The Artificial Intelligence Course at the Faculty of Computer Science in the Polytechnic University of Madrid

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Abstract

This paper presents the experience of teaching an Artificial Intelligence course at the Faculty of Computer Science in the Polytechnic University of Madrid, Spain. The objective of this course is to introduce the students to this field, to prepare them to contribute to the evolution of the technology, and to qualify them to solve problems in the real world using Artificial Intelligence technology. The curriculum of the *Artificial Intelligence* course, which is integrated into the Artificial Intelligence Department's program, allows us to educate the students in this sense using the *monographic teaching method*.

1. Introduction

The transfer of knowledge and technology between universities and companies has become a key factor in the progress of the most developed countries. Right now, in the Artificial Intelligence (AI) field in Spain, AI technology is in a process of transition from the universities and research laboratories to the market place. In this transition, universities and the knowledge taught in them, play a very important role. Sometimes, the quality of business applications is the direct outcome of our teaching practices.

This paper summarizes in section Two the state of AI in Spain. Section Three describes the basic concepts that the program covers, and the interactions of the AI courses with the whole curricula of the Faculty of Computer Science. Section Four shows how the instruction of the *Artificial Intelligence* course at the Faculty of Computer Science at the Polytechnic University of Madrid is performed using the *monographic teaching method*. Section Five includes an evaluation of the success of the monographic method. Finally, section Six analyses its advantages and how this method improves the students' capabilities to use AI to solve problems in the real world.

2. The State of Artificial Intelligence in Spain

The first step in solving a problem is to make clear its existence. In this sense, if we want to transfer AI technology from universities and research laboratories to the market place, it is necessary to analyse its evolution over the time. That means: to learn from the past to know the previous successes and errors, to identify the strengths and weaknesses that AI has right now, and to project where AI should go and why.

This approach will give us a realistic perspective about how healthy AI is now in Spain. If we know our weaknesses in the universities, in the research laboratories, in the companies, and the communication problems among them, and if we compare the Spanish situation with the international circumstances, then we can gather enough information to carry out a multidisciplinary approach to treat these weaknesses. In this way, the university, as the engine of the transfer of knowledge and the pioneer of new research lines, can play the main role in this set of private and public interactions among institutions.

The following summarizes the most important points in a recent study (Juristo, Maté, & Pazos 1994) about the past, present and future of knowledge engineering in Spain (the survey also presents a description of the past, present and future of AI in general).

a) The most important errors in the past were that: 80% of the products developed were prototypes, 63% of the failures were due to a bad task selections, and the remainder was due to a wrong expert evaluation and/or the use of ad hoc methodologies for knowledge acquisition and expert systems development.

b) At this moment, the Faculty of Computer Science carries out two complementary approaches to transfer AI technology from the laboratories to the market place. The first one focuses our efforts in the selection of the task and the development of a sound methodology with an associated life cycle. The second one, known as CETTICO (Center of Technology Transfer in Knowledge Engineering), was set up with the aims of: technological exploration; identification and classification; research and education; technology transfer and transition, involving technology maturation; technology dissemination and technology insertion.

c) The future can not be predicted, but we expect a full integration between Software Engineering and Knowledge Engineering products in the market place in Spain.

3. Artificial Intelligence Courses

The Faculty of Computer Science's curricula is consistent and coherent with the computing curricula proposed by ACM and IEEE in 1991 (ACM/IEEE-CS 1991). The whole curricula cover not only undergraduate but an advanced and deep curricula in different computer science areas for graduates in computer science and other disciplines. In its undergraduate curricula, the *Artificial Intelligence* course is the first AI course that an undergraduate student can take in this area in the fourth (of six years) of the Computer Science undergraduate curricula. This course is one of the 14 courses that the Artificial Intelligence Department of the Computer Science Faculty offers to undergraduate students.

In a teaching AI survey, D. Strok (Strok 1992) says: "On average, each School offers two undergraduate and three graduate AI-related courses", and "while most Schools don't require an undergraduate AI course, as many as three quarters of computer science majors take it as an elective". In comparison, the Faculty of Computer Science's curricula offers:

a) Two mandatory courses called *Artificial Intelligence* and *Knowledge Engineering and Expert Systems*, five optional courses, and many seminars to undergraduate students.

b) For graduate students, the graduate curricula offer a MSc course in Knowledge Engineering (Gómez-Pérez & Juristo 1993) and 14 courses for Ph.D. students. These courses provide a deep and advanced analysis in AI areas like: Knowledge Engineering, Methodologies for KBS, Software Engineering and Knowledge Engineering, Robotics, Knowledge Sharing, Fuzzy Logic, Logic Programming, Neural Networks, and Learning.

In the same survey, Strok shows the relationships between the number of undergraduates in Computer Science programs in different schools (from 12 to 2,700) and different AI-related courses (from 1 to 800). In the 1993/1994 academic year in the School of Computer Science at the Polytechnic Universitity of Madrid, there were 2,500 students in the undergraduate program, 400 of them took the *Artificial Intelligence* course, and 300 the Knowledge Engineering and Expert Systems course.

The *Artificial Intelligence* course covers three hours per week over nine months. The two objectives of this course are: to guarantee a solid instruction in the foundations of AI, and to apply the concepts learned to solve problems in the real world. Its prerequisites are: Mathematics, Logic, Programming, and Statistics. The curriculum of the *Artificial Intelligence* course is divided in the following *Didactic Units*:

Unit I.	Introduction to Artificial Intelligence
Unit II.	Lisp
Unit III.	Formulation and Modelization of problems in AI
Unit IV.	Search: blind search, heuristic search and adversary search
Unit V.	Knowledge Representation
Unit VI.	Planning
Unit VII.	Learning
Unit VIII.	Natural Language and Automatic Translation

The relationships with other undergraduate AI courses are:

a) After this course, the student must take the mandatory course named *Knowledge Engineering and Expert Systems*. It deals with methodologies to build expert systems and uncertainty management.

b) The students may choose some of the following optional courses in their fifth and sixth year. For the fifth year: *Computational Perception*, *Models and Simulation* and *Computational Theory*. For the sixth year: *Complexity of Algorithms* and *Algorithmic Logic*.

4. The Monographic Method

Although there is much literature about different teaching methods for different goals, environments, and subjects, the ideal teaching method is not yet known. In the course of *Artificial Intelligence* in the

Faculty of Computer Science at the Polytechnic University of Madrid, we started four years ago an optional method called the *Monographic Method* (Pazos 1988). The Monographic Method (MM) divides the *Artificial Intelligence* course into modules called *Didactic Units*. This teaching method is consistent with Bloom's Taxonomy (Bloom 1956) about educational goals. This method is an active learning method for students because they play the main role in it, working hard to apply AI concepts in problems which resemble real world applications. The method is performed along the following steps:

1. General overview of the didactic unit, its place in the Artificial Intelligence field, and the kind of problems that can be solved with the techniques covered by the unit. The lecturer provides to the students the basic and necessary knowledge of the didactic unit in a clear, coherent, open to discussion, and extendible *Master Lesson*. The master lesson explains the basic techniques in each didactic unit, the conceptual differences between them, and provides references to extend the knowledge acquired in class. The students will apply the concepts learned in class and by themselves in the resolution of problems which resemble real world problems. Each master lesson should cover the following five subjects:

   1.1 Goals.

   1.2 Presentation and exposition of the contents in an ordered way, mixing theoretical and practice knowledge.

   1.3 Summary and conclusions of the addressed aspects.

   1.4 References to be consulted.

   1.5 The lecturer proposes a *Monographic work* related with the subject of the didactic unit. A monographic work covers practical, and sometimes theoretical, aspects that allow the student to learn in deep the techniques covered by the didactic unit using the references recommended.

2. The student, in an individual and active way, learns by himself or herself when (s)he starts the monographic work using the recommended references. These references include classic and recognized papers and books, and sometimes new lines of research in the area covered by the didactic unit.

3. After this study, students gather in small groups of three or four in order to analyze and discuss the questions individually studied and solved at home. This task implies the decomposition of the problem into subproblems, modularization of tasks, how the theory that they have studied at home can be applied to solve the practical monographic work, and so on.

4. When each group has discussed and analysed the problem, the discussion and analyses involve the entire group. During this step, some groups explain during the class their partial conclusions and the lecturer presents a partial summary of the useful results. Interactions between groups are useful to show and compare different approaches to solve the same problem. The objectives of this step are:

   4.1 Focus the attention of students on the relevant points.

   4.2 Connect the monographic work with the knowledge studied in class and at home by themselves.

   4.3 Solve some theoretical and practical questions.

5. When the monographic work is done, the groups summarize the works performed in the previous steps by the lecturer, the works accomplished in groups, in class, and at home. This step is carried out following the following script:

   5.1 The lecturer reviews in a few minutes the activities to be solved in the monographic work, why they were proposed, the goals to be reached and which of them are going to be analyzed and discussed in class.

   5.2 Each group, itself, will agree how to explain the activities proposed by the lecturer.

   5.3 The lecturer selects randomly some groups and, for each group, a spokesperson is randomly chosen. The spokesperson will explain how his/her group has performed each one of the activities.

   5.4 The lecturer summarizes the advantages and limitations of the different approaches.

   Steps Two to Five are repeated for each didactic unit in the *Artificial Intelligence* course.

6. When all the didactic units has been taught, each student performs an individually written exam about the whole theoretical course. If the results are favorable the method ends and the student passes successfully the *Artificial Intelligence* course.

5. Evaluation of the Monographic Teaching Method

The monographic method (MM) has been applied in both the Artificial Intelligent (AI) course and the Knowledge Engineering and Expert System (KE&ES) course. In the AI course, during 1993 there were about 400 students, while in the KE&ES course there were 300.

For the evaluation (Juristo 1993) of the method we used two similar experiments. One for the AI course, and the other for the KE&ES course. We performed the experiments with two different courses to assure that:

a) The results of the experiment for the AI course were generated because of the method, and not because of any special attribute of the AI subject.

b) The results of the experiment were the same for both courses, and therefore correct.

Till here we have described the premises of our experiment. To carry out an experiment, besides the premises we need: first to establish the hypothesis we want to verify; then, the empirical checking or contrast of the hypothesis. In our case:

a) We applied the statistic inference (Freeman, 1970) to carry out the experiment.

b) The experiment consists in dividing the students of the AI course in four groups of 100 students each. In two of them we teach following the monographic method. In the two others we teach through the old traditional teaching method. For the KE&ES course we created three groups of 100 students each. In only one group we followed the monographic method. In the two others we applied the old method.

c) The null hypothesis (H_0) stands that the results of the experiment will be the same for the groups applying the monographic method than for the others.

d) The alternative hypothesis (H_1), which is the one we want to verify, says that the results will show a difference between the groups using the MM and the others.

e) To be exigents, we asked for a significance level of 0.01 (it is usually enough with 0.05 as significance level for experiments). NOTE: It is not possible to stablish an exact limit to the question when the probability of a result is low enough to reject the null hypothesis. However, traditionally, a result is considered rare or uncommon when it turns out five of 100 times. That is, when the result has a probability of 0.05. When H_0 is rejected because it has a probability of 0.05 or more, it is said that the result is significative at the level 0.05, and, therefore, 0.05 is the significance level.

To analyze the results of the experiment, we perform two tests on the marks obtained by the students in the different groups. The results of the tests were:

a) By the parametric test, the marks obtained by the students in the MM groups (2 for AI, 1 for KE&ES) were 2.5 points/10 points higher than in the other groups. The difference among the marks in the MM groups was 0.3points/10points.

b) Using the non-parametric test of X^2 the results were even better. For the X^2 test with three degrees of freedom and 0.01 significance level, the critical point is 11.3. The value obtained in our case for the X^2 test applied between any MM group and any traditional group was more than twice the critical point. The value obtained for the X^2 test between the monographic groups or between the traditional groups was always no significative. Therefore, there exist significant differences between the results obtained using the MM and those got using the traditional method.

c) The line (curve, function) representing the marks obtained by all the students, using the traditional method was slanting (bias) towards the fails, while using the MM was slanting over the highest marks. The meaning of these results is that the MM is more efficient regarding the success of the students, than the traditional evaluation through exams, in more than 600%. That is, the evaluations of the MM are passed six times more students than the exams of the traditional method.

Finally, we would like to point out that according to our information, most of the american universities use teaching-learning methods half-way the MM and the traditional spanish methods, being closer to the MM. While in Europe, the methods are also half-way but nearer the traditional.

Monographic Method

Marks:	0 to 5	5 to 7	7 to 9	9 to 10
Expected Frecuency	10	42	31	1 7
Remarked Frecuency				
1st. AI Group	10	43	30	17
2nd. AI Group	12	44	29	15
1st. KE&ES Group	9	40	32	19

Traditional Method

Marks:	0 to 5	5 to 7	7 to 9	9 to 10
Expected Frecuency	45	33	16	6
Remarked Frecuency				
3th. AI Group	43	35	17	5
4th. AI Group	46	33	15	6
2nd. KE&ES Group	50	36	11	3
3th. KE&ES Group	41	32	19	8

6. Conclusions

The experience acquired in the last four years allows us to conclude that although some points can be improved, the results achieved by the students who optionally chose the *Artificial Intelligence* course using the monographic method is more than satisfactory. The most important characteristic that the monographic method provides is that it *combines* two opposite teaching strategies.

1. The first strategy starts when the lecturer describes techniques and how these techniques can be applied to solve several kinds of problems.

2. The second strategy starts when the lecturer proposes to the students a practical, and a few times theoretical, monographic work. At this time, the student has to look for new techniques that attempt to solve the problem posed.

The advantages of the combination of these two strategies are:

1. Each student is motivated during the whole learning process. In the monographic method, students play the main role.

2. The students are qualified to follow the evolution of the technology further into the future, make easier their adaptation to the continuous changes of this area.

3. Students apply AI technology to solve specific and constrained problems in the real world. Consequently, they have the ability to detect what kind of problems can be solved using AI technology. They are also more qualified than before to work as a team in companies that require AI by itself or AI applied to Software Engineering products.

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