DOI: 10.20472/TEC.2019.007.013

SALVADOR PINEDA MORENTE
University of Málaga, Spain

NATALIA ALGUACIL CONDE
University of Castilla-La Mancha, Spain

JUAN PEREZ RUIZ
University of Málaga, Spain

SEBASTIÁN MARTÍN RIVAS
University of Malaga, Spain

ANTONIO RUIZ GONZÁLEZ
University of Málaga, Spain

INDIVIDUALIZED EXERCISES FOR CONTINUOUS ASSESSMENT IN ENGINEERING

Abstract:

This project focuses on the development of a web application that automatically grades the solution to engineering exercises. The input data of each exercise is different for each student in order to reduce plagiarism and increase motivation. Students can access the web app from any device with internet access (computer, laptop, phone, ...) at any time. The fact that the exercises are enunciated and evaluated in an individualized way eliminates the possibility for students to share the solutions and divert the profitable collaboration between students towards the learning of the resolution procedure itself. From the professor's perspective, this tool allows an efficient and continuous evaluation of students. Besides, the storage of the data (number of attempts, time required, etc.) provides valuable information both for the self-assessment of the professor and for the analysis of the individualized learning process of each student. The web application is coded in Python, which easily allows the incorporation of additional features according to the needs of professors and students. The web application has already been tested during two academic years in two Spanish universities and for several engineering degrees. Ten professor and more than 2000 students have already benefit from this web application.

Keywords:

continuous evaluation, individualized exercises, university teaching, engineering courses

JEL Classification: A22

1. Introduction

Traditionally, university courses have been assessed according to a final examination valued with 100% of the final grade. Since the creation of the European Higher Education Area (EHEA), new bachelor's and master's degrees have included continuous evaluation procedures as a relevant part of the evaluation process. Using open-source learning management systems such as Moodle is one possible way to implement continuous assessment activities in university courses. This tool allows, among other, the opening of folders for students to upload files with their solved exercises, or the creation of questionnaires that self-evaluate with the answers of the students.

After a few years already working in this direction, we have been able to observe the shortcomings of these options. First, correcting one by one the files uploaded to the web platform took a significant amount of time for professor, especially in undergraduate subjects with a high number of students. Second, the Moodle platform is not as flexible as some courses require regarding the use of mathematical tools to find the solution to exercises. For example, at the University of Málaga, we could not include operations with complex numbers in such questionnaires. Finally, in the specific subjects of engineering studies, the numerical values included in the final result are inevitably linked to simple errors in the initial calculations. Consequently, it is practically inevitable that this automated qualification will be null due to simple calculation errors.

In addition to these drawbacks, we must add those that are derived from the students' response to these continuous assessment exercises. On the one hand, particularly motivated students demand additional exercises that allow them to acquire the necessary skills to face the exercises that are going to be evaluated. On the other hand, those students who do not have this motivation face the temptation of asking for the final solutions to a classmate, who has already solved the exercise, with the immediate objective of not losing those points of the continuous evaluation.

Consequently, convinced of the relevance of the continuous evaluation system and with the purpose of reducing the previously mentioned inconveniences, we understand that the time has come to take a further step in the direction of conserving the advantages of this evaluation system but eliminating, or at least reducing, the aforementioned drawbacks as much as possible. In this paper, we propose a methodology based on the automatic correction of individualized exercises in engineering university courses using a web application coded in Python.

Continuous assessment in higher education is one of the major changes affecting university courses in the last years (Hernández, 2012). Among the different options to implement continuous assessment, gamification activities are one of the most promising

ones (Antonaci, 2017). Besides, there exists also an increase in the use of new technologies in the teaching and learning process (Ekanayake, 2015). One possibility to use new technologies to provide continuous assessment to student relies on e-platforms such as Moodle (Costa, 2012). While Moodle is available in most universities, writing the code to solve complex engineering problems may be hard or impractical. In this work we explain a web application for continuous assessment developed entirely in Python, which is one of the most popular programming languages nowadays.

2. Methodology

The project presented in this paper focuses mainly on the development of a web application that allows the generation and automatic qualification of individualized exercises for each student. This application will lead to a new framework for continuous evaluation in which the main innovative aspect arises from the advantages associated with continuous evaluation and the elimination of the drawbacks associated with the usual practices.

The first step to carry out this continuous evaluation is the division of each subject involved in a series of blocks or didactic units (I, II, III, ...). Each block has a series of learning objectives clearly differentiated from the rest. Then, the professors of each subject has to propose a series of exercises (1, 2, 3, ...) for each of the blocks. The different exercises are ordered from lower to higher difficulty. The same exercise can have several questions (a, b, c, ...). Each exercise is assigned a maximum score in relation to the number of learning objectives involved in its resolution.

Once the exercises of the different subjects have been selected, the professors have to adapt the statements of the same for each student to solve a different exercise. This is achieved by using some data that depend on a numerical code that is different for each student. The code to solve each exercise is programmed in Python by the professors and, then, is uploaded to the web application. These resolution codes are not accessible in any case for the students, who will have to solve the problems "by hand" according to the procedure explained in each subject.

The use of the web application and the individualized problems during the course is explained in more detail below. When the theoretical contents of a block are covered in class, the professor proposes the students to solve the exercises corresponding to that block. The professor can optionally solve some representative problems on the blackboard using data different from the students' data. In this way, students can begin to familiarize themselves with the concepts of each block by solving the same problem as the professor but with different data and checking whether the solution obtained is correct

or not. In the same way, the professor can decide which exercises can be solved by the students in class, and which exercises will be left as homework. In both cases, it is very important that the professor encourages collaboration between students who have solved exercises correctly and students who have not done so yet. The exercises centered on theoretical concepts and resolution methods will be proposed in the first place, while those including more practical aspects will be presented at the end of each block.

When a student correctly solves an exercise, the score of that exercise is added to the total points of the student. Each professor must decide if the total score obtained by each student will have an impact or not on the final grade of the subject. Professors can also decide to publish a ranking and award "prizes" to students with the highest number of points. Rankings can be a competitive element that increases student participation.

When a student incorrectly solves an exercise, he is advised to ask a classmate who has solved the exercise correctly, or go to the office hours of his professor. In any case, the student is encouraged to reflect on the resolution procedure and apply it correctly to their particular exercise.

At any time, the professor can open the web application and access the results of the different exercises proposed in real time. The professor can see what percentage of students have correctly solved each problem, what exercises have been solved by a lower percentage of students, what exercises have been repeated more times by students, etc. This information will be used, for example, to review the concepts related to the exercises that are becoming more difficult for the students, or even the resolution on the blackboard of these exercises with data different from those of the students.

The main characteristics that define this new framework are summarized below:

- The use of the point system associated with the continuous evaluation process is retained, which is in itself an incentive for the students' continued work.

- An automation process is added through this web application, which facilitates the application of the continuous assessment system to courses with a high number of students.

- The door to collaboration among students is left open, which we understand to be very beneficial. The exercises are enunciated and evaluated individually with different final numerical results, so that the collaboration must focus on the solution procedure and not on sharing the final numerical result.

- Also, since the use of the application focuses on the approach and evaluation of the exercises, it is also completely open to students both the choice of operating

system (Windows, Linux, Mac ...) and the calculation programs to be used (Excel, Matlab, Python, Julia, R ...).

- Being an automated application, the generation of exercises substantially reduces the time required by the professor, which naturally gives rise to the option of increasing the number of exercises intended for training.

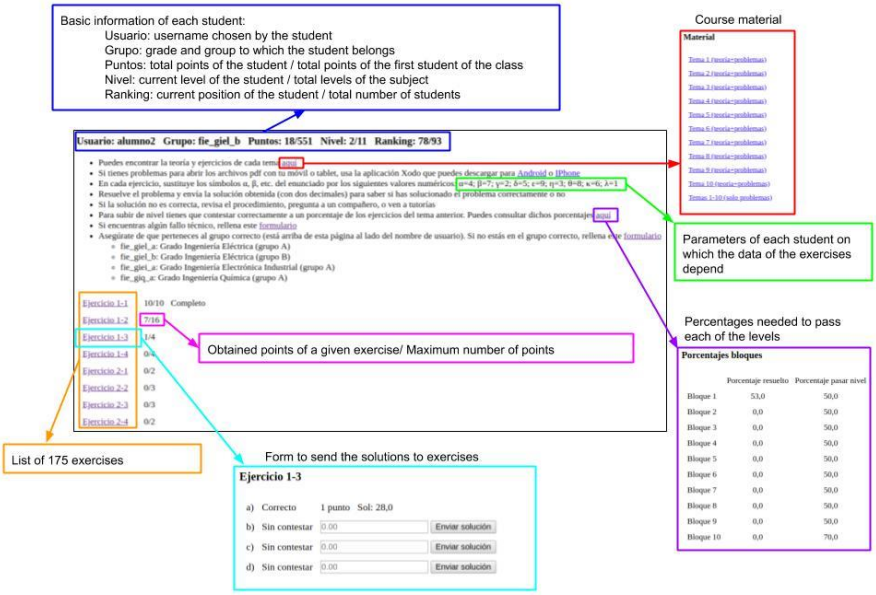
- Complex exercises can be divided into smaller partial exercises and, therefore, the current dependence between the final numerical solution and the qualification associated with the exercise is substantially reduced.

- Finally, when the data associated with each student is recorded in each attempt (time spent, number of attempts, etc.), both for the learning exercises and for the evaluation ones, a very valuable information is obtained both at a global level of the group, in relation to the self-evaluation of the professor's work on the knowledge acquired by the group, as well as at the individual level of each student, in relation to their attainment of learning outcomes.

3. Implementation

The web application is developed using Python and Django, and is hosted on a server provided by the Central Computing Service of the University of Malaga. The Python programming language allows us to include problems whose resolution involves complicated mathematical procedures as necessary (use of complex numbers, resolution of systems of equations, etc.).

Figure 1: Student view of web application



As an example, we provide above a generic student view of the web application. The home screen includes basic information about the student (user and group) as well as information about their progress in the application (total number of points, current level and position in the class ranking). The homepage also includes links to the teaching material of the subject, the percentage of points necessary to level up, as well as an overview of those exercises that have already been solved correctly. When clicking on the link of each exercise, the student moves to another screen where he has to enter the numerical solution to the different sections of the exercise. If a section is answered correctly, the word “Correct”, the number of points obtained, as well as the numerical value of the solution appears on the screen.

Currently, the web application includes exercises of four different engineering courses at two different universities. The main characteristics of each course are summarized below.

- Electric circuits (EC) at University of Castilla-La Mancha (UCLM):
  - Degrees in which the course is taught:
    - Bachelor Degree in Mechanical Engineering
    - Bachelor Degree in Electrical Engineering
    - Bachelor Degree in Electronic Engineering
  - 2nd year course
  - 100-120 enrolled students per academic year (all degrees jointly considered)

- Electric circuits (EC) at University of Málaga (UMA):
  - Degrees in which the course is taught:
    - Bachelor Degree in Mechanical Engineering
    - Bachelor Degree in Electrical Engineering
    - Bachelor Degree in Electronic Engineering
    - Bachelor Degree in Industrial Technology Engineering
  - 2nd year course
  - 700-750 enrolled students per academic year

- Power systems I (PS1) at University of Málaga (UMA):
  - Degrees in which the course is taught:
    - Bachelor Degree in Electrical Engineering
    - Bachelor Degree in Industrial Technology Engineering
  - 4th year course (Electrical Eng.) and 3rd year course (Ind. Techn. Eng.)
  - 60-80 enrolled students per academic year (both courses jointly considered)

- Power systems II (PS2) at University of Málaga (UMA):
  - Degrees in which the course is taught:
    - Bachelor Degree in Electrical Engineering
    - Bachelor Degree in Electrical and Mechanical Engineering
    - Bachelor Degree in Electronic and Electrical Engineering
  - 4th year course (Electrical Eng.) and 5th year course (Electrical-Mechanical, Electronic-Electrical).
  - 40-50 enrolled students per academic year

4. Results

The results of the web applications are presented in three categories:

- Use of the application: number of users, exercises solved correctly, etc

- Impact on grades: percentage of student who pass the course

- Answer to survey regarding the use of the web application

4.1 Use of the application

We provide below a table with the numbers of the web application for the different courses:

Table 1: Use of web application

Course	# Exercises	# Users	# Questions answered correctly
EC (problemasfie)	175	1428	305999
PS1 (problemassee)	62	127	10300
PS2 (problemasexp)	25	54	2649

As observed, the electric circuit course is the one with a larger number of exercises, students and questions answered correctly. Electric circuit is a basic course included in all engineering degrees, while the other more specialized courses are only available for certain degrees.

4.2 Impact on grades

4.2.1 Electric Circuits

The web application has been tested both at the University of Málaga and at the University of Castilla-La Mancha. In the later university, this course has been taught from 2014 to 2017 by the same instructor using similar teaching and evaluation methodologies. Thus, we could carry out a sound analysis on the impact of the web application usage on the overall evaluation. In order to do that, we have compared the markings of the midterm exams, which cover 50% of the course contents for each of those years. Note that the web application was used in 2017 for the first time. The results are shown in the table below. The column “Average” includes the average results for the years 2014, 2015 and 2016.

Table 2: Impact of web application on second year student grades

	2014	2015	2016	Average	2017
Non attendance rate of enrolled students (%)	10	12	14	12	22
Pass rate of students attending the exam (%)	26	13	33	24	64
Pass rate of enrolled students (%)	23	12	28	21	50

It can be noted that in year 2017 the percentage of students who did not attend the exam was significantly higher than in past years. The reason for this is that in order to be eligible to take the midterm exam they had to receive a certain grade in the web application. The students who used the web application on a daily basis were more likely to receive higher grades. However, the percentage of students that passed the midterm exam in 2017 was markedly higher than in past years.

4.2.2. Power Systems I

In the course Electric Power Systems Analysis, included in the 4th grade of the Bachelor Degree in Electrical Engineering, the individualized exercises of this project have been offered as supplementary material for personal training without any influence on the final mark. The grading criteria of the course are: homework (25%), lab exercises (15%) and final-term exam (60%). Even though the exercises of this project were voluntary, results included in the table below reflect a considerable impact on the improvement of the results. In that table, the overall results of the June 2018 marks, the first year with this course included in the project, are compared to those in the previous 3 years. It is worth noting a considerable increase in all the indicators presented:

i. the pass rate was increased from around 50 % to over 66 % of the students attending the exam.
ii. the mean mark of the students attending the exam was considerable increased (around 40%), from the range 3.7-3.8 to 5.21.
iii. and the analysis of the three marks quartiles (Q1, Q2 & Q3) of those students attending the exam also reveals a remarkable influence of these volunteer exercises.

Table 3: Impact of web application on fourth year student grades

	2015	2016	2017	2018
Number of students attending the exam	34	36	26	25
Number of students passing the exam	18	15	13	17
Pass rate (% of students attending the exam)	52.94	41.67	50.00	68.00
Mean mark	3.80	3.71	3.70	5.21
Q1	1.81	1.43	1.43	2.89
Q2	4.46	2.94	4.43	5.66
Q3	5.14	5.94	5.26	6.53

4.2.3. Power Systems II

The course Power Systems II holds in the second semester on the final year in the Bachelors of Electrical Engineering (4th course), Electrical-Mechanical (5th course), and Electronic-Electrical (5th course). This course is focused on the operation of Electric Power Systems including the problems of: Economic Dispatch, Unit Commitment, Electricity Markets, Automatic Generation Control, State Estimation, and operation of the Power Grid.

Solving these problems requires the use of a few economic concepts (marginal price, market equilibrium, etc.) jointly with the typical physical models for devices in the power system (generators, lines, etc.). And usually the problems are posed as mathematical programming problems. Most of the students find some difficulties in the use of the economic concepts and the mathematical programming techniques. Both, the concepts and the mathematical techniques, are illustrated through examples and problems solved in the classroom.

Most students find quite helpful the web application proposed here as a complement to the material provided in the classroom. The web application for this course provides

additional problems that students can solve at their own pace, reviewing the concepts. They instantaneously know whether their responses are right or not, what is a quite valuable feedback, that helps them with their self-assessment, and to clarify what are the points they do not understand well. They can ask the professor about those points and advance in their learning process.

The course evaluation is based on theory (60%) and problems (40%). The web application was used in the course 2018, and it can be observed the Table below, how the mean mark and also the percentage of students passing the exam (regarding the students attending the exam) have been considerably improved regarding the results in years 2016 and 2017.

Table 4: Impact of web application on fourth year student grades

	2015	2016	2017	2018
Enrolled	56	47	35	43
Attending the exam	49	38	19	23
Passing the exam	43	25	12	19
Passing/attending (%)	87.8	65.8	63.2	82.6
Passing/enrolled (%)	76.8	53.2	34.3	44.2
Mean Mark	6.8	5.8	5.0	5.9
Q1	9.1	7.2	8.3	8.2
Q2	7.5	6.1	6.7	6.5
Q3	6.2	5.6	3.8	5.2
Q4	4.5	4.4	2.6	3.4

4.3. Answers to survey

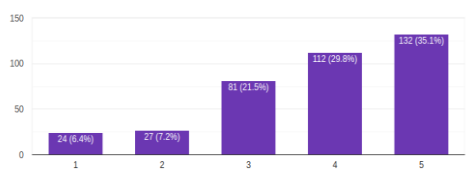
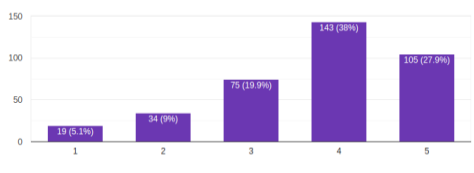
Additionally, students using the web application have been invited to answer a survey about the usefulness of the individualized exercises for the learning of the subject as well as the aspects of the web application that could be improved. The survey included a list

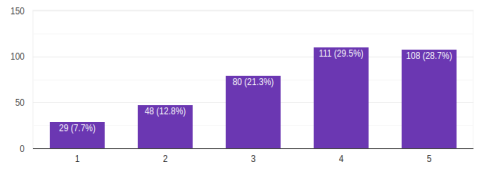
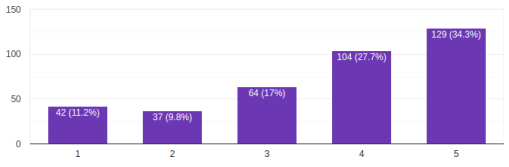
of statements that students had to grade from 1 (totally disagree) to 5 (totally agree). In some of the courses, answering the survey has been encouraged by transferring an extra 5% score. In such course, the percentage of students who participated was 45% of those enrolled in the application.

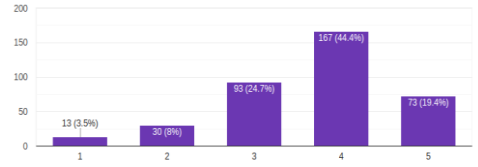
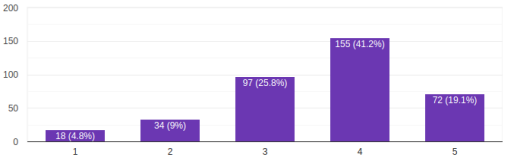
In general, the survey answers showed an overall satisfaction with the web application. Most of the students commented that the use of the web application helped them to work on a daily basis and to better understand the course contents. Despite this, the students also suggested some improvements. Many students claimed that there was a glitch in the web application. Although they correctly solved some exercises, the application may lead to an incorrect answer by rounding the decimals. That is, the required accuracy of the results was pointed out as one of the main drawbacks of the application. This is a sensitive issue because it is not easy to generalize a level of general accuracy for all numerical values. It should be also noted that, in some subject as Power System, the per-unit system is mainly employed. Hence, the required precision must be a trade-off between a narrow margin, forcing to work with a large number of decimals, and wide margin that may recognize wrong results as correct ones, providing then a fake feedback. Since the negative effect of the later is considerably higher, in the framework of those subjects in which these exercises has no any influence on the final mark, the use of a double-precision computational tool (MATLAB or similar) was recommended to solve the problems and 4 four decimals was set as required accuracy. Currently, we are working on solving this and other issues.

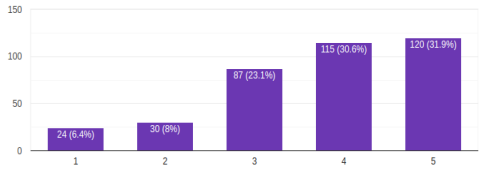
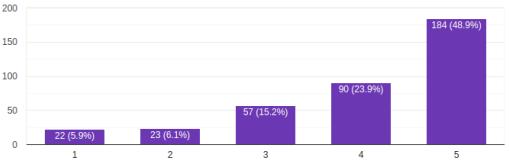
Since the electric circuit course is the one with the highest number of students, we provide below some figures summarizing their answers to the survey. These results show an overall satisfaction with the web application. Most of the students point out that the use of the web application has helped them to work on a daily basis and to better understand the course contents.

Figure 2: Summary of survey about web application

The webapp has helped me to work daily on the course	The application has helped me to better understand concepts of the subject
	

The application has helped me identify concept errors	The ranking of the application has increased my motivation in the subject
	

The variety of the exercises of the application is adequate	The difficulty of the exercises of the application is adequate
	

The application is a good preparation for the exam	I would recommend the use of the application to other students of this subject
	

5. Conclusions

In this paper we present a teaching innovation project based on the development of a web application to continuously assess the learning at engineering university courses. The web application is coded in Python and its main aim is to automatically correct individualized exercises and give points to students that answer correctly. The web application has been tested in two universities and four different courses. More than 1600

university students have used the application and almost 320000 questions have been already answered correctly.

The web application has proven to be an adequate tool for both professors and students. The use of individualized exercises that are automatically corrected allows the professors to continuously evaluate the level of students without requiring too much time. In addition, the global results by group provide valuable information about the knowledge acquired in theory classes, making it possible to detect those parts of the agenda to which more time should be devoted. The use of individualized exercises also motivates students to study the subjects on a regular basis. In fact, students have also recognized the positive impact of the web application on their understanding of the subject and most of them agree that it has been a very good preparation for the exam. By analyzing historical data of students' marks, we have also demonstrated the positive effects of using the web application on different engineering courses.

6. References

Antonaci, A., Klemke, R., Stracke, C. M., & Specht, M. (2017, April). Gamification in MOOCs to enhance users' goal achievement. In 2017 IEEE Global Engineering Education Conference (EDUCON) (pp. 1654-1662). IEEE.

Costa, C., Alvelos, H., & Teixeira, L. (2012). The use of Moodle e-learning platform: a study in a Portuguese University. Procedia Technology, 5, 334-343.

Ekanayake, S. Y., & Wishart, J. (2015). Integrating mobile phones into teaching and learning: A case study of teacher training through professional development workshops. British Journal of Educational Technology, 46(1), 173-189.

Hernández, R. (2012). Does continuous assessment in higher education support student learning?. Higher education, 64(4), 489-502.