

CAS integration into learning environment

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Abstract: In order to successfully integrate computers into education, it is necessary to organize effectively the prerequisites of human-machine interaction. In the organization of competence-centred education computers could provide valuable assistance for both personal- and group- learning activities. In this paper, we will examine various applications of Computer Algebra Systems (CAS) in classroom settings. The elements of the learning environments are CAS, E-Learning-portal, and Tight VNC remote control system. CAS assisted teaching can become genuinely effective in a complex learning environment if students' instrumental-genesis evolve into instrumental-orchestration. We will demonstrate the evolution of this process by using one of our developed applications. As an example, we developed, tested, and evaluated our model in the Department of Engineering at the University of Pécs. The study took place during the 2004-2005 academic year with computer science and computer engineering participants.

Kurzreferat: Um Computer erfolgreich in Bildungsprozesse zu integrieren ist es notwendig, die Bedingungen der Interaktion zwischen Mensch und Maschine wirksam zu planen. Bei der Ausrichtung an kompetenzorientierter Bildung können Computer sowohl Hilfestellungen für Lernaktivitäten von Einzelpersonen, als auch von Gruppen liefern. In diesem Beitrag werden verschiedene Anwendungen von Computer-Algebra-Systemen in Lernsituationen gegeben. Elemente der Lernumgebung sind dabei das CAS, E-Learning Portale, sowie ein VNC Kontrollsystem. CAS unterstützendes lehren wird besonders dann in einer komplexen Lernumgebung effektiv, wenn instrumentelle Ansichten entwickelt sich zu instrumentellen Werkzeugen bei Lernenden. Die Entwicklung dieses Prozesses wird anhand einer selbst entwickelten Anwendung aufgezeigt. Dazu wurde das Modell am Department für Ingenieurwesen an der Universität Pécs entwickelt, getestet und evaluiert. Die Untersuchung fand während des akademischen Jahres 2004-2005 mit Studenten der Informatik und technischen Informatik statt.

ZDM-Classification: C30, C70, U70

1. Introduction

1.1. The didactical functions of CAS

As it is known, Computer Algebra Systems are interactive software packages that include symbolic features beyond the traditional numerical capabilities. CAS could become the source, medium, and generator of mathematics teaching. However, the use of CAS in actual teaching poses considerable didactic challenges. Originally, CAS were developed to assist mathematical applications and research, but for teaching. Thus, teachers should be aware of the difficulties of using CAS. They

should use CAS as a tool in education in order to adequately assist in the development of students' mathematical knowledge. Nevertheless, careful integration of CAS into mathematics teaching and learning opens new opportunities for mathematics educators. CAS may shorten the time required for complex computations and offer additional class-time to work on conceptual issues. In this way teachers can devote more time to interpret concepts and students may further recognize the connection among mathematical topics. In other words, students' knowledge-representation web becomes increasingly thicker.

1.2. The process of CAS integration into education

We aimed to integrate CAS into our programme by keeping in mind human, psychological, and didactical objectives rather than by taking a technical-centred approach (Artigue, 2001). We introduced CAS into our courses in a measured pace considering two positions. First, we introduced various CAS activities into our courses step by step. Second, we tried to incorporate more and more features gradually. We followed the cyclical activity structure described by Lagrange and Py (2002).

The elements of the cycle are:

- **The analysis of constraints and conditions.** We must consider many different conditions in this part. The integration of CAS into a course or a section of course should take into consideration the type of the courses, the available time, students' preparedness, and the available resources.
- **The integration of new CAS functions into the educational setting.** To integrate CAS into a new part of a course we must carefully consider the existing elements and the objective of this specific course. Furthermore, we must harmonize new elements with existing ones and then carefully control the didactic process. We should also take into account the opportunities CAS offers for these courses. For instance, in what circumstances a particular CAS function can be applied? What are the side effects of its applications? The latter question refers to our didactical analysis as the use of CAS in teaching and learning could significantly alter the dimensions of the mathematical teaching/learning processes by providing such novel opportunities. Thus, it is necessary to carefully plan the incorporation of all novel CAS function into mathematics teaching and learning.
- **The analysis of CAS use.** In this phase we examine and measure the efficiency of the integrated CAS functions and its variants. We must carefully examine the extent of change, due to CAS integration, in epistemological and pragmatic values. In addition, the evaluation of different CAS tools should also investigate their effects on students' concept development and their problem solving techniques. Furthermore, we must also analyze whether or not the

coordination between CAS and paper-pencil procedures was appropriate.

- **The design of new applications and functions.**
The analysis of use could reveal whether or not the effectiveness of methods improved due to the added complexity of the system. This new system enables us and even requires us to integrate further tools, algorithms, and procedures into the system.

1.3. The instrumental orchestration

The didactical tools offered by the instrumental orchestration have presented considerable assistance in the effective development of our programme. Similar to other tools applied in mathematics education CAS use is

task. (Trouche, 2003, 2005). In this process, the users develop their own schemes, the so called instrumental schemes. These schemes, together with the actual artefact form an instrument. (Figure 1) Furthermore, these schemes consist of several closely interwoven **technical** and **mental components**. Technical components are a sequence of actions that users execute on computers, such as writing commands and creating algorithms. Mental components consist of conceptualizations of mathematical objects, problem solving processes, and mental images of these actions. Thus, instrumental genesis is the process of construction of instrumental schemes. In this construction, mental schemes assist in the comprehension of technical schemes. The instrumental genesis is a personal construction within a social setting. Its guidance is called **instrumental orchestration** (Trouche, 2003).

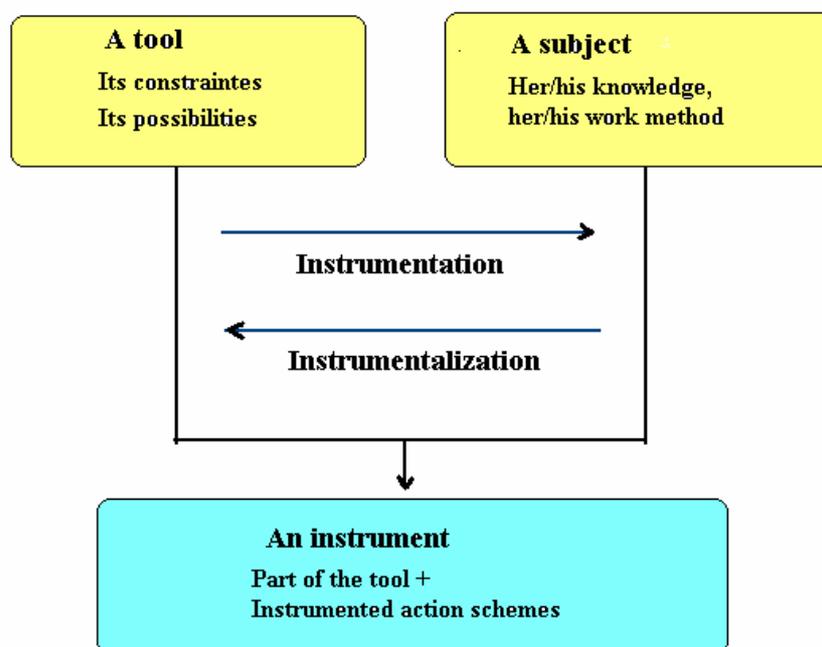


Figure 1. From artefact to instrument (Troche, 2005)

a complex process. As Trouche (2003, 2005) explains CAS is only a sole tool, an artefact, but through the learning process as a result of a complex and two-way process, it eventually becomes a mathematical instrument. “An artefact is a material or abstract object aiming to sustain human activity in performing a type of task (a calculator is an artefact, an algorithm for solving quadratic equations is an artefact. An instrument is what the subject builds from the artefact” (Trouche, 2005). This building called the **instrumental genesis**. Instrumental genesis is a process (it needs time) and has two components. The first one, instrumentalization, is directed toward the artefact. The second one, instrumentation, is directed toward the subject. The subject builds an instrument in order to perform a type of

2. The model

1.4. The educational environment

In our programme, the effective integration of CAS into university-level mathematics teaching, or in other words the instrumental orchestration, is assisted by two new components in addition to the traditional setting: 1) the E-Learning educational internet website and 2) the computer laboratory equipped with Tight VNC control system and computer projector. TightVNC (VNC is an abbreviation for Virtual Network Computing) is a client/server software package allowing remote network access to graphical desktops. The system allows several connections to the same desktop, providing a tool for collaborative or shared work in the classroom.

Students in our department are required to enrol in mathematics courses for three consecutive semesters. The primary aim of our courses is to provide adequate knowledge for computer science students for their

studies. In the class, Matematika I, we only use CAS as tool for demonstrating mathematical objects. The restricted use of CAS derives from two main causes. First, a large number of students do not have adequate mathematical knowledge to begin working with CAS immediately. Second, unfortunately our department does not yet have enough computing capacity to accommodate all our students in computer laboratories. In courses, Matematika II and III, students may opt to enrol into traditional or CAS-assisted courses.

2.1. CAS course material on our intranet and on the Internet

Students may access all course material on our intranet and on the Internet. Students may download the content of lectures in the form of Maple-worksheets in html, Pdf, or Word formats. Thus, students can obtain files that are most convenient for them personally. In addition to the lecture notes, laboratory worksheets, are integral parts of our courses, will be available. These worksheets contain Maple-procedures, previous test material, a set of problems, and problems from our Maple club.

2.2. The didactical function of our E-Learning portal

Although it can be assumed that E-Learning is a distance-learning system, we designed this website primarily as a supplement of our regular courses, keeping in mind our needs of CAS courses. By using the E-learning website, we can easily modify our course materials, which conveniently can be varied for the

needs of different student groups. Obviously, our CAS-based course materials have different layers. They consist of algorithms, procedures, and modules, as well as other traditional course materials. Therefore, we needed to design a tool that would provide us with the opportunity for interactivity and effective communication.

Our website can be found on the following link: www.matserv.pmmf.hu/e-learning. The didactical functions of the E-learning site:

- Sources of course material, thematic course material organization
- Documentation, administration
- Communication
- Feedback

Description of these functions are below.

2.2.1. Sources of course material, thematic course material organization

E-learning enables us to position our course materials in a well-structured place. We can also connect the related course materials by using the „SysTeMath” system. In this way, students may select materials for their given course assignments (Maple worksheets, html files and other documents). In addition, they may review other curriculum modules, such as lecture notes, lab worksheets, past tests, and course reviews. The instructor can modify the system on the website (Figure 2).

Figure 2. Thematic course-material organization with SysTeMath functionality

2.2.2. Communication

One of the most significant features of the E-learning site is that it enables effective communication between instructors and students. In addition, the announcement section contributes to the organization of the course by continuously providing crucial course information for students. Furthermore, the forum allows students to share their thinking about specific topics.

2.2.3. Documentation and feedback

Providing adequate feedback for students is a fundamental element of teaching. The E-learning

system together with the Tight-VNC system assists instructors to reduce the time between evaluation and feedback. In this way, instructors may improve the effectiveness of teaching and learning. Students can submit their homework, lab worksheets, and challenge problems through the E-learning portal. The system stores students' results and grades, which are accessible all that time for instructors and students.

2.3. Instrumental orchestration in our programme

By employing a variety of mathematical representations of the materials, we can attain elements of the **instrumental orchestration**. (Figure 3)

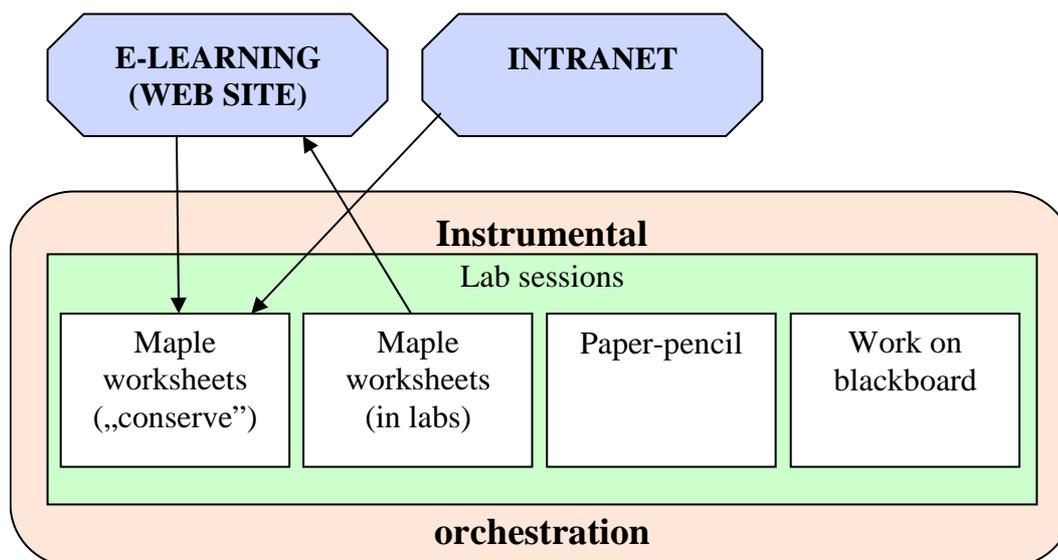


Figure 3. Instrumental orchestration in labs

We designed our labs based on the slightly modified version of the sherpa-student method described by Trouche (2003). Its main features are:

- There are 20 students and two instructors in each class
- Computers are organized into a common network, and classrooms are equipped with computer projectors.
- Initially the computer screen of the teacher is projected, but with the help of Tight-VNC system students' screens can be projected also. Thus, nice solutions and common errors can be shared easily with all the students. In addition, the teacher can modify students' worksheets from his/her computer. The screen of "sherpa" students is projected on the board, but this role changes from problem to problem. This technique is important, because we can motivate students and expose syntactic and schematic errors, as well as to offer immediate teacher control.

We designed the following phases based on the method described above:

- Initially, we simultaneously use and encourage the board, projector, and **paper-pencil work**. This phase is very important for students' mental development of new concepts and

procedures. From our experience, omitting this phase considerably deprive the effectiveness of CAS applications for students' learning.

- Closely monitored work. The projector enables us to monitor the computer work of either the teacher or a selected student. In this phase the instrumental genesis is guided strictly. Due to such work students acquire the necessary CAS functions and procedures.
- Simultaneous individual work and projection. In this phase the instrumental genesis is fairly free. We follow this process when the aim of the class is to have students practice and acquire skills in the newly learned subject matter.

However, feedback is provided all the time from the projected work.

- Individual work on computers without the assistance of the projector. In this phase, the instrumental genesis is "slightly controlled".

We followed Trouche's (2003) description of the phases described above. Then, we added the E-learning system that provided new kinds of applications:

- Students must save their independent work in a specific folder on the E-Learning site. The collection of solutions in this folder is available for assessment by teachers and for

students' self-reflection. However, at the end of sessions we usually project the exceptionally good solutions and/or frequent errors. This is a well-liked method among students, because they are able to revise their own solutions and ascertain the work of their fellow students.

- In the beginning of labs students can discuss their solutions of their homework assignments by projecting results from their E-Learning folders. According to our experience this method clearly motivates students to develop and perform high-quality work. Due to the use of CAS, the analysis of a variety of procedures and problems becomes easily performable and illustrative.
- At the end of the lab sessions, students are required to save their work into their E-learning folder for further accessibility and analysis.
- The work on teachers' machines are also saved and later supplemented with additional details and comments to assist students' class preparation. The documentation of the lab work from the semester is accessible for students in two different forms providing significant assistance for students' work at home and their preparation for the examinations.
- Test material is immediately uploaded to E-Learning after students have taken the test. In this way, during the upcoming lab session, students may verify their own solutions and teachers may choose to project high-quality solutions and/or common errors. Furthermore, instructors can illustrate solutions in collaboration with students by projecting a student solution using the Tight-VNC system.

3. Evaluation of the learning process

The evaluation of our model is a complex process. We were able to measure the expansion of mathematical topics covered in our classes. In addition, both epistemological and pragmatic values of our courses have been elevated. Also, we were able to add real-world problems to our course material and to model these problems with CAS.

We were able to compare the effectiveness of our CAS-assisted courses with traditional classes, because a large number of students still enrolled in paper-pencil classes. However, this comparison should be treated carefully. It is difficult to compare the didactical values of the two kind of teaching methods. Thus, in our comparison, we considered the differences between the difficulty levels of problems provided in traditional and CAS-assisted courses (Macogain, 2002). We found essentially no difference between the grades of the two groups, but when we investigated students' conceptual understanding, we found differences. We conducted our

investigation using three different kinds of problem sets:

- Conceptual problems, measuring students conceptual understanding (T);
- Problem solving skill measurement problems, evaluation problem solving skills (P);
- Operative problems (O).

Score were equally distributed among the three categories. Table 1 show this distribution.

	T (%)	P (%)	O (%)
Maple-assisted teaching	17.6	39.1	43.3
Control group	21.7	31.0	47.3

Table 1 Results of comparative analysis

It can be seen that students in Maple-assisted classes scored higher than those enrolled in traditional classes.

4. Summary

Although we must treat our result of the effectiveness CAS-assisted courses cautiously due to our restricted sample, we can make comments about the work of the system:

- CAS enable teachers to introduce mathematical topics into the curriculum that were not previously possible
- The conscious employment of the instrumental orchestration enhanced the effectiveness of CAS-assisted teaching
- The use of the E-Learning website contributed to the quality of instruction by assisting individual learning and by improving communication and accessibility

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