The Impact of Calculus Reform as Seen by Engineering Seniors

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Abstract

During the academic years of 2001-2003 Rose-Hulman Institute of Technology participated in a NSF sponsored project to determine The Impact of Calculus Reform on Long-term Student Performance. The project was broken down into three major components. The first component was to compare registrar data for students who had taken a traditional calculus curriculum with those who had taken calculus in a "reformed" curriculum. The second component was a questionnaire to discover the views of graduating seniors to the use of technology in their education. The third component was a series of interviews with graduating seniors. We obtained their responses to their calculus and engineering education. This report will focus on the responses made by senior engineering students attending Rose-Hulman Institute of Technology to the questionnaire concerning the use of technology in their undergraduate education.

The results of the survey showed that the engineering students at Rose-Hulman Institute of Technology used mathematical software or graphics calculators not only in mathematics courses but in other courses either as part of the class, or to check their homework. The students also believe that learning how to use mathematical software or graphics calculators is a very important part of their educational experience, and in many cases helped students to better understand the mathematical concepts presented.

Section I Survey Data

Background

In the spring of 2002 senior engineering students, who took calculus I in the fall of 1998, were asked to complete a forty-nine question survey. The invitation was e-mailed to the students. To complete the survey students logged on to a website at Duke University. 134 (107 male and 27 female) Rose-Hulman seniors were asked to participate in the survey. A total of 54 students (38 men and 16 women) responded. While a greater percentage of women responded to the questionnaire than were in our original sample this did not seem to significantly influence the results. In no question was there a significant difference between the responses of the male students and the female students.

The first four responses were background questions. The remaining forty-five questions (5-49) were used to measure the each student's attitude towards mathematics. There were six major categories of questions:

b = Beliefs about Mathematics
m = Effective Motivation in Mathematics
t = Using Technology to Learn Mathematics
o = Learning with Others
c = Confidence in Learning Mathematics
u = Mathematics Usefulness

The responses to the questions were marked as strongly agree (SA), agree (A), neutral (N), disagree (D), and strongly disagree (SD). For statistical purposes strongly agree was equivalent to a 1 and strongly disagree was equivalent to a 5. About half of the questions were asked in a negative manner. These questions are referred to with an "a" after the question number. For example t9a means than question nine was asked about "using technology to learn mathematics" and was worded in a negative way. Note that all 54 students answered every question.

Results

Below are the results of the survey relating the use of technology in the undergraduate education of students attending Rose-Hulman Institute of Technology.

Question	Quest	%SA	%A	%N	%D	%SD	mean	s.d.
In some courses, I am never allowed to use mathematics software or graphing calculators on tests.	t9a	7.4	37.0	1.9	27.8	25.9	3.28	1.39
I use mathematics software or graphing calculators in classes other than mathematics classes.	t16	48.1	40.7	3.7	5.6	1.9	1.72	.92
I often use mathematics software or graphing calculators to check my work on homework assignments.	t28	29.6	55.6	3.7	11.1	0	1.96	.89
Learning to use mathematics software or graphics calculators is a waste of time.	t32a	1.9	1.9	1.9	35.2	59.3	4.48	.79
Using mathematics software or graphing calculators has significantly decreased my ability to do calculations by hand.	t36a	9.3	35.2	16.7	35.2	3.7	2.89	1.11
Using mathematics software or graphing calculators helps me to better understand mathematics concepts.	t39	9.3	38.9	25.9	22.2	3.7	2.72	1.04
Learning to use technology was a valuable part of my educational experience in college.	t47	63.0	33.3	0	3.7	0	1.44	.69

It was interesting to note that on fifteen, of the forty-five, questions the students seemed to have strong agreement, with an average response under 2. Three of these questions dealt directly with the use of technology.

Of the forty-five questions asked, the one that the students agreed with most was question 47 (t47) "Learning to use technology was a valuable part of my educational experience in college." This question had an average response of 1.44.

Question	Quest	%SA	%A	%N	%D	%SD	mean	s.d.
I use mathematics software or graphing calculators in classes other than mathematics classes.	t16	48.1	40.7	3.7	5.6	1.9	1.72	.92
I often use mathematics software or graphing calculators to check my work on homework assignments.	t28	29.6	55.6	3.7	11.1	0	1.96	.89
Learning to use technology was a valuable part of my educational experience in college.	t47	63.0	33.3	0	3.7	0	1.44	.69

Of the forty-five questions asked, there were five questions which students most strongly disagreed with, with an average response over 4. One of these questions dealt directly with technology.

The question with the highest negative rating was question 32 (t32a)
"Learning to use mathematics software or graphics calculators is a waste of time." This question had an average response of 4.48.

Question	Quest	%SA	%A	%N	%D	%SD	mean	s.d.
Learning to use mathematics software or graphics calculators is a waste of time.	t32a	1.9	1.9	1.9	35.2	59.3	4.48	.79

Bar Charts and Correlations

Below are the bar charts for each of the 7 questions dealing with the use of technology. The bar charts have been grouped in clusters which are strongly correlated.

Questions 9, 16, 28, 32, 36, 39 and 47 dealt with the students' beliefs regarding "Using Technology to Learn Mathematics". Questions 9 and 28 were considered outliers in the student belief in "Using Technology to Learn Mathematics". These two questions did not correlate to any other questions in the group and will be treated separately.

The questions, analysis, and bar graphs follow.

Question 16: I use mathematics software or graphing calculators in classes other than mathematics classes.

Question 32: Learning to use mathematics software or graphics calculators is a waste of time.

Question 36: Using mathematics software or graphing calculators has significantly decreased my ability to do calculations by hand.

Question 39: Using mathematics software or graphing calculators helps me to better understand mathematics concepts.

Question 47: Learning to use technology was a valuable part of my educational experience in college.

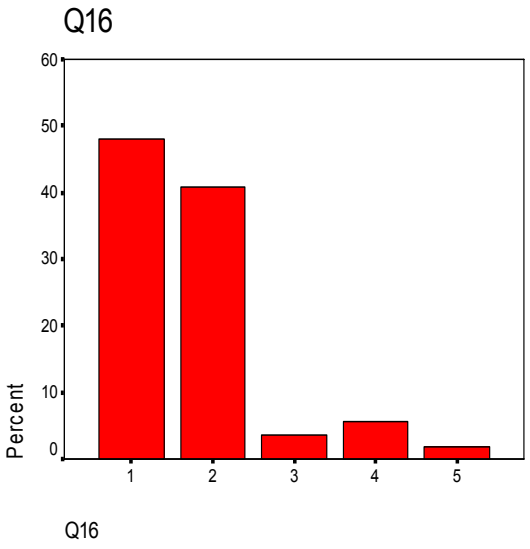
Heading	%SA	%A	%N	%D	%SD	mean	s.d
Question16 t16	48.1	40.7	3.7	5.6	1.9	1.72	.92
Question32 t32a	1.9	1.9	1.9	35.2	59.3	4.48	.79
Question36 t36	9.3	35.2	16.7	35.2	3.7	2.89	1.11
Question39 t39	9.3	38.9	25.9	22.2	3.7	2.72	1.04
Question47 t47	63.0	33.3	0	3.7	0	1.44	.69

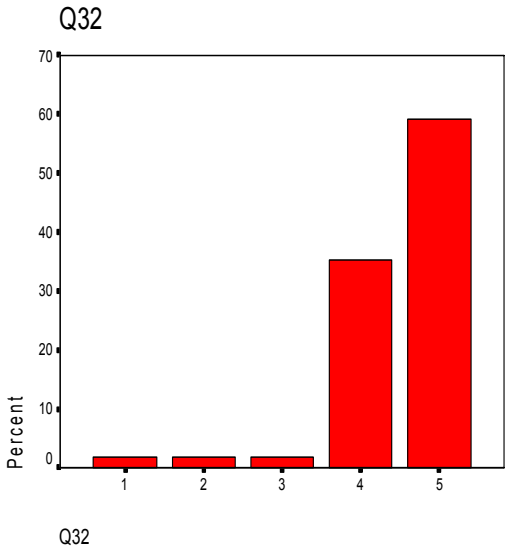
Below are the bar graphs showing the results of the questions 16, 32, 36, 39, and 47. Remember that the following numerical scale was used:

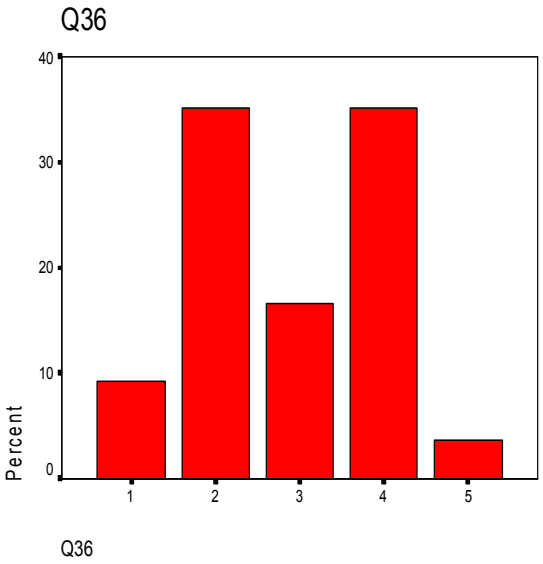
1= Strongly Agree
2= Agree
3= Neutral
4 = Disagree
5 = Strongly Disagree

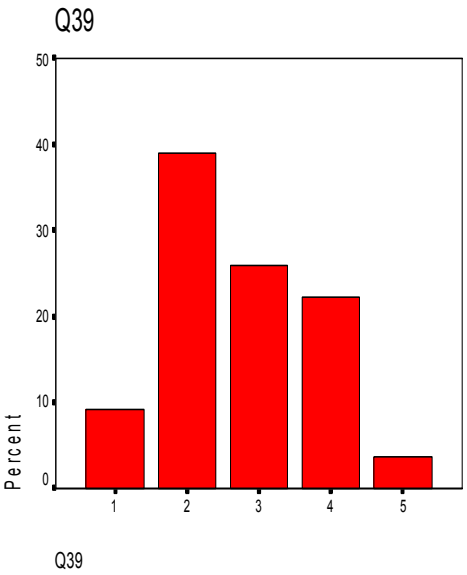
In looking at the bar graphs one should note the following:

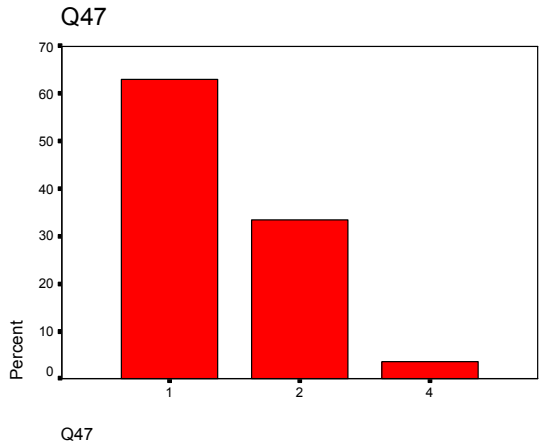
On question 16, 88.8% of the students agreed or strongly agreed, while 7.5% disagree or strongly disagreed. On question 32, only 3.8% agreed or strongly agreed, while 94.5% disagreed or strongly disagreed. On question 36, 44.5% agreed or strongly agreed, while 38.9% disagreed or strongly disagreed. On question 39, 38.2 % agreed or strongly agreed while 25.9 % disagreed or strongly disagreed. Here 25.9% were neutral. On question 47, 96.3% agreed or strongly agreed while 3.7% disagreed.











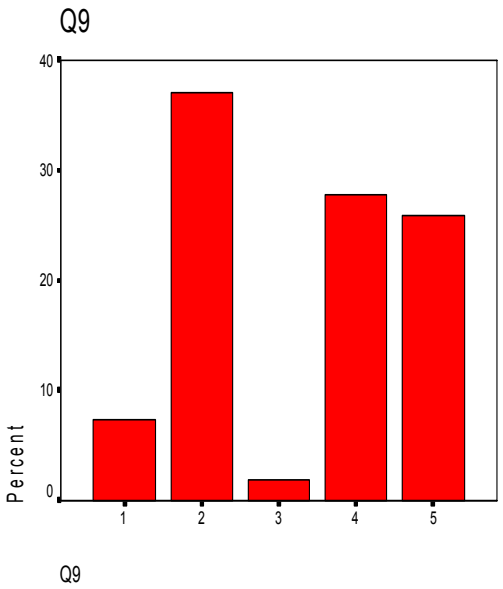
Question 9: In some courses, I am never allowed to use mathematics software or graphing calculators on tests.

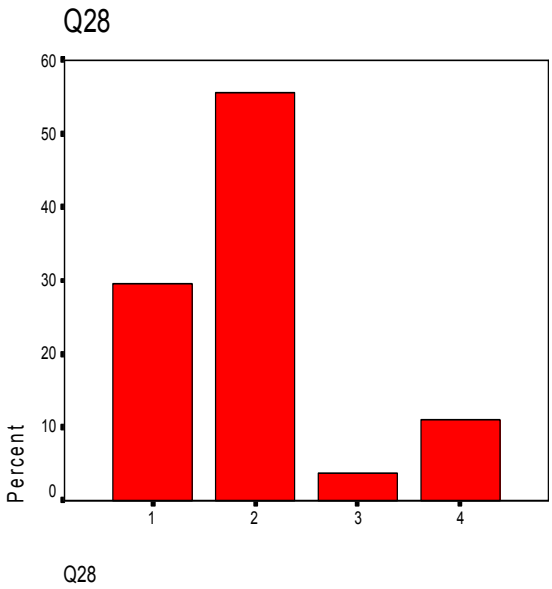
Question 28: I often use mathematics software or graphing calculators to check my work on homework assignments.

Heading	%SA	%A	%N	%D	%SD	mean	s.d
Question9	7.4	37.0	1.9	27.8	25.9	3.28	1.39
Question28	29.6	55.6	3.7	11.1	0	1.96	.89

In looking at the bar graphs one should note the following:

On question 9, 44.4% of the students agreed or strongly agreed, while 53.7% disagreed or strongly disagreed. On question 28, 85.2% of the students agreed or strongly agreed while 11.1% disagreed.





Below is the correlation Matrix which shows how each of the questions concerning technology is related to the other technology questions. High correlation numbers are in bold print.

Correlation Matrix for Technology

Correlations

		t16	t28	t32a	t36a	t39	t47	t9a
t16	Pearson Correlation	**1.000**	**.518**	**.510**	**.456**	.294	**.465**	.115
	Sig. (2-tailed)	.	.000	.000	.001	.031	.000	.406
	N	54	54	54	54	54	54	54
t28	Pearson Correlation	**.518**	**1.000**	.081	.157	-.011	.119	.113
	Sig. (2-tailed)	.000	.	.560	.257	.935	.390	.414
	N	54	54	54	54	54	54	54
t32a	Pearson Correlation	**.510**	.081	**1.000**	**.382**	**.545**	**.774**	.252
	Sig. (2-tailed)	.000	.560	.	.004	.000	.000	.066
	N	54	54	54	54	54	54	54
t36a	Pearson Correlation	**.456**	.157	**.382**	**1.000**	**.356**	**.451**	-.004
	Sig. (2-tailed)	.001	.257	.004	.	.008	.001	.977
	N	54	54	54	54	54	54	54
t39	Pearson Correlation	.294	-.011	**.545**	**.356**	**1.000**	**.439**	.089
	Sig. (2-tailed)	.031	.935	.000	.008	.	.001	.520
	N	54	54	**54**	**54**	**54**	**54**	54
t47	Pearson Correlation	**.465**	.119	**.774**	**.451**	**.439**	**1.000**	.170
	Sig. (2-tailed)	.000	.390	.000	.001	.001	.	.220
	N	54	54	54	54	54	54	54
t9a	Pearson Correlation	.115	.113	.252	-.004	.089	.170	**1.000**
	Sig. (2-tailed)	.406	.414	.066	.977	.520	.220	.
	N	54	54	54	54	54	54	54

Correlation is significant at the 0.01 level (2-tailed) for values in bold type.

Observations about the use of Technology

The students used mathematics software and calculators regularly, they felt that learning technology is important, and in general helped their understanding of the material.

The students were however mixed as to whether using technology diminished their by-hands skills. The survey showed that 44.5 percent of the students said their hand skills were diminished by using mathematics software while 42.9 percent said that their hand skills were not diminished. This question may also tie into question 39 as to whether mathematics software helps in understanding mathematical concepts.

When asked if using mathematical software helped the students understand mathematical concepts, 47.2 percent said software helped their mathematical understanding while 25.9 percent said software did not help their mathematical understanding. There are a couple of possibilities for the relatively high number who "disagree". One possibility is that the students either understood (or didn't understand) the mathematical concepts presented and the mathematical software didn't make any difference. A second possibility is that the software was used in such a way as to actually prevent the students from understanding the mathematical concepts. Some students simply like to learn "by-hands" methods without using any technology.

The average value of the mean for questions 16, 32, 36, 39, and 47 was 2.10. Note the responses in questions 32 and 36 were reversed when computing the cluster average so all questions would be stated in a positive way.

The results of question 9 are rather interesting result since the students are required to buy a laptop computer. However, 44.4% of the students say there are instances when they are prohibited from using the technology on examinations. It is not clear if the students responding about upper division courses, mathematics courses, or all the courses they took. Some faculty members teaching mathematics and engineering courses regularly refuse to let students use their computers on tests. In the basic physics courses computers are not allowed but calculators are used. Thus we have a bit of a dichotomy where we require students to buy a computer, but sometimes refuse to let them use it.

The results of question 28 are also very revealing. The survey showed that 85.2% of the students use mathematics software or calculators to check homework. This tends to agree with the results of the other questions in which the students said that learning and using mathematical software was useful.

Section II Conclusions

The senior engineering students at Rose-Hulman Institute of Technology universally agree that learning and using technology, as well as learning and using mathematics software is an important part of their education. This is not really surprising since all the students own laptop

computers and those students stated that they used mathematical software and calculators regularly.

Some of the other results of the questionnaire should cause us to pause. While 48 % of the students said mathematical software helped in their understanding of the mathematical material presented, 25% percent said the mathematical software did not help their understanding of the mathematical concepts. It was also seen that 44.5% of the students felt that using mathematical software or calculators had significantly decreased the students ability to do calculations by hand while 38.7% of the students said their by hands skills were not decreased.

These last two results may be a consequence of the way the courses are taught. It seems rather clear, that in order to be a good engineer, students need to know how to do some basic skills by hand. If the course is taught totally using mathematics software with no "by hands" component, the students may get bogged down in the mechanics of the software and computer, and may not be able to grasp the underlying mathematical concepts. For weaker students this would be particularly true. Teaching a course in this manner would also lead weaker students to lose even more of their already weak by hands skills.

Do these conclusions mean that we should not use the computer or calculators in calculus? We believe the answer is no. The calculus courses we teach now and those that were taught thirteen years ago are vastly different. In 1990 we would spend weeks on topics such as integration techniques. We now only cover the mathematically "interesting" ones such as simple subsititutions, integration by parts, and partial fractions. We spend more time on what the integral and derivative can do for us, or show us, rather than tediously teaching students all the little nuances of differentiation and integration. Instead of spending a lot of time showing students how to solve the non-linear equations that arise in using Lagrange multipliers, we let the computer handle the algebra. Thus, a topic that took a week now takes just a day or two.

In addition, the upper division courses that our students take have changed. More and more engineering professors are relegating tedious algebraic calculations to the computer and are spending more time discussing the mathematical and engineering concepts behind the courses they are teaching.

Students believe that learning to use and using mathematical software and calculators is very important, and that in many cases these tools help the students understanding of mathematical concepts presented. However, as educators we should not overlook the fact that students need some basic "by hands" mathematical skills. Thus, a balanced approach to teaching mathematics should be employed. The philosophy we might want to follow is: If it is easier to do a problem by hand, do it by hand. If not, use the computer.

Elton Graves is a member of the Mathematics Department at Rose-Hulman Institute of Technology, where he has taught since 1981. He received his doctorate in mathematics from Idaho State University in 1981. He co-authored the first $100,000 ILI Grant to incorporate the use of CAS into the teaching of calculus, and differential equations.