USING CAS TECHNOLOGY IN MATH EDUCATION – ASSESSMENT AND SURVEY RESULTS

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In 1999 a project was launched in 8 of the 107 grammar schools in Thuringia to investigate the effects of using CAS technology in math education. For 3 consecutive years grade 10 students in these schools were given Texas Instruments TI-89 calculators for use in math courses (and examinations) over a period of 3 years. Some earlier results were presented at the 15th ICTCM, for which only highly aggregated data was available.

In November 2002 an assessment was carried out with all grade 11 students from the 8 project schools and from 5 control schools. In this assessment the use of electronic calculators was not permitted. The questions in the assessment ranged from fairly elementary (e.g. simplify $x = 2 \cdot 6^{65} + 4 \cdot 6^{65}$) to more demanding (e.g. find all real solutions of $2(1-3x)(x-5) = 0$). They also contained some applied problems such as working out the probability of getting "tail" and "not a 6" when a coin is tossed and a die thrown simultaneously. The amount of time available for solving the 20 problems was 30 minutes, implying the students had to work really fast. Students had on average only 90 seconds to understand and solve a problem, and this may explain in part why all (859) tested students got on average only 34 percent of the points. Results from the assessment are analyzed in the next section.

Since the assessment was carried out with all grade 11 students, those in basic courses (BC) as well as those in advanced courses (AC) were tested. All students have to attend at least one type of math course in every school year; only those with a particular interest in math opt for the more intensive advanced course instead of the basic one. Hence, students in AC are expected to perform better in a test because they are more interested in math than those in BC and are also taught more hours per week. Two of the 8 project schools offer special classes in mathematics for the most talented math students in Thuringia who have to apply for acceptance in these classes. They are taught even more math hours per week than AC students in a normal grammar school. No BC or regular AC level students of these two schools are in the project.

A survey was carried out in the same month to find out the students' attitudes towards the use of the TI-89 in math education. All grade 11 and 12 students in the 8 project schools were given the one-page questionnaire and slightly more than 1000 students participated. In this questionnaire the students had to give some personal information (sex,

grade, course type, mark for math in last report), and give their opinions on 8 statements concerning the use of the TI-89 by making marks on a scale. Students were also asked to agree or disagree with the statement "If given the choice I would decide in favor of lessons with the TI-89". Only 9% of all students said "No", 91% answered "Yes". This means that 9 out of 10 students who have used technology in math education for up to two years would like to do so again. More results from this survey are presented in the final section.

Assessment Results

There were 20 (sub-) problems to solve in the assessment. A student got 1 point (full credit) if he or she solved it, otherwise no point. Only at one school (P3) could a student apparently get ½ points (partial credit). Each school had to fill in a form for each course type (BC or AC), reporting the total number of points of all students for each problem. Some larger schools did not report on the course type level but on the course level. Results from the same course level of these schools were combined so that the data set consists of 14 observations from project schools (6 schools with both basic and advanced courses plus 2 with only a special class) and 10 from control schools. The data is given in Tab. 1. The columns PS (Project School), AC (Advanced Course), and SC (Special Class) contain a "1" if the observation refers to the respective group. *N* denotes the number of students in a certain course (type), and PoP (Percentage of Points) was calculated by dividing the total number of points (for all problems together) by 20*N*.

School	*PS*	*AC*	*SC*	*N*	*PoP*	School	*PS*	*AC*	*SC*	*N*	*PoP*
P1	1	1	0	24	52.3	P8	1	1	0	63	35.8
P1	1	0	0	24	16.7	P8	1	0	0	74	16.0
P2	1	1	0	33	38.2	C1	0	1	0	69	26.1
P2	1	0	0	37	26.8	C1	0	0	0	41	17.4
P3	1	1	0	33	53.2	C2	0	1	0	15	43.3
P3	1	0	0	33	43.1	C2	0	0	0	39	30.6
P4	1	1	1	21	76.9	C3	0	1	0	10	35.5
P5	1	1	0	44	48.0	C3	0	0	0	23	13.5
P5	1	0	0	75	33.3	C4	0	1	0	36	40.0
P6	1	1	1	27	67.4	C4	0	0	0	42	21.0
P7	1	1	0	26	34.6	C5	0	1	0	20	54.0
P7	1	0	0	35	15.1	C5	0	0	0	15	28.3

Tab. 1: Assessment Results

We now want to try to predict the performance of students from different schools by applying Linear Regression Analysis to the data. We start by looking at a 2-dimensional graph (Fig. 1) with the PoPs from Tab. 1 on the vertical and a project school (PS) dummy variable on the horizontal axis (1 = project school, 0 = control school; as in Tab. 1). Each point in the graph represents either the basic course(s) or the advanced course(s) in one school, with the markers indicating the course type. The number of students represented

by each point therefore varies (between 10 and 74). Fig. 1 also includes the straight line fitted by the following Linear Regression (t-values are given in parentheses below the respective estimated coefficients; cases weighted by *N*):

$$PoP = 28.5 + \underset{(7.68)}{7.87}PS \qquad \left(R^2 = .06\right)$$

According to this result, a control school student is expected to achieve 28.5% of the total points in the test, and a project school student 36.5%.

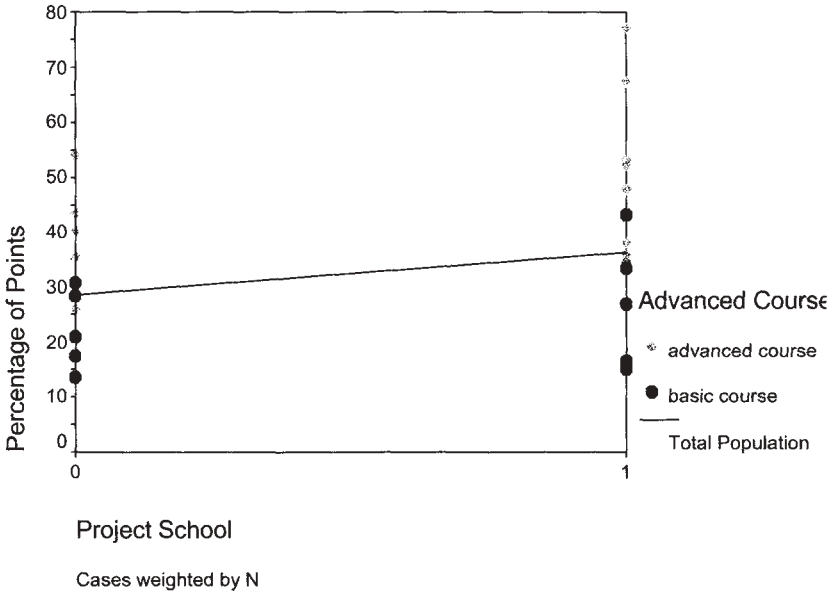

Fig. 1: Percentage of Points vs. Project School dummy variable

Adding a second dummy variable reflecting whether a student is in AC or BC, we get

$$PoP = 19.2 + \underset{(10.1)}{7.68}PS + \underset{(26.4)}{19.3}AC \qquad \left(R^2 = .49\right)$$

Here, a control school student in BC is expected to achieve only 19% of the total points in the test. A student in AC is expected to get 19 percentage points more and a project school student (regardless of whether in BC or AC) 8 percentage points. Also taking into account if a student is in a special class (SC), we find

$$PoP = 20.8 + \underset{(8.31)}{5.12}PS + \underset{(26.6)}{15.9}AC + \underset{(22.3)}{29.7}SC \qquad \left(R^2 = .67\right)$$

While a BC student from a control school is expected to achieve just 21% of the total points, an AC student is expected to get 16 percentage points more, a student from a project school (regardless of which class he or she attends) another 5 percentage points and one in a special class a further 30 percentage points, i.e. a project school student in a special class is expected to get 72% of the total points.

The results from the assessment thus provide some evidence that the use of the TI-89 in math education has indeed somewhat improved the students' abilities in math, keeping in

mind that the use of the TI-89 (or any other electronic calculator) was not permitted in the assessment. If we control for all known other factors (course type; special class) there is still a statistically significant improvement in the students' performance in the test by some 5 percentage points.

Survey Results

In this section results from the November 2002 survey of all students in grades 11 and 12 of the project schools are presented. 1014 students participated in this survey, which was carried out to find out their attitudes towards the use of the TI-89 in math education. In the questionnaire the students had to give their opinions on 8 statements concerning the use of the TI-89 by making marks on a scale of "1 = definitely true" to "6 = definitely not true". From Fig. 2 it is evident that students particularly liked being able to work faster, and to have more possibilities to check results, when using the TI-89. On the other hand, according to the students' opinions the TI-89 was not so strong in terms of avoiding mistakes, and not so much used in other lessons. However, the largest mean value came up for the statement "I like math lessons", reflecting the moderate enthusiasm many students have for mathematics. The mean values for most of the statements were between 1.8 and 2.6 (on a scale from 1 to 6), reflecting an overall pretty positive attitude towards the TI-89.

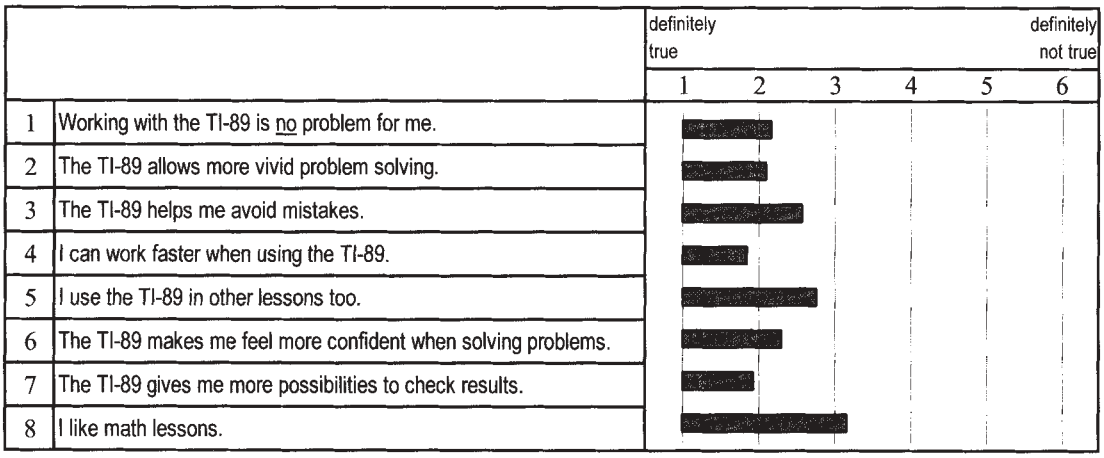

Fig. 2: Mean Values of Students' Marks ($N = 1014$)

Tab. 2 provides some insight into how the opinions of certain subgroups of the students differ. In general, differences smaller than 0.3 are not highlighted. Light shading indicates a difference of 0.3, medium shading 0.5, and dark shading at least 0.9 between any two subgroups. Next to the "all" column we find how the opinions of male and female students differ. The most striking distinction is that female students use the TI-89 much less in other lessons. They also like math lessons considerably less than male students. Perhaps most interesting is the difference concerning the statement "Working with the TI-89 is no problem for me": female students obviously have more problems when working with the TI-89. Note also that there is not a single statement to which female students agree more than male students.

		all	M	F	11	12	AC	BC
	N	1014	468	537	488	507	508	495
1	no problem working with	2.2	1.9	2.4	2.2	2.1	1.9	2.4
2	more vivid problem solving	2.1	2.1	2.1	2.1	2.1	2.0	2.2
3	helps avoid mistakes	2.6	2.6	2.6	2.6	2.5	2.5	2.6
4	can work faster	1.8	1.8	1.9	1.8	1.8	1.7	2.0
5	use also in other courses	2.8			2.7	2.8		
6	more confidence	2.3	2.3	2.3	2.3	2.3	2.2	2.4
7	more possibilities	1.9	1.9	2.0	1.9	2.0	1.8	2.1
8	like math lessons	3.2	2.9	3.4	3.3	3.0		

Tab. 2: Mean Values of Students' Marks for Certain Subgroups

Further right in Tab. 2 we find that grade 12 students like math lessons slightly more than grade 11 students. Looking at the mean values of students in AC compared to those in BC reveals that AC students agree to all 8 statements more than BC students. The difference is in 3 cases quite small, but somewhat larger for the two statements with the overall strongest agreement (being able to work faster, and to have more possibilities to check results). With respect to the statement "Working with the TI-89 is no problem for me" we find that there exists the same difference between AC and BC students as between male and female students. This is also true for the differences in the use of the TI-89 in other lessons. Note that 70% of the male but only 33% of the female students opt for the AC. The biggest difference, and not a genuine surprise, is that AC students like math lessons a whole lot more than BC students. In fact, the mean value of 3.9 for all BC students means that they on average disagree with this statement.

Finally, we provide regression results on how certain personal characteristics influence the students' view of the TI-89. Estimated coefficients in Tab. 3 are shaded if they are statistically significant (at the 5% level), where light shading is used when a coefficient's sign is negative, and dark shading when positive. Note that a negative (positive) sign implies stronger (weaker) agreement with the respective statement. Note also that the independent variables G12, M, and AC are dummy variables, and that the independent variable MM can be used straightforwardly since the German marking system from 1 (=A) to 5 (=F) does not require any recoding.

dependent variable:	R^2	const.	G12	M	AC	MM
no problem working with	0.176	1.775	-0.083	**-0.398**	**-0.205**	
more vivid problem solving	0.034	1.514	0.059	0.020	0.014	
helps avoid mistakes	0.022	2.116	-0.057	0.000	0.057	
can work faster	0.043	1.562	0.020	-0.077	**-0.169**	
use also in other courses	0.118	2.707	0.090	**-0.683**	**-0.542**	
more confidence	0.024	1.869	0.022	0.027	-0.035	
more possibilities	0.055	1.462		-0.051	-0.093	
like math lessons	0.375	2.444	**-0.243**	-0.061	**-1.052**	

Tab. 3: Regression Results (G12=grade12; M=male; AC=advanced course; MM=math mark)