AN EXPERIENCE ON CONTEXTUALIZING LAB SESSION MATERIALS FOR NUMERICAL METHODS IN ENGINEERING

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Abstract

In this work we describe our teaching experience based on the implementation of a methodological change in the laboratory sessions of Numerical Methods, a subject of the first course in Engineering´s Degree of the Universidad de Oviedo.

We designed didactic tools with varying degrees of contextualization, that is, activities that were more or less related to the professional focus and the daily life of students, in order to improve their motivation, attitude and ultimately their learning. We compare, evaluate and analyze the results obtained by students in each activity with the aim of obtaining their significance level.

More specifically, the methodology implemented in the labs consisted on the use of a scientific computing software to implement codes for the different numerical methods introduced in the theoretical lectures to solve a variety of problems with a different degree of contextualization. We provided the students with three types of activities:

- Activities with a high degree of contextualization, based on solving problems highly connected with the students everyday life.
- Activities with a moderate degree of contextualization, based on solving problems connected to society general interest applications.
- Activities without contextualization, based on solving traditional mathematical problems with no reference to applications.

The lab sessions consisted of two parts, a fundamental part, which was of mandatory fulfilment, and an optional "extension" part, which was where the experience took place. We evaluate the results of the different levels of contextualizing the lab materials through objective measures, such as the level of permanence of the students in the optional part of the sessions, and subjective measures such as the apparent level of involving and collaboration during those parts.

The final goal of our approach was to build meaningful learning. This means that students are able to apply all their knowledge significantly not only in the context of their professional development as engineers but also in other situations of everyday life.

Keywords: Mathematics, Numerical Methods, contextualization, computer codes, laboratory sessions, meaningful learning, motivation.

1 INTRODUCTION

After years of teaching experience it has been made clear that students generally do not see the need for learning mathematics, beyond passing their tests. This is because they feel that mathematics simply consists on following a set of given instructions to obtain a result from some given data which are meaningless for them, e.g., students are set to learn rules, but without attributing any meaning to those rules.

The result is a system in which students are not particularly motivated and see mathematics as a rigid system of instructions created by ancient people, governed by the standards of rigour and accuracy, and generally useless for them, although reputatedly important in the outer world.

This system is characteristic of the traditional model of teaching that has dominated our schools and universities for many years, with a teaching methodology that focuses on memorization and repetition and which skips students participation in the learning process. However, without an understanding of what they are doing and why, this traditional approach does not contribute to meaningful learning.

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Meaningful learning involves applying what is learned to new situations in different contexts, and this is why not memorizing but understanding is needed to acquire the skills and abilities to achieve it. As noticed by Ausubel [1], students must attribute meaning to the contents they study, for which teachers must create a training environment in which students understand what they are learning and are able to relate it to their prior knowledge.

Under other point of view, Novak [2] stresses the importance of emotions in the cognitive learning (memoristic versus meaningful). Thus, when the new information is related to some aspects already present in the student's cognitive structure, and these are emotionally positive, a process driving to meaningful learning does arise. On the contrary, memorizing is produced when an affective relevant link between the new information and the underlying cognitive structure of the individual may not be stablished. Therefore, a favorable training environment should include, among other things, taking into account motivational issues as motivation seems to influence the affective stimuli and therefore the way of thinking and of learning, see also Alonso Tapia [3]. In this sense, Mc Robbie and Tobin [4] argue that when academic tasks are perceived as interesting, important and useful, students may be more willing to learn meaningfully.

Realising that motivation for learning is creating the conditions to move students to learn, we are led to the task of designing activities that have a positive impact on students' motivation in order to make them construct meaningful contents in their mathematical activities, see Suarez, R. [5] and Devlin [6].

Based on the foregoing, in the teaching experience we present tasks have been designed to try to capture student interest, influencing their motivation, with the ultimate goal that they may apply their knowledge significantly not only in contexts of their professional development but also in any situation of everyday life.

The article is organized as follows. In Section 2, we describe the context of application and state the main goals of our work. In Section 3, we present the new teaching methodology activities performed with students, and in Section 4 we describe the corresponding changes in the methods of evaluation. Finally, in Section 5, we give our conclusions on the results obtained in our experience.

2 CONTEXT OF APPLICATION AND GOALS

The experience we describe in this paper was undertaken in the Escuela Politécnica de Mieres, Universidad de Oviedo, during the scholar year 2010-2011. It is important to notice that this was the first course in which the new methodologies introduced by the Bolognia Plan took place.

Three new Degrees were introduced in the Escuela Politécnica de Mieres as a result of the Bolognia Plan, which are: Engineering on Mining and Energy Resources, Engineering on Forestry and Environment, and Engineering on Geomatics and Topography. All of them share the same subjects on the first course, among them the one selected for our experience, Numerical Methods, a subject framed on the general matter of Mathematics, which is within the Basic Module of the Plan of Studies.

The experience was implemented on a group of about thirty students. The Bolonia's teaching methodology includes three kinds of lectures: theoretical lectures (18 hours) and aula practices (8 hours), in which all the students were present together in an aula equipped with a blackboard and a beamer; and labs of informatics (28 hours), where the students were split in three subgroups of about ten students each, and equipped with personal computers (one for each student) and blackboard and beamer for the teacher.

The main goal of this experience was improving students learning through a change of methodology in the core part of the subject, the mathematical codes programming task taking place at the lab of informatics. In previous teaching experiences performed in the last Plan of Studies in the Universidad de Oviedo, on similar but different subjects (Calculus, Linear Algebra) with a much smaller weight of the labs section, we had already noticed the stimulus that computers use has on the students. Therefore, we decided to investigate in this new subject, Numerical Methods, with a high content of lab activities, the effect of contextualization in the mathematical learning process. In addition, the contextualization of mathematical concepts was also introduced in the other activities, specially in the aula practices, although the short time available for these activities makes difficult its evaluation.

In the theoretical lectures we followed an expositive strategy. Each chapter was introduced by examples connected to the areas of interest of the students (mining and energy, forestry or topography) trying as much as possible to lie in the intersection among them. For instance, resorting to problems on Hydrodynamics, Signal Theory, etc. In these examples, the mathematical models were difficult or tedious to solve in a closed form (exact computation) and so the numerical methods (approximate computation) were showed to be preferable. Although we tried to create an atmosphere of participation, which sometimes did occur, the time limitation was an obstacle since the program of the subject was, perhaps, too ambitious.

Therefore, we focused the student's participation motivation on the aula practices. The students were given the task to choose a problem arising in any field of their interest in which some numerical method had to be applied to solve the problem. Each student had to give a short exposition, using the blackboard, on the physical and mathematical modeling of the problem and explain the reasons why she/he had chosen a specific numerical method to solve it. Then, a turn of questions was opened to the listening students (and the teacher) and possible criticisms about the selected methodology had to be given with reasoned motivations.

However, the motivation for the participation was not only reduced to the aula practices. In the core of the course, the labs, participation was induced by collaboration among the students in the problem solving. It is important to observe that although the theoretical mathematical knowledge of our students is rather uniform, their computer skills differ hugely, so we may find students which a high degree of expertise in computer programming as well as to find students who are essentially digital illiterates. In this context it is clear the importance of collaboration among students, apart from other many good reasons to motivate this collaboration.

3 METHODOLOGY AND IMPLEMENTATION

The methodology implemented in the labs was the use of scientific computing software to implement codes for the different numerical methods introduced in the theoretical lectures to solve a variety of problems with a different degree of contextualization. We provided the students with three types of activities:

- Activities with a high degree of contextualization, based on solving problems highly connected with the everyday life of the students.
- Activities with a moderate degree of contextualization, based on solving problems connected to society general interest applications.
- Activities without contextualization, based on solving traditional mathematical problems with no reference to applications.

These activities took place on the lab of informatics, where a introduction/motivation to the subject was given by the teacher using a beamer. Afterwards, the students were provided of a script with the problems to be solved as well as some essential steps to be followed. The specific software resource we used was Matlab [7], a well known scientific computing software among the mathematical and engineering community, which apart from its unquestionable good performance has the added advantage of having a student's version (cheaper) and a free-ware clone, Octave [8]. Nowadays, most of the handbooks written for Matlab also include Octave versions, see for instance [9].

Once the students had been taught the theoretical issues of a chapter, they attended one or more lab sessions in which those issues were applied to specific problems. En each session the students were provided with a script containing the activities to be fulfilled during the session. In these scripts the goals of the session and the numerical methods to be used were described in detail. A short introduction by the teacher was given at the beginning of each session and following, the students had to read and understand the goals and to prepare the matlab codes to accomplish the task. Collaboration among students was encouraged.

The scripts were organized in two parts. A basic or fundamental part, being its realization mandatory, and a "extensions" part, consisting in the implementation of more sophisticated codes or to the application of the fundamental methods to problems with a different level of difficulty and contextualization. The realization of the extensions was optional.

The experience took place on three of the ten lab sessions, once the students were familiarized with the scientific computing program. More concretely, in the extensions of the sessions 4, 6 and 8, with a time interval of two weeks between them. En each of the sessions we introduced a different level of contextualization, in the following way:

- *High contextualization.* In the extension of the session 4 we dealt with the problem of eigenvalues and eigenvectors computation. We chose the mathematical model of inter-urban connections, see [8]. The script included a map of the railway transportation of our region, similar to which one can find in any local train station. It also included a table with the figures of the populations of the cities inter-connected by the railway net. The problem to solve was that of ordering the cities according to their better or worse connectivity with the other locations. It is important to notice that many of the students studying in the Escuela Politécnica de Mieres use this transportation (and others) due to the geographical situation of the city and the high geographical population segmentation of the region.

- *Moderate contextualization*. In the extension of the session 6 we studied the problem of interpolation and approximation of functions. The model problem we chose was the analysis of data of meteorological precipitations in the region in order to illustrate the trigonometric interpolation and to introduce the notion of power spectrum of a periodic function. The students had to download data files provided the National Institute of Meteorology from the Virtual Campus of the Universidad de Oviedo. Before solving this contextualized problem the students had to solve a more simple but non-contextualized problem in order to (1) have a more clear idea of the steps to be given for the resolution of the precipitation problem, and (2) visualize an "ideal" result before experimenting with a "noisy" situation. The final goal was to give an interpretation to the seasonal components of the data.
- *Null or low contextualization*. In the extension of session 8 we dealt with the problem of numeric integration. In this case the script indicated how to implement a code for numerical quadrature (trapezoidal rule) and to apply it first to the quadrature of non-contextualized functions and second to the computation of the arc length of several graphics of functions joining the same two points. The goal was to realize that the minimum length is attained by a straight line.

4 EVALUATION

The evaluation implies realizing the extent of achievement of objectives obtained for the subject. Besides these, in this experiment, we intend to evaluate and compare the degree of learning at each level of contextualization of laboratory practices, and thus, determining the significance of the experience.

4.1 Learning evaluation

As already mentioned, the lab sessions consisted of two parts, a fundamental part, which was of mandatory fulfilment, and an optional extension part. Students who attended and successfully fulfilled the mandatory part were given the minimum passing mark. To improve the mark, students could optionally attend, at the end of the semester, to an individual oral assessment in which during 15-20 minutes they had to answer to questions related to the extensions of the practices, writing the corresponding codes using the computer.

The students' results were, in approximate figures, the following: Around 80% of the students achieved the objectives in the extensions with a higher level of contextualization, while for the cases of low or no contextualization, these figures dropped to under 50%.

4.2 Experience evaluation

We used both objective and subjective methodologies of experience evaluation.

Objective indicators. Each laboratory session was three hours length. During the first two hours students had to work the mandatory fundamental part. Afterwards, they could optionally continue with the extension part. Thus, we considered as a tool for evaluating the experience the number of students remaining in the classroom during the extensions part of the session. We must keep in mind that the students did not get an additional score for remaining in the extensions although they knew they could be asked about them the final examination, at the end of the semester. In any case, passing the minimum grade was guaranteed with the completion of the fundamental part.

In this aspect, the experience was apparently very succesful since all the students were interested in remaining in the high contextualized sessions ("to see how it does finish") while many of them were leaving in advance the non-contextualized sessions with some excuses ("to take the train").

Subjective indicators. In addition, in each session, we try to assess the motivation and involvement of students in the realization of the different exercises and thereby gain subjective indicators of the process of contextualization. In this sense, since the lab sessions were conducted in an environment that promoted participation and teamwork, we used as an indicator the level of participation estimated from the interventions and discussions following the programs development and results. The tool was the teacher direct observation guide, see Fig. 1.

Figure 1. Teacher direct observation guide

Assesment criteria	Max. score	Score	Notes
The statement of questions arising from the growing knowledge of the subject	3		
Participation in discussions, debates: provides ideas, is alert, distracted...	2		
The interest in the job: is taking notes, is passive, has a rational habit of working...	3		
The attitude and the depth at the point of view taken in the interventions.	2		

The subjective evaluation gave interesting results. In the case of contextualized extensions (high and moderate), in which students dealt with daily life problems, around 70% of them achieved the maximum score, around 20% overcame the minimum levels of involvement and interest and only about 10% were passive. In contrast, in the case of no contextualization, these figures were essentially reversed and only about 10% of the students kept with the maximum score. In addition, in these sessions the questions were mostly directed to the teacher and related to theoretical contents based on memoristic approaches to learning and, therefore, with very low chances of interaction among students.

5 CONCLUSIONS

For the authors, this experience has constituted a first step for departing from traditional teaching techniques to new methodologies based on contextualized learning. The idea supporting our approach, obviously not original but not sufficiently present in the aula, was that if the learning process is to become meaningful this will occur more likely under a contextualized teaching.

The contents learned (meaningfully) by students, which would allow to stablish the success of the experience, have not been systematically evaluated due to the early stage of our project. However, we have subjectively noticed the increase of interest in the matter through the questions set by students to the teacher, many of them also contextualized questions, and the overall good atmosphere of the lab sessions in which “interesting” problems were analyzed. In this respect, we tried to design contextualized problems leading to meaningful learning thorough actions such as discussions, criticisms, experimentation and so on [10].

As we described, we have chosen examples, exercises and problems which were, under our point of view, related to situations of the daily life and interesting for the students such as the local railway network or the climatological peculiarities of the region. However, we have become aware of the sensibility of this part of our approach since although students may be more interested in their railway network than in some non-contextualized version of the same problem, perhaps better contextualizations may be found in order to capture their attention and interest.

Therefore, we believe that it would be convenient to perform a more detailed research on the links between student’s interests and numerical mathematical contents, identifying their interests' patterns and thus contributing to define better contexts for the teaching units.

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