Swapping students is similar to swapping integers and strings.

Comparing Approaches (1/5)

- How both approaches compare to each other?
 - Version Two : Using individual arrays
 - Version Three: Using a Student class and only one array

Comparing Approaches (2/5)

- Which one is more error prone? Why?

Comparing Approaches (2/5)

- Which one is more error prone? Why?
 - **Version Two: Using individual arrays**
 - students' data being splitted by 3 arrays
 - Arrays are “linked” by their position (indexes) on such arrays.
 - Index is not a reliable option for this coupling

Comparing Approaches (3/5)

- Which one is easier to maintain and evolve? Why?

Comparing Approaches (3/5)

- Which one is easier to maintain and evolve? Why?
 - **Version Three: Using a Student class and only one array**
 - (i) a single array has all the data about students
 - (ii) each student owns its own data
 - (iii) check next question/answer

Comparing Approaches (4/5)

- How well each solution would handle if one need to store several other student attributes (e.g. birthdate, address, email, id card)?

Comparing Approaches (4/5)

- How well each solution would handle if one need to store several other student attributes (e.g. birthdate, address, email, id card)?
 - **Version Two: Using individual arrays**
 - it implies adding and managing a new array by each attribute and revising sorting methods.
 - **Version Three: Using a Student class and only one array**
 - it implies adding such attributes on Student class, but sorting methods do not need to be revised.

Comparing Approaches (5/5)

- Which one is closer to the human-beings conceptual level?


Comparing Approaches (5/5)

- Which one is closer to the human-beings conceptual level?
 - Definitely the latter one.
 - But, hopefully there is still room for improvements.

Revising previous “So, what if we...”

- Could **define novel data types** to represent the things (e.g. students, course units) that one observe in the (business) domain we are dealing with?
- Could **manage those data types** (e.g. Student) similarly to the “*built-in*” data types (e.g. int, char, boolean)?
- Could **express and operate closer to the human-beings** conceptual level?

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Summary

- Two OO fundamental notions were introduced
 - Classes
 - Objects (or instances)
- OO was applied (by now...)
 - As data structures – a very simple and rudimentary approach
 - On software engineering activities: Design and Coding
 - To develop an (alternative) solution to Problem III
- Comparison between developed solutions was done
 - Advantages of adopting OO are becoming clear and evident

What's next on OO?

- Some OO concepts (or principles)
 - Encapsulation
 - Abstraction
- Some OO Design principles and patterns
 - Tell, Don't Ask
 - Information Expert
- Association between objects
- Objects' equality