A Survey on the Use of Computer Algebra in Spain in Relationship to Its Secondary School System

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Abstract: At university level, Computer Algebra Systems (CAS) are well accepted (especially in the first years of engineering studies). But at secondary school level, the situation can be resumed in the sparse implementation of isolated experiments (with a lot of enthusiasm, but little support).

We shall try to briefly describe the Spanish educational system and the development of Computer Algebra (CA) in Spain in the context of secondary education.

Kurzreferat: *Ein Überblick über die Anwendung von Computeralgebra in Spanien in Beziehung zum Sekundarschulwesen.* An Hochschulen sind Computeralgebrasysteme (CAS), vor allem in den ersten Semestern der Ingenieurwissenschaften, gut eingeführt. An Sekundarschulen gibt es jedoch nur eine dürftige Implementierung isolierter Experimente (mit viel Enthusiasmus, aber wenig Unterstützung).

Wir versuchen, kurz das spanische Bildungswesen und die Entwicklung der Computeralgebra (CA) an Sekundarschulen in Spanien zu beschreiben.

ZDM-Classification: D10, R20, U70

1. Preliminary note

Comparing the sales in Spain of the different general purpose CASs (REDUCE, Macsyma, Axiom, DERIVE, Theorist, Mathematica, Maple V), it seems that the first three have either a testimonial or residual diffusion. The last four share the market in teaching and the last two in research.

MatLab is not included, as it is not strictly a CAS (although the latest versions can make a call to Maple's kernel, in order to support exact arithmetic). Mathcad is not included either, as it is something between a word processor and a mathematical system.

In secondary education, nearly all the experiments we know choose DERIVE (possibly because the classic version allows its use in computer classrooms where obsolete PC-ATs and XTs still survive – along with other modern models!). The only data that we do have about sales to secondary schools in Spain talks about 400 licenses of DERIVE, Theorist and Mathcad (together) during the last year. There were no important sales of other CASs to secondary schools.

As there is no exact translation, we shall refer to the Spanish studies following the primary school ("Educación Secundaria") either as high-school or secondary school.

2. Non university education in Spain

Remark: When giving the *age* of students below for plans, two figures will be mentioned. When advancing in the studies at the appropiate speed, students begin the period with the *age* in the left hand side and finish it with the *age* in the right hand side.

2.1 Previous plans

Traditionally, primary education covered the 6–10 year old age group. Teachers had a non-university education. A full university degree was needed for high school teachers (10–16 year old age group).

2.2 The 1970 law

Fundamentally, this law transfers the students between the ages of 10–14 to primary schools. Secondary education is shortened to 3 years (14–17) plus a pre-university course (COU) for those students that are going to enter superior (university) studies. Therefore, secondary studies are basically extended one year. Secondary education is divided into BUP ("Bachillerato"), propedeutic and FP ("Formación Profesional"), which consists of two obligatory years, followed by optional 2-year courses, and is aimed at making students fit for immediately joining the labour market.

This reform lasts for about 25 years. Teachers for primary schools study a short specific course in teacher training at University (3 years) and teachers of secondary education must hold a standard degree which takes 5 years.

2.3 The "Reforma" (reform) of 1990

Primary school is shortened to the ages of 6–12, which is followed by secondary school. The latter now has two stages: the compulsory "ESO" (12–16), itself divided in two cycles (12–14, 14–16), plus a non-compulsory "Bachillerato" of two years (16–18). Both the pre-university course (COU) and the first cycle of "Formación Profesional" disappear.

3. New technologies in primary and secondary education in Spain

After some isolated and non structured beginnings, mathematics teachers in some centres began to have small computers (Sinclair Spectrum, Commodore VIC ...) around 1982. The purpose was to solve small problems with programs written by the students themselves.

A first attempt to institutionalise these isolated experiments appeared in the mid-eighties, but never developed from the embryonic stage.

Immediately after, the so called "Proyecto Atenea" appeared (in an experimental five-year stage), with its own budget. It was aimed both at primary and secondary education. It tried to incorporate computers as an aid in the acquisition of contents during the learning process. It was not implemented in all schools.

Computers were shipped with BASIC, and the project included the legal distribution of LOGO to all the centres in the project. Specific versions of LOGO were developed in Spanish (following the LCSI standard for Apple and IBM, and, at the end, versions emulating Windows and under Windows were also developed).

But the main goal was to help in acquiring techniques for problem solving, in developing a geometric intuition ...

An integrated package (Open Access or Writing Assistant), Knosys, De Luxe Paint, ... (depending on the schools and levels) were included.

Nowadays, almost every centre has at some moment be-

longed to the program, and they have computer classrooms with around 10 PCs that are partially updated from time to time. New lines have been included lately: telematics, multimedia ... . CA was not included.

In autonomous districts with the independence to make decisions in the educational level, similar programs were implemented. Although Spain is not a federal state, it is divided into "Comunidades Autónomas" (something similar to the German "Länder"). There are 17 of them, each with their own president and parliament. Some depend, from the educational point of view, on the Ministry of Education of the central Government (MEC) – what is called the MEC territory. Others have independence to take decisions in the educational level (for instance Valencia or Cataluña).

4. Institutional support

4.1 Appearance in support documents

Despite what has been explained above, in the official guidelines for 16–18 year olds, DERIVE and Mathematica are explicitly mentioned: page 90 of MEC 1995a and page 71 of MEC 1995b.

But, surprisingly, in MEC 1995c, i.e. the guide for didactic aids for both cycles of the new ESO (12–16), CASs are neglected. Although they mention many different kinds of computer programs (from Computer Assisted Learning – in Mathematics – to MS-Works or De Luxe Paint II), no CAS is recommended – see page 161 of MEC 1995c.

4.2 Appearance in textbooks

Some of the Spanish textbooks for secondary students between 14–18 years of age include exercises to be done with DERIVE or at least mention DERIVE.

For instance, the collection of textbooks for the new ESO (Arias et al. 1996a–d) includes in their lessons exercises to be solved with the classic calculator and others to be solved using DERIVE (beginning at the 1st year of the ESO, age 12–13).

But, as far as we know, there are no specific books of CA for secondary level (for instance for the non-compulsory subject EATP (computer science)). There is a contrast with what happens at a university level (where, for instance, the excellent books by García et al. (1994) – already translated into German – and Llorens (1993a) have been on the market for several years).

Articles regarding experiences with CASs in secondary classes are also rare (Burrel 1996) in comparison with university level, where a wide literature is available: Llorens 1995, Llorens 1993b, García et al. 1995, García 1993, Población 1993, Hervás et al. 1996 ...

Some years ago, different programs and books with disks, aiming at the introduction of the computer as an aid in the mathematics classroom were developed: Función, Graphics ... – by the "Ministerio de Educación" –, Roanes/Roanes 1988, Menéndez 1994 ... – by independent authors. But now, almost all lessons are directly carried out on CASs.

4.3 Calculators

The use of the scientific calculator (like TI-82 or TI-85) in the mathematics classroom is not as widely accepted in Spain as, for instance, in the US. Some experiments have taken place – see, for instance Tortosa 1995, Salinas 1996, Millán 1996, Botella 1996. Only for the lessons regarding statistics, the scientific calculator is generally accepted – see CEP Burgos 1993, page 62.

Computer statistical packages are usually welcome too. For instance Llovet (Universidad de Alcalá) directs an experimental project to use the computers in the statistical lessons of COU (17–18 years). The experiment is carried out in three high-schools simultaneously. Statgraphics is the software chosen.

Curiously, one of the more successful Spanish authors nowadays, commented recently that, of her two series of textbooks (by the same publisher and commercialised with the same marketing), the more successful one was the classic one that did not use the calculator for many of the examples.

This attitude is a disadvantage for the new generation of symbolic calculators (like the TI-92), in a higher range of prices and, apparently, more difficult to use than the scientific ones (probably just because we are not used to the way it looks!).

4.4 Institutional implementation

Nevertheless, as far as we know – and we have contacted some former members of the Spanish New Technologies Program –, the administration – including the administrations of the different Autonomies – have not developed any global project regarding CA (software buying, courses ...) to make their use easier.

For instance the case of the "Comunidad Autónoma de Valencia" is commented upon below. But we think that experiments like that of Valencia (although a first step) can not be considered as a global project.

Because of all this, experiments carried out in the 14–16 year old group are isolated, generally directed by competent and enthusiastic teachers. The buying of licenses is generally restricted to one for each centre (in the best case). And this buying is usually done thanks to an economic effort of the centre or through the "parents' association".

For some topics – as the early introduction of LOGO –, we think that our country is in a leading position. But for Computer Algebra we are still in an initial stage (especially compared with leading cases such as the Austrian – see for instance The International Derive Journal Vol. 3 No.1).

We think that CA, statistical packages and other mathematical programs should be introduced during secondary education. Our opinion is that, although growing slowly, this is the general feeling.

4.5 Some general obstacles to the use of CA

In order to confirm our opinions voiced above, we include some of the difficulties mentioned by the Working Group in Secondary Education in the 1995 Spanish DERIVE Workshop – see Anon. 1995a, pages 24–25:

- LCD for overhead projectors are very rare
- Lack of teachers for splitting groups when going with the students to the computer classroom
- Overcrowded computer classrooms

– Legal software not easily available.

4.6 Diffusion in magazines and bulletins

Some Spanish Mathematical Societies include in their publications (sparsely or as a fixed section) articles about CA in education (at every level). We would like to mention:

– Bulletin of the Mathematical Society "Puig Adam" (Professor Puig Adam was a member of the International Association for Improving Mathematics Teaching around the middle of this century. He was a Professor both at University – Engineering School – and at a High-School. His research interests included both Applied Mathematics and Education)
– Epsilon Journal (of the Andalusian Mathematical Society "Thales")
– Suma Journal (of the Federation of Mathematical Societies)

For concrete articles, see the bibliography at the end.

Of course, journals like The Bulletin of the DERIVE Users Group, The International DERIVE Journal, MapleTech or The Mathematica Journal are well known in Spain, but there is nothing similar dedicated to CA here.

5. Courses

5.1 Undergraduate subjects

Unfortunately, as far as we know, there is no university in Spain that includes a subject devoted to CA and education at undergraduate level.

For instance, in the "Universidad Complutense de Madrid" (one of the government-owned universities in Madrid), Roanes-Lozano, one of these authors, teaches a non-compulsory undergraduate subject entitled "Sistemas de Cómputo Algebraico" ("Computer Algebra Systems"). The idea is to give an introduction to DERIVE and Maple V for students from the Faculties of Mathematics, Physics and Computer Science (the Faculty of Mathematics has a Maple site license and the Faculty of Education has a DERIVE site license plus a 10-machine Maple license). This subject is oriented towards the use of these tools by the student during his university training.

5.2 Teacher training courses

More related to the topic of this article, authors Roanes-Lozano and Roanes-Macías have taught, during 1994–95, 1995–96 and will teach during 1996–97, in a "Curso de Posgrado de Experto en Educación Matemática" ("Postgraduate Course: Expert in Mathematical Education") a subject entitled "Sistemas Computacionales y Enseñanza de la Matemática" ("Computational systems and Mathematics Teaching"). The content of the course is split into CA, Geometric Problem Simulation and Dynamic Geometry (Sketchpad, Cabrí).

The CA part we are interested in, is oriented to:

i) Give an introduction to DERIVE and Maple V – notes Roanes/Roanes 1996 are used.
ii) Show how a CAS can be used in a class in secondary education as an aid to deal with some of the hardest topics (concepts of limit, derivative ...), in a line similar to that in Kutzler 1996, and choosing some parts of Roanes/Roanes 1994.

The course mentioned above has also been taught twice (with the same orientation) at the "Colegio de Doctores y Licenciados" ("Association of Doctors and Bachelors") – an institution specially related to secondary education.

5.3 General courses in CA

Different universities give more or less regularly intensive courses (approximately one week long) as an introduction to CASs. Among them, we could mention those given by Olazábal at the Universidad de Santander (REDUCE and CASs in general), Montes (et al.) at the Universidad Politécnica de Cataluña (Maple), Grané (et al.) at the Universidad Politécnica de Cataluña (Mathematica), Llorens at the Universidad Politécnica de Valencia (DERIVE) ...

To finish this section it should be mentioned that some CEPs ("Centres for Teachers", depending on the administration) have organised similar courses. For instance, authors Roanes-Lozano and Roanes-Macías gave one at the CEP of Avila in 1995. Recio (Universidad de Santander) gave some very interesting lectures about the topic at different CEPS during 1988–1990 (Recio 1990a).

6. Contrast with the use of CA in university

There is an added disadvantage in this poor adoption of CASs in secondary education.

As mentioned above, its use during the subjects of the first years at university is very frequent. The qualitative and quantitative jump in the level of the required contents between secondary and university education pose severe problems to many students (scholar failure). We think that this contrast could be reduced if useful tools like this were well known previously (something that would be perfectly possible in secondary education).

This disconnection was a conclusion expressed in Anon. 1995a, page 25.

7. Real implementation

7.1 The general frame

A poll regarding these topics is included in Anon. 1995a. The number of centres where it was sent is enough to consider it very representative. The data (approximately) is:

– Number of centres where it was sent: 1000
– Answers received: 200
– CAS preferred: DERIVE
– Number of teachers that use a CAS in their classes: 50 (generally in the non-compulsory subject EATP that does not have rigid objectives like the subject "Mathematics", and with fewer students than the latter).

7.2 One initiative of the "Autonomia Valenciana"

During the 1990–91 course, the Computers in Education Dept. of the "Autonomía Valenciana" distributed 10 DERIVE licenses among 10 secondary education centres. They asked each of them to produce a final report about the experiment to be distributed afterwards to the remaining centres.

Different experiments took place, most of them with students aged 17 and 18. Among the experiments up to the age of 16, we can underline those that took place at the following centres:

1) "Instituto" (this is the Spanish name for high-school) Figueras Pacheco of Alicante: about plotting simple functions and graphic resolution of equations – see Grupo Cero 1995, pages 154–161.
2) "Instituto" Ferrer i Guarda and "Instituto" Masamagell (both from Valencia): about the use of the computer to study elementary functions and trigonometric functions
3) Denia group (formed by teachers from six different centres in the district) that worked together and shared their experiences. They undertook the following:
   – Production of manuals to use DERIVE and MatLab
   – Design of activities to study with the computer: sequences, trigonometric functions and other elementary functions
   – Creation of specific sets of questions for students from "Formación Profesional"
   – Design of activities for teacher training in these technologies
   – Implementation of an experiment of curriculum development for the study of functions with the computer (this experiment was done by the author Burrel, and is detailed below).

8. One exemplary experiment

8.1 The classroom experiment

Burrel taught both the subjects "Mathematics" and "Computer Science" (EATP) in two groups in the 2nd year of BUP (15–16 years). The objective was to observe the differences between a group working with DERIVE and another one without it. At the same time, materials designed during previous years were to be checked.

The project had three parts:

– Development of a curriculum about functions for the 2nd year of BUP, where the computer is used in the classroom (it could be adapted to be used in 4th year of ESO or 1st year of the new "Bachillerato")
– Detailed analysis of each session with the computer using the material previously designed
– Design of an objective exam to check how ideas related to visualisation are kept by students one month after studying the lesson (for students in BUP-2nd year).

8.2 Sample and procedures

The experiment was organised with one group. They had three sessions of 110 minutes (during the EATP schedule), plus two more equally long (outside the normal scholar schedule), plus two 55 minutes sessions during the mathematics schedule. The group was split into two groups, each of 20 students, when going to the computer classroom.

The other group was used as reference group, as they receive the same mathematics classes, with the same teacher, but did not use the computer. The same exams were presented to both groups.

8.3 Development

8.3.1 The curriculum for functions in 2nd year of BUP

It is divided in four sections, all of them structured in a similar way.

The first part is introduced through a situation that allows the student to observe different variables and to analyse the relationship between them. Afterwards, the relation between the shape of the plot and the operations made on the independent variable are analysed. From the canonical forms of the most commonly used functions, others are obtained by translations parallel to the axes.

In the second, asymptotes are introduced. The computer is used to visualise the progressive approach of the function to the asymptotes. Moving the axes allows one to study discontinuous functions with asymptotic branches and to visually recognise the existence of asymptotes.

The third part is devoted to the introduction of the idea of changing the domain of a function in order to transform a discontinuous one into a continuous one (an idea needed in later courses and very easy to understand with the help of the computer). This forces the student to deal with both concepts (continuity and domain).

The fourth part is dedicated to studying the changes in the slope of the tangent line in the different points of a curve (which can help in understanding what the gradient is).

8.3.2 Computer sessions

Students are placed in couples who work together at one computer.

Different methodological methods are used for each session. Some are research classes that allow the existence of different levels and are based on the trial-and-error procedure. Others are directed at the acquisition of certain concepts and the know-how with the application. A third kind is devoted to strengthening and enlarging already known concepts.

A set of questions that the student has to answer is provided by the teacher. The answers are checked by the pupils themselves or collected and corrected by the teacher.

8.3.3 Implementation of the experiment

It was considered interesting that the students could:

– Pick out (visually) the shape of the plot and the corresponding expression
– Compare graphically and analytically the consequences of translating the axes
– Recognize discontinuities and asymptotes.

A first list of possible questions was produced. Some were obtained from Tall 1985 and others were inspired by the previous experience in teaching. Twelve of these questions were given to twenty mathematics teachers who were asked to put the questions in the order of their suitability for evaluating the knowledge of the student (one month after having studied the topics). This way eight questions were selected.

Students from the two groups took the same exam (in which they were not allowed to use the computer).

8.4 Conclusions of this experiment

In general, an improved domain of the Euclidean Plane and graphic representations was found. Also a better capability to plot and visualize functions. The acquisition of the concepts "continuity" and "domain" was also better.

In the poll there was a special (positive) deviation in the group that had used the computer in visualisation-related

topics.

This group had dedicated three hours less than the contrasting group to the study of functions.

9. A similar experiment

A similar experiment was carried out for several years by Julián Martínez at his secondary school. He introduces DERIVE in the 3rd year of BUP (16–17) and uses it to study functions and also geometrical aspects of the concept "derivative".

The positive attitude of the students and the spontaneous use of the CAS in other subjects is underlined.

Something remarkable is the fact that students often rediscover the existence of functions $\mathbb{R} \times \mathbb{R} \to \mathbb{R}$ by playing with DERIVE.

10. A Ph.D. thesis in CA and education

Llorens holds a Ph.D. in mathematics, and his dissertation (Llorens 1996) is related to the topic of this article. He studied the influence of the use of a CAS in the learning process (he teaches at an engineering school, where he has long experience in teaching and evaluating the subjects "Algebra" and "Calculus" – of the first year –, using a CAS).

To be precise, his thesis was dedicated to proving that there is very little evolution in the errors in the acquired concept of tangent (necessary to acquire the concept of derivative) between students aged 16 and those in their first year of university. He also justifies the importance of the use of CASs for the correct acquisition of this concept, by checking the differences between those students that have worked with DERIVE and those who have not (this experiment took place with students at their first year at university).

11. Final remark

In the last few years we assisted with the major Spanish conferences in the field of CA and education:

i) "Tecnología en Educación Matemática en la Universidad" (TEMU, "Technology in Maths Education at University"): Montes/Brunat 1995, Anon. 1990, Anon. 1991, Hueso et al. 1993.
ii) Algebra Computacional (EACA): González-Vega 1995, Anon. 1996a.
iii) Maple V: Anon. 1995b, Anon. 1996b.
iv) DERIVE: Anon. 1995a.

and we also checked the proceedings of the latest Mathematica conference (Hervás et al.1996).

Our connection with this environment is close: for instance, author Roanes-Lozano was a member of the Scientific Committee of the last TEMU (1995), of the Organising Committee of the DERIVE Spanish Conference of 1995, belongs to the Maple Software Development Team and is a beta-tester of DERIVE and DERIVE for Windows. Authors Roanes-Lozano and Roanes-Macías are foundation members of the "Sociedad Española de Cálculo Simbólico y Aplicaciones" ("Spanish Society for Symbolic Calculus and Applications").

Information from different "Comunidades Autónomas" (regions) of Spain has been compiled. Also, information from the distributors in Spain has been obtained.

We think we have done some serious and detailed work. Nevertheless, and due to the huge difficulty of obtaining a global overview, we would like to apologise for any possible omission of all the interesting initiatives (institutional or personal) that we may have missed out.

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– Add-Link Software Científico (importers for Spain of most CASs).

13. Conclusions

As said in the abstract, at secondary school level, the situation can be resumed in the sparse implementation of isolated experiments (with a lot of enthusiasm, but little support).

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