

# THE USE OF QUIZZES ON MOODLE FOR TEACHING DIFFERENTIAL EQUATIONS TO ENGINEERING STUDENTS

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*This paper explains the design and psychometric quality of a battery of multiple-choice quiz as formative e-assessment for teaching differential equations. It was a preliminary experiment conducted inside a second course of calculus (Mathematical Analysis 2) for about 200 students in Managerial and Electronic Engineering at University of Udine. A survey was also administered to evaluate the appreciation of the students about the quizzes. From the survey, we found out that the quizzes were well chosen, and they discriminated adequately between higher and lower student subject knowledge. Moreover, they helped students to find gaps in their preparation and to keep up with the lessons.*

*Keywords: e-learning, quizzes, engineering students, differential equations, psychometric analysis, survey*

## 1. INTRODUCTION

Formative assessment is defined “as the iterative processes of establishing what, how much and how well students are learning in relation to the learning goals and expected outcomes in order to inform tailored formative feedback and support further learning, a pedagogical strategy that is more productive when role is shared among the teacher, peers and the individual learner” (Gikandi, Morrow & Davis, 2011).

According to the OECD “students need considerable, regular and meaningful feedback; teachers need it to understand who is learning and how to orchestrate the learning process” (Dumont, Istance & Benavides, 2010) and e-assessment can provide systematic, timely, rich and personalized feedback (Albano & Ferrari). In these way, online formative assessment can play a crucial role in enhancing learning by creating improved learning environments that motivate students to actively engage and regulate their studies (Chung, Shel & Kaiser, 2006).

One advantage of regular quizzes is that they encourage students to keep up with the course content as it is presented, (Sales-Morera, Arauzo-Azofra, & Garcia-Hernandez, 2012; Angus & Watson, 2009). Additionally, online quizzes provide immediate feedback to students about their level of learning (Hattie & Yates, 2014), and help the tutor identify parts of the course content that students are struggling with and that require further explanation in class. Angus and Watson (2009) found out that regular, low-stakes, online quizzes improved student learning, as evidenced in the final exam. However, it is essential to bear in mind that the whole process should be permanently revised and updated (for the analysis of a bridge course see Lepellere, Cristea & Gubiani 2019).

The concept of a differential equation (DE) in Italy is introduced in high school (especially in science-based schools) and will be an important subject of study throughout the University, especially in the degrees of science and engineering. It has strong correlations with many mathematical concepts including functions, derivatives, integrals, etc. Therefore, students should understand these concepts in order to understand DEs and vice versa; if they understand DEs conceptually, they will understand these concepts better. Research has revealed that students hardly even understand what a differential equation is and what it is for (Raychaudhuri, 2008). The experience has indicated that an engineering

perspective may improve both students' motivation for learning mathematics and students' ability to transfer their mathematics learning to engineering contexts (Pennell, Avitabile & White, 2009; Varsavsky 1995). Moreover, in mathematics education, researchers have suggested that instructional design capitalize on students' intuitions by using realistic settings for DE problems (Rasmussen & King, 2000; Rasmussen, 2001).

Differential equations, for Management and Electronic Engineering students at the University of Udine, is a topic taught inside Mathematical Analysis 2: a second course in calculus (9 credits corresponding to 72 hours of lessons), held in the second semester of the first year. It is preceded by Mathematical Analysis 1 (12 credits) and Linear Algebra (6 credits) and it is simultaneously with Physics 1. Mathematical Analysis 2 includes topics (in the order presented during the lessons) as: first and second order differential equations; integrals on curves; differential and integral calculus in several variables; surfaces and integral calculus of vector fields; systems of linear differential equations with simple studies of stability; Fourier series. Unfortunately, many students end up preparing the exam in the second year after having successfully passed Mathematical Analysis 1 and Linear Algebra exams slowing down their studies. In the current academic year, it was decided to propose quizzes on Moodle to encourage them to keep up with the lessons and participate in the two partial tests proposed one at half semester and the other one at the end. Moodle (Modular Object-Oriented Dynamic Learning Environment) is an e-learning platform designed to stimulate interactivity between teachers and students used at university of Udine. We used the quizzes not to assess students, but to make them study more, to encourage them not to postpone their studies. Several applets have also been provided with GeoGebra to facilitate the graphical representations of the concepts.

In this contribution we limited ourselves, for the sake of brevity, to the design and the psychometric analysis of ten quizzes about first and second order differential equations. We have also proposed to the students a survey to test how the quizzes were dealt with and whether they served their purpose.

The research questions addressed by this study are therefore:

1. Were the quizzes of a suitable level of difficulty and discriminate well between higher and lower mathematical abilities?
2. Did the use of quizzes on Moodle help the students to find gaps in their preparation and to keep up with the lessons? How do they tackle quizzes on Moodle and deal with the doubts that emerged during the study?

## 2. METHODS

In engineering careers, the study of Differential Equations is one of the core subjects for undergraduate students. It is not a new subject for undergraduate students in Italy, since they already have a first approach in secondary school.

Students received 10 hours of instruction in first and second order differential equations, 8 hours of exercises class and 2 hours of applications of the subject for engineer and physics.

A researcher in mathematical analysis, a researcher in geometry and a didactic collaborator expert in physics and engineering applications were involved.

From the wide range of tools offered by Moodle, we focused on the multiple-choice quiz format. The aim of the quizzes was not to assess students, but to make them study more, to encourage them not to postpone their study, and to provide more balance in their study program; and to make students more aware of their level of understanding (often students only realise that they cannot solve the exercises when they get the first test, in the middle of the semester). The quizzes were available in

Moodle and the staff repeatedly reminded students that the aim of the quizzes was to help their study of the subject and be aware of their level of understanding.

To answer the first research question we use the psychometric analysis method, for the second we use a survey. We start to present the design of the quizzes proposed.

## 2.1. THE QUIZZES

Six batteries of quizzes were administered online, every two or three weeks, one for each chapter of the course. They were not randomly generated and did not have a time limit to answer the questions, but it was mandatory for the students to reach a certain level to enter the midterm test. We have designed questions to supervise students' progress articulated in specified learning outcomes and skills: knowledge, comprehension and applications.

The ten quizzes designed for first and second order DEs were the following:

1. **Recognizing equations with separable variables:** Students often find the exercises on books or on the net already grouped according to the typology, consequently they can use the solution formulas without paying the right attention. Here we wanted to force them to think on the structure of the equations with separable variables. Furthermore, the advantage of quizzes is the fact that the equations must not be solvable as in standard exercises.
2. **The use of initial conditions:** Here we focused on a critical passage (remove the absolute value) in a differential equation with separable variables and a parametric Cauchy condition. By isolating the critical passage, we allowed the students to concentrate and analyze in depth the question linked to the initial conditions. In a complete exercise, students sometimes "content themselves" with studying only a particular case or removing the absolute value because "the exercise is too hard however the teacher will see that I understood".
3. **Recognizing a solution from the graph:** In order to understand the definitions and the theorems involving differential equations, students need to handle graphical representations.
4. **The use of the Overlapping Principle:** It was mainly used to review the additive property. Once again, the structure of the quiz allows us to show "long" solutions without the student losing hours doing tedious calculations.
5. **Similarity or variation of constants method?** Analogous to quiz 1, but now for second order differential equations. They had to identify whether one is forced to use the method of variation of constants.
6. **Resonance yes or no:** Instead of giving them one of those horrible summary tables that are often used by the students, we designed a quiz to make most cases appear where the resonance phenomenon occurs. Here as well, the advantage of the quiz is that it does not require boring calculations but only to focus on the problem.
7. **Choose the particular solution of first order DEs:** Since students tend to use the pre-packaged formula, we required a specific intermediate result to force them to use the method of variation of the constant.
8. **Forcing piecewise function:** This question was made to underline the fact that, in the case of forcing piecewise function, different constants are needed for each case and subsequently the solutions must be connected. Here also, the problem was that, for relatively long exercises, students sometimes have a drop in attention in the final step or "settle" for a partial result.
9. **Qualitative study (with the help of a GeoGebra applet):** The question wanted to guide the students to the use of the GeoGebra software in the analysis of a qualitative study where it is not possible to calculate an explicit solution (for example in the study of models applied to real cases).

Sometimes the engineers' studies concentrate only on the explicit solution, they do not analyze the result obtained.

10. **Resonance in RLC circuit:** We wanted to force the students to study the RLC circuit. Usually when they see the "applications" they think: "this question can't be asked in the exam, so I don't need to study it" or "I can study this topic at the end of the course since I'll only need it for the oral part of the exam".

Quiz questions were not randomly generated, so all students got the same questions and naturally, students shared the solutions with each other. To avoid unfairness, it was strongly emphasised that quizzes were important to students, to allow them to test themselves and get feedback on their level of understanding.

## 2.2. THE PSYCOMETRIC ANALYSIS

Moodle offers a wide range of resources to carry out a psychometric analysis of quizzes, we utilized the Facility Index (FI), the Discrimination Index (DI) and the Discrimination Coefficient (DC) (Martins, 2018; Blanco, Estela, Ginovart & Saà, 2009). FI describes the overall difficulty of the questions, it represents the ratio of users that answer the question correctly. In principle, a very high or low FI suggests that the question is not useful as an instrument of measurement. There are two descriptors to measure effectiveness, DI and DC, both ranging from -1 to +1. The DI index provides a rough indicator of the performance of each item to separate high scores vs. scorers. The DC is a correlation coefficient between scores at the item and at the whole quiz. In both cases, positive values indicate items that discriminate proficient learners, whereas negative indices mark items that are answered best by those with lowest grades, hence not helping to discern between the good and the bad performers. In short, these coefficients can be used as powerful methods of evaluating the effectiveness of the quiz when assessing differentiation of learners. The advantage of using DC over DI is that the former uses information from the whole population of learners, and not just the extreme upper and lower thirds as DI. Thus, this parameter may be more sensitive to detect item performance.

## 2.3. THE SURVEY

The other research question of this study was: are the quizzes a fair and effective tool to increase students' learning? To answer, we proposed the following queries:

- Q1: Do you think the use of quizzes on Moodle has helped you to find gaps in your preparation?
- Q2: Do you think the quizzes on Moodle have helped you to keep up with the lessons?
- Q3: How do you tackle quizzes on Moodle? (respond with the utmost sincerity)
- Q4: How did you deal with the doubts that emerged during the study?

## 3. RESULTS

### 3.1. THE PSYCOMETRIC ANALYSIS

In this section we analyze, through the psychometric quantity FI, DI and DC, the quality of the assessments. They help to answer whether the questions were appropriate, well chosen to demonstrate concepts, of a suitable level of difficulty and whether they discriminate well between higher and lower mathematical abilities.

The results were summarized in the following table:

Questions	FI	DI	DC
1 Recognizing equations with separable variables	88.37%	51.34%	58.53%
2 Use of initial conditions	84.16%	40.97%	48.12%
3 Recognizing a solution from the graph	85.15%	41.60%	50.91%
4 The use of Overlapping Principle	79.70%	46.59%	52.85%
5 Similarity or variation of the constants	76.73%	61.47%	64.37%
6 Resonance yes or no	<b>68.07%</b>	57.67%	59.71%
7 Choose the particular solution of first order DEs	80.69%	49.00%	56.84%
8 Second member defined in two pieces	80.69%	52.69%	61.40%
9 Qualitative study (GeoGebra applet)	75.87%	65.25%	<b>66.95%</b>
10 Resonance in RLC circuit	78.71%	47.86%	54.79%

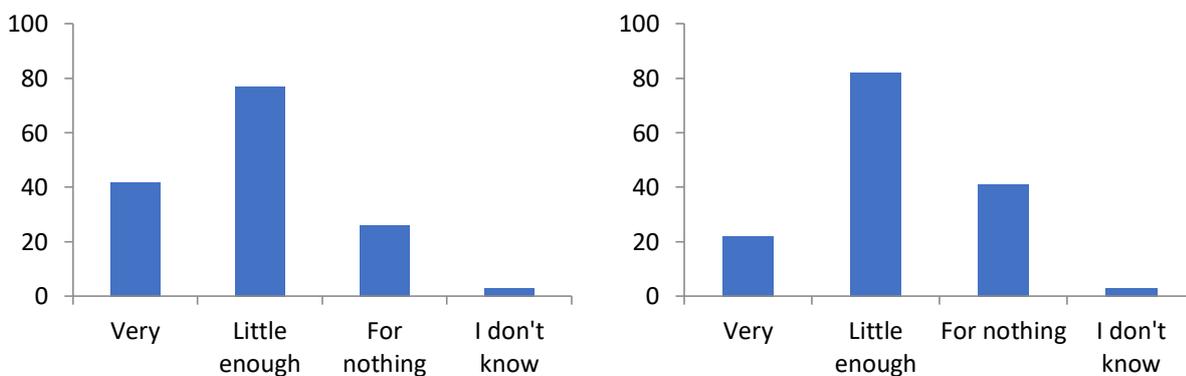
**Table 1. Psychometric results**

For the psychometric analysis of the ten quizzes involved, as seen in Table 1, FI ranges from 68% to 88% says that the quizzes were quite easy for the students. Moreover, most of the questions show high values for DC, yet lower values for DI, this means that the quizzes were excellent. An ideal item will be the one which has average FI between 50% and 70%, high discrimination ( $D_p > 30\%$ ), most of the items met the criteria of acceptable difficulty level and good discrimination. The most difficult quiz has been the recognition of the resonance phenomenon. While the one with worst discriminatory power has been the use of initial conditions.

### 3.2. THE SURVEY

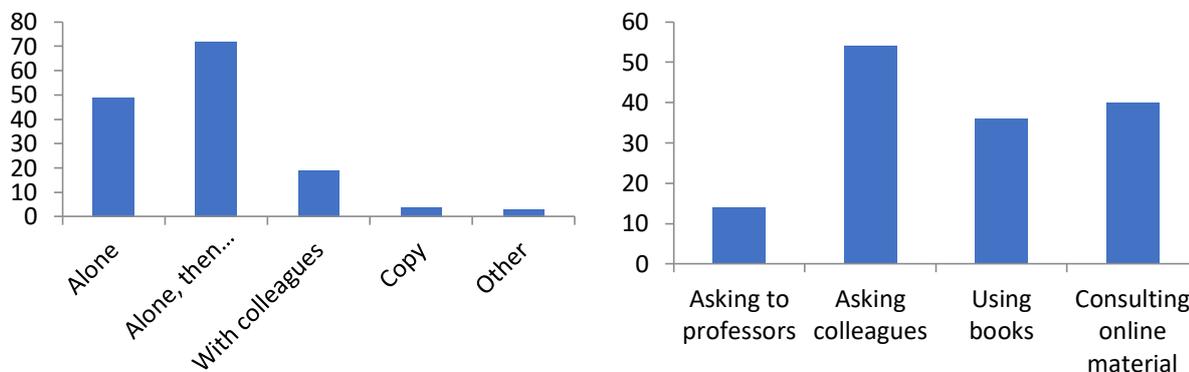
In this section we present the results of the survey. From 202 students who participated in the quizzes, 148 responded to the survey. Of these, 120 participated to the midterm test.

The answers to the question “Do you think the use of quizzes on Moodle has helped you to find gaps in your preparation?” are summarized in Figure 1, left side. 42 students answer “Very”, 77 “Little enough”, 26 “For nothing” and 3 “I don’t know”. To the question “Do you think the quizzes on Moodle have helped you to keep up with the lessons?” (Figure 1 right side) 22 students answer “Very”, 82 “Little enough”, 41 “For nothing” and 3 “I don’t know”.



**Figure 1: On the left Q1: Do you think the use of quizzes on Moodle has helped you to find gaps in your preparation? On the right Q2: Do you think the quizzes on Moodle have helped you to keep up with the lessons?**

The answers to the question “How do you tackle quizzes on Moodle?” are summarized in Figure 2, left side. 49 students answer “Alone”; 72 “Alone, then I double check my answers with my colleagues' before submitting them”; 19 “With the colleagues”; 4 “Copy”; 3 “Other”. Finally, to the question “How did you deal with the doubts that emerged during the study?” (Figure 2 right side) 14 students answer “Asking professors”; 54 “Asking the colleagues”; 36 “Using books”, 42 “Consulting online material”.



**Figure 2: On the left Q3: How do you tackle quizzes on Moodle? On the right Q4: How did you deal with the doubts that emerged during the study?**

The results of the survey show that the students appreciate the use of the quizzes: they consider them useful to highlight their gaps and to keep up with the study of the course. In addition, many students prefer to deal with colleagues for fear of making mistakes and lost so the possibility to participate to the midterm test. The comparison with the colleagues is also widely used by students to resolve their doubts, followed by consulting online material and then the use of books. Nonetheless asking to professors is the least chosen, there have been frequent requests for clarification especially at the end of the lessons principally about the subject of the lesson just taught.

## CONCLUSIONS

As a preliminary experience regarding the use of Moodle quizzes we can say that they surely helped most of the students to keep up with the lectures. The fact that the students had to reach a certain grade with the quizzes to be able to take part in the mid-term tests, led them to collaborate even more among themselves. In light of this, psychometric analysis rightly presents coefficients that exceeds the expectations. We used the quizzes not to assess students, but to make them study more, to encourage them not to postpone their studies. The quizzes were designed to highlight the most important aspects of the various topics discussed in the lessons and to remark the crucial points where students usually get into trouble. Next year the quizzes will be repeated after a review based on the results of the psychometric analysis and the performance of the students to the exams.

The collaboration between students is a positive fact and it will be encouraged even more next year. For example, we are thinking to propose specific activities such as working group projects to exhibit to the whole class.

The results of the partial tests were encouraging, more than 50% (versus 30% of the previous year)

of those enrolled in the first one passed the exam but we cannot correlate this result only to the use of the quizzes. The participation to the mid-term test was higher in this academic year than in the previous one too.

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