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Advanced quiz development for students' self-learning in power generation, transmission and distribution

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Abstract

Students' learning can be improved by using online quizzes with a valuable feedback, especially in large groups, making it very interesting for engineering subjects which are based on mathematics. This paper presents the evaluation of an online quiz experience based on a case study in two university subjects. Quizzes were created by using Wiris Quizzes (WQ) that can register the complete solution with all the steps involved. WQ has a calculator that allows us to solve the mathematical part of the quiz. The first aim of the online WQ experience is to provide feedback to students through automatic grading and clues to find the correct answers. The second aim is to promote autonomous student learning. The teachers also have excellent feedback about faulty interpretations or weaknesses in the students' understanding. Consequently, teachers can provide corrective information to clarify ideas about what they want to be understood and what is understood by students. WQ allows teachers to develop algorithms for the quizzes by using random data, figures realized through programming, and multiple solutions that depend on the values of a table. The teaching experience of using

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WQ has shown that this tool can be useful in university technological subjects with large groups that require advanced and customized quizzes.

Keywords

Moodle, online quizzes, self-learning, power system

An excellent method of teaching is the problem-based learning to understand engineering subjects in and out of the class.[1] Problem-based learning is widely adopted in small groups, but teachers need powerful tools to extend this approach to large groups. The use of web-based learning and online assessment tools is increasing.[2,3] Active learning[4] of engineering students is encouraged by the use of online tools, and the quality of online teaching and learning in engineering will improve, as online tools improve.[5]

Online quizzes can provide teachers excellent feedback about faulty interpretations or weaknesses in the students' understanding, allowing the teacher to know the students' progress and how they proceed.[6]

Many learning management systems offer quizzing tools to record students' performance. QuizMaker and iQuizmaker allow us to generate, administer and score simple quizzes (multiple choice and true/false questions). iQuizmaker allows us to create quizzes for mobile devices. Flinders Learning Online of Flinders University is based on quizzes consisting of a large variety of question types, including multiple choice, true–false, short answer, drag and drop images and calculated questions into the text. QuizStar is a Web-based quiz maker that enables to create quizzes online. The Hot Potatoes suite includes six applications, enabling you to create interactive multiple-choice, short-answer, jumbled-sentence, crossword, matching/ordering and gap-fill online exercises. There are many tools to perform quizzes because they are considered useful. In general, some quizzes contain only the calculated questions that support a formula and perhaps some variable of the formula supports a range of values for random question statements. Then, the questions are different for each student. However, this type of question is not enough for any engineering subject where more mathematical calculation is required. Some authors use the Matlab software to avoid that problem. However, they have to achieve interoperability between Moodle and Matlab to reach their goals.[7,8] Overall, it is a challenge to incorporate mathematical tools in the Learning-Management-System.

At the Polytechnic University of Catalonia (UPC), Spain, the learning management system is based on Moodle and is called Atenea. Moodle allows us to automatically manage, write and assess the quizzes. Wiris Quizzes (WQ)[9] upgrades

Moodle quizzes, so no interoperability issues are taking place. UPC has chosen the WQ and calculator (Wiris Cas)[9,10] because they can be used to solve any mathematical problem in any of the offered engineering subjects. In fact, currently WQ and calculator are incorporated in Atenea for all bachelor's degrees, master's and doctoral programs offered by the UPC.[11] Apart from the experience shown in this paper, WQ also has been used in other subjects as a Calculus Course of the Bachelor's degrees in the UPC.[12]

This paper presents the evaluation of an online quizzes experience, based on a case study of one degree subject and specifically in one master subject for which advanced quizzes were created, and it is a continuation of the work presented in Bogarra et al.[13] WQ is used for developing advanced custom quizzes with different solutions (depending on the proposed design), where figures are different (depending on the randomly generated data), and where the practical problem must be solved using the appropriate standards or manufacturer data tables. The main aim of the online quizzes experience is to provide more problems and feedback to students through automatic grading and clues to find the correct answers in subjects with many students.

Wiris Quizzes

Online WQ has been offered in response to the need to provide flexible learning choices for cohorts of students with different mathematical backgrounds. WQ, created by the mathematical software company Maths for More, allows self-quizzes in or out of class. Wiris calculator[9] is integrated in WQ. This powerful tool offers many mathematical functions, e.g., integrals, limits calculation, solution of differential equations, matrix and polynomials calculation, function graphing in 2D or 3D and symbolic equations manipulation, using rational, irrational or complex numbers, making it easier for students to solve practical problems despite the complexity of the mathematical solution. Wiris calculator covers all mathematical topics from primary school to university level (Calculus, Algebra, Geometry, Differential Equations, etc.).

WQ also includes a programming language[10] that combines programming sentences with mathematical capabilities, so it allows us to develop personalized quizzes whose complex arithmetic operators, random data and conditional instructions, constitute an improvement on Moodle. WQ allows the integration of randomness at any level: in the question data, in a graph, or in the definition of a mathematical object, and implements all the steps involved in the mathematical solution, while also performing automatic correction.

WQ verifies, not only the numerical values, but also symbolic comparisons between student answers and programming expressions. The ability to work Wiris symbolically resembles some automated programming assessment system (APAS) made to evaluate programming exercises. APAS[14–16] is a computer-aided approach to check students' programming exercises, without the inconvenience of doing them. In computer science, the teachers are challenged to automatically correct syntax errors and semantic errors that happen when the statements written, are grammatically correct but logically wrong.

All mathematical items are generated in a single calculation section and they can be used anywhere in the content.[17] Wiris Company[17] shows us all the steps to solve a question as an example. From the point of view of the student, once he has made some calculations using Wiris calculator, he just has to click the *Copy answer* button and it will automatically appear in the formula editor. Then the student submits his answer and automatically obtains the mark for his submission. From the point of view of the teacher, Wiris company presents the calculations performed in the development of the same question.

WQ can be successfully used for both formative and summative assessment. The automatic e-assessment can make the teacher's work more efficient, because verifying the assignments manually and giving feedback to large groups is a time-consuming task. Moreover, the versatility of Wiris allows each student to solve a different quiz.

Audiovisual material to improve Wiris learning

In the previous pilot project using WQ in the subject entitled Electrical Circuits, the students were introduced to the operation of the calculator receiving a 20-min class presentation. They were provided with a tutorial and they were able to view a quiz solved previously, which served as an example. In the opinion survey, students said they had difficulty learning the Wiris calculator syntax. Therefore, authors participated in an educational project for generating audiovisual material (AM) to help students learn. Video resources have been used widely and with success in on- and off-campus engineering education, see for instance Palmer[18] and Wieling and Hofman.[19] We chose MediaTIC to handle the video component of our courses. The system is composed of one computer for the author and another computer for capturing and encoding the material into an mp4 video, with the author's video and the digital content presented on the computer as illustrated in Figure 1. The students watching the video have the feeling of being in class, because they are watching the lecture and the presentation at the same time. This kind of format is being used in other Spanish universities. AM does not contain a complete tutorial of the tool but only highlights some issues chosen by teachers.

The first AM shows the features of WQ and the windows that make up the working environment: statement, calculator, WIRIS editor and grade obtained, and its application in an Electric Circuits (EC) quiz. In the other 10 AMs, the Wiris calculator menus are shown.[20] Figure 1 shows the analysis menu of the calculator that is used to solve an integral, derivative or limit. All these material replace the classroom presentation.

Advanced quiz development using Wiris Quizzes

Power generation, transmission and distribution (PGTD) and EC are taught in the UPC's Terrassa School of Audiovisual, Aeronautical, and Industrial Engineering

Figure 1. Audiovisual material image showing the analysis menu WIRIS Calculator.

(ESEIAAT). The EC course is offered during the fourth semester of the Bachelor's degrees in Aerospace Technology Engineering and Aerospace Vehicle Engineering, and PGTD during the second semester of the Master's degree in Industrial Engineering. In the PGTD subject, advanced quizzes are used that were not necessary for EC's subject.[13]

WQ gives students feedback on their mistakes, verifying not only the numerical values but also allowing symbolic comparisons between student answers and programming expressions. These quizzes not only use questions with random data, but they are also personalized for each student by using:

- figures controlled by programming algorithms,
- different solution options depending on the data,
- tables extracted from catalogues and standards.

Students of PGTD completed three quizzes. The aim of the first quiz is for students to learn how to model a power line. Data from the quiz are: the line length randomly selected from a value list, the wire diameter, the wire resistance per unit length, the figure with the geometric wire distribution, and the distances in meters. Wire distribution is randomly selected from a table (Figure 2), which corresponds to 11 standard high voltage towers. In this case, the figure is controlled by programming algorithms and table data are extracted from catalogues. The unknown values are: the electrical parameters, the overall impedance and admittance, and the transmission coefficients.

The aim of the second quiz is for students to analyse the power line's operating conditions by using the model as simply as possible, so different solution options can be provided depending on the data. Randomly selected data from the value

```
EsqCond=[["tipus","Cable 1","Cable 2","Cable 3","Cable 4","Cable 5","Cable 6","Simple o doble"],
["R1",point(-1.25,0),point(0,0),point(1.25,0),point(0,0),point(0,0),point(0,0),"Simple"],
["R3",point(-1.75,0),point(0,0),point(1.75,0),point(0,0),point(0,0),point(0,0),"Simple"],
["T1",point(-1.25,0),point(0,0.6),point(1.25,0),point(0,0),point(0,0),point(0,0),"Simple"],
["T3",point(-1.75,0),point(0,1.2),point(1.75,0),point(0,0),point(0,0),point(0,0),"Simple"],
["T4",point(-2,0),point(0,1.8),point(2,0),point(0,0),point(0,0),point(0,0),"Simple"],
["S1",point(-1.25,-1.20),point(-1.25,1.2),point(1.25,0),point(0,0),point(0,0),point(0,0),"Simple"],
["S4",point(-2,-1.8),point(-2,1.8),point(2,0),point(0,0),point(0,0),point(0,0),"Simple"],
["D1",point(-1.25,-1.2),point(-1.25,1.2),point(1.25,0),point(-1.25,0),point(1.25,-1.2),point(1.25,1.2),"Doble"],
["D4",point(-2,-1.8),point(-2,1.8),point(2,0),point(-2,0),point(2,-1.8),point(2,1.8),"Doble"],
["BP15",point(-1.5,0),point(0,0),point(1.5,0),point(0,0),point(0,0),point(0,0),"Simple"],
["B15",point(-1.5,0),point(0,0.35),point(1.5,0),point(0,0),point(0,0),point(0,0),"Simple"]]
```

Figure 2. Geometric wire distribution used for the overhead line.

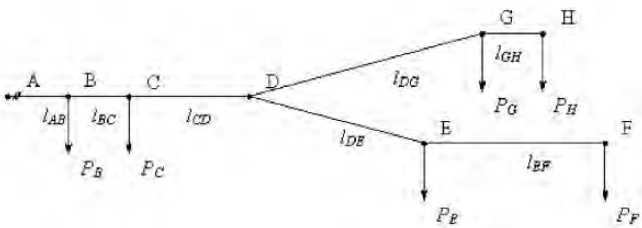

Figure 3. Low Voltage installation analysed.

lists are: the electric parameters, line length, voltage, and power delivered at the receiving end. The unknown values are: voltage, current, and power at the sending end. The quiz must be solved using different equations, depending on the length; so three options are possible, depending on the accepted level of simplification.

The aim of the third quiz is for students to correctly use the standards. Data randomly selected from value lists are: the type of insulation, the type of wire installation, the wire lengths, the voltage drop in each stretch, the consumed power, and the power factor for each load. Developed algorithms allow random values to arrive at a possible solution; otherwise, they generate new random data to ensure that the solution is possible. The installation scheme (Figure 3) and copper conductivity serve as fixed data. The wire sections for stretches A-D, D-H and D-F are the unknown values for the low voltage installation with distributed loads. The selected section must satisfy the current standards.

Every student has different data that lead to different solutions. In this way, WQ has proven to be a useful tool for particularizing quizzes, in which students must use tables to find solutions, that correspond to standards or the component features provided by manufacturers. This is a common requirement in technological subjects. However, because of the high teaching load involved, the traditional method makes it difficult to introduce much variability.

Quizzes shown in this section could be extended for other mathematics-based subjects.

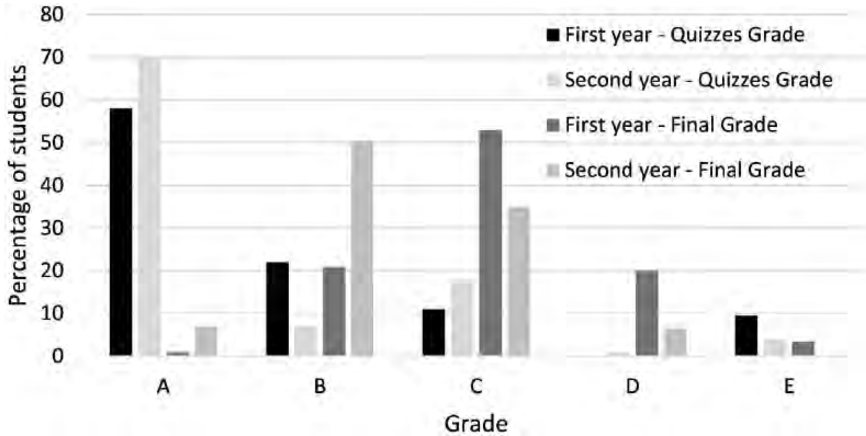

Figure 4. Grades for the quizzes and final grade of Electrical Circuits (EC) during the two-years project.

Experience of online quizzes

This experience started with a previous pilot project using WQ in EC. Lessons learned were explained in Bogarra et al.[13] The positive results encourage us to extend the experience. So a new project was designed and developed for two scholar years. The first student assessment indicated that quizzes could be positive for their learning; so, during the second academic year the project was continued in the subject of EC and also extended to PGTD.

During the first year, students who participated in the experimental group commented on the excessive workload (seven quizzes). The number of attempts was deemed to be excessive (an average value of 6) and they were not reflected in the final grade. Therefore, during the second year of the project, the number of quizzes and attempts were limited to three, for both EC and PGTD. The average time needed to perform a quiz was 1 h, although the quiz was enabled for a week, so that students could organize their time accordingly within that period.

To assess whether the quizzes enhance learning, student grades for the quizzes and final grades (final result of the academic year) were considered. First, the outcomes for EC are shown. Figure 4 shows the percentage of students who achieved each grade, both for the quizzes and for the final grade, and including the two academic years of the project. The students who completed the quizzes during the first and second year were, respectively, 53 (versus a total of 73) and 80 (versus a total of 86). When comparing the outcome, we can see that the percentage of students passed (A, B, C rank) have risen slightly in both the quizzes and the final grades. Given that the WQ is conducted outside the classroom and the students have all the training material, the pass rate for quizzes is higher than for the overall subject. These results, besides other factors, encourage and reward us for

Table 1. Student participation in electrical circuits (EC) and power generation, transmission and distribution (PGTD) Wiris quizzes during the second year of this project.

Percentage of students who have taken part	Wiris quiz number 1 (%)	Wiris quiz number 2 (%)	Wiris quiz number 3 (%)
EC	93.0	90.7	93.0
PGTD	60.1	58.1	49.3

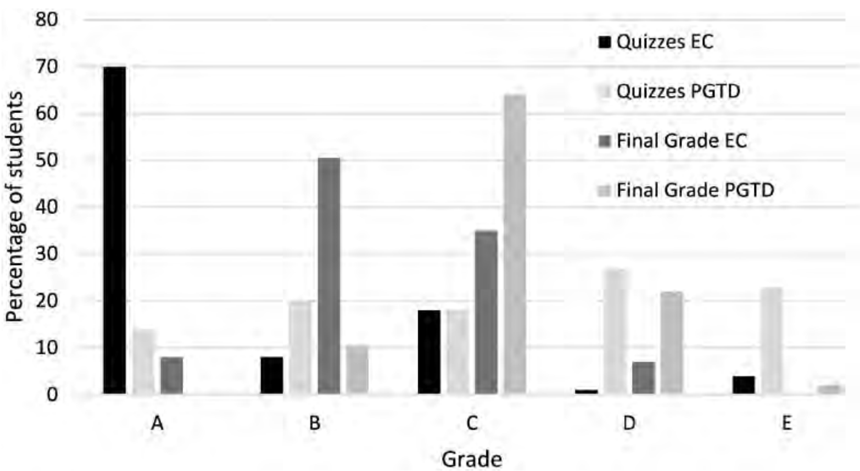

Figure 5. Grades for the quizzes and final grade of Electrical Circuits (EC) and Power Generation, Transmission and Distribution (PGTD) in the second year of this project.

the time devoted to the search of the tool that allows us to propose problems with the same difficulty as those made in the classroom.

Table 1 shows the percentage of students who took each quiz in both the subjects of EC and PGTD. To establish a comparison, Figure 5 shows grades for the quizzes and the final grades for EC and PGTD in the second academic year. In the PGTD course, 89 students completed the quizzes versus a total of 148 enrolled students. In PGTD, the second quiz was worse than the first quiz because the statement did not specify if the results were polar or rectangular representation. The automatic solution was made with polar representation. This led some students to abstain from taking the third quiz. However, the students who continued and took the third quiz improved their grades. If we compare the grades between the two subjects, students in EC obtained better academic results. Important factors may have been the access grade to the university and the student participation in the quizzes (Table 1), both were higher.

The aim of this work is to set out the usefulness of WQ more than the identification of the characteristics of the studied cohorts, their personal or academic

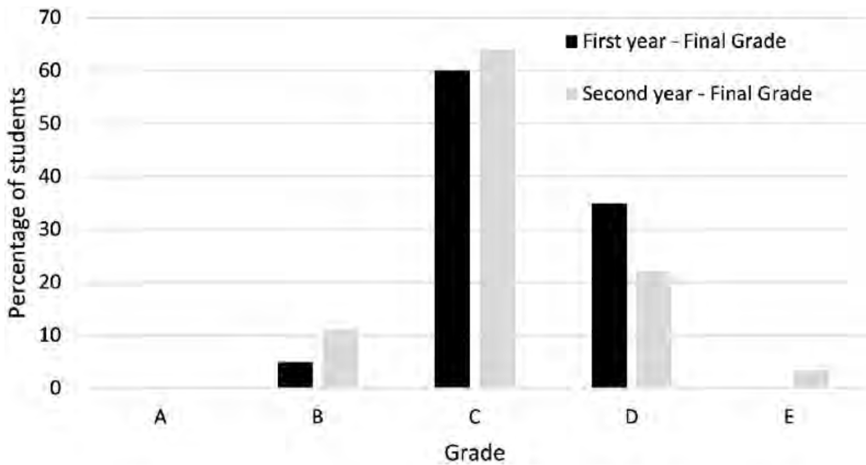

Figure 6. Final grades for Power Generation, Transmission and Distribution (PGTD) subject.

variables and the relationship of these with the academic performance because of doing the quizzes.

In order to compare the academic outcome, Figure 6 shows the final grades of the two academic years for the PGTD subject. As mentioned previously, WQ was only used in the second academic year. In this year, the final grade trend is better than in the previous one, as in the EC subject. It would be necessary to analyse more years to be able to affirm that WQ could be responsible for the improvement. However, for us, the results have encouraged us to continue using WQ because it is the only way to propose online problems with the same complexity as those made in classroom, without an extra burden for the teacher.

At the end of the semester, after the students did the mid-semester test and completed all the quizzes, and before they did the final test, a survey was conducted to obtain feedback from students in the subjects of EC and PGTD. The survey questions were about the AM, documents (Wiris manual and worked example) and quizzes. Each survey included seven questions. In this paper, only the questions about the quizzes are shown, with the aim to simplify.

Questions about the content of the quizzes were:

- S1. I think the quizzes promote learning.
- S2. I think the syntax of the quizzes is easy to understand.
- S3. I think the quizzes have allowed me an autonomous work.

Questions about the product of the quizzes were:

- S4. I had trouble when I was taking the quizzes.
- S5. I think the quiz format is right.

Table 2. Student feedback from electrical circuits (EC) and power generation, transmission and distribution (PGTD) about the quizzes content and quizzes as product.

	Statement													
	Quizzes content						Quizzes product							
	S1 (%)		S2 (%)		S3 (%)		S4 (%)		S5 (%)		S6 (%)		S7 (%)	
Degree of agreement	EC	PGTD	EC	PGTD	EC	PGTD	EC	PGTD	EC	PGTD	EC	PGTD	EC	PGTD
Strongly agree	38	19	18	11	20	9	5	25	17	6	42	25	33	40
Agree	40	49	22	28	35	30	15	21	42	40	28	28	39	38
Neutral	17	26	44	42	27	38	38	30	28	32	15	30	15	8
Disagree	5	4	13	15	15	19	29	20	7	17	10	15	13	8
Strongly disagree	0	2	3	4	3	4	13	4	6	5	3	2	0	6
Don't know or no answer	0	0	0	0	0	0	0	0	0	0	2	0	0	0

- S6. I think the length of the quiz is right.
- S7. Quiz level agree with the subject level.

Table 2 shows the results of the student opinion of the quizzes for EC and PGTD subjects, respectively. A very small percentage of EC and PGTD students disagree or strongly disagree that the quizzes promote learning (S1 in Table 2). However, the sum of the percentage of students who disagree or strongly disagree that the syntax of the quizzes is easy to understand is 16% and 19% for EC and PGTD, respectively (S2 in Table 2). Thus, the provided material has allowed students to solve the quizzes, despite the difficulty they express about the syntax. The percentages of students who disagree or strongly disagree that the quizzes allowed them autonomous work are slightly higher than in other statements (S3 in Table 2). These indicate that it is important to teach more about the advantages of self-learning.

The EC and PGTD students think that the quiz format and the length is right (S5 and S6 in Table 2). A low percentage 13% of EC and 14% of PGTD students disagree or strongly disagree that the quiz level is appropriate to the subject level (S7 in Table 2). The majority of students of both subjects agree that the level of the course is equivalent to the quizzes, so student perception of question difficulty matches teacher perception.

In conclusion, despite the complicated syntax and the occasional problems when connecting online to do the quizzes (S4 in Table 2), students say that these are a good complement to the traditional classroom and that they also promote learning. Therefore, the new possibilities provided by WQ are interesting for both the teacher and the student.

Conclusion

WQ has been successfully applied in the EC and PGTD subjects with the aim of improving autonomous learning and self-evaluation. The teaching experience of using WQ has shown that it can be useful in any subject where math is needed to solve the problems, and where an advanced and customized quizzes are required. WQ allows the development of the algorithms for the quizzes by using random data, figures realized through programming, and multiple solutions that depend on tables based on standards and electrical components catalogues. In addition, the steps of the problem solution are recorded allowing the teacher to give accurate feedback to students, and also the teacher may adjust some contents of the subject if it is necessary.

The student feedback has demonstrated that they liked the created AM. They consider WQ a good complement that promotes their learning.

The incidence of the quizzes in the final marks for the selected group of students that follow the experience is positive, but the accurate evaluation of the association between the exposed students and the final marks requires additional information. In the first pilot experience with few students, the results were conclusive, since those who did the quizzes were the most motivated students and they passed the subject. Several cohorts cannot always be compared, due to differences in average ability or experience, especially in mathematics-based subjects. Therefore, we have tried to minimize the differences in this regard.

The teacher can easily review and reflect the difficulties in the learning process, and identify what needs to be improved in order to make the learning of this or other cohorts more efficient. It is not possible to establish a correlation between the improvement of the marks and the completion of the quizzes, but this improvement encourages us to perform a deeper analysis. It is hoped that many, if not all, of the achievements could be adapted to other cohorts, and other courses, in other disciplines.

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