ICT ENHANCED LEARNING EXPERIENCE FOR AN INTRODUCTORY OBJECT ORIENTED PROGRAMMING COURSE
A Case Study

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Abstract: Anyone used to teaching programming is aware of the difficulties that are behind this discipline. This, of course, is also true for students who find programming very hard to learn. These difficulties are of many orders: the teaching of the theoretical aspects of the language, the elaboration of adapted and relevant practical labworks, the constant fight against plagiarism (either between learners in the same class, from work done by learners in previous years or from the Internet) and finally the accurate assessment of the students' programs. This paper presents a case study in which an online tool was used during a beginner's course on "Object Oriented Programming in Java" to help counter balance these difficulties. The tool we present here, not only supports the students by giving them constant feedback on their work and on its adequacy with what is expected, but also helps the instructors in charge of the course in following the students' progression, detecting potential cases of plagiarism and assessing the practical work done by the students. This tool was developped using simple Java APIs and opensource applications, and was made available to the learners through the course's page on the school's Moodle e-campus.

1 INTRODUCTION

Learning programming is one of the first steps a student wishing to study computer science has to face. However, it is a very difficult task (so difficult that it is claimed that it takes as long as 10 years for a novice programmer to become an expert programmer (Winslow, 1996)) and teachers regularly need to redesign their courses to try and make the learning process easier and more efficient. Many studies have revealed some of the reasons that make programming such a difficult subject to learn (and consequently to teach) and what are the main difficulties faced by novice students when learning programming (de Raadt et al., 2004; Garner et al., 2005; Lahtinen et al., 2005; Milne and Rowe, 2002; Robins et al., 2003). Several articles have discussed issues related to this topic (Pears et al., 2007) and tried to determine the languages and programming paradigms that are most suitable for such introductory programming courses (Kölling, 1999; Mannila and de Raadt, 2006), the types of pedagogical activities that are most adapted (Ásrún Matthíasdóttir, 2006; Dijkstra, 1989) and the tools and environments that can help support the students during the learning process (Al-Imamy et al., 2006) or help the teachers during the assessment of the students' work (Mutka, 2005; Gerdes et al., 2010).

In this article we focus on one of the aspects listed above: the use of a tool to support the students and the teachers during the course. More precisely, we present the practical application of the "Test and Assessment Tool Suite" a set of software tools designed, both, for students and teachers during the lab work associated with an "Object Oriented Programming in Java" course. On the one hand, our tool provides the students with constant feedback on their work and informs them of whether or not the programs they are writing conform to what is expected. It also helps the students in building an archive of the work they have done at the end of a practical session so that it can be handed in and marked. On the other hand, the tool automatically assesses the students' works and verifies that the work handed in by a student is, indeed, personal work and not plagiarism of another student's work.

We begin, in Section 2, by describing the context of the case study: the design of the course and of its various activities, the level and the number of students and the way the various activities are organised. Section 3 focuses on the individual tools in the suite; how the suite is used, both, by the students for feedback and by the teacher for automatic assessment and plagiarism detection. This section also presents some implementation details of the tool suite. Section 4 discusses the benefits and drawbacks of the tool and how it influenced the students' work. In Section 5 we conclude and present future directions of work to improve the tool.

2 CONTEXT

This case study is relative to an "Object Oriented Programming in Java" course taught to students in their third year of Bachelor degree studies in ESEO, a French graduate school of engineering in the fields of electronics, computer science, networks and telecommunications.

The first two years of studies at ESEO, referred to as the "preparatory cycle", are mainly dedicated to fundamental scientific disciplines - *i.e.*, mathematics and physics. During each of their first two years of studies, approximately 50 hours of the mathematics course is dedicated to a, mainly practical, introduction to C programming. The students thus reach their third year of study with a basic programming knowledge.

During the first semester of the third year, our students follow a 30 hours course on "data structures and algorithms". This course consists of 15 hours of lectures and an equal amount of time is devoted to practical sessions. In order not to confuse the students with a new language and syntax, a simplified dialect of the C programming language is used to illustrate the different aspects presented during the lectures and to put them in practice during the practical sessions.

The "Object Oriented Programming in Java" course starts at the beginning of the spring semester and runs in parallel with an introductory course on the UML language. The objectives of the course are manifold:

1. Introduce the students to the fundamental principles of object oriented programming (classes, inheritance, instanciation and message passing): UML class diagrams together with a pseudo object oriented language are used to illustrate these principles.
2. Teach the core of the Java language: an explanation of the way the fundamental principles are implemented in Java is followed by a presentation of some of the important classes of the Java API (exceptions, streams, Swing/awt and threads).
3. Show the students, through a guided practical example, how the object oriented paradigm can be put in action to develop a graphic application and introduce them by example to design patterns.
4. Show the students that, through the course, they have acquired enough competency to develop a practical project of their own and give them the opportunity to practice their skills and discover, by themselves, new aspects of object oriented programming in Java.

The course has a total audience of 180 students and approximately 70 hours over a total period of 16 weeks are allocated to it. This time is divided into three clear parts: the first 6 weeks are for lectures, theoretical tutorial classes and practical tutorial classes, during the following 5 weeks the students are guided in the individual development of a real application and for the last 5 weeks they develop a personnal project in pairs.

The teacher in charge of the course has 15 years experience in teaching object oriented programming mainly in Java, but also with object-oriented Lisp dialects and Smalltalk, to various audiences, both in the academic and professional contexts. For the tutorial sessions and the practical aspects of the course he is assisted by another teacher with over 5 years experience in the teaching of computer science and involved in various aspects of the computer science curriculum. He is the developer of the tool suite discussed in this paper. Two PhD students are also involved in the tutoring of the practical activities and the tutorial classes related to this course.

2.1 Lectures (17.5 Hours) and Tutorial Classes (10 Hours)

This part of the course consists of 2-4 lectures and 1-2 tutorial classes a week. The lectures are rather traditional and the number of students does not allow for much interaction between the teacher and the students. However, for the tutorial classes, the students are divided in smaller groups of approximately 30 students. Half of these classes (5 hours) concentrate on theoretical (non-practical) aspects of the course and are aimed at giving the students a first experience with the object oriented modelling of small problems and to show them how these models can be translated into Java. One of the objectives of these tutorial classes is to help the students shift their mind-set from a procedural to an object-oriented view of the world. The rest of the time (5 hours) is dedicated to practical tutorial classes and give the students an occasion to get used to the practical aspects of Java and learn by example the use of the compiler, the virtual machine, the API's documentation. The results of the exercices seen during the theoretical tutorial classes are used as examples and put into practice during these sessions.

2.2 Practical Lab Sessions (20 Hours)

The practical lab sessions are held over 5 weeks, after the students have gone through the lectures and the tutorial classes. By that time, they have had a chance to be introduced to the main aspects of object orientation and of the Java language, both at the theoretical and practical levels. A total of 20 hours, held as 4 hour weekly sessions are dedicated to this part of the course. During these sessions, the students are given access to the written subject of the project. In its first parts, this document gives very detailed instructions of the work to be done: creation of the package directories, explanations of the Java classes to be used and written. As the students progress in the subject, the explanations are much less detailed to encourage the students to study the official Java API specification and to learn by themselves. All the classes the students are asked to develop are illustrated by UML class diagrams in order to get them used to the semantics of these diagrams and to make them practice their translation in Java. For this first practical part of the course, each student works individually and is forbidden to use an integrated development environment. The aim of pushing the students to use such a "command line" approach is to help them understand the various steps involved in Java programming: compilation of the source code, understanding of the error messages and correction of compile time errors, interpretation of the byte code, correction of run time errors. We prefered to go through this manual approach rather than have them rely on a IDE such as Eclipse or NetBeans. Indeed, we believe the capacity of these IDEs to "automagically" correct compile errors by adding missing *import* statements, methods or constructors should only be used once the programmer has a first idea of how these errors should be corrected errors manually.

2.3 Practical Project Sessions (20 Hours)

The last 5 weeks of the course is dedicated to the development of a practical project. Weekly 4 hour sessions are scheduled for this activity. The aim of the practical project is to give the students an occasion to broaden their knowledge on the Java programming language through the development of an application of their own. For this project, the students have the choice between developing a totally new application of their choice or of providing evolutions to the application they developed over the previous 5 weeks during the practical lab sessions. To give the students a first taste of team programming this work is done in pairs and the students can use programming environments to support their developments.

This article concentrates on the practical lab sessions presented in Section 2.2. More specifically it presents an online tool suite that was developed for this part of the course to help the students verify their work and hand it in at the end of each session. The tool suite is also for the teachers to detect blatant cases of plagiarism, to follow the progression of their students and to serve as a first pass for marking the work done.

3 THE TEST AND ASSESSMENT TOOL SUITE

The tool suite discussed in this section is a set of 3 online software tools made available to the students and teachers through the course's page on the school's Moodle e-campus. During the practical lab work, the students are asked to use two of them for: 1) checking whether their work conforms to what is asked for in the subject and 2) packaging their work so that it can be handed in for marking through the course's page on the e-campus. A third tool is the teacher's counterpart for this software and serves for plagiarism detection and as an aid for assessment. This section will present these two sides of our tool suite and, in the final subsection, describe the technologies that were used for its implementation.

3.1 Student Side of the Tool

3.1.1 The Test Centre

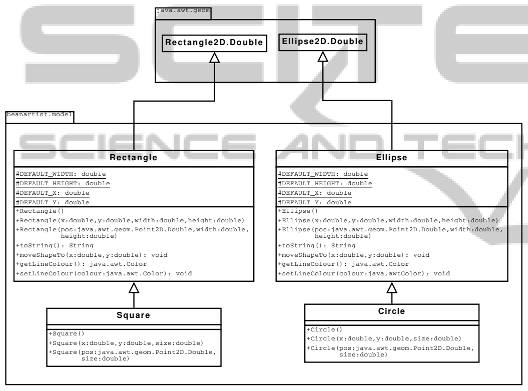
The aim of the practical sessions is for the students to develop a graphical editor giving a user the capability to draw various shapes (rectangles, squares, ellipses, circles, lines, ...) using the mouse. The application implements the Model-View-Controller pattern and the graphic editor obtained should ressemble the typical applications delivered with most operating systems. To guide their work, the students are given a subject in which all the details are given concerning what is expected from them. These details include the names of the different packages that are expected, the exact names of the public classes and methods that are asked for and, of course, the specifications of the methods to write. For instance, the wording of the first question, given in Figure 1, gives

3.1.1) Create the directories `beanartist`, `beanartist/model`, `beanartist/view` and `beanartist/controller` in which the Java classes of the packages `beanartist`, `beanartist.model`, `beanartist.view` and `beanartist.controller` will be stored.

Figure 1: First question of the subject.

3.1.2) Define the classes:

1. `beanartist.model.Rectangle`, subclass of `java.awt.geom.Rectangle2D.Double`
2. `beanartist.model.Ellipse`, subclass of `java.awt.geom.Ellipse2D.Double`. as they are represented in the class diagram in the following figure.


java.awt.geom
Rectangle2D.Double
Ellipse2D.Double
beanartist.model
Rectangle
#DEFAULT_WIDTH: double
#DEFAULT_HEIGHT: double
#DEFAULT_X: double
#DEFAULT_Y: double
+Rectangle()
+Rectangle(x:double,y:double,width:double,height:double)
+Rectangle(pos:java.awt.geom.Point2D.Double,width:double, height:double)
+toString(): String
+moveShapeTo(x:double,y:double): void
+getLineColour(): java.awt.Color
+setLineColour(colour:java.awt.Color): void
Ellipse
#DEFAULT_WIDTH: double
#DEFAULT_HEIGHT: double
#DEFAULT_X: double
#DEFAULT_Y: double
+Ellipse()
+Ellipse(x:double,y:double,width:double,height:double)
+Ellipse(pos:java.awt.geom.Point2D.Double,width:double, height:double)
+toString(): String
+moveShapeTo(x:double,y:double): void
+getLineColour(): java.awt.Color
+setLineColour(colour:java.awtColor): void
Square
+Square()
+Square(x:double,y:double,size:double)
+Square(pos:java.awt.geom.Point2D.Double, size:double)
Circle
+Circle()
+Circle(x:double,y:double,size:double)
+Circle(pos:java.awt.geom.Point2D.Double, size:double)

The default constructors (with no arguments) should create shapes (`Rectangle` or `Ellipse`) whose width (respectively height) is given by the value of the protected class constant `DEFAULT_WIDTH` (respectively `DEFAULT_HEIGHT`). A default shape should be placed at point (`DEFAULT_X`, `DEFAULT_Y`) where `DEFAULT_X` and `DEFAULT_Y` are, also, class constants. The `toString()` method of these two classes will be written in the next question.

Figure 2: Asking for classes.

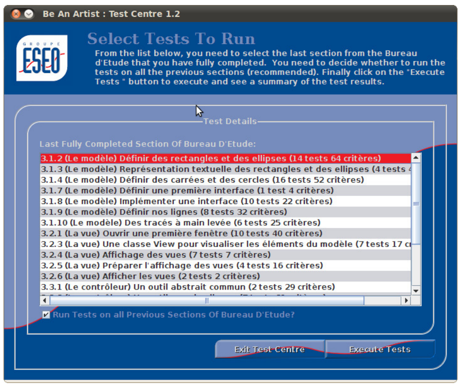
no freedom concerning the names of the packages to be used for the application.

The same level of detail is given when the students are asked to write a class. For example, Figure 2 shows the explanations given to help the student write the first two classes, `Rectangle` and `Ellipse`. Together with these details, the subject also give explanations concerning the software architecture implemented and on the API classes to be used.

It is expected that the students respect all the details (class/method/attribute visibilities, names, implementation of public methods and constructors) in their code. However, they are totally free to write all the private methods they wish to support their implementation. Furthermore, all the functionalities described in the subject are mandatory and should be respected.

The subject is subdivided in three distinct sections each corresponding to one of the facets of the MVC approach - i.e.; the model section, the view section and the controller section.

The first tool in our suite, the "Test Centre", comes in handy after the completion of each of the subject's questions. The students are then asked to submit the code they have written to the "Test Centre" to check that what they have written conforms to what is expected. The tool is written in Java and can be executed directly, using the Java Web Start technology, from the course's Moodle page on the school's e-campus. When run, the tool asks the student to point to the directory that hosts the project's top package. The student is then invited to choose, in a list, the last question that was completed and to run the tests (in Figure 3 the user has just completed question 3.1.2 in the model section of the subject). When the tests are executed, the student's code is tested and its adequacy with what is expected is verified. If the submitted work contains errors and does not verify the specified functionnalities or if it does not contain the required methods, attributes or constants, the user is informed that some tests have failed.



Select Tests To Run

From the list below, you need to select the last section from the Bureau d'Etude that you have fully completed. You need to decide whether to run the tests on all the previous sections (recommended). Finally click on the "Execute Tests " button to execute and see a summary of the test results.

Test Details

Last Fully Completed Section Of Bureau D'Etude:

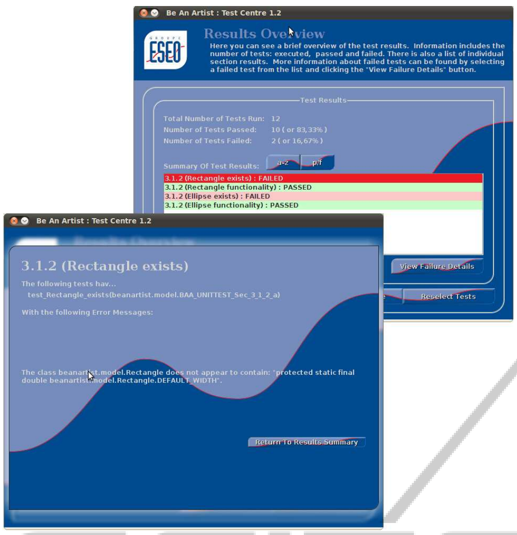
3.1.2 (Le modèle) Définir des rectangles et des ellipses (14 tests 64 critères)
3.1.3 (Le modèle) Représentation textuelle des rectangles et des ellipses (4 tests
3.1.4 (Le modèle) Définir des carrées et des cercles (16 tests 52 critères)
3.1.7 (Le modèle) Définir une première interface (1 test 4 critères)
3.1.8 (Le modèle) Implémenter une interface (10 tests 22 critères)
3.1.9 (Le modèle) Définir nos lignes (8 tests 32 critères)
3.1.10 (Le modèle) Des tracés à main levée (6 tests 25 critères)
3.2.1 (La vue) Ouvrir une première fenêtre (10 tests 40 critères)
3.2.3 (La vue) Une classe View pour visualiser les éléments du modèle (7 tests 17 c
3.2.4 (La vue) Affichage des vues (7 tests 7 critères)
3.2.5 (La vue) Préparer l'affichage des vues (4 tests 16 critères)
3.2.6 (La vue) Afficher les vues (2 tests 2 critères)
3.3.1 (Le contrôleur) Un outil abstrait commun (2 tests 29 critères)

[✓] Run Tests on all Previous Sections Of Bureau D'Etude?

Figure 3: Choosing the last question handled by the student.

The user can then ask to see the details of the failure in order to be guided for its correction.

In the example in Figure 4 the user is informed that two tests have failed for question 3.1.2 (those dedicated to the static structure of classes `Rectangle` and `Ellipse` - we will see later in Section 3.3 that these tests are referred to as "existence tests"). The student is also informed that the classes submitted for testing have the required functionalities and have passed this category of tests. The student can, on demand, have a detailed report on the fail-


Be An Artist : Test Centre 1.2

Results Overview

Here you can see a brief overview of the test results. Information includes the number of tests: executed, passed and failed. There is also a list of individual section results. More information about failed tests can be found by selecting a failed test from the list and clicking the "View Failure Details" button.

Test Results

Total Number of Tests Run: 12
Number of Tests Passed: 10 (or 83,33%)
Number of Tests Failed: 2 (or 16,67%)

Summary Of Test Results:

3.1.2 (Rectangle exists) : FAILED
3.1.2 (Rectangle functionality) : PASSED
3.1.2 (Ellipse exists) : FAILED
3.1.2 (Ellipse functionality) : PASSED

Be An Artist : Test Centre 1.2

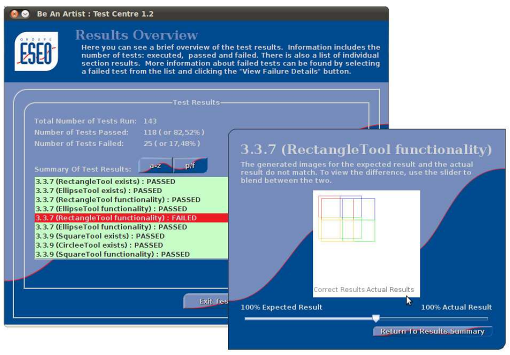
3.1.2 (Rectangle exists)

The following tests hav...
test_Rectangle_exists(beanartist.model.BAA_UNITTEST_Sec_3_1_2_a)

With the following Error Messages:

The class beanartist.model.Rectangle does not appear to contain: "protected static final double beanartist.model.Rectangle.DEFAULT_WIDTH".

Figure 4: Overview and detailed view of the test results.


Be An Artist : Test Centre 1.2

Results Overview

Here you can see a brief overview of the test results. Information includes the number of tests: executed, passed and failed. There is also a list of individual section results. More information about failed tests can be found by selecting a failed test from the list and clicking the "View Failure Details" button.

Test Results

Total Number of Tests Run: 143
Number of Tests Passed: 118 (or 82,52%)
Number of Tests Failed: 25 (or 17,48%)

Summary Of Test Results:

3.3.7 (RectangleTool exists) : PASSED
3.3.7 (EllipseTool exists) : PASSED
3.3.7 (RectangleTool functionality) : PASSED
3.3.7 (EllipseTool functionality) : PASSED
3.3.7 (RectangleTool functionality) : FAILED
3.3.7 (EllipseTool functionality) : PASSED
3.3.9 (SquareTool exists) : PASSED
3.3.9 (CircleeTool exists) : PASSED
3.3.9 (SquareTool functionality) : PASSED

3.3.7 (RectangleTool functionality)

The generated images for the expected result and the actual result do not match. To view the difference, use the slider to blend between the two.

Figure 5: Feedback given on failure of graphic functionnalities.

ure. In the example in Figure 4 the problem comes from the inexistence of the `protected` class constant `DEFAULT_WIDTH` in class `Rectangle`; The student should thus correct this oversight before going any further in the subject and should only move on to the next question in the subject once question 3.1.2 has been totally corrected.

The students are invited to follow such a test driven iterative approach throughout the whole subject and, as explained above, they should run the “Test Centre” to check their answers to each question of the subject. In the examples presented previously, the “Test Centre” is only used to verify very simple characteristics of a class, constructor or method. However, this type of test is possible for all types of functionality, and the “Test Centre” can verify graphic functionalities, response of the application to user events or other more complex specification details. In the case of a failure in a graphic functionality, the “Test Centre” shows the result obtained by the application under test and the expected result, in order to help the student correct the problem. Figure 5 shows the details given by the “Test Centre” in case of such a graphic failure. In this view, both the expected result and the actual result are shown to the student. Using the slider, the student can switch between the two views to try to determine what is wrong with the program’s result.

At the end of each session, the students should upload the current state of their application on the Moodle e-campus. For this, and to ease the assessment process, they are required to use the second tool on the student side of the suite: the “Jar Creation Centre”.

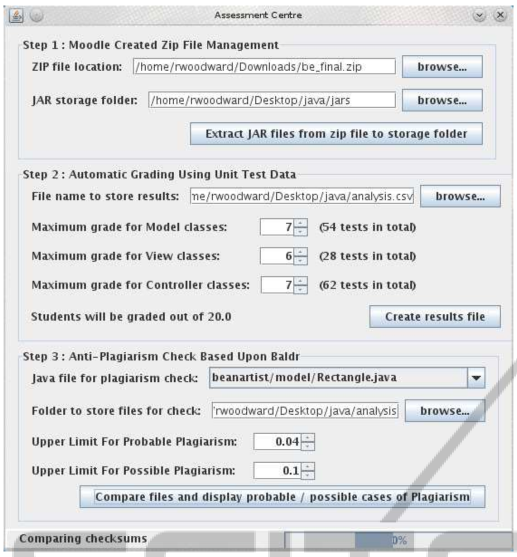
3.1.2 The Jar Creation Centre

The “Jar Creation Centre” is the second tool for the students. Its main aim is to take care of the packaging of a student’s work before it can be uploaded for evaluation on the e-campus. Just like it is the case with the “Test Centre”, when the students submit their work to this tool, they should: 1) point to the directory containing the root package of their application and 2) select the item in the subject that was last completed. Once given this information, the “Jar Creation Centre” starts by testing the submitted classes using the “Test Centre” tool. After achieving this pass, the “Jar Creation Centre” knows: the number of steps achieved by the student, and for each of the subject’s sections (model, view and controller): the total number of tests gone through by the submitted program and the number of tests that failed. Once this has been done, the student’s source files are added to the archive and, finally, the information resulting from the tests is included in the archive’s manifest.

Before exiting, the “Jar Creation Centre” informs the student of the name of the archive and of where it was stored on the local machine and copies this path in the clipboard. The student then, just needs to upload it to the Moodle e-campus.

3.2 Teacher Side of the Tool

Once it has been uploaded on the course’s space on the e-campus, the students’ works can be graded and checked for plagiarism. To help the teacher in this task a third tool was developed: the “Assessment Centre”. This tool takes a bundle (we chose to use a zip archive because of their easy creation and retrieval through the Moodle platform) of all the java archives handed in by the students as input and processes them in order to calculate an individual grade for each of the student’s work and check whether there are no bla-


Assessment Centre

Step 1 : Moodle Created Zip File Management

ZIP file location: /home/rwoodward/Downloads/be_final.zip

JAR storage folder: /home/rwoodward/Desktop/java/jars

Step 2 : Automatic Grading Using Unit Test Data

File name to store results: me/rwoodward/Desktop/java/analysis.csv

Maximum grade for Model classes: 7 (54 tests in total)

Maximum grade for View classes: 6 (28 tests in total)

Maximum grade for Controller classes: 7 (62 tests in total)

Students will be graded out of 20.0

Step 3 : Anti-Plagiarism Check Based Upon Baldr

Java file for plagiarism check: beanartist/model/Rectangle.java

Folder to store files for check: rwoodward/Desktop/java/analysis

Upper Limit For Probable Plagiarism: 0.04

Upper Limit For Possible Plagiarism: 0.1

browse...
Compare files and display probable / possible cases of Plagiarism

Comparing checksums 0%

Figure 6: Using the "Assessment Center".

tant cases of plagiarism between the students.

3.2.1 Configuration of Storage Spaces

Figure 6 shows a screenshot of the "Assessment Centre". In a first step the teacher is asked to point to the *zip* archive file containing all the work that was handed in by the students and to give the directory in which the system should extract all the *jar* files it contains. Once this information has been given to the system, the teacher can ask for the extraction of the files in the storage directory and move on to the second step of the "Assessment Centre" devoted to the marking of the work.

3.2.2 Assessment

Before proceeding to the actual assessment of each student's program, the teacher should choose the number of points that should be assigned to each of the sections of the subject. In the example in Figure 6, 7 points are assigned to the *Model* part of the subject, 6 points to *View* part and another 7 points are for the *Controller* classes of the application. For this second step, the teacher should also indicate the name of the file in which the "Assessment Centre" should store the detailed assessments for each student work; in our case file *analysis.csv*.

The assessment phase is rather simple, since it only uses the information added by the "Jar Creation Centre" in the Java archive's Manifest file. As stated in Section 3.1.2, the Manifest file contains information regarding the proportion of passed tests per section. This information, together with the points assigned per section are sufficient to calculate a grade per section and thus a total grade for the work. In this first version, the calculation of the grade is somewhat basic, giving a grade that is directly proportional to the number of successful tests. In future versions of the "Test and Assessment Tool Suite", rather than assigning points to entire sections of the subject, we have planned to let the teacher dispatch the points with more precision on a per item basis.

The result provided by the "Test Centre", takes the form of a CSV file giving the grade obtained by each student, the details of its calculation, the number of files in the bundle handed in by each student and the size of the bundle. For example, table 1 shows the first 10 lines of the "Assessment Centre's" result file. Each line reports the score (with a maximum of 20) obtained by the student whose userid on the schools network is given in the first column. The details concerning this global evaluation are given in the following columns. For instance, columns 3, 4 and 5 give the number of tests passed in the model (out of a total of 54 tests), view (out of a total of 28 tests) and controller (out of a total of 62 tests) sections of the subject by the student. The last column is an indication of the last item of the subject completed by the student. This last information is used when the sudying the progression of a student's work over the 5 weeks of the lab work.

3.2.3 Plagiarism Detection

Finally the third step, is used to configure the plagiarism detection phase. The teacher should first give the name of the file to be checked (`Rectangle.java` in our example), the working directory in which the system should store the files (or classes) it checks and two threshold values (between 0 and 1) indicating the upper limits between "no plagiarism", "probable plagiarism" and "possible plagiarism"; all pairs of files, of the given name, are checked for plagiarism. We will discuss in Section 3.3 the tool and the mechanism used for this verification.

3.3 Implementation

The implementation of the various applications in the "Test and Assessment Tool Suite" is done in Java and relies on opensource softwares and platforms for testing and plagiarism detection. The deployment of the various tools in the tool suite relies on the Java Webstart technology; By using this technology, all the tools can be run locally on the user's machine and do not stress the servers or the network. Moreover, with this technology, we can ensure that the students always execute the last and most up to date version of the software. This facilitates maintenance and allows

Table 1: Excerpt of an “Assessment Centre” result file.

userid	**score**	**model tests passed**	**view tests passed**	**controller tests passed**	**last section com- pleted**
beulepi	20.0	54	28	62	3.3.14
beaubeju	18.0	54	28	44	3.3.9
nogueral	11.7	54	22	0	3.2.4
bertinpi	13.0	54	28	0	3.3.1
diallo	13.1	54	28	1	3.3.1
razmkhre	7.0	54	0	0	3.1.10
crepinem	17.9	54	28	43	3.3.11
deberle	8.3	54	6	0	3.2.6
nivollpi	14.0	54	28	9	3.3.2
faligopa	11.5	52	22	0	3.2.4
⋮	⋮	⋮	⋮	⋮	⋮

for transparent evolutions of the “Test Centre” resulting from corrections or modifications of the subject.

3.3.1 Testing

The “Test Centre” relies on the Junit unit testing platform. Every item of the subject is verified using a number of Junit test cases. Each test case consists of several assertions to check the criteria that should be verified by the program under test. The “Test Centre” counts a total of 151 tests and 565 assertions to test the entire application. The test cases are subdivided in two large categories: existences tests and functionality tests.

Existence tests rely on the Java reflection API. They check whether the submitted classes respect the static requirements. Existence of the required classes is tested together with the proper declarations of their `public` and `protected` members (constants, variables and methods).

Functionality tests fall in two subcategories: Input/output testing and graphical interface tests. Input/output tests are the simplests of these tests to implement. They check that the results returned by the tested methods are indeed what they should be when they are given certain specific parameters. This category of tests is also responsible for verifying that all the required side effects expected by the execution of a method occur.

The graphical interface tests are in charge of verifying the correct response of the application to specific user interactions. They are implemented in comparing the image obtained by the application under test when events are artificially fired and feeded to the event loop with the expected image drawn directly in a graphic context.

3.3.2 Plagiarism Detection

For the plagiarism detection step, the “Assessment Centre” relies on Baldr, an opensource tool [1] that uses measures of similarity distance between source code to detect plagiarism amongst a, potentially, large collection of source code. The Baldr software is written in Java, it was thus naturally interfaced with the “Assessment Center” and its functionalities were quite simply integrated in the tool.

In this version of the Assessment Centre”, the teacher must choose which class needs to be checked for plagiarism. For the chosen class, the system then checks all of the students versions of this class for plagiarism, using Baldr.

For some parts of the subject, the classes and methods requested are short and simple and false positives could be detected if solely the code were to be tested. For those questions, it is the commented code that should be submitted to plagiarism detection. If the code is similar and the comments are also similar then there is suspicion of plagiarism. Other questions demand more sophisticated answers for which the resulting code differs quite significantly from one student to another. For these questions and to prevent students from just modifying the comments in plagiarised code it is the uncommented code that should be checked for plagiarism. In order to allow for these two types of comparisons, two versions of the code are submitted to plagiarism detection: one complete version including the comments and another version from which all the comments have been removed by the “Assessment Centre”. This can help the teacher

[1] Baldr was developped by *H. Wassner* and can be downloaded from *http://sourceforge.net/projects/baldr/* .

when trying to determine cases of plagiarism before visually verifying the suspected programs.

4 DISCUSSION

The "Test and Assessment Tool Suite" was experimented with 180 students dispatched in 3 groups of 60 students. Each of the groups were supervised by three teachers. Discussions with the students regarding the use of this tool showed that, on the whole, they appreciated the tool and considered it of great help when programming. One of the most cited reason for such positive evaluation was the capacity for the students to obtain an immediate feedback concerning each step of their work. Such feedback gives them a better understanding of the subject, both concerning the translation of UML class diagrams to Java classes and regarding the MVC architecture of the application. It was also noted that both novice programmers and students with prior experience in Java benefitted from the "Test Centre". Novice students were mostly guided by the tool's functionality tests, when students with more experience relied on it to get hints on the architectural aspect of the application. This immediate feedback also helps those students who wish to work on their programs outside the timetabled practical sessions in verifying, as they progress in the subject, the adequacy of their work and its compliance with what is expected.

Another positive point of the "Test Centre" lies in its incremental testing policy. Since all the functionalities are tested incrementally, there is little possibility that errors in the first steps of the subject influence further steps. This is of course helpful for the students and helps them in writing software incrementally and allows them to rely on existing and tested pieces of software. It is also of great help for the supervisors who, usually, do not have to go back to very early stages of the subject to help a student find a problem in the code.

On the supervisor's side, the "Assessment Centre" makes it easy to obtain an immediate view of the progression of the whole class on a weekly basis, thus helping the supervisors to target their interventions for the following week.

Concerning the plagiarism detection capacity of the "Assessment Centre", the students were informed of its use and of the tool that was used. By communicating widely on the use of such a tool, we noticed that the students tended to help each other through explanations rather than by using a much less pedagogical copy/paste solution.

The use of the tool suite also has certain drawbacks compared to a more traditional approach in which the students need to write the code to test their programs. For instance, we noticed that some students tended to not test their programs at all before submitting it to the "Test Center". It was not rare to see students that had never executed their program prior to submitting it to the "Test Centre" and, some of the code submitted to the "Test Centre" looped indefinitely or raised exceptions during execution. The first of these problems was simply solved by using the timeout functionality inherent to Junit. However, with the latter, the "Test Centre" was quite confused and returned unexpected messages sometimes not related to the cause of the error. Similar problems arose when a class did not compile or had not been compiled; the "Test Centre" did not detect the existence of the source code and simply reported the fact that a class was missing. These problems were only due to an incomplete study of user behaviour. Innocently, we thought that the students would follow a traditional *code-compile-test* approach before submitting their work for verification to the "Test Centre". We had not thought about them adopting a less traditional *code-compile-"Test Centre"* approach or even less a *code-"Test Centre"* cycle forgetting the compilation step altogether.

Another problem we faced with the tool suite concerned the fact that it was specifically tailored for the subject. For this reason, modifications or corrections in the subject were sometimes difficult to integrate in the "Test Centre".

On the whole however, we feel this first experience with the tool suite was very positive and definitely helped the students in their productivity. As an example, a very similar subject was given, for the same course, the previous year but was not supported by such tools. This year, we noticed that, after 5 weeks, more students had managed to complete the entire application than the previous year. Some of them even managed to go through the entire subject after as little as 3 weeks. Is this due to the use of these tools or to more competent students? This has not been measured and is thus not clear. However, after discussions with the students the impact of these tools on the work done is undoubtedly positive.

5 CONCLUSIONS AND FUTURE WORKS

In this paper we have presented our experience of an ICT enhanced approach used for the practical aspects of an object oriented programming course in Java. We have described the different elements of a tool suite that helped both, the students and the teachers in their work. The first tool of the suite, the "Test Centre", helps the students in verifying, through a unit test driven approach, that their work respects the subject's requirements. With the second tool of the suite, the "Jar Creation Centre", they can package their work, together with information concerning it, in a format that can easily be managed by the last tool in the suite: the "Assessment Tool". This last tool allows the teachers of the course to follow each student's individual progression, to automatically assess their works and to detect plagiarisms amongst the students' works.

On the whole, the introduction of these tools in our Java course was very much appreciated by the students and helped them in their work. It was also of great help for the teachers, since they could base their assessments on the response of the student's programs to functional requirements stated in the subject.

Yet, we have pointed a number of limitations of the approach and are working to overcome them. Our first objective is now to develop a more generic tool that can easily be adapted (or parameterised) for a given set of tests, a given subject, a specific assessment scale and a sample solution. For this we are investigating a model driven approach in which, given a set of models, a specific "Test and Assessment Centre" is generated from a generic specification of the tool suite, using an appropriate transformation (see Figure 7).

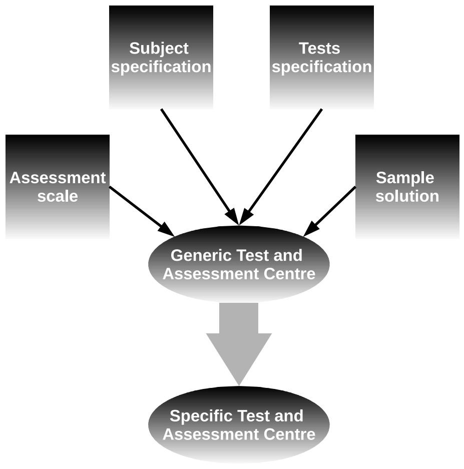


Figure 7: Generation of a specific Test and Assessment Centre.

In order to prevent the students from submitting code that still contains run time errors and raise exceptions, we will refine the error messages returned by the "Test Centre" and have three types of messages those indicating that a test failed or passed and a third message indicating that a test has failed because an exception prevented its execution. In parallel to that, to make it easier for the students, we are also thinking of merging both, the "Test Centre" and the "Jar Creation Centre" into one single tool. With this new approach, a Java archive is created everytime the tests are run. We believe this will make things less confusing for the students when having to decide which tool to use. We are also planning on asking the students to digitally sign the submitted work declaring it is their own which will clarify matters when faced with cases of plagiarism.

Furthermore, our exploitation of the results of the Baldr plagiarism detection tool is very minimal, we must find a means for the detection to set the thresholds that define *probable* and *possible* cases of plagiarism. These threshold will most probably have to be specific to each class for the results to be realistic, such dynamic assignment still needs to be studied. Together with these reflections, we must also study ways to intuitively display the detection results to the teacher.

Another direction of work would be to study the portage of our approach to other langages using the appropriate *Xunit* framework as support. Such a choice could then be included in our model driven generation approach.

Moreover, and this is probably the most important point, the subject of the practical assignment should be very precise and still needs to be refined.

Finally, we must study and quantify the impact of the "Test Centre" on the students' learning process. In future runs of the course we are planning on setting up intermediate tests and questionnaires as an attempt to quantify this issue.

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