Assessment of the learning competence of Mathematics for freshmen of the Computer Science degree

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Abstract— **Mathematics is an important core of the syllabus of any Computer Science degree. We have studied the relation between the learning competence of Mathematics for first-years at the Universidad Politécnica de Valencia, and their success in the subjects of mathematics in the degree. Its relevance for their success in the whole first academic year is also reported.**

Keywords-component; Bologna Process, Competences, Computer science education, Management education.

I. INTRODUCTION

Before 2010, all higher education institutions of the European Higher Education Area (EHEA) would have had adapted their degrees to the Bologna Process. This process has the purposes of promoting lifelong learning, widening access to higher education, and stimulating the mobility across the EHEA [1]. This change does not only consist on a new measurement of the credits of the subjects in terms of the student workload instead of the teaching hours. All contents of the new syllabus should be addressed to the achievement of certain prescribed learning outcomes and competencies associated to the degree [2]. These could be related to general skills or to specific requirements of the professions corresponding to the degree. In both cases, the initial level, if exists, must be known and the desired level should be realistic and achievable. Therefore, an assessment of the initial situation is required.

A project supported by the Spanish Government has been conducted on several Schools and Faculties of Computer Science in Spain [3] in order to state the initial level of competencies of first-years. Reading comprehension, English, and Mathematics were evaluated by analytic rubrics, as a quality label for competences acquisition. The results can be compared with the PISA reports of 2003 and 2006 [4]. Such studies usually cover the period of compulsory education, until 16 years old. However, at least in Spain, nothing can be said about the competence level of the students after the High School period, before enrolling in the University. This is quite surprising since the degrees designed in the frame European Higher Education Area should be designed thinking on learning outcomes and competences that graduate students must have achieved at the end of the degree.

At the Escuela Técnica Superior de Ingeniería Informática (ETSINF) of the Universidad Politécnica de Valencia (UPV) in Spain, we have compared the results on the mathematics competence of our freshmen with their success in mathematical subjects included in the first academic course of the degree. We have also analyzed the level of the students on this competence with their success in all the subjects of the first year. These results can also be compared with other analysis conducted at this institution for first-years [5][6]. Besides, we also try to relate students who drop out of the institution after the first year with their initial level of competence in Mathematics. See also [7][8].

In Spain, children have to take compulsory education until 16 years old. After this period, a Baccalaureate period of two years should be taken in order to apply for a university. We should point out that freshmen of Computer Science have shared Mathematics in the Baccalaureate with students that have finally enrolled in other studies of engineering or science. So that these contents are dedicated to these kind of studies. However, contents of Mathematics in this last year of Baccalaureate are mainly focused on helping the students to pass the university entrance examination (*Selectividad*) that students ought to take in order to access to the University. Therefore, a general improvement of the competence in Mathematics is not the main goal of this course.

II. COMPUTER SCIENCE DEGREE AT THE ETSINF

Until 2009/2010 the syllabus of the Computer Science degree at the ETSINF has been made up of 10 semesters (5 years). The number of Spanish credits for the whole syllabus is 375 (1 Spanish credit is equivalent to 10 teaching hours), divided into two stages. The first one takes 6 semesters and the second one takes 4. One academic year comprises two semesters and every semester lasts 14 weeks of teaching, with around 37’5 credits (375 teaching hours), and a period of 3 weeks for examinations.

From 2010/2011 the new degree, according to the new EHEA, will consist on 240 ECTS split in 8 semesters (4 years). Later, there will be a Master degree which will have between 90 and 120 ECTS. Some facts about the adaptation procedure were reported in [9].

Nowadays, Mathematics in the first year of the Computer Science degree at our institution mainly appear in the syllabus of these two subjects:

- **Mathematical Analysis** (Análisis Matemático - AM), 12 credits. It deals with calculus of one and several variables, complex numbers, numerical sequences and series, Fourier series, and ordinary differential equations.
- **Mathematical Structures for Computer Science I** (Estructuras Matemáticas para la Informática I - EMI1), 9 credits. It includes contents of linear algebra (such as systems of linear equations, vector spaces, eigenvalues and eigenvectors), logic (propositional logic and predicate logic), and discrete math (mathematical relations and graph theory).

In the future degree of Computer Science, that will start in the course 2010/2011, the contents of these subjects will be redistributed as follows: **Mathematical Analysis** (6 ECTS), **Discrete Mathematics** (6 ECTS), and **Linear Algebra** (6 ECTS). This distribution will imply a new revision of the syllabus of each subject.

III. THE COMPETENCE LEVEL TEST

In the flavor of the tasks used in the examinations proposed in the frame of the PISA Project, some tests were proposed in order to measure the following competences for the Computer Science freshmen: *Reading comprehension*, *English*, and *Mathematics*. The following Spanish universities were involved in this project: Universidad de Almería, Universidad de Castilla La Mancha, Universitat Politècnica de Catalunya, Universidad Politécnica de Madrid, and Universidad Politécnica de Valencia. A number of 425 students conducted these tests, 107 of them where from the Universidad Politécnica de Valencia.

Depending on the results of the activities related to each competence, rubric procedures were developed in order to classify the level of each student on each competence as *Low*, *Medium*, or *High*. A complete description of this study and its outcomes can be found in [3], see also [11].

All tests and tasks were expected to be done in 2 hours. The Mathematics part was prepared to be done in 20 minutes. Nearly all questions where proposed in a True or False way.

At the ETSINF in the Universidad Politécnica de Valencia, we have deeply analyzed the particular results of our students in the Mathematics competence. For this purpose the questions in the test of the mathematical competence were divided up in two parts: *Calculus* and *Algebra*.

The evaluated Calculus contents are basically included in the subject *Mathematical Analysis*. On the other hand, Algebra is related with *Mathematical Structures for Computer Science I*, since half of its contents are of linear algebra.

The items treated in the Calculus test were graphic representation and elemental properties of functions, derivatives, and primitives. On the other hand, in Algebra we considered algebraic computations, solution of inequalities, lines on the plane, and the solution of systems of linear equations.

IV. RESULTS AND DISCUSSION

The results in the test of Mathematics’ competences, measured using rubrics, have been compared with the marks obtained by this same cohort at the end of the academic year. In Spain the students who fail the final exam after the teaching period can sit for an additional examination during the same course. For these students, we have considered the higher mark obtained in both exams.

In Figure 1 we show the percentages of students obtaining the low, medium, or high level on each of the rubrics (100 % are 107 students from the Universidad Politécnica de Valencia). In both rubrics more than half of the students show a low level of competence (52% in Algebra and 55% in Calculus). These results show us that the level of the questions was quite similar in both cases.

The number of students with a medium level of competence is higher in Algebra than in Calculus (45% and 30% resp.) However, only a 3% of students in Algebra, and a 14% in Calculus got the high level. This could depend on the fact that the text contained some questions on geometry of the plane that are treated in the first year of the baccalaureate period, and they are not considered neither in the university entrance examination nor in the university courses.

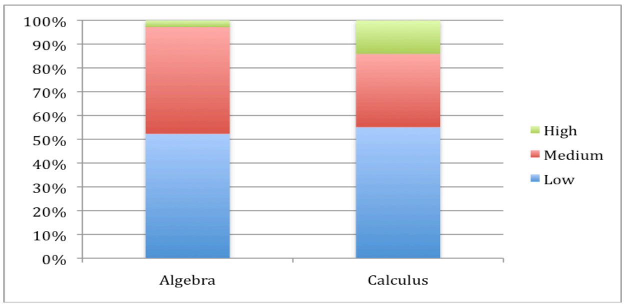

Figure 1. Percentage of students in each level of the rubric.

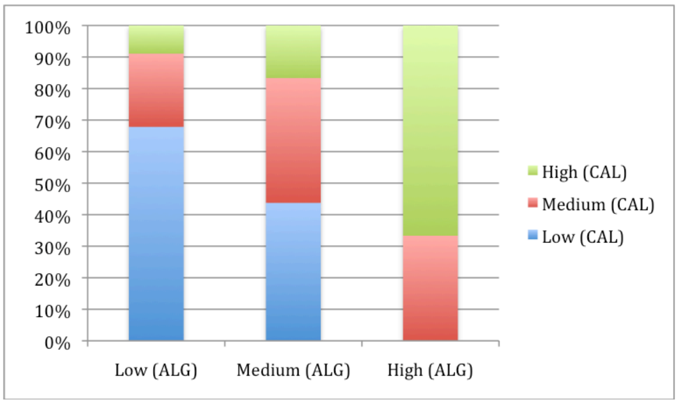

Figure 2. Percentages of students in each level of the Calculus and Algebra rubrics.

Secondly, we have studied the relation between the level on Calculus and Algebra of each student. (See Figure 2). Almost 70% of the students with a low level in Algebra have also a low level in Calculus. The medium level in Algebra corresponds with the medium level in Calculus for the 40% of the students. Finally, almost 70% of the students with a high level in Algebra have also a high level in Calculus. This also Confirms the level of the questions was quite similar in both rubrics.

The levels obtained in each rubric by the students can be compared with the marks that they have obtained in the subjects of EMI 1 (for the rubric of Algebra) and AM (for the rubric of Calculus) at the end of the academic year. This relation can be seen in Figure 3. It is important to recall that in Spain the marks obtained in a subject are from 0 to 10. A mark of 5 is required to pass a subject.

We should point out that in order to compute this average, students who did not sit for examination but did the test were also considered. A mark of 0 was assigned to these students. This fact makes the average of the marks lower than the corresponding average of the students who sit for examination in these subjects. However, we consider that exclude the results of these students will distort our study.

In Figure 3, we have represented, for each level, the mean plus/minus the standard deviation of the marks. For EMI 1 the standard deviation of the marks corresponding to each level of the rubric was (2.7 for low, 2.92 for medium, and 0.45 for high).

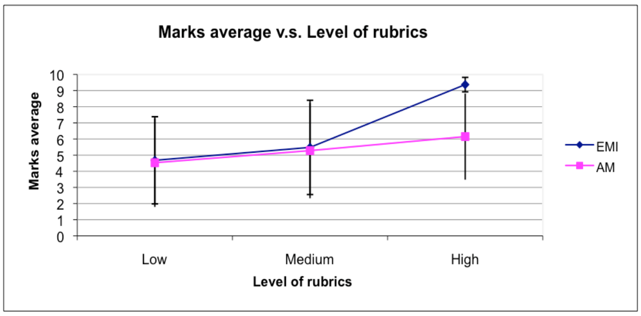

Figure 3. Marks average on EMI 1 and AM vs. level on each rubric.

In AM the corresponding standard deviations were quite similar for students with a low or medium level (2.74 for low, 2.95 for medium), and much more bigger for students with a high level (2.67).

The fact that some students who did not sit for the examination were considered makes that the deviations were quite significant for the low and medium levels, where these students were supposed to be classified.

We also see that the small number of students having a high level in the Algebra rubric show a mark very high in EMI 1 (about 9.5). This fact is different from the rest of groups where a linear relation has been established between the level on the rubric and the average of the marks in the corresponding subjects.

At this point one can wonder if the differences observed in the results of rubrics and the corresponding marks on AM and EMI 1 would imply, really, different populations. In order to measure if the means of the marks obtained in each of the cases correspond to different groups, we have used the t-statistic test, by computing the probability that the different means of the marks were significative. In the next table we show the probability (percentage) that the differences in marks between different pairs of groups are significative. The study has been carried out between the different groups of Algebra, and on the other hand, the different groups of Calculus:

TABLE I. PROBABILITY (EQUAL OR HIGHER) THAT THE DIFFERENT MEANS OF THE OBTAINED MARKS ARE SIGNIFICATIVE. GROUPS COMPARED ARE H (HIGH) VS. M (MEDIUM) LEVEL, H VS. L (LOW), AND M VS. L, BOTH IN ALGEBRA AND CALCULUS.

	Algebra	**Calculus**
High-Medium	95%	60%
High-Low	99%	95%
Medium-Low	80%	70%

These data shows that the groups established by each rubric have in fact different means with a probability, at least, of 60%. In the case of the comparison between the high and low level, the probability is higher than 90% (95% for the Algebra rubric).

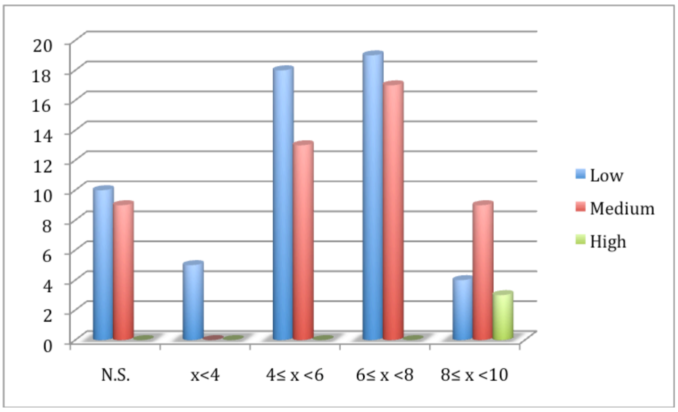

Figure 4. Distribution of the marks in EMI 1 depending on the level of competence in Algebra.

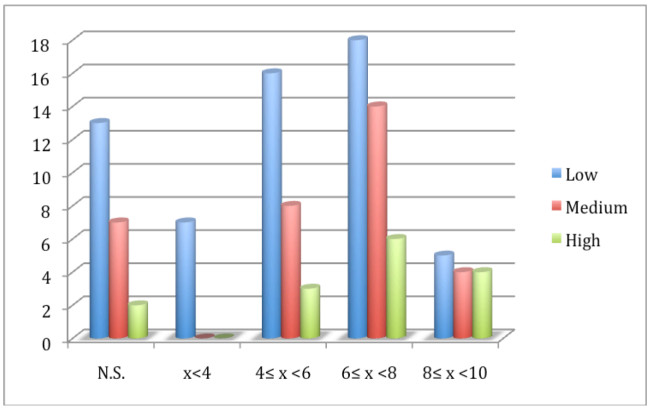

Figure 5. Distribution of the marks in AM depending on the level of competence in Calculus.

In addition, we have considered the relation between the level obtained on the rubrics and the distribution of marks in the subjects of EMI 1 and AM. These distributions can be seen in Figures 4 and 5. We have considered the following groups NS (who did not sit for examination), less than 4, greater or equal than 4 and smaller than 6, greater or equal than 6 and smaller than 8, and finally, greater or equal than 8.

In both rubrics it can be found similar patterns for the distribution of marks:

- In all groups of each rubric, most of marks in the corresponding subject are between 4 and 8; for the low level, the highest weight is between 4 and 6, and between 6 and 8 for the medium level.
- For the high and medium levels, the weight of the marks greater than 8 increases. In the case of Algebra it covers the 100%.
- All students with marks smaller than 4 in AM or EMI 1 got a low level in its corresponding rubric.
- The number of students who did not sit for examination is similar for the students with a low or medium level in the corresponding rubric.
- Only students with a low level in the rubric get a mark smaller than 4 in the subject.

The number of credits passed by the students is strongly related with the marks obtained by them in the subjects of EMI1 and AM, as Figure 6 shows: There is a linear increase in

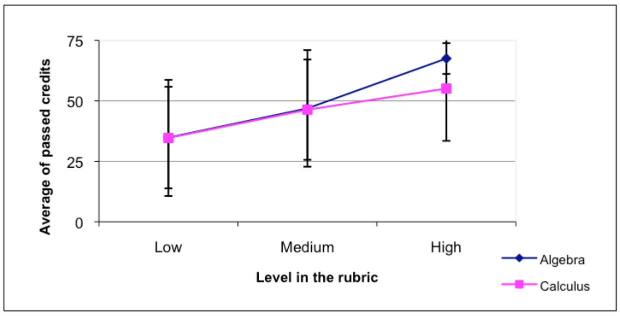

Figure 6. Approved credits by pupil vs. the level of the rubric for each group.

the number of passed credits in the first academic year as the results in the rubric are improved.

Finally, we have to point out that all students that did the test were also enrolled in the degree the next year. Nearly none of them has dropped out of the degree.

This was not the expected situation observed some years ago in [8]. This situation has probably happened because the test was taken during the second semester of the first academic year.

The interesting point is that we have noticed that all students who will not go on with the degree have already taken their decision in this moment of the academic course. On the other hand, the economic crisis is probably forcing the students to keep on studying at the university, as they cannot find easily a job.

V. CONCLUSIONS

To sum up, in both cases, Calculus and Algebra, the classification of the students in rubrics have similar results. This fact is an evidence of the coherent design of both, the tests and the rubrics. Therefore we can affirm that the level of competence in Mathematics acquired during High School of the students of the Computer Science degree, is strongly related with the success in all Mathematics subjects of this degree.

Also, students with lower level of competence can even pass the subjects of Mathematics. This can happen because in some cases they know the solution procedure of some problems but they do not really understand the meaning or intuition of the mathematical topics.

In any case, students with a low level of competence in Mathematics have smaller chance to succeed in the mathematical subjects of the degree. Furthermore, the level in Mathematics is strongly related with the success in the rest of the subjects of the first academic year.

The PISA reports [4] set the competence in Mathematics of the Spanish students a little below than the average of the OCDE countries. This situation is not getting better during the sequent years. The High School period has only two courses, and in the second one the students should be prepared to pass the University entrance examination. All questions and

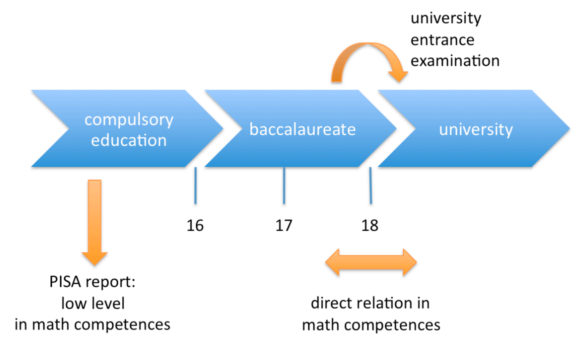

Figure 7. Diagram of the situation of the mathematical competences in secondary education and university.

contents of this examination are quite defined, so during this second course the outcomes expected are focused on solving the problems that will appear in this exam. The develope of the mathematical intuition plays second fiddle.

Since it is clear that the good level in the mathematical competences improves the success in the Computer Science degree, then the level on it should be improved. Great efforts must be done in compulsory education as the PISA reports suggest. Another option is to propose an enlargement of the Baccalaureate, probably separating the students in the last year of compulsory education depending on their interests, or adding one more year to the Baccalaureate.

Until the changes in these periods happen, the Faculties and Schools of Computer Science should try to improve the mathematical competences of their students. This can be done offering groups, during the first academic course, to support the students having great deficiencies in basic notions of mathematics. Besides, in the programs of mathematics subjects in the new Computer Science degrees, more attention must be paid to mathematical notions and concepts, despite that the number of ECTS has probably been reduced.

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