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EFFECTS OF COMPUTER ALGEBRA ON CLASSROOM METHODOLOGY AND PUPIL ACTIVITY

Abstract:
This field study focuses on the changes in classroom activities resulting from the use of the computer algebra system (CAS) DERIVE. 20 lessons with and 37 lessons without the use of computers, held in Austrian grammar schools with 15 to 17 year old pupils in 1994, have been observed with a special pattern covering important aspects of classroom methodology in teaching mathematics.
The pattern is composed of seven dimensions split up into three to seven categories. The results indicate persistent structures of the lessons according to most methodological dimensions, as 'situation', 'didactical function', 'aim of qualification' and 'basic form of the method' on the one hand and a significant increase in pupil activities on the other hand. Some aspects of this trend could be due to differences in the progress of lessons with or without CAS. The situation of the teacher has been investigated by a questionnaire and found to be subject to some very important changes.

1. Introduction

Computer algebra is a relatively new stream in school mathematics. The first systems were available in the early 1980s and the first report on teaching in schools - as far as I know - was "Experiments with muMATH in Austrian High Schools" presented by ASPETSBERGER and Funk at ICME 5, Australia, 1984. A dozen years later many software products are on the market and adequate hardware is part of the common equipment of today's high schools. A broad discussion has started on the way computer algebra should be used in teaching mathematics.

In Austria today there are three mainstreams:

– All grammar schools (Gymnasien) have been provided with DERIVE-licences by the Federal Ministry of Education and therefore DERIVE is used in most of these schools. The ACDCA group (Austrian Centre for the Didacticals of Computer Algebra) has run some conferences (e.g. international Krems conferences 1992 and 1993) and research projects. A big project on the TI-92 computer algebra calculator involving about 70 classes will start autumn 1997.
– In Austrian technical high schools several CAS-packages are in use. The teachers get support by the AMMU organisation (Working group for modern mathematics education) providing teacher training and various materials.
– A more commercial option has been taken by a team of teachers on business high schools in Styria producing and selling interactive mathematics notebooks for common topics in upper secondary schools.

In Germany computer algebra has been discussed at meetings and conferences for many years. Some conferences have been dedicated to this topic exclusively, e.g. "Derive-Days" (Düs-seldorf 1995) and "Teaching Mathematics with Derive and the TI-92" (Bonn, 1996). Several working groups and school experiments have been established by the state school boards, mainly assisted and evaluated by universities. For example, there is a group of several grammar schools (Gymnasien) in Baden-Württemberg working with Maple on approval.

In general the situation in Austria has been characterised by a common availability of hard- and software for nearly a decade and therefore today computer algebra has been used in schools before its use in teacher training at universities. So even today most activities are set by school teachers. In Germany most activities develop from university projects or are initiated by school boards, resulting in a variety of testing approaches rather than using CAS as an everyday tool in teaching mathematics. Teacher training in Austria and Germany has been supported by T^3 (Teachers Teaching with Technology) since spring 1997.

2. Experimental Design

This study is part of the research project "Symbolic Computation Systems in the Classroom" which took place in Austria in 1993/94. It was initiated by Helmut HEUGL and Bernhard KUTZLER and realised by ACDCA in collaboration with Soft Warehouse by order of the Austrian Federal Ministry of Education.

As earlier mentioned, Austria bought a general licence for the use of DERIVE in all its grammar schools in 1991, so most of the teachers involved in the project had a lot of experience in using CAS to teach mathematics. Many reports on what has been done, what should be done or what could possibly could be done with computer algebra are available in the literature. Our aim was not to evaluate specially designed experimental situations but to uncover the reality of CAS in everyday lessons.

The study is based on an open and systematic observation of regular lessons with experimental/control group design (with/without use of computers). All observations have been carried out without any control of the contents of the lessons by the head of the project. In general the computer-lessons would have been carried out in the same way without observation. Therefore, the terms ‘experimental’ and ‘control’ group will be replaced by the terms ‘computer’ and ‘standard’ in the following chapters.

The experimental design was inspired by a research project by HAGE, BISCHOFF et al, in North Rhine-Westphalia in 1985. As their project was more general and had no reference either to mathematics to certain technical aids, we had to adapt the design to fit our purpose to get empirical data about the didactical structure of lessons and the impact of CAS on them. Additionally it was necessary to correspond to the infrastructural facilities of the total project.

The theoretical approach is to divide a lesson into two parts, (mathematical) content and methods the teacher uses to teach that content. This study only investigates the second part. Within the German pedagogic of the 20th century the terms ‘didacticals’ and ‘methods’ have been discussed very controversially. (The English word ‘didactics’ has a somewhat different meaning than the German word ‘Didaktik’, which is nearer to ‘pedagogy’. Though different educationalists have different definitions of ‘Didaktik’ even within Germany I will still use the translation ‘didacticals’ further on. The main point of controversy was whether methods can be seen to be independent from the contents or not.

The ‘disciples’ of Erich WENIGER (1894-1961) maintained his “theorem of the primacy of didacticals (theory of content and curricula) in relation to the methodology (theory of ways to perform teaching and learning)“. In the 1960s Paul HEIMANN, Gunter OTTO and Wolfgang SCHULZ developed the so-called ‘Berlin Didacticals’ (Berliner Didaktik), where ‘didacticals’ stands for a complete theory of education. Their thesis was that teaching is based on two determining factors (socio-cultural and anthropological conditions) and four decisive factors (aims, topics, methods and media).

There was a controversy about the assertion of interdependency among all six factors. Today advocates of both theories have come to the agreement that methodological decisions have to be motivated by didactical decisions, but these depend on the realisation by adequate methods of teaching and learning (KLAFKI, 1984). As the use of computer algebra alters the decisive factor media we advanced the hypothesis that this would effect all other factors. My part within the ACDCA project was to investigate the effects on the factor ‘methods’.

2.1 Questionnaire - Methodology (Observation Pattern, see Appendix 1)

During a lesson many things can happen and we did not want to make case studies with single lessons analysing all aspects of what happened, but to have an instrument to get an overview of the methodological repertoire of teachers and the way they use it in the two observed groups (computer/standard). To be able to run an observation and to evaluate the results later on it is necessary to reduce the observation to a limited number of items.

In this study the structure of a lesson is considered to be a chronological sequence of different educational methods, each composed of several dimensions. During the observation these dimensions have been classified in their chronological sequence with a special pattern. The dimensions and their categories are described in section 3 below. It made no sense to use a pattern with more items than we saw during pre-tests. We would need several observers and that would influence the 'natural' behaviour of teachers and pupils.

These dimensions cover a wide range of educational aspects. We wanted to know whether there was normal instruction or some special 'situation'. It was important to see if and which 'technical aids' have been used, mainly to identify phases with use of computer algebra. Then every normal part of a lesson has a 'didactical function' combined with an 'aim of qualification'. To achieve those goals the teacher has to organise the classroom activities, i.e. who is in control of the progression of the lesson ('basic form of the method'), what is the 'social structure' and what is the 'pupil activity'. We think these aspects of classroom activities to be most important in the comparison between computer and standard lessons and we expected a lot of differences. The categories should be in regard to teacher's common vocabulary.

Observers are not able to notice every single activity in a classroom. We wanted them to mark the main activities. So each lesson (50 minutes in Austria) is divided into ten periods and the observer had to mark every five minutes for each dimension what category appeared to be dominant during the previous five-minute-period. Usually they sat in the back of the classroom watching what's going on and after every five minutes they filled in one column of the questionnaire.

By using such a five-minute-pattern the structure of the lesson can be reflected very well, the observers can cope with the situation and it is practicable to make additional entries in the case of short, but important episodes. The first period starts with the teacher entering the classroom, so the resulting timelines are comparable, although some lessons have only nine periods (see section 4 and appendix 3).

2.2 The Sample

57 lessons in mathematics (age 15 to 17) have been observed (we did more, but some have been eliminated for formal or substantive faults), covering a broad cross section through the curricula of the inspected stages.

- 20 computer lessons (held by 11 different teachers in 11 different classes at 8 different schools),
- 37 standard lessons (18 teachers, 21 classes, 9 schools),

resulting in a total of 11 schools, 28 classes, 23 teachers and 531 pupils (253 male, 278 female) involved. No teacher has been observed more than twice in each group (computer/standard).

The employment of young teachers in their 'practice year' as observers resulted in pupils acting normally throughout all observations because the trainees' presence in the classroom is common for pupils and teachers.

3. Comparison Questionnaire - Methodology

In general computer lessons and standard lessons showed similar structure in most dimensions, significant differences can be found in the dimensions 'social structure' and 'pupil activity'.

3.1 Dimension of the Situation

This dimension was mainly designed to identify periods used for technical and organisational measures, e.g. the additional time needed if working with computers. There are five categories:

1. Instruction
'Standard case' of teaching (teaching in its broadest sense)

2. Disciplinary measures
The progress of the lesson becomes considerably disturbed and the teacher busies himself during the 5-minute-interval, mainly with trying to regain the attention of the pupils.

3. Technical measures
Interruption of the 'standard teaching' due to setting up the equipment, starting the programmes, rearranging the seating-plan and other activities of that kind.

4. Patterns concerning homework
Phases in which the progress of the lesson is interrupted by checking, discussing or setting homework (mostly at the beginning or end of the lesson), and no direct 'organic' production from the subject of the lesson is recognisable (so no instruction).

5. Organisational, notices
Activities that do not have any direct connection with the lesson such as, filling in the register, taking care of form teacher concerns, discussion of school events and other notices.

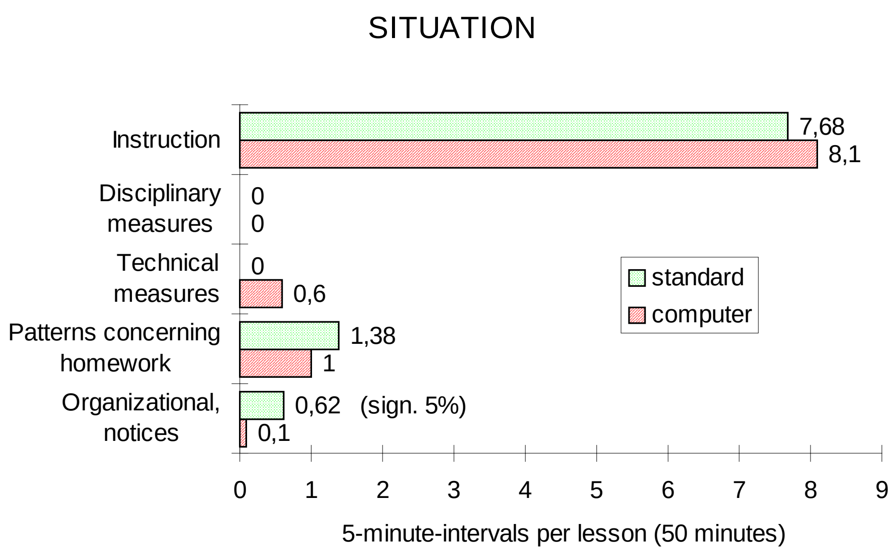

Figure 1: Situation

Hardly any difference can be noticed between the two groups. The additional expenditure for 'technical measures' in computer lessons requires an average of 0.6 intervals per lesson. The significant difference in the category 'organisational notices' results from limited access to computers at most schools, because every teacher tries to avoid wasting this precious time. 'Disciplinary measures' arose as short episodes only and have never been dominant in any interval.

3.2 Dimension of Didactical Function (Teaching Methods)

The following six points are a compromise between desirable refinement and operability for the observers in order to inspect the intentional structure of a lesson.

1. Introduction

Introductions systematically lead to a new educational topic, they can just be purely informative, as well as addressing a particular way of looking at a problem. It should take up a longer phase (e. g. 5-minutes!), not only a short introductory impulse.

2. Acquisition

Pupils should acquire new knowledge or new skills.

3. Repetition/systematisation

Reproduction of already imparted knowledge can serve both as a reminder of earlier content, as well as a strengthening of that which has just been taught. (No explicit assessment is apparent here!) This category is also filled if trains of thought are generalised, abstracted or organised. Making connections between the content of various lessons, for example.

4. Practice

Automation of intellectual and practical course of events, as, for example, mathematical calculations (no new problems, no explicit assessment)

5. Application

An already learned procedure or concept should be used by the pupils in order to deal with a new problem (so no practice!). In the process the knowledge can be used analytically (understanding) as well as constructively (productively).

6. Examination/assessment

Checking of the levels of achievement, whether with or without assessment, written or oral, prepared or unprepared. It can also be carried out by means of application exercises, but the main intention of the examination must be discernible.

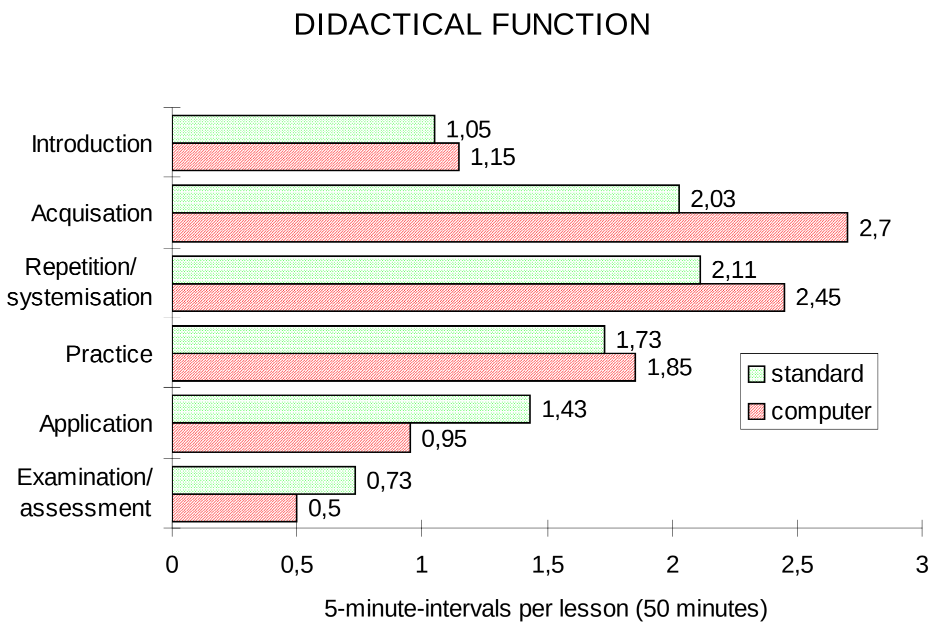

Figure 2: Didactical function

There are no significant differences in the categories of this dimension. The hypotheses that the parts of ‘practice’ and ‘application’ will be higher in computer-lessons could not be proved. The reason may be the necessity to impart knowledge about handling the computer and the program additionally (compare: ‘acquisition of computer knowledge’ in the dimension ‘aim of qualification’). In my opinion an intensification of applied mathematics has to go along with a corresponding understanding of school mathematics by the teachers. This could be achieved by teacher training rather than by the availability of a new technical device.

3.3 Dimension of Aim of Qualification

The criteria of this dimension have been investigated to measure the time necessary to teach the pupils the way of working with the computer algebra package.

1. Acquisition of mathematical knowledge
Acquisition of ‘mechanically’ reproducible mathematical knowledge, e.g., mathematical operations or methods.

2. Acquisition of computer knowledge (program handling)
Acquisition of ‘mechanically’ reproducible knowledge about computer science, for example, learning how to use a certain computer package.

3. Acquisition of intellectual skills and capabilities
The emphasis lay on the 5-minute-interval in the areas understanding, transforming, application, analysing, synthesis, etc.

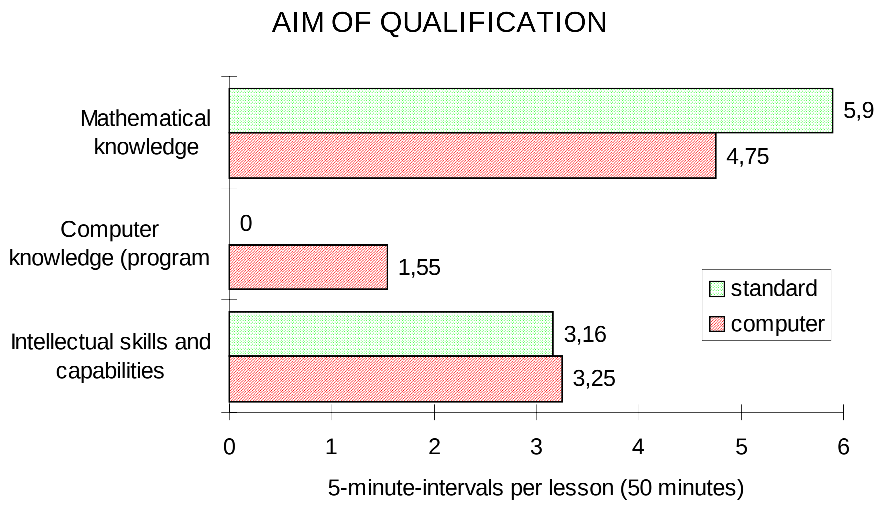

Figure 3: Aim of qualification

The part of the mathematical content is reduced as some time is spent in order to enable the pupils to handle the CAS software, but a gradewise analysis reveals this effect decreases down to nearly zero as the use of CAS becomes common in higher grades. Besides this effect the structure of this dimension is persistent: Two parts of ‘acquisition of knowledge’ to one part of ‘acquisition of intellectual skills and capabilities’.

3.4 Dimension of the Basic Form of the Method

The hypothesis on this dimension was that CAS increases ‘pupil activity’ at the expense of ‘teacher activity’. Therefore the set of categories focuses mainly on that point:

1. Teacher activity (lecturing, explaining, calculating)
Parts of the lesson dominated by the teacher. Within this category is the calculating of examples on the blackboard. It is filled when, for instance, a pupil writes on the blackboard, but the activity is actually guided by the teacher.

2. Discussion
Teacher-pupil discussion or free discussion. This category is only filled, if the pupils also have the opportunity to put forward their views and ideas. 'One-sided discussion' in which only the teacher has something to say, with little class input, is to be categorised under '1. Teacher activity'.

3. Calculating (pupil)
As with 1., but this time a single pupil is active. Guidance and advice from the teacher only happens if difficulties occur.

4. Pupils - silent work
Narrowly limited to individual, dependent conduct. For example, copying from the blackboard.

5. Independent pupil activity
Teacher not active, or only as an adviser, who discusses problems individually with pupils, either when these are recognised, or if a pupil requests advice.

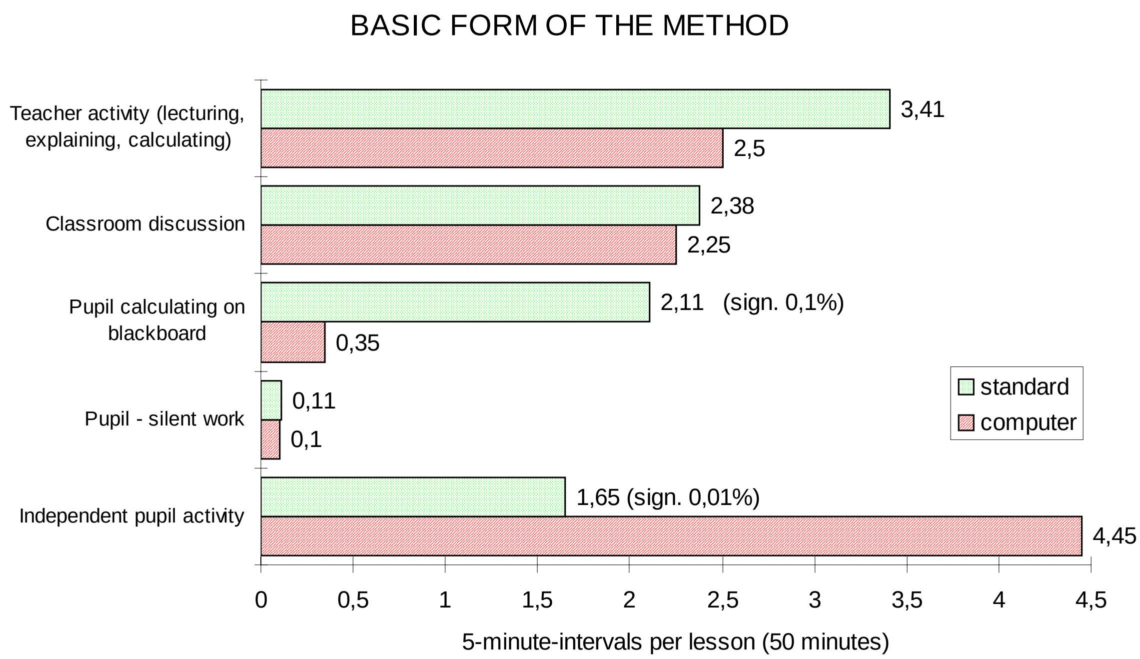

Figure 4: Basic form of the method

The segment of pure 'teacher activity' was lower (not significant) during computer-lessons. The increase of 'independent pupil activity' nearly erased 'pupil calculating on blackboard'. This trend was not unexpected, but we did not anticipate the still very large parts of teacher guided activities ('teacher activity', 'discussion').

The rise of pupil activities is a main argument for using CAS: Instead of one pupil working on the blackboard and the others watching, with computers everyone is forced to work and think independently. This may justify the time spent on learning how to handle the program. On the other hand the higher intensity of independent activities may considerably raise the individual stress on the pupil.

3.5 Dimension of Social Structure

We expected the trend towards independent pupil activity to be reflected in clearly visible shifts of the relative quota among the subsequent four types of social structures:

1. Class teaching

The class works as a whole unit, e.g., with the traditional didactical teaching (teacher calculating on a blackboard, lecture, etc.), or discussions, if there is no division of the class into groups.

2. Group work

Dispersal of the class into work groups (mainly with more than two pupils) in order to carry out the same or differing activities.

3. Partner work

Pupils work together in pairs on a task or problem.

4. Individual work

Each pupil works alone. An extreme case of individual work is an examination.

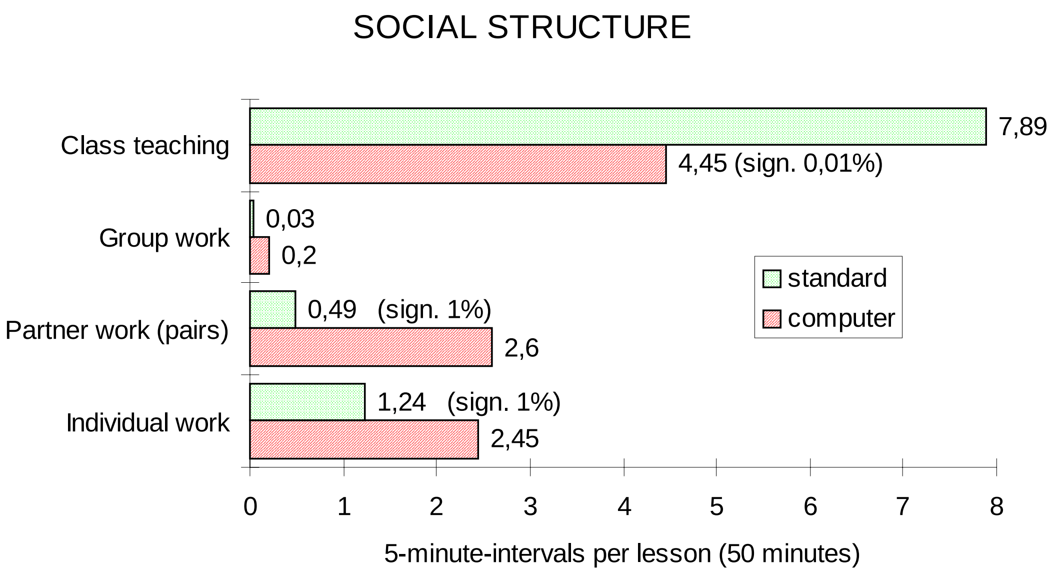

Figure 5: Social structure

Our hypothesis that the use of computer algebra systems increases the proportion of individual forms of working has been strengthened by the results of this dimension, that indicates the most significant differences between the two groups throughout the whole study. The distribution between class teaching and individual learning is seen to be better balanced in computer lessons.

3.6 Dimension of Pupil Activity

We wanted to see in which proportion the practical function of the individual pupil is altered by the use of CAS. Therefore the categories focus on the following essential points:

1. Note-taking

Picking up knowledge without explicit personal activity. The teacher (or class-mate) imparts the facts, the activity of the pupil is reduced to listening, reading, thinking, making notes etc.

2. Repetition

Reproduction of that which has been taught, in which memory capacity is most important.

3. Production

The pupils make their own contribution, which exceeds the already learned structure. This includes, for example, transforming and reshaping knowledge, analysis and synthesis, creative thought, etc. This is fulfilled by independent problem solving, for instance.

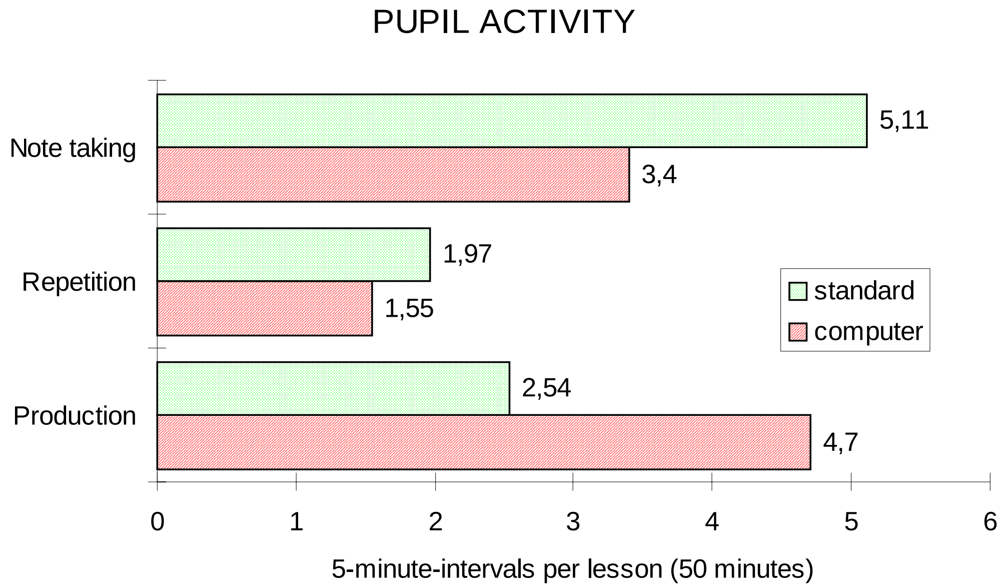

Figure 6: Pupil activity

The outcome of 'note taking' dominant in standard computer lessons and 'production' dominant in lessons confirms the hypothesis that CAS-support leads to a more 'productive' learning.

The sample issmall, and the Austrian teaching style may differ considerably from those in other countries, but the results show clearly that even without changes in 'didactical function' and in spite of 'lost' time through handling-problems, there is one big advantage that justifies the use of CAS from the higher standpoint of the general curriculum: **more independent productive pupil activity.**

3.7 Dimension of Technical Aids

'Technical aids' (blackboard and school-book are not included) are rarely dominant during a 5-minute-interval. Very interesting is the low value in the category 'pocket calculator' with an average of 0.59 intervals per lesson in standard groups compared to the very intensive use of CAS in computer lessons with an average of 6.8 intervals. This fact indicates the capacity of DERIVE as well as a trend I would like to call 'CAS laboratory effect'. It results from limited access to computer equipment on the one hand and the tendency to continuous use of the devices, as soon as the program is already loaded, on the other hand. Couplings of computers with other aids are rare.

4. Comparison of the Progress of Lessons (Appendix 2)

Although the sample is too small to develop 'normal-profiles' as e.g. defined by HERBART and later on by REIN, GEISSLER *et al* (formal step scheme) or GRELL & GRELL (recipe to run a lesson), some distinct trends can be identified:

- In standard lessons a longer initial period can be seen because of organisational matters and patterns concerning homework.
- In contrast to computer lessons standard lessons show more distinct time-profiles, which means that certain categories accumulate in certain parts of the lessons.
- In both groups ‘teacher activity’ was dominant at the start, then ‘pupil activity’ increased (essentially earlier and higher in computer lessons) and gradually decreased in the last intervals.
- A hypothetical ‘normal profile’ for the progress of a ‘perfect’ lesson, as we often see in literature, would consist of a succession of repetition/systematisation (connections to existing knowledge) - introduction - acquisition (information input) - practice (individual) - application (group or partner work) - feedback and finally again repetition/systematisation (contents of the present lesson). The results point at the existence of some of these features in standard lessons. Particular phases are probably too short to perceive in a 5-minute-pattern. ‘Laboratory effects’, as mentioned before, might be a reason for the lower degree of differentiation in computer lessons.

5. Situation of the Teacher

Some questions of the ‘Teacher-Questionnaire - Methodology’ focused the central query: How does the teacher feel during and after a lesson and on which parameters does this depend?

An analysis of interdependencies manifests some common correlations, e.g. the connection between ‘working climate’ and ‘satisfaction of the teacher’ is as trivial as that between ‘satisfaction’ and ‘stress’, which is still more distinct in computer-lessons.

‘Satisfaction of the teacher’ goes down with increasing number of pupils in both groups, but the parameter ‘stress’ shows this effect only in the computer lessons, because the higher level of noise, the continual fast ‘take over’ of screens, etc. are much more stressing than regular class-teaching.

In computer lessons the teacher estimates the ‘working climate’ more independently from the ‘ability of the class’, because the pupils work more actively. ‘Working climate’ as well as ‘stress’ increase with the ‘number of the pupils’ in computer lessons, but not during standard lessons.

6. Summary and conclusion

The values in the dimensions ‘situation’, ‘didactical function’, ‘aim of qualification’ and ‘basic form of the method’ indicate that the structures of the lessons are very similar. On the other hand the use of CAS achieves an essential aim of a general curriculum by leading to more independent productive pupil activity.

Time-profiles of lessons indicate a greater variety within most categories in standard lessons, which means that certain categories accumulate in certain parts of the lessons. In computer lessons laboratory effects contribute to more constant distributions.
The fact that the average number of pupils in classes has been increasing during the last few years in Austria due to budget cuts, is an obstacle to achieving a higher degree of CAS acceptance among teachers, because of the significant correlation between the ‘stress of the teacher’ and the ‘number of pupils’ during computer-periods, while during standard lessons this parameter is not crucial, but ‘working climate’ is decisive. Maybe as a result from a higher proportion of pupils’ activities ‘Working climate’ has been found to be better in computer lessons.
To locate some of the math lessons in special computer-labs results in ‘laboratory effects’ as described above. One result of the ACDCA-project is that the permanent availability of CAS during every lesson as well as at home is indispensable. The use of notebooks or TI-92 CAS calculators is one way towards a more integrated use of computer algebra.

The stress of the teacher increases significantly in computer lessons with growing number of pupils. In order to keep the situation of the teacher bearable we recommend small tutor groups, at least in a part of the weekly lessons and at lower grades.

The sample was too small to allow further statistical analysis, e.g. comparisons of different grades and schooltypes, time-series analysis, evaluation of the training of teachers etc. An international project would be useful to identify and compare different national styles in teaching mathematics.

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Robert J. Nocker teaches mathematics, geometry and computer science at the grammar school in Mittersill, Austria. Robert's interests are in the teaching and learning of mathematics and computer science to children aged 15-18 on the one hand and in teaching/learning software for PCs and Internet on the other hand.

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Appendix 1: **QUESTIONNAIRE - METHODOLOGY**

IDNr. : ___/_____

		1	2	3	4	5	6	7	8	9	10
Situation	1. Instruction										
	2. Disciplinary Measures										
	3. Technical Measures										
	4. Patterns Concerning Homework										
	5. Organizational, Notices										
Didactical Function	1. Introduction										
	2. Acquisition										
	3. Repetition/Systematization										
	4. Practice										
	5. Application										
	6. Examination/Assessment										
	Direction by the Pupils										
Aim of Qualification	1. Mathematical Knowledge										
	2. Computer Knowledge (Program Handling)										
	3. Intellectual Skills and Capabilities										
Basic Form of the Method	1. Teacher Activity(Lecturing/Explaining/Calculating)										
	2. Classroom Discussion										
	3. Pupil Calculating on Blackboard										
	4. Pupil - Silent Work										
	5. Independent Pupil Activity										
Technical Aids (multiple answers possible)	1. Overhead-Transparencies										
	2. Overhead-Computer Palette										
	3. Pocket Calculator										
	4. Computer-Spreadsheet (e.g. SuperCalc, Excel)										
	5. Computer-Algebra System (e.g. DERIVE)										
	6. Worksheets										
	7. Other (please mark under Special Comments)										
Social Structure	1. Class Teaching										
	2. Group Work										
	3. Partner Work (Pairs)										
	4. Individual Work										
Pupil Activity	1. Note Taking										
	2. Repetition										
	3. Production										

Special Comments (e.g. other technical aids, problems with technical aids, individual differentiation, disciplinary or behavioural conspicuousness ...) :

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Appendix 2: **Questionnaire-Methodology**

ABSOLUTE FREQUENCIES IN THE TIME-INTERVALS

Lessons with engagement of computers (C) : n=20 in intervals 1-9, n=16 in interval 10
Lessons without engagement of computers (S) : n=37 in intervals 1-9, n=25 in interval 10
(The sums of the first columns may differ from n, because in the occurence of categories 3-5 in the dimension 'situation' sometimes no category could be observed in other dimensions)

DIMENSION	CATEGORY	INTERVAL										
			1	2	3	4	5	6	7	8	9	10
SITUATION	1. Instruction	C	8	12	15	16	19	19	20	20	19	14
		S	7	15	25	32	34	36	37	36	37	25
	2. Disciplinary measures	C	0	0	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0	0	0
	3. Technical measures	C	7	1	0	3	0	0	0	0	0	1
		S	0	0	0	0	0	0	0	0	0	0
	4. Patterns concerning homework	C	3	7	5	1	1	1	0	0	1	1
		S	14	16	11	5	3	1	0	0	0	0
	5. Organizational, notices	C	2	0	0	0	0	0	0	0	0	0
		S	15	6	1	0	0	0	0	1	0	0
DIDACTICAL	1. Introduction	C	6	5	2	2	2	2	3	1	0	0
FUNCTION		S	1	1	3	10	4	4	4	5	5	2
	2. Acquisition	C	1	2	5	6	5	7	7	7	8	6
		S	1	4	4	4	11	8	12	11	12	8
	3. Repetition/systematization	C	6	7	2	5	6	5	3	6	5	4
		S	10	15	15	8	7	6	3	6	4	4
	4. Practice	C	2	3	5	3	4	4	4	4	5	3
		S	0	4	6	8	5	10	8	7	9	7
	5. Application	C	0	0	3	4	3	1	2	2	2	2
		S	1	1	3	5	8	9	10	8	4	4
	6. Examination/assessment	C	1	3	3	0	0	1	1	0	0	1
		S	9	6	5	2	2	0	0	0	3	0
AIM OF -	1. Mathematical knowledge	C	7	12	11	10	8	9	9	11	9	9
QUALIFI--		S	18	24	26	22	22	21	22	24	25	16
CATION	2. Computer knowledge (handling)	C	3	3	4	4	4	4	3	2	2	2
		S	0	0	0	0	0	0	0	0	0	0
	3. Intellectual skills and capabilities	C	5	5	5	6	8	7	8	7	9	5
		S	4	8	10	15	15	16	15	13	12	9

DIMENSION	CATEGORY	INTERVAL										
			1	2	3	4	5	6	7	8	9	10
BASIC FORM	1. Teacher activity(lecturing, expl...)	C	10	6	5	5	3	3	6	4	6	2
OF THE		S	16	13	7	12	13	11	14	16	17	7
METHOD	2. Classroom discussion	C	4	8	5	3	4	4	5	4	3	5
		S	10	9	15	7	8	9	6	10	8	6
	3. Pupil calculating on blackboard	C	1	3	2	0	1	0	0	0	0	0
		S	8	14	11	12	8	8	5	4	4	4
	4. Pupil - silent work	C	0	0	1	1	0	0	0	0	0	0
		S	0	0	0	1	0	1	1	0	1	0
	5. Independent pupil activity	C	2	3	7	11	12	13	9	12	11	9
		S	2	1	4	5	8	8	11	7	7	8
TECHNICAL	1. Overhead-transparencies	C	3	3	5	2	1	1	3	2	0	0
AIDS		S	2	1	2	3	4	4	4	4	5	1
(multiple-	2. Overhead-computer projection	C	1	1	1	1	1	1	1	1	1	1
answers		S	--	--	--	--	--	--	--	--	--	--
possible)	3.Pocket calculator	C	0	0	0	0	0	0	0	0	0	0
		S	0	0	3	4	4	2	3	2	3	1
	4. Computer-spreadsheet	C	0	1	1	1	1	1	1	1	1	0
		S	--	--	--	--	--	--	--	--	--	--
	5. CAS (DERIVE)	C	9	9	11	16	17	16	15	15	15	13
		S	--	--	--	--	--	--	--	--	--	--
	6. Worksheets	C	1	2	2	1	1	1	1	1	1	0
		S	0	0	1	1	1	1	0	0	0	0
SOCIAL	1. Class teaching	C	14	18	11	6	5	6	9	6	8	6
STRUCTURE		S	35	36	33	30	29	28	24	30	29	18
	2. Group work	C	0	0	0	1	1	1	1	0	0	0
		S	0	0	0	1	0	0	0	0	0	0
	3. Partner work (pairs)	C	2	1	5	5	6	7	5	8	7	6
		S	0	0	0	0	3	6	4	2	2	1
	4. Individual work	C	2	1	4	8	8	6	5	6	5	4
		S	1	1	4	6	5	3	9	5	6	6
PUPIL-	1. Note taking	C	10	9	7	7	6	5	8	5	7	4
ACTIVITY		S	22	17	15	19	22	18	19	24	23	10
	2. Repetition	C	5	9	4	2	1	2	2	2	3	1
		S	13	18	16	7	2	4	2	4	5	2
	3. Production	C	2	2	9	11	13	13	10	13	10	11
		S	0	2	6	11	13	15	16	9	9	13