A continuous evaluation for a new pedagogy: Mathematics for teaching engineers

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INTRODUCTION

Today, the gap is widening more and more between the engineers' training and the real requirements of the profession which trigger several reflections of the engineering schools around the non-adequacy of the curriculum with the enterprise needs. The implementation of an active and innovative pedagogical device such as the problem or project-based learning appears to be a reasonable compromise for the engineers' future. In fact, working in groups on a real project puts the students in a challenging situation, thus enhances their motivation to learn by preparing them adequately to face the difficulties of the professional life. Therefore, since three years, the Tunisian Engineering School ESPRIT has redefined the objectives of its training content following a new slogan "to get oneself trained in a different way". The student is now the master of his/her own training; he/she works into small teams on multidisciplinary projects and starts to find out the real purpose of each training. Putting engineering students into a particular state of need for research, discovery, reflection, initiation, creativity, conception and innovation, means making them more effective. By contrast, this pedagogical shift has affected all the disciplines even the most fundamental among them such as Mathematics. It is obvious that the challenge was particularly demanding for these abstract and theoretical teaching. However, this leads us to adjust our traditional teaching methods with this new teaching reform.

The mathematics courses are made through team based learning using a mix of the traditional course and the innovative one [3] with the aim of finding a link between the theoretical notions and the real applications both in the every day and professional life. We devote a section of this paper to the description of this approach through the use of an example from a mathematics course of second year of the first-cycle engineering curriculum. Certainly, we have noticed a big shift in the students' behavior and attitude towards the teaching of mathematics [1], but we were not able to measure effectively its benefits. We have thus decided to evaluate our students differently by opting for a continuous evaluation for an innovative teaching approach, which consists of quizzes at the end of each session and tests at the end of each chapter allowing the students to better position themselves as well as the teacher to have an idea about the degree of the learning acquisition. Another part of this article is dedicated to the description of the new evaluation method supported by statistical tests.

1 THE ACTIVE APPROACH FOR TEACHING MATHEMATICS

1.1 Motivation

In the frame of the implementation of this new teaching method -an active and innovative method adjusted to engineers training-all the taught disciplines in ESPRIT have undergone a shift affecting not only the teaching form but also its content.
As we have always noticed, direct instruction or lecturing with theoretical content are not highly appreciated by students. We note that through the high absenteeism, demotivation, the passive attitude and often poor results [3]. Accordingly, getting rid of this discipline from the new teaching reform will likely aggravate the situation. While, integrating it into the new active teaching device will require several reflections about the form and the content of courses. Mathematics has turned out of crucial importance in the training of engineers since it presents one of the basic pillars in all the engineers curricula. Nonetheless, the trend is towards the effective, dynamic and motivating learning in the service of new technologies and meeting enterprise needs. It is thus crucial to find out a modern and attractive method for the course of mathematics [1] to clearly communicate the notions required for the training and having interesting applications in the everyday and professional life.

1.2 Process

It is natural to opt for the same form of teaching used by the other disciplines namely dividing the class into small groups of five or six students by indulging them into a process featuring cooperative and collaborative working from where the name of mathematics courses "Team Based Learning" comes [1] where the teacher plays the role of a coach while the student is placed in a challenging, research-driven and collaborative situation.

What about the course content?
In fact, the work in teams should be based on one or several problems from which develops the idea of contextualizing the courses or more accurately reconstructing the traditional course by creating small problem situations [3]. The latter are taken, depending on the case, from a professional context or a daily life application or from a reasoning or logic-based problem. It is clear that for certain fundamental and abstract notions, it turns out difficult to find concrete applications to present them effectively and in an attractive way. It is thus good to introduce some reminders and little tasks, having recourse, to the students' prerequisites. By complexifying the questions and increasing gradually the degree of difficulty, the students are placed into a situation of need of acquisition of a new notion. At this moment, we will

introduce the theoretical information which will help to solve the problem. Classic tutorial classes are intended to complement the active courses in the place of course restructuring.

Not forgetting that it is necessary to harmonize the content of our courses with the content of the other disciplines in order to prove the utility of the acquired notions in the required applications. The implementation of such a method requires a redefinition of all the learning objectives and a revision of the prerequisites. The latter are the starting point for each course drafting in TBL where the students' prerequisites will enable them to solve partly the proposed problems and to feel the need to acquire new notions. We have nevertheless reviewed the apportionment of the workload hours attributed for each lesson since such a method requires more time for preparation in attendance and in non-attendance both for the students and teachers.

1.3 Description through an example

In this section, we present an example of the method used in the teaching of mathematics to the students from first cycle mathematics curriculum. We start with an example from professional life to let them discover progressively the new theoretical concepts. The teacher plays the role of a coach.

Encryption and matrices:

A banking agent would like to send a code in the form of two integers x_1 and x_2 to a client. Being afraid the message be intercepted, the banking agent decides to encrypt a message in the following manner:

He chooses a square matrix A of size two and puts $X = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$. He then calculates the product matrix $AX = \begin{pmatrix} y_1 \\ y_2 \end{pmatrix}$, and sends the numbers y_1 and y_2, let's take the example:

Assume that the code to be transmitted is composed by the numbers $x_1 = 2$ and $x_2 = 3$, the agent uses the matrix $A = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix}$, to encrypt his message. Which message will be sent to his client?

This may be done simply by computing the matrix product $Y = AX$. This question will be an occasion for students to review the multiplication of a matrix by a vector, a notion which is familiar to them. They will then proceed to computing and will not find any difficulty to determine the encrypted message. Having received the encrypted message, the client should be able to reconstitute the original message. What procedure should be followed? Students may think: Since we want to return to the original state, we should then go in the reverse direction of the encryption phase. The word "reverse" is then meaningful to them but they are not able yet to define the notion of the inverse matrix. We may propose the following figure *Fig. 1* and ask them to complete the following property:

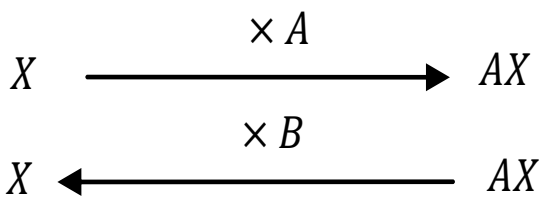

Fig. 1. Encryption and decryption

To decode a message, one should multiply AX by a matrix B that satisfies $BAX = X$. Students will deduce that the matrix Bsatisfies $BA = I_2$, which will allow us to define the notion of the inverse matrix. Now the question arises about the existence of such a matrix:

Let be $B = \begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix}$, demonstrate that $BA = I_2$. Then verify that the matrix B enables to reconstitute the original message. Student may think that in this case such a matrix does exist. Some of them may be wondering: If we don't give the inverse matrix of A then how we can compute the inverse matrix? This question may open up a window for a new point in the course: How to calculate the inverse of an invertible matrix?

2 EVALUATION OF MATHEMATICS

Once we decided to change the teaching method, one of the most legitimate questions which may came to our mind is to review and to adjust the evaluations of our teaching methods to the new teaching approach. We choose to opt for an active and innovative-based learning approach which leads to a major shift in the type of the course and the proposed tasks namely the practical aspect which takes the lead over the abstract and classical aspect. As a result, the evaluation of students through the use of tests and exams of unchanged content seems to be inconsistent with the active pedagogy. Moreover, the teacher in its new role of coach is unable, at the end of each session, to distinguish the degree of assimilation of the objectives of one group from another or one student from another. In fact, the students are able to exchange ideas within their groups, endeavor to solve problems and make progress on small problems, while the leaders of groups will provide usually an important help to their classmates which will make the task easier for them, this will affect partly the good assimilation of notions in certain students and could result in passivity and lack of effort and reflection.

These different points prompted us to implement a continuous evaluation [2] or several brief, quick and concise evaluations which will empower the students in order to guarantee a better attendance, a better mental presence and a better assimilation.

The evaluation of the knowledge and the acquired know-how in training is based on the teaching goals attainment scaling by means of different tools [5]. Obviously, the latter should be adjusted to the population in question and the acquired knowledge.

We have developed an evaluation system including three types of evaluation namely mini quizzes during the session, tests at the end of each chapter and a classical exam at the end of each semester. We will propose statistical information on the marks obtained in the quizzes and tests of the same class composed of twenty five students from first cycle mathematics curriculum.

2.1 Evaluation during the session

This evaluation shall be rated to 2 and shall include two questions [2], one concerning the concepts and the disciplinary, scientific and technical knowledge, the other concerning the methods, the processes and the operating procedures on conducting an exercise or a problem which will enable the students to evaluate themselves and work individually on their comprehension difficulties. We have applied this evaluation mode on the class of first cycle common core curriculum. Below you will find a figure showing the marks of two quizzes on chapter functions of two variables *Fig. 2.* We note a significant decrease in the percentage of students having a note strictly inferior to 1 and an increase of the percentage of students having a maximum mark. As for the teacher, he/she will be able to better distinguish the level of each of the students who discuss and work in groups during the course

session which will enable him her to evaluate effectively the student level and the degree of assimilation of notions [4]. He/she will be able to meet the difficulties encountered on which he/she will focus in the tutorial classes which have the role of restructuring course.

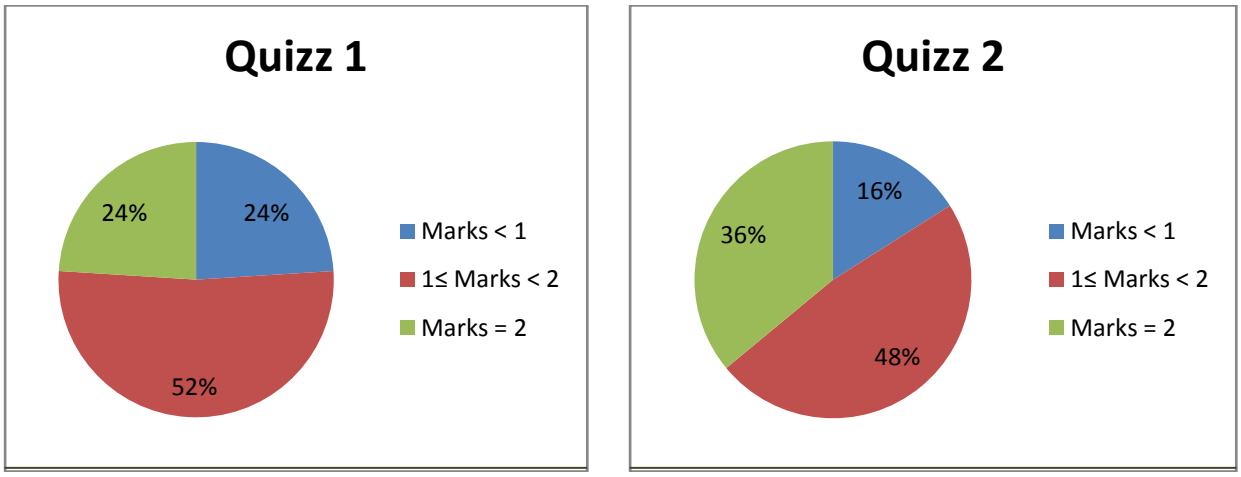

Fig. 2. Quizz 1 and Quizz 2

2.2 Evaluation at the end of the course

After the completion of the course and the tutorial classes, the student will have accumulated several quizzes and have focused its energy on the different encountered difficulties [4], next comes the evaluation test which will look like a little exercise of synthesis covering the major objectives of the chapter. This test is intended to summarize all the knowledge gained in the form of an assessment of knowledge and know-how. At the end of the test the teacher and students will ensure the achievement of learning goals. This evaluation will be graded on five points, and each class will undergo four different tests, and the sum of the marks will constitute the final mark out of twenty. Below you will find a figure illustrating the marks of two tests. Test 1 is on chapter two variable functions and test 2 is on chapter integral calculus *Fig. 3.*

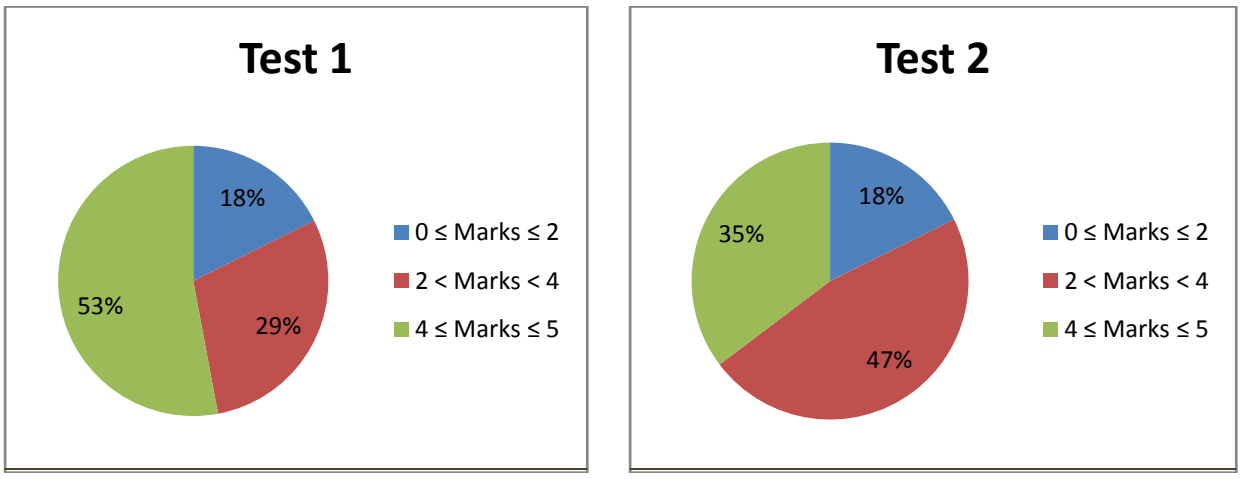

Fig. 3. Test 1 and Test 2

Note that the tests and quizzes are proposed to the same class.

2.3 Semestrial exam

We have kept the classical exam to represent fifty percent of the semestrial evaluation which will deal with all the acquired knowledge. This choice has been made to avoid rushing students towards the great shift in their old habits and to secure our new experience. While, our last reflections are directed to the implementation of a mini project as a substitute for the final exam.
Our principal motivation is to allow measuring the students communication skills and their reactivity towards the new problem situations in a limited amount of time.This will enable us to view the three major components of the evaluation method namely, the knowledge, the know-how and the know-how-to-be.[5].

3 SUMMARY AND ACKNOWLEDGMENTS

Thanks to our experience, we can today assert through TBL mathematics courses in the training of engineers that the students are not limited anymore to passively receive the information, but they are able to construct the information and adjust it to their needs. This new method has allowed to create a dynamic and reactive class animated by the different students questions, fascinating exchange among the groups quite often in a great spirit of competitiveness. It is crucial to stress that the continuous evaluations of these courses have remarkably drawn the students' attention during the course as well as their attendance rate. They are in permanent hunting and memorization for the new information to get ready for the exam. Our immediate goal today is to arrive to replace the final exam by the conducting of a project combining the most important learning goals and tie them to interdisciplinary objectives.

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