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ARTICLE

A Proposal for Formative Assessment with Automatic Feedback on an Online Mathematics Subject

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Abstract

This article presents a new teaching methodology implemented on a basic mathematics course for Engineering students at the Open University of Catalonia (UOC). The experience of its implementation in the 2010/11 academic year is described and the results are discussed. This methodology is based on formative assessment. As well as doing the activities contained in the course materials, students take weekly practice and assessment quizzes and receive automatic feedback. Not only are they told whether their answers are correct, but they also receive suggestions and comments on the possible sources of their errors. The results suggest that this teaching methodology gives students the opportunity to regulate their own learning processes while allowing lecturers to identify and react to problems in a responsive, timely manner. They also suggest that it fosters interaction among students and between students and lecturers. Moreover, since the teaching methodology was introduced, the number of students dropping out of the subject has fallen considerably.

Keywords
activity-based learning; online formative assessment; automatic feedback; immediate feedback; teaching methodology

¿Por qué una propuesta de evaluación formativa con feedback *automático en una asignatura de matemáticas en línea?*

Resumen
En este artículo se presenta una nueva estrategia docente en un curso básico de matemáticas para estudiantes de ingeniería de la Universitat Oberta de Catalunya; se describe la experiencia de su implementación en el curso 2010-2011 y se discuten los resultados obtenidos. Esta metodología, basada en la evaluación formativa, se concreta en la realización semanal de cuestionarios de práctica y de evaluación con feedback *automático, además de la realización de actividades propias del material del curso. En la retroalimentación del sistema, no solamente se informa de la validez de la respuesta, sino que se proporcionan sugerencias y comentarios del posible origen de su error. Por un lado, los resultados obtenidos sugieren que la metodología docente implementada da a los estudiantes la oportunidad de regular su propio proceso de aprendizaje y al profesorado, la posibilidad de detectar problemáticas y reaccionar con agilidad; por otro lado, fomenta las interacciones con contenido matemático tanto entre estudiantes como entre estudiante y profesor. Además, con esta estrategia docente, el número de estudiantes que abandonan la asignatura se ha reducido notablemente.*

Palabras clave
aprendizaje basado en la actividad, evaluación formativa en línea, feedback *automático,* feedback *inmediato, estrategia docente*

1. Introduction

The inclusion of mathematical content in Engineering courses has traditionally given rise to much debate and controversy. While the arguments about why, how and the extent to which they should be introduced have traditionally been disputed, the Spanish Ministry of Education and Science's directives for elaborating Science and Technology bachelor's degree curricula have been very clear (BOE [Spanish Official State Gazette] No 260 of 30/10/2007, 18770). On the one hand, they underscore the expediency of designing bachelor's degree courses to include basic competencies in each branch of knowledge. On the other, they make it compulsory to include the fundamentals of calculus, linear algebra and descriptive statistics in most of them. Indeed, any future Engineering graduate should be able to manage mathematical objects and process numerical data using basic statistical techniques. However, the reality of the situation shows that there are serious problems in this regard.

The poor academic performance of students in their initial years and evidence of a lack of mastery of basic mathematical concepts —as well as their application to specific problems— create a general sense of unease (López-Gay, 2001). In many cases, such a sense of unease leads to a questioning of educational practice, of the appropriateness of teaching methodologies and assessment systems, and of the incorporation of information and communication technologies (ICTs) into learning. In e-learning, technology is part of the educational context, and the learning methodology is radically different.

This article presents a new teaching methodology implemented on an online basic mathematics subject. Based on a student activity-based learning model, the new methodology uses an automatic assessment and feedback tool. The impact of this methodology on subject-taking is analysed, as is the degree of student engagement and the drop-out rate.

2. Immediate feedback, a key factor for formative assessment

Situated within the framework of online education, the proposed assessment model incorporates summative assessment tools to promote formative assessment. In order to define formative assessment, the authors have drawn on Black and Wiliam's (2009) definition and have adapted it to the context of e-learning. They therefore consider that an activity is formative if students obtain evidence of their performance and then interpret and use it to decide which steps they need to take in the teaching-learning process.

A review of the literature on research into formative assessment in online higher education allowed Gikandi et al. (2011) to assert that if the viability, reliability and absence of fraud in an assessment model can be validated, then online formative assessment can function as a new teaching methodology. To that end, such assessment must facilitate: an engagement with critical learning processes, the promotion of a fair education, and immediate, formative feedback. According to the same authors, online formative assessment helps to create attractive learning environments and promotes not only significant interaction between a student and other participants, but also student self-interaction by means of self-corrected quizzes for example.

As mentioned earlier, one of the factors required to make formative assessment work is the existence of immediate, formative feedback. To assess whether feedback is formative or not, Nicol and Macfarlane-Dick's (2006) conceptual model of processes of self-regulation has been taken as the reference. It is a model that takes account of both internal feedback (generated by a student) and external feedback. This article focuses on external feedback. Nicol and Macfarlane-Dick describe good feedback practice as "anything that might strengthen the students' capacity to self-regulate their own performance" and propose seven principles, asserting, in their words, that good practice:

1. helps clarify what good performance is
2. facilitates the development of self-assessment in learning
3. delivers high quality information to students about their learning
4. encourages teacher and peer dialogue around learning

5. encourages positive motivational beliefs and self-esteem
6. provides opportunities to close the gap between current and desired performance
7. provides information to teachers that can be used to help shape the teaching

Regarding formative feedback, another aspect of interest is the impact it can have on student engagement. Indeed, drop-out rates among adult students is a characteristic problem in online higher education, and particularly so in mathematics and physics subjects on Engineering courses, where the drop-out rate it high (Smith & Ferguson, 2005). While many different factors might have an impact on a student's persistence (Castles, 2004), formative feedback can foster students' engagement and enhance their motivation to learn (Crisp & Ward, 2008).).

3. Teaching proposal for the Introduction to Mathematics for Engineering subject

The teaching methodology proposed here was developed for a basic mathematics subject for undergraduates on Computer Engineering and Telecommunications courses at the Open University of Catalonia (UOC): Introduction to Mathematics for Engineering. The subject has two basic objectives: a) to acquire the terminology, techniques and fundamental concepts of algebra and mathematical analysis; and b) to apply the mathematical concepts studied properly.

The need to improve teaching quality for mathematics subjects on Engineering courses and the authors' experience over the past 10 years of these types of environment have led them to consider a student activity-based design. Activities are followed up and regulated by means of a (semi-) automatic assessment and (semi-) automatic feedback tool. This design was developed within the framework of a teaching innovation project that enabled the course design to be specified, quizzes to be elaborated (using WIRIS Quizzes, www.wiris.com) and a pilot test to be carried out. Bearing in mind that doing things, verbalising things and making mistakes is, as many studies have shown, the best way to develop basic mathematics competencies (Prince, 2004), a learning methodology based on studying each topic by doing activities and taking practice and assessment quizzes was designed. Such quizzes, whose statements are parameterised, constitute an infinite bank of exercises for each topic, all of which have their respective automatic correction.

To be precise, the subject is divided into two blocks: Algebra and Analysis. In the first, there are five topics: Numbers, Equations, Systems, Polynomials and Matrices. In the second, there are six topics: Polynomial Functions, Trigonometric Functions, Exponential Functions and Logarithms, Continuous Functions, Derivation and Integration. For each topic, there is a practice quiz and assessment quiz and, at the end of each block, a summary quiz. This amounts to a total of 26 quizzes. Students can take the practice quizzes at any time, as many times they want; the assessment quizzes have start and end dates and, once that period has been opened, students have two days to submit them. The question types are varied: multiple choice, true/false and short answer. A particular feature of the assessment quizzes is that they include an open question to which students need to provide a reasoned answer; the answer is then corrected by their lecturer (this is the reason why feedback or semi-automatic correction is often mentioned). Students not only receive a grade with an indication of the validity of their answers, but also suggestions and comments on the possible sources of their errors. The grade obtained in each assessment quiz is recorded, and the final grade for each block is the mean of all of them (excluding the one with lowest grade), with one condition: the mean of the questions to which a reasoned answer has to be given (excluding the one with the lowest grade) must at least be a pass.

The proposed methodology was implemented over the two semesters of the 2010/2011 academic year. There was a class of 49 students in the first semester and of 41 in the second.

4. Results of the experience

Presented below are the results for taking practice and assessment quizzes, for interaction among students and between students and lecturers, and for the subject drop-out rate. While the main results are for the 2010/2011 academic year, the results for the semesters prior to the implementation of the proposed model are also shown.

4.1. Taking quizzes

Before the results are presented, it is necessary to highlight several elements that may have been responsible for some of the differences between the two semesters in which the new methodology was implemented. In the first semester of the 2010/2011 academic year, there were a number of technical problems. These problems prevented the students from taking the quizzes for the first topic (Numbers). In the second semester, however, they were able to take them correctly. In the second semester, there were two additional tests in the Analysis block; owing to the difficulties observed for the Derivation and Integration topics, the authors decided to devote two weeks and two quizzes to studying each of them (instead of devoting one week, which would normally have been the case).

This section presents the results for the number of times the students attempted to take the practice quizzes, topic by topic; for the relationship between taking the practice quizzes and the grades obtained by the students in the assessment quiz of the respective topic; and for student profiles in relation to taking quizzes throughout each block.

Figures 1 and 2 show the number of attempts made for each practice quiz in the two semesters of the 2010/2011 academic year. The students are grouped as follows: those who made zero attempts, those who made only one attempt and those who made two or more (some of them made up to 13 attempts). For the purposes of this study, it is considered that a student made an attempt when a quiz was opened, even if it was not submitted to obtain the respective grade.

Figure 1. Percentage of students making 0, 1, 2 or more attempts for each practice quiz. First semester 2010-11.

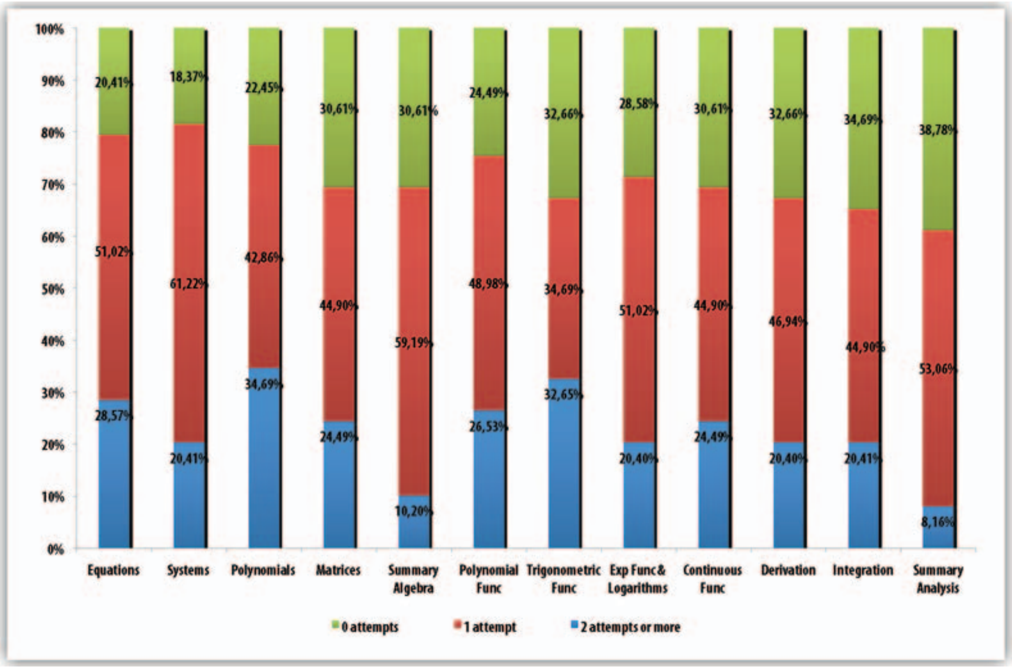
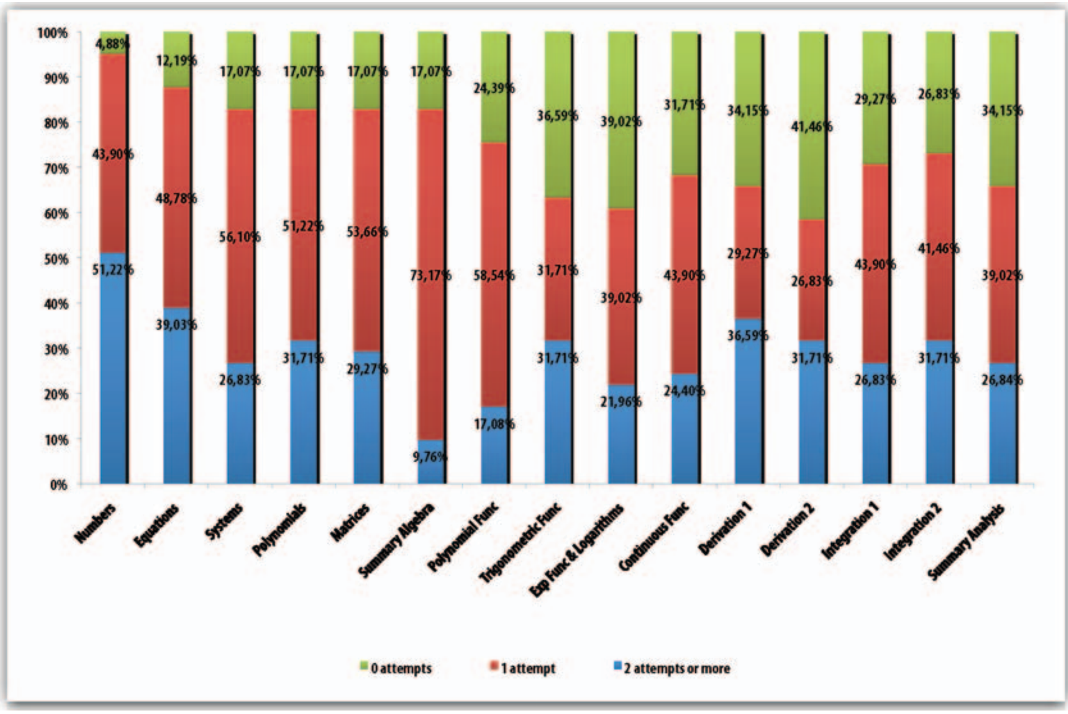


Figure 2. Percentage of students making 0, 1, 2 or more attempts for each practice quiz. Second semester 2010-11.



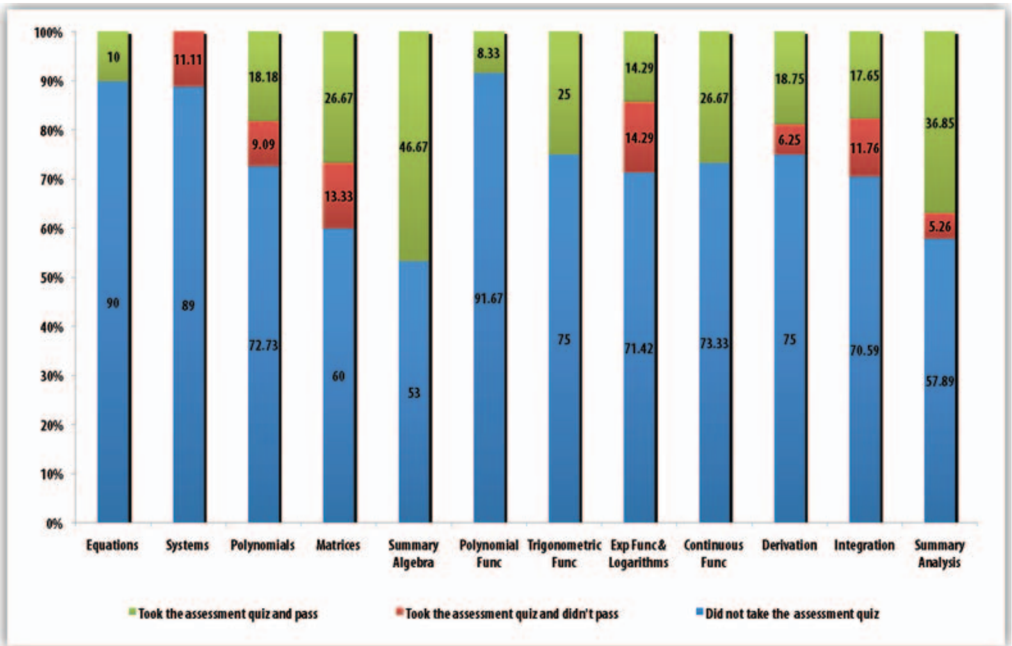
In the first semester, there was a drop in the number of attempts to take the summary quizzes.

In the second semester, worthy of note is the difference between the students' behaviour in relation to taking the quizzes for the Algebra block and the Analysis block. In the Algebra block, the percentage of students that made zero attempts was low (stable at around 15%). In the Analysis block, however, this percentage was up to twice as high. In addition, at the start of the semester, for the Numbers and Equations topics, the percentage of students making two or more attempts was 50.22% and 39.3%, respectively. This was clearly much higher than the percentage of students making two or more attempts for the rest of the semester's subjects. These high percentages for making two or more attempts were probably due to the novelty of the tool. This percentage once again exceeded 30% in the Derivation quizzes, particularly for the first part of the topic (Derivation 1).

Presented below are the results for the relationship between taking the practice quizzes and the grades obtained by the students in the assessment quiz of the respective topic. To simplify the reading of the results, they are shown as follows: the percentage of students that did not take any assessment quiz; the percentage of students that took but did not pass it; and the percentage of students that took and passed it. No details about the grades obtained are given. Before the results are presented, it is necessary to clarify that there are no data for the Trigonometric Functions assessment quiz in the second semester. Owing to a technical hitch, the students were unable to take it.

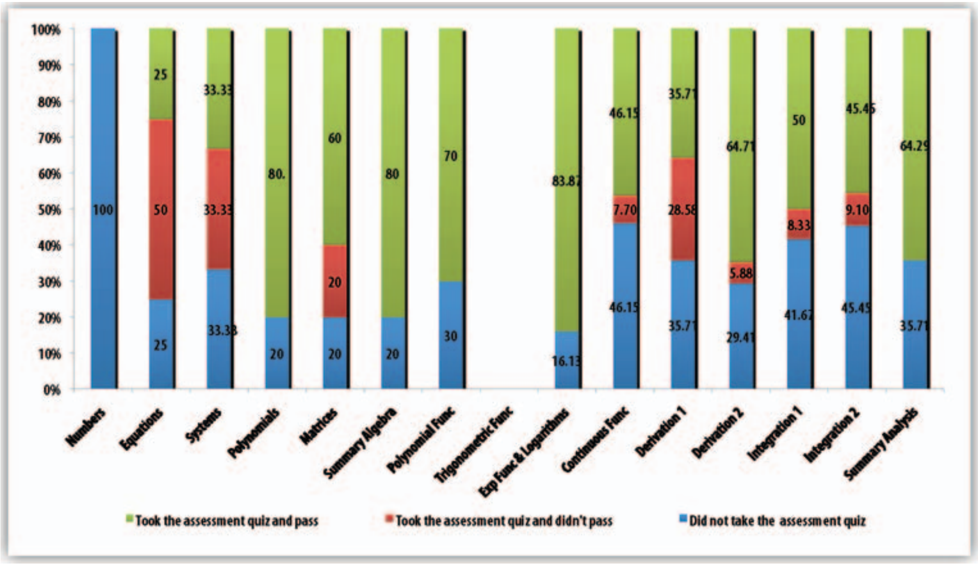
Figures 3 and 4 show the percentages for the grades obtained in the assessment quizzes by those students that made zero attempts to take the practice quizzes in either semester.

Figure 3. Percentages for the grades obtained in the assessment quizzes by those students that made zero attempts to take the practice quizzes. First semester 2010-11.



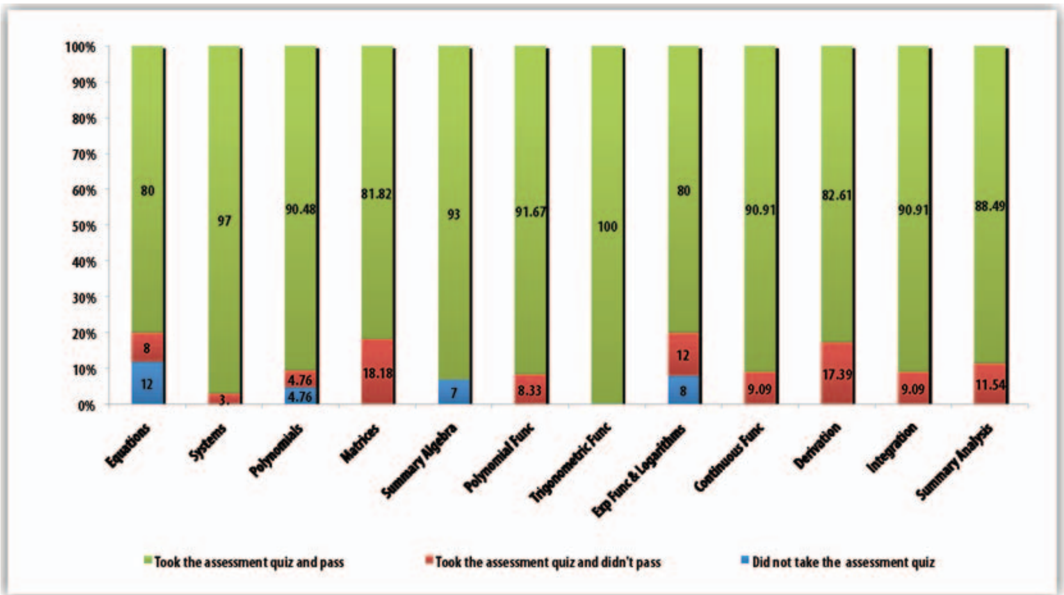
In the first semester, most of the students that did not take any practice quiz did not take the respective assessment quiz. In contrast, in the second semester, the percentage of students that did not take any practice quiz but took and passed the respective assessment quiz was considerably higher for most of the topics, and particularly so for the topics in the Analysis block. Indeed, this is the block in which, as seen earlier, the percentage of students that did not take any quiz was higher than in the Algebra block.

Figure 4. Percentages for the grades obtained in the assessment quizzes by those students that made zero attempts to take the practice quizzes. Second semester 2010-11.



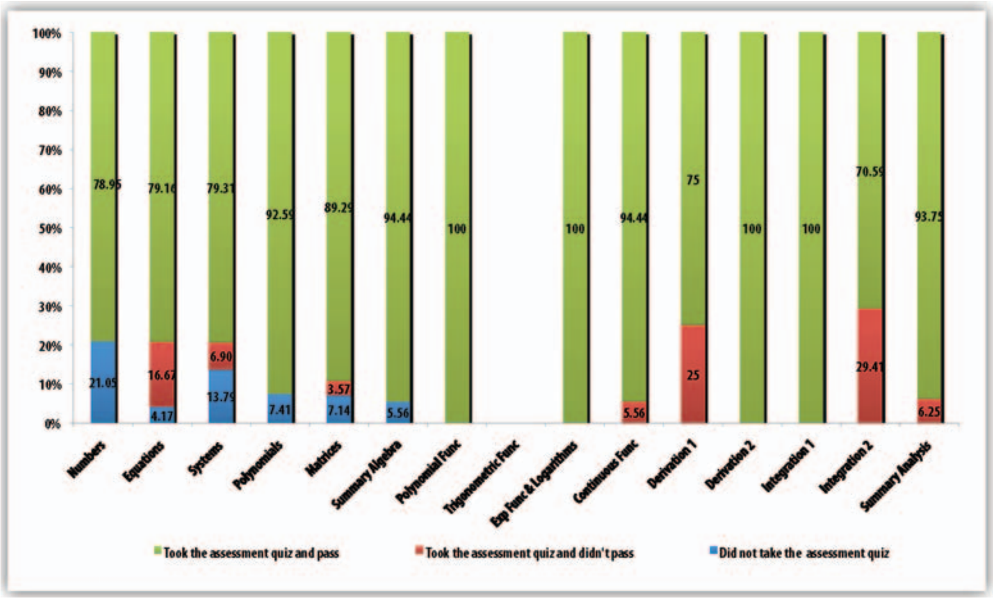
Figures 5 and 6 show the percentages for the grades obtained in the assessment quizzes by those students that made only one attempt to take the practice quizzes.

Figure 5. Percentages for the grades obtained in the assessment quizzes by those students that made only one attempt to take the practice quizzes. First semester 2010-11..



In both semesters, the percentage of students that made only one attempt to take the practice quizzes and then did not take any assessment quiz was low, and for most of the topics it was zero. In the second semester in particular, the percentage of students that did not take any assessment quiz was zero for the topics in the Analysis block. It is necessary to underscore the fact that there was a change in the students' behaviour in that semester; the percentage of students that made only one attempt decreased, while the percentage of students that made zero attempts and the percentage of students that made two or more attempts increased in a similar fashion. In relation to students that took but did not pass the assessment quizzes, the highest percentages were for the Matrices and Derivation topics in the first semester, and the Derivation 1 and Integration 2 topics in the second semester.

Figura 6. Percentages for the grades obtained in the assessment quizzes by those students that made only one attempt to take the practice quizzes. Second semestrer 2010-11.



Figures 7 and 8 show the percentages for the grades obtained in the assessment quizzes by those students that made two or more attempts to take the practice quizzes.

Figure 7. Percentages for the grades obtained in the assessment quizzes by those students that made two or more attempts to take the practice quizzes. First semester 2010-11.

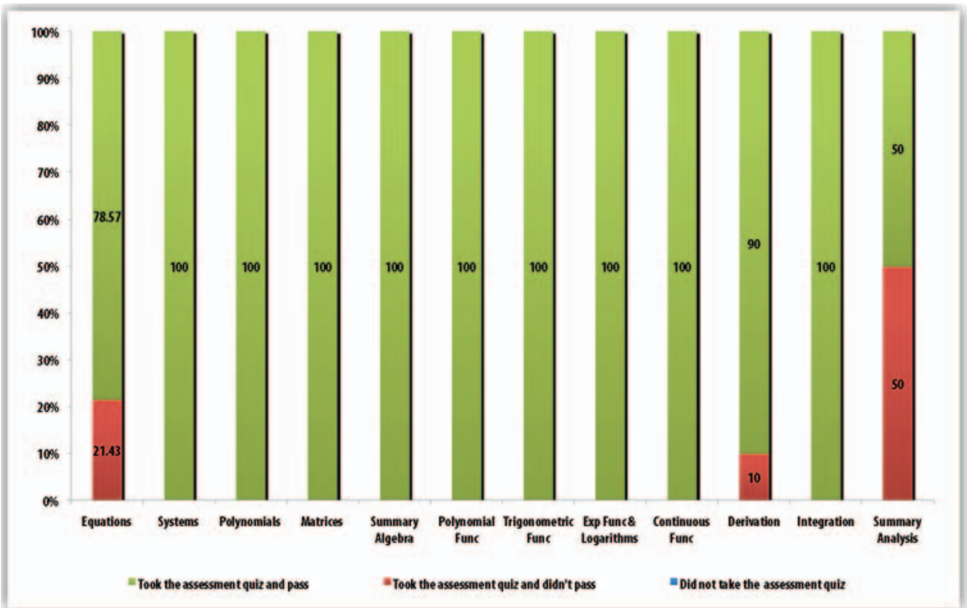
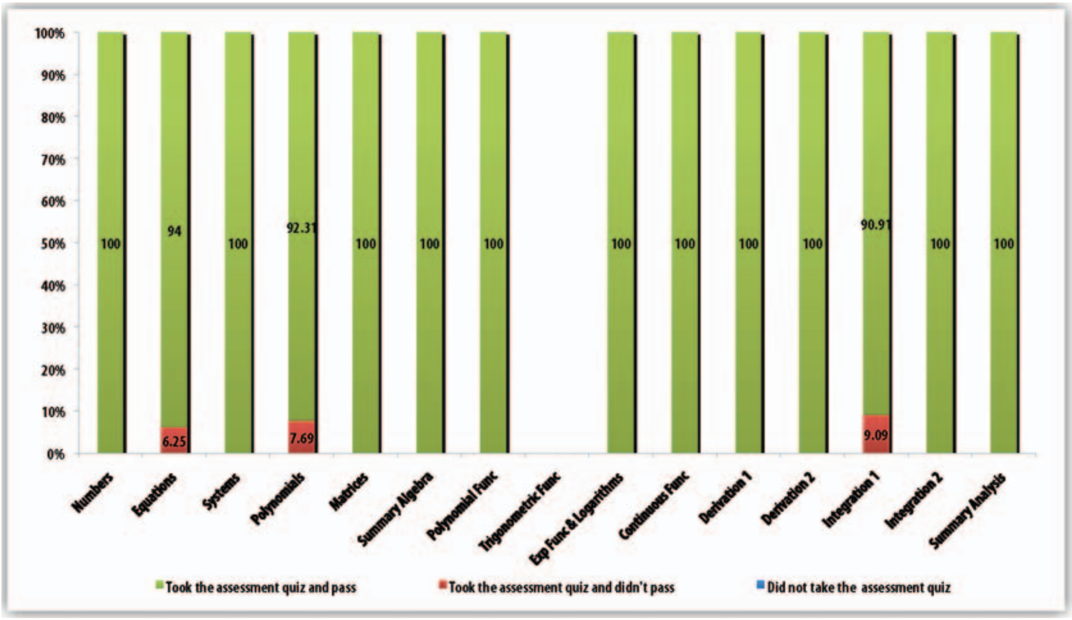


Figure 8. Percentages for the grades obtained in the assessment quizzes by those students that made two or more attempts to take the practice quizzes. Second semester 2010-11.



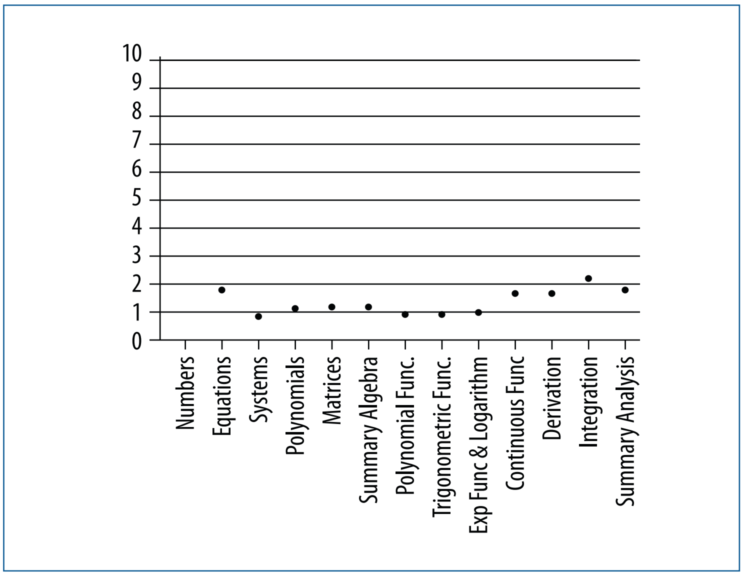
Worthy of note is that all of the students that made two or more attempts to take the practice quizzes took the respective assessment quiz. Every student took and passed most of the topics. However, for the Equations topic, and especially in the first semester since this was the first topic that the students took an assessment quiz for, the percentage of students that took but did not pass the assessment quiz was high. Regarding the Analysis block, not every student passed the Derivation quiz in the first semester or the Integration 1 quiz in the second semester. In the summary quiz for the Analysis block of the first semester, the percentage of students that did not pass was high, though it should be borne in mind that only four students made two or more attempts, two of whom did not pass.

Figures 9 and 10 show, for each topic, the mean of the differences between the highest grade obtained in the practice quizzes and the grade obtained in the assessment quiz by each student. It should be noted that, in this calculation, only the students that made only one attempt (with a grade) and the students that made more than one attempt were taken into account.

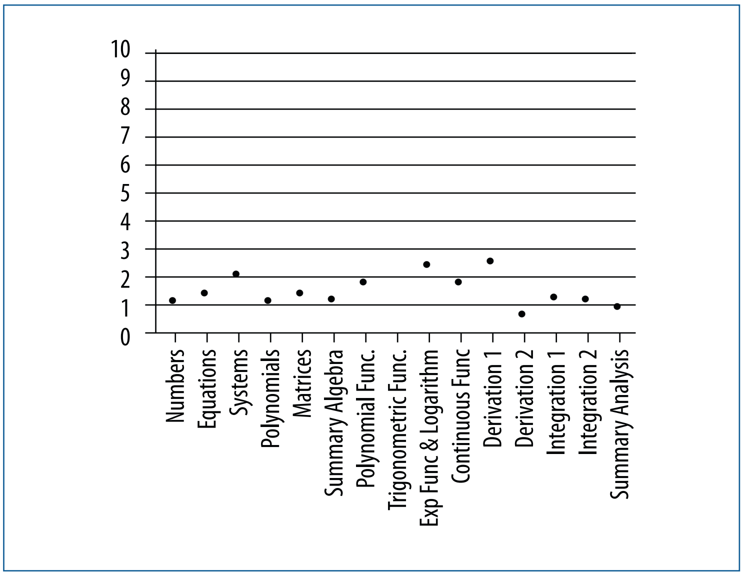
In the first semester, the calculated mean was around one point; it was higher for the first topic (into which the assessment tool was introduced) and for the Continuous Functions, Derivation and Integration topics. In the second semester, the distribution was not as uniform, though it was generally below two points. After the technical hitch in the Trigonometric Functions topic, the greatest differences were in the Exponential Functions and Logarithms topic, and in the Derivation 1 topic. When comparing the results for both semesters, there is a drop in the mean of this difference in the Derivation and Integration topics in the second semester (excluding Derivation 1, which was more conceptual).

Besides studying the students' behaviour topic by topic, the authors wondered if it would be possible to establish student profiles in relation to their behaviour throughout the semester. On the basis of the results, four student profiles were defined: students that make zero attempts to take practice quizzes; students that make one attempt to take practice quizzes; students that make two or more attempts; and students that adapt the number of attempts according to the grades obtained (the lower the grades, the higher the number of attempts, and vice versa). In order to classify a student into a specific profile, it was considered that there should be at least a two-thirds prevalence of the number of attempts. In the odd case where no number of attempts reached two thirds, a student's trend or evolution throughout the block prevailed.

Figure 9. Mean of the differences between the highest grade obtained in the practice quizzes and the grade obtained in the assessment quiz by each student. First semestrer 2010-11.



Figur3 10. Mean of the differences between the highest grade obtained in the practice quizzes and the grade obtained in the assessment quiz by each student. Second semester 2010-11.



Figures 11 and 12 show the percentage of students that fit into these profiles for the Algebra and Analysis blocks for the first and second semesters, respectively, of the 2010/2011 academic year.

Figure 11. Percentage of students that fit into the profiles defined.
First semester 2010-11.

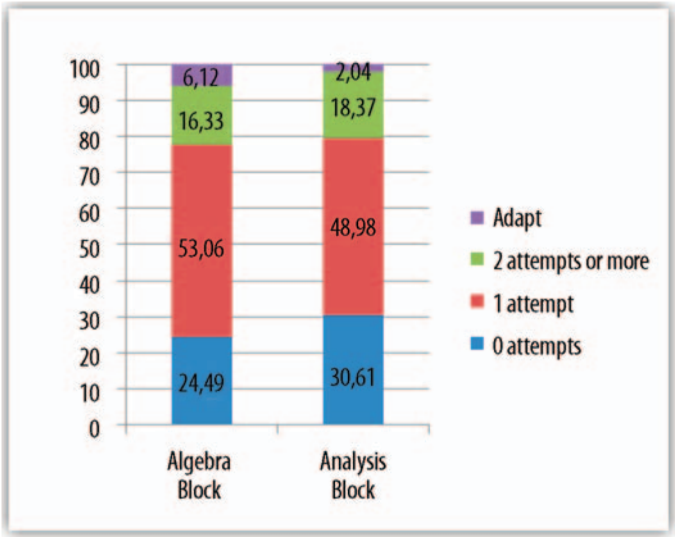
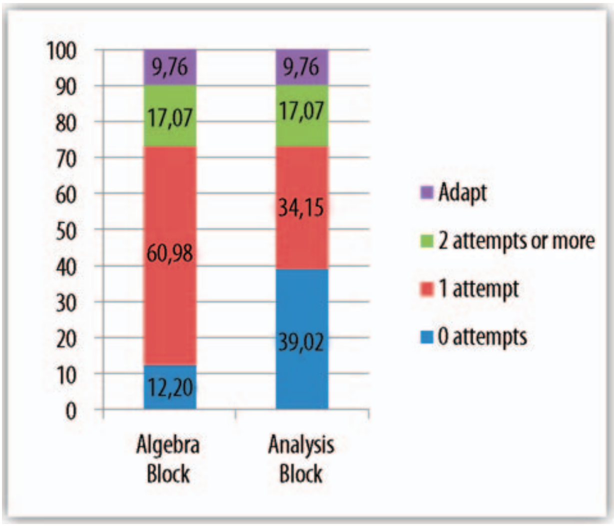


Figure 12. Percentage of students that fit into the profiles defined.
Second semester 2010-11.



When changing from one content block to another, two profiles remained stable: students that made two or more attempts and students that adapted the number of attempts according to the grades obtained. Notwithstanding, in both semesters, albeit particularly so in the second, in each content block there was a different behaviour among the students that made fewer attempts (one or none). With the data available, there are no clear signs that would enable an explanation to be given for these students' change of behaviour.

4.2. Discussion board and e-mail messages

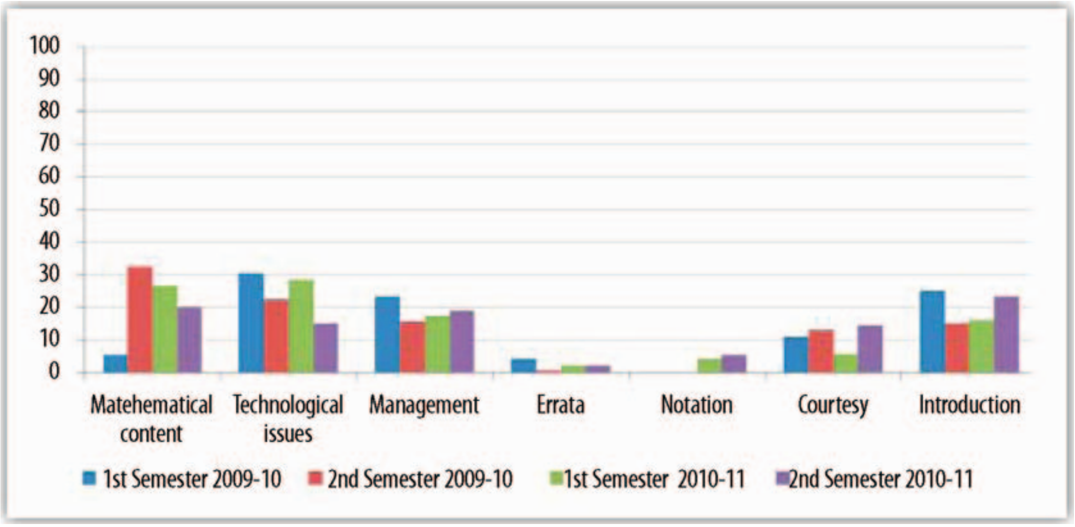
Presented below are the in-class interaction data based on the messages that the students posted to the discussion board, and student-lecturer interaction data based on the messages that the students sent to the lecturer's e-mail address.

Figure 13 shows the percentage of messages that the students posted to the discussion board, by the thematic area of their content, in the final four semesters. In order to interpret the data, it is necessary to explain the dynamics of the subject in the 2009/2010 academic year. In the first semester, there were two assessment tests, one at the end of each block, each with six exercises that had to be done using a text editor. In the second semester, while the assessment model was the same as in the first, quizzes were introduced, which could be taken voluntarily. The messages have been categorised in the following manner:

- Mathematical content: messages containing an explicit or implicit question about a mathematical concept or procedure. They can originate from reading subject materials, from taking practice quizzes or from solving assessment quizzes.
- Technological issues: mainly messages for informing on or updating information about particular technical hitches or classroom incidents, and suggestions for solving fellow students' technical problems.
- Management: messages connected with managing materials (how to locate certain documents or links, complementary materials, etc.), managing quizzes (how to take them, the purpose of and engagement in assessment, etc.) and managing assessment (how to present the documents in the previous assessment model, requests to review the automatic correction in the current assessment model, how to obtain the final grade for a subject, complaints, etc.).
- Errata: messages asking about or informing on errata in subject resources.
- Notation: mainly queries about the notation that should be used to enter answers for automatic correction (new assessment model).
- Courtesy: messages thanking other participants for their answers or for clarifying a minor detail in relation to a question asked previously, or messages regarding social relations between or among students.
- Introduction: messages sent at the start of a subject, at the lecturer's request, for students to introduce themselves to each other.

In messages on technological issues, the differences between the various semesters were linked to both individual and classroom incidents occurring throughout a semester. But the greatest differences were those relating to messages containing mathematical content. There was a low percentage of messages of this type in the first semester of the 2009/2010 academic year, when the assessment model was different from the one in the 2010-2011 academic year. In the second semester of the 2009/2010 academic year, it is necessary to clarify that the increase in the number of messages was not particularly due to the introduction of quizzes, which could be taken voluntarily, but rather to one highly active student on the discussion board. That student alone posted just over one third of all the messages posted on the discussion board (36.2%) and posted nearly half of all the messages containing mathematical content (49%), thereby offering regular reflections as well as submitting queries and requests for confirmation of having understood the content. Comparing the percentage of messages containing mathematical content posted in the first semester of the 2009/2010 academic year with the percentage of messages posted in both semesters of the 2010/2011 academic year, it was found that it increased considerably, and this was despite the fact that there was no noteworthy intervention by a particularly active student.

Figure 13. Percentage of messages that the students posted to the discussion board, by the thematic area of their content.



Honing in on messages containing mathematical content, presented below are the results for the origin of the messages (materials, quizzes or assessment tests giving rise to the message).

Figures 14 and 15 show the origin of the messages containing mathematical content that the students posted to the discussion board and sent to the lecturer's e-mail address, respectively. It is important to clarify that very few messages containing mathematical content were sent to the lecturer's e-mail address (17.9% and 10.3% of all messages sent to that address in the first and second semesters, respectively)

Figure 14 shows that quiz-related issues prevailed in the messages posted to the discussion board, particularly in the first semester. In contrast, Figure 15 shows that assessment-related issues prevailed in messages sent to the lecturer's e-mail address, usually as a result of some disagreement with a correction, giving rise to a mathematical discussion of the concept in question.

Figure 14. Origin of the messages containing mathematical content that the students posted to the discussion board

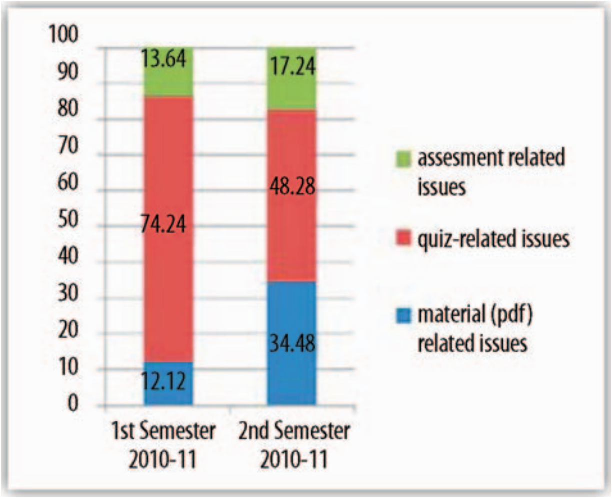
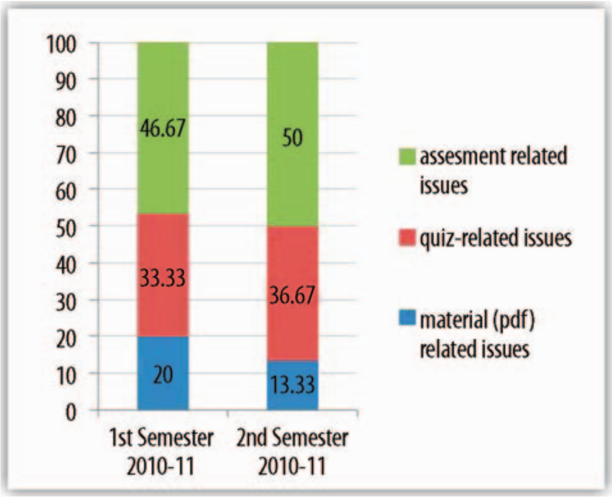


Figure 15. Origin of the messages containing mathematical content that the students posted to the discussion board lecturer's e-mail address



4.3. Drop-out

Figure 16 shows the percentage of students that dropped out of the subject in the Algebra block. This includes drop-outs both at the start of and during this block. With the new assessment model implemented, it was possible to establish exactly when a student dropped out of the subject.

In the first semester of the 2010/2011 academic year, of the 18.4% of students that dropped out, 12.2% did so at the start of the subject, without taking any practice or assessment quiz, and only 6.2% did so during the Algebra block. In the second semester of the 2010/2011 academic year, 2.4% of students dropped out at the start of the subject, and only 4.9% did so during the Algebra block. It was not possible to establish what percentage of the students that dropped out of the subject in earlier semesters (in the period prior to the experience presented here: from the second semester of the 2007/2008 academic year to the second semester of the 2009/2010 academic year) did so without starting to study the materials. Indeed, it is believed that there may be a high degree of fluctuation in such values because the students' personal reasons for not starting a course of study are varied and unpredictable (Castles, 2004). Consequently, a comparison between the results for the 2010/2011 academic year and the results for earlier semesters in the Algebra block is not reliable. Despite that, however, it is clear that, for the semesters of the 2010/2011 academic year, the drop-out rate while taking the subject was very low.

Figure 16. Percentage of students that dropped out of the subject in the Algebra block.

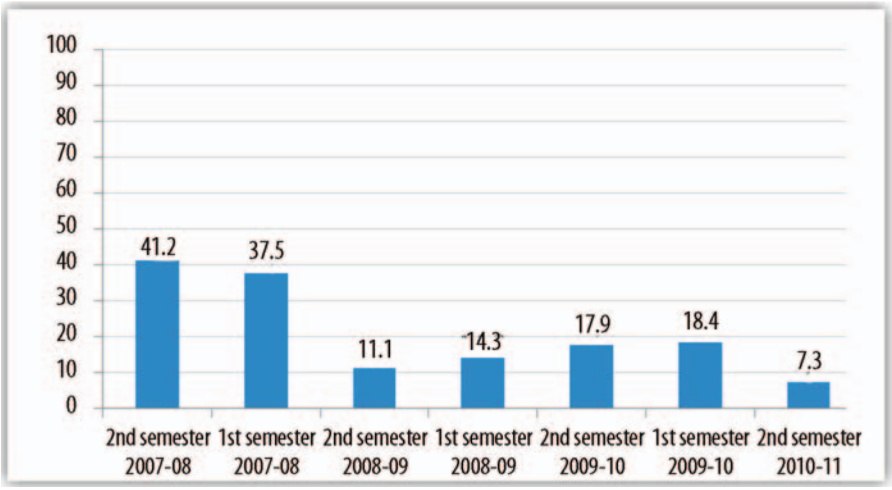
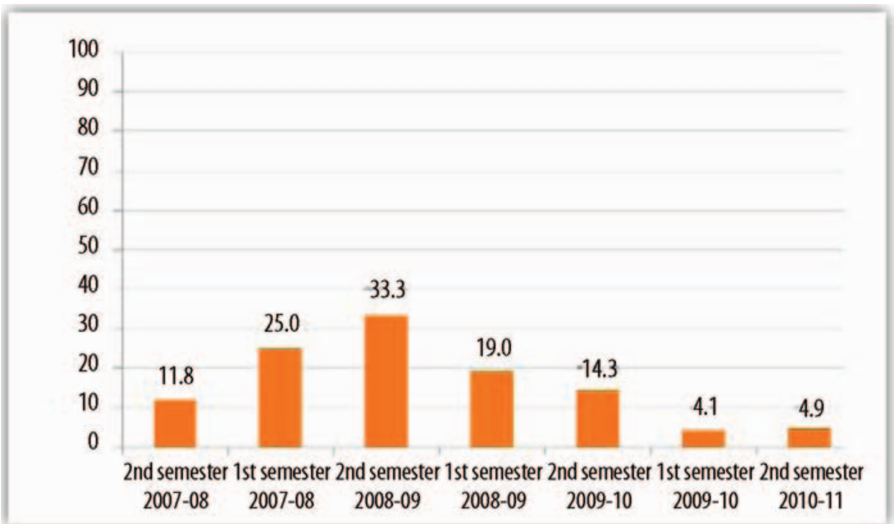


Figure 17 shows the percentage of students that dropped out of the subject in the Analysis block. This includes drop-outs both at the start of and during this block. The students usually considered that the content in this block was more difficult than in the Algebra block. Worthy of particular note, therefore, is the fact that the new approach helped to reduce the number of drop-outs during the Analysis block. The percentage of drop-outs in the semesters prior to the 2010/2011 academic year fluctuated between 10% and 30% of students. So the values had never been as low as they were in the semesters of the 2010/2011 academic year.

Figure 17. Percentage of students that dropped out of the subject in the Analysis block.



5. Discussion

The first research question was to establish whether taking practice quizzes with immediate, automatic feedback was a formative activity, that is, if it helped students to decide on their learning processes. To that end, the number of times students attempted to take practice quizzes was studied. It was found that the number of attempts fluctuated depending on the topics studied in both semesters. The students therefore decided to increase or decrease the number of attempts depending on the difficulties that they had in terms of answering questions or studying each topic. In both semesters, there was an increase in the number of attempts in the Analysis block, which is generally the one that causes most problems. Furthermore, and also in both semesters, all the students that practiced regularly (made two or more attempts to take a practice quiz) successfully passed the assessment quizzes for most of the topics. Similarly, most of the students that made only one attempt also passed the respective assessments. In addition, the existence of two particular student profiles —students that adapt the number of attempts according to the difficulties that arise (the stability of this profile is also worthy of note) and students that make two or more attempts throughout the semester— means that it is possible to assert that this methodology allows students to self-regulate their learning processes. Despite that, however, it is not possible to rule out any other factors that might have an impact on the number of attempts made.

The second research question was to establish whether the model worked as a new teaching methodology. In order to answer this question, two aspects were studied: the existence of actions promoting significant interaction and the practical quality of the feedback in relation to the principles proposed by Nicol and Macfarlane-Dick (2006). In the context of this subject, significant interaction is considered to be interaction that contributes to discussions on mathematical content. For the semesters over which the assessment proposal was implemented (2010/2011 academic year), there was an increase in the percentage of messages containing mathematical content that the students posted to the discussion board. Likewise, messages of this type, both posted on the discussion board and sent to the lecturer's e-mail address, originated mainly from taking practice and assessment quizzes. The results indicate that this model encourages mathematical dialogue between students and lecturers, and among students (principle 4).

Moreover, grading the practice quizzes by means of automatic correction allows students to be aware of how they are performing in relation, that is, to an optimum level of performance and, as already seen, to adapt their strategies to achieve better performance in their learning. Therefore, the feedback given firstly helps students to clarify what good performance is (principle 1) and secondly provides opportunities to close the gap between current and desired performance (principle 6).

If the analysis of the experience is complemented by information generated from the implementation of the proposed model, then lecturers are in a position not only to take decisions about teaching, but also to properly assess such decisions (principle 7). For example, on the basis of the results for the first semester of the 2010/2011 academic year, the authors decided to modify the duration of the Derivation and Integration topics. The improvement in the grades obtained by students that made one or more attempts and the reduction in the mean of the differences between the highest grade obtained in the practice quizzes and the highest grade obtained in the assessment quizzes for these subjects allowed for a positive evaluation of that decision. Moreover, it was possible to locate the difficulties that the students experienced with those subjects more precisely. Indeed, in terms of the results for the first part of Derivation and the second part of Integration, room for improvement was observed.

Finally, the fall in the subject drop-out rate was studied. In both the Algebra block —if account is not taken of the drop-outs at the start of the subject, which could be due to any number of factors, such as excessive optimism at the time of enrolment, unforeseeable work-related events, illness of a student or a family member, etc.— and the Analysis block, the subject drop-out rate fell to its lowest in seven semesters. Despite that, however, in order to assert that such a low drop-out rate was due not only to an increase in the students' motivation, but also to an increase in their engagement, a specific study on students' motivations and perceptions while taking the subject is required.

6. Conclusion and future lines of innovation and research

This article presents the results obtained from the implementation of new teaching methodology on an online basic mathematics subject for future engineers. The proposed methodology is based on the conviction that learning should be based on student activities, and that students should have the necessary resources available to do them. In e-learning, the fundamental problem associated with a proposal of this type resides in the timing and the content or quality of the feedback that students receive in the course of their leaning processes. In the authors' opinion, feedback is key, both emotionally and cognitively, to the acquisition of basic competencies in subjects of this type.

Specifically, they have considered a methodology consisting in taking weekly practice and assessment quizzes with (semi-) automatic correction and qualitative feedback. On this point, it is important to bear in mind the two aspects that guided the design of the quizzes. First, all the subject topics had to be covered and, second, specifying the source of a student's error had to be possible, as did providing proper explanations to facilitate an understanding of related content. This consideration led to the introduction of formative assessment as the principal axis of the teaching and learning process: it allows students to regulate their own learning processes and lecturers to accompany students properly, thus enabling them to certify the degree of competency acquisition.

In the light of the results of the experience in the classroom, the authors are able to assert that taking practice quizzes with immediate, automatic feedback is a good way of achieving a process of student self-regulated learning; furthermore, it allows lecturers to identify and react to problems in a responsive, timely manner in order to solve them. In addition, it has a decisive impact on increasing dialogue on mathematical issues on the classroom's discussion board. Finally, a particular aspect of the proposal's success is the significant reduction in the subject drop-out rate. Managing to achieve low student drop-out rates is one of the main concerns in an online education context, and the fact that, over the two semesters in which the new model was implemented, such low rates were regularly achieved allows for a positive evaluation of the methodology implemented.

The proposal presented in this article is a significant contribution to existing models of student assessment and follow-up on mathematics subjects, not only because of the results obtained, but also because it opens up a whole host of future lines of innovation and research in the field of online mathematics education.

The success of the experience in terms of its impact on the self-regulation of learning, the increase in mathematics communication and the reduction in the drop-out rate encourages the authors to continue working on this line of innovation and research. Firstly, on the definition and elaboration of adaptive quizzes that lead to greater customisation of learning; secondly, on the analysis of mathematical argumentation in dynamics of this type; and thirdly, on the impact of immediate feedback on emotional aspects, like trust for example. Consequently, the authors intend to examine the problem of students' self-efficacy, motivation and academic performance.

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