The Usefulness of Mathematics as Seen by Engineering Seniors

By

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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. One component of this project was a questionnaire which asked senior engineers about their view on mathematics. A second component of the study was a series of interviews held 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 concerning the usefulness of mathematics. All responses are from students who attended Rose-Hulman Institute of Technology. Both questionnaire and interview responses will be presented in this the paper.

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 the 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 does not seem to significantly influence our 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 45 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

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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 u14a means than question seven was asked about "usefulness of 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 to the usefulness of mathematics in the undergraduate education of students attending Rose-Hulman Institute of Technology.

Question	Quest	%SA	%A	%N	%D	%SD	mean	s.d.
I'll need a firm mastery of mathematics for my future work.	u5	33.3	44.4	18.5	3.7	0	1.93	.82
Mathematics has no relevance to my life.	u14a	0	5.6	7.4	29.6	57.4	4.39	.86
I see mathematics as a subject I will rarely use in my daily life after college.	u20a	1.9	13.0	9.3	38.9	37.0	3.96	1.08
Mathematics is a worthwhile and necessary subject.	u29	55.6	40.7	3.7	0	0	1.48	.57
I will use mathematics in many ways in my life.	u33	37.0	51.9	9.3	1.9	0	1.76	.70
Mathematics will not be important in my life's work.	u37a	1.9	5.6	16.7	42.6	31.5	3.98	.95
Knowing mathematics will help me earn a living	u43	25.9	53.7	11.1	9.3	0	2.04	.87
I expect to have little use for mathematics which I get out of college.	u48a	0	5.6	16.7	40.7	37.0	4.09	.87

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 usefulness of mathematics.

Question	Quest	%SA	%A	%N	%D	%SD	mean	s.d.
I'll need a firm mastery of mathematics for my future work.	u5	33.3	44.4	18.5	3.7	0	1.93	.82
Mathematics is a worthwhile and necessary subject.	u29	55.6	40.7	3.7	0	0	1.48	.57
I will use mathematics in many ways in my life.	u33	37.0	51.9	9.3	1.9	0	1.76	.70

Of the forty-five questions asked, the two questions that the students agreed with most were question 47 (47t) "Learning to use technology was a valuable part of my educational experience in college.", with an average of 1.44; and question 29 (u29) "Mathematics is a worthwhile and necessary subject.", with an average of 1.48.

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

Question	Quest	%SA	%A	%N	%D	%SD	N	mean	s.d.
Mathematics has no relevance to my life.	u14a	0	5.6	7.4	29.6	57.4	54	4.39	.86
I expect to have little use for mathematics when I get out of college.	u48a	0	5.6	16.7	40.7	37.0	54	4.09	.87

The two questions the students most strongly disagreed with were question 32 (t32a) "Learning to use mathematics software or graphics calculators is a waste of time.", with an average of 4.48, and question 14 (u14a) "Mathematics has not relevance to my life", with an average of 4.39.

Bar Charts and Correlations

Below are the bar charts for each of the 8 questions dealing with the usefulness of mathematics.

Questions u5, u14a, u20, u29, u33, u37a, u43, and u48a dealt with the students' beliefs on "Mathematics Usefulness". Since all the questions were highly correlated there was no reason to cluster the answers.

Question 5: I'll need a firm mastery of mathematics for my future work.
Question 14: Mathematics has no relevance to my life.
Question 20: I see mathematics as a subject I will rarely use in my daily life after college.
Question 29: Mathematics is a worthwhile and necessary subject.
Question 33: I will use mathematics in many ways in my life.
Question 37: Mathematics will not be important in my life's work.
Question 43: Knowing mathematics will help me earn a living.
Question 48: I expect to have little use for mathematics which I get out of college.

Heading	%SA	%A	%N	%D	%SA	NR	mean	s.d
Question5 ut5	33.3	44.4	18.5	3.7	0	54	1.93	.82
Question14 u14a	0	5.6	7.4	29.6	57.4	54	4.39	.86

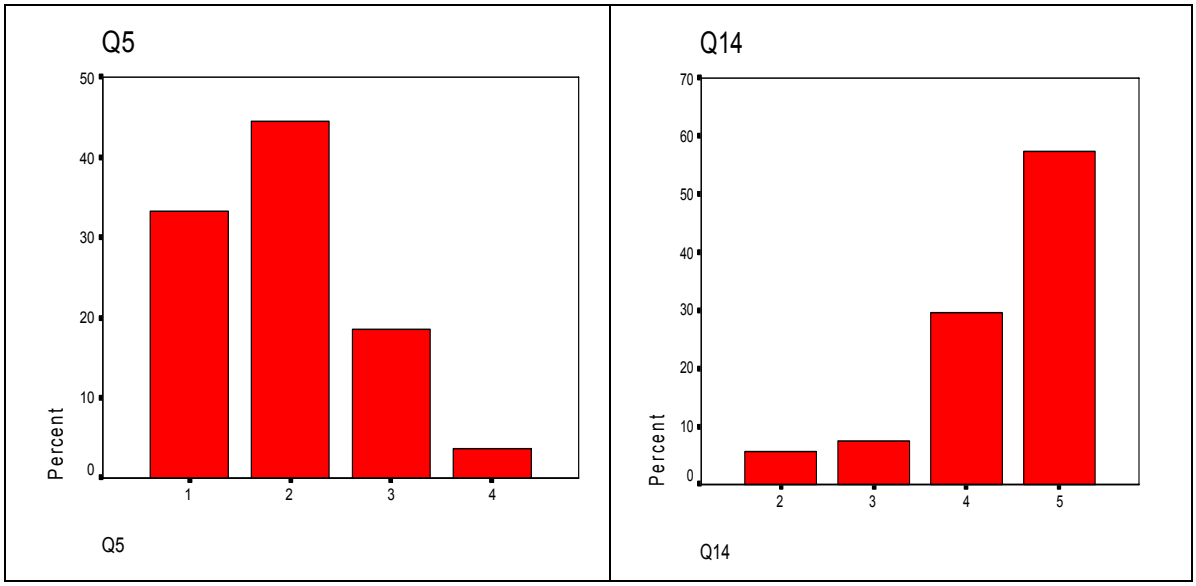
Question20 u20	1.9	13.0	9.3	38.9	37.0	54	3.96	1.08
Question29 u29	55.6	40.7	3.7	0	0	54	1.48	.57
Question33 u33	37.0	51.9	9.3	1.9	0	54	1.76	.70
Question37 u37a	1.9	5.6	16.7	42.6	31.5	53	3.98	.95
Question43 u43	25.9	53.7	11.1	9.3	0	54	2.04	.87
Question48 u48a	0	5.6	16.7	40.7	37.0	54	4.09	.87

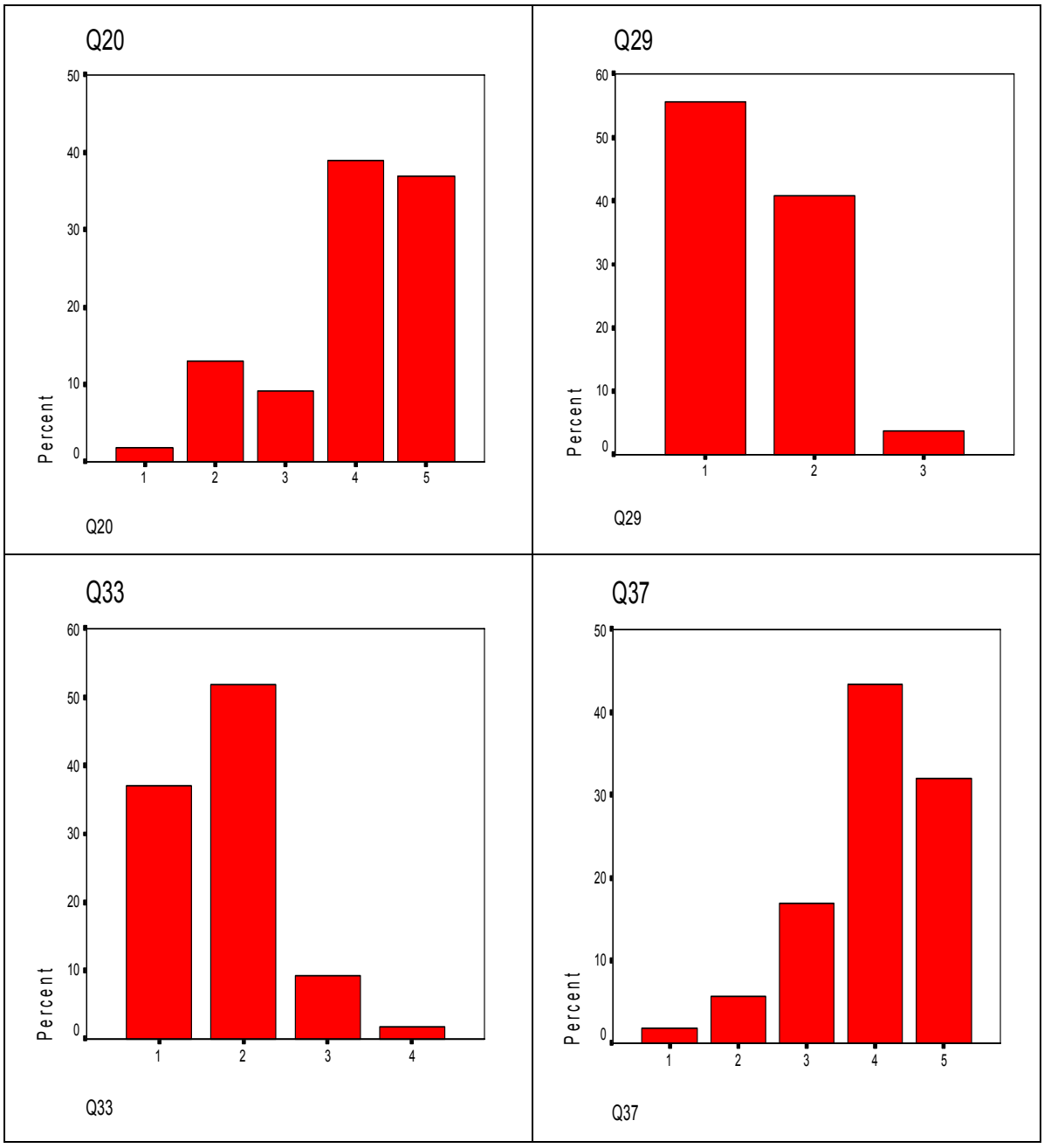
Below are the bar graphs showing the results of questions 5, 14, 20, 29, 33, 37, 43, and 48. Remember that the following numerical scale was used:

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 5, 77.7% of the students agreed or strongly agreed with only 3.7% disagreed. On question 14, 5.6% agreed while 87% either disagreed or strongly disagreed. On question 20, 14.9% agreed while 75.9% either disagreed or strongly disagreed. On question 29, 96.3% agreed or strongly agreed while nobody disagreed. On question 33, 88.9 % agreed or strongly agreed while 1.9% disagreed. On question 37, 7.5% agreed or strongly agreed while 74.1% disagreed or strongly disagreed. On question 43 79.6% agreed while 9.3% disagreed. On question 38, 5.6% agreed while 87.7% disagreed or strongly disagreed.




Q20
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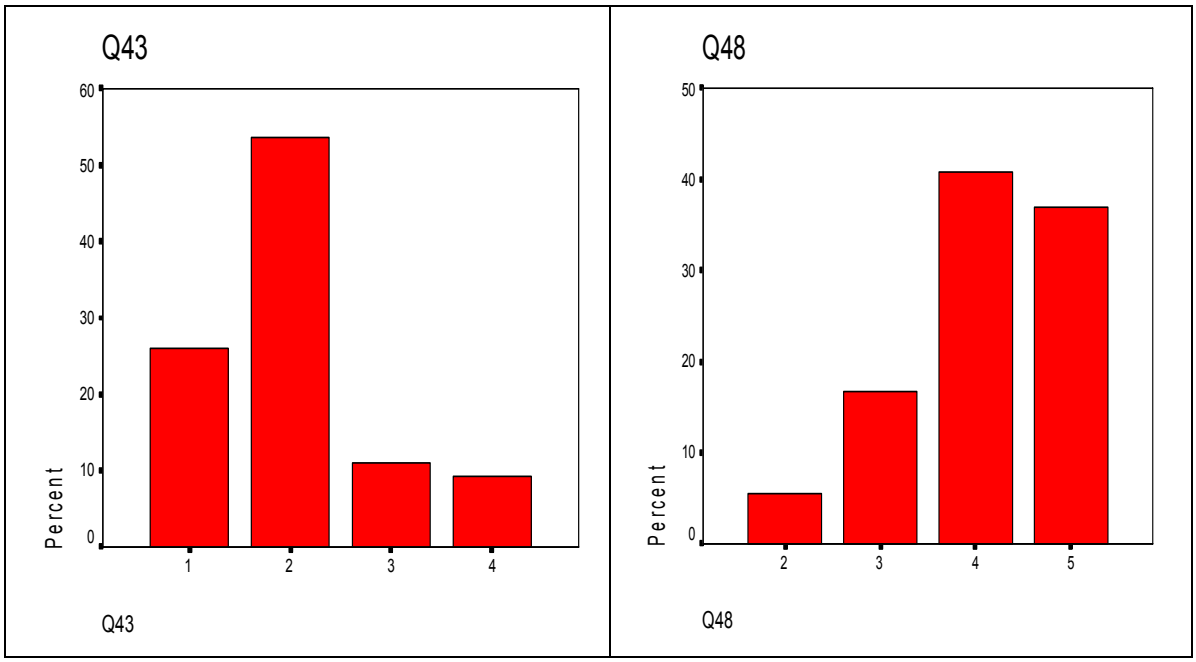

Below is the correlation matrix which shows how each of the questions concerning the usefulness of mathematics is related to the other "usefulness" questions. High correlation numbers are in bold print. As you can easily see every question is highly correlated to every other question.

Correlation Matrix for Mathematics Usefulness

Correlations

		u14a	u20	u29	u33	u37a	u43	u48a	u5
u14a	Pearson Correlation	**1.000**	**.546**	**.465**	**.503**	**.364**	**.528**	**.657**	**.603**
	Sig. (2-tailed)	.	.000	.000	.000	.007	.000	.000	.000
	N	54	54	54	54	54	54	54	54
u20	Pearson Correlation	**.546**	**1.000**	**.427**	**.637**	**.447**	**.642**	**.742**	**.556**
	Sig. (2-tailed)	.000	.	.001	.000	.001	.000	.000	.000
	N	54	54	54	54	54	54	54	54
u29	Pearson Correlation	**.465**	**.427**	**1.000**	**.529**	**.502**	**.493**	**.579**	**.437**
	Sig. (2-tailed)	.000	.001	.	.000	.000	.000	.000	.001
	N	54	54	54	54	54	54	54	54
u33	Pearson Correlation	**.503**	**.637**	**.529**	**1.000**	**.552**	**.575**	**.704**	**.692**
	Sig. (2-tailed)	.000	.000	.000	.	.000	.000	.000	.000
	N	54	54	54	54	54	54	54	54
u37a	Pearson Correlation	**.364**	**.447**	**.502**	**.552**	**1.000**	**.477**	**.526**	**.452**
	Sig. (2-tailed)	.007	.001	.000	.000	.	.000	.000	.001
	N	54	54	54	54	54	54	54	54
u43	Pearson Correlation	**.528**	**.642**	**.493**	**.575**	**.477**	**1.000**	**.775**	**.507**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.000	.000
	N	54	54	54	54	54	54	54	54
u48a	Pearson Correlation	**.657**	**.742**	**.579**	**.704**	**.526**	**.775**	**1.000**	**.674**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.	.000
	N	54	54	54	54	54	54	54	54
u5	Pearson Correlation	**.603**	**.556**	**.437**	**.692**	**.452**	**.507**	**.674**	**1.000**

	Sig. (2-tailed)	.000	.000	.001	.000	.001	.000	.000	.
	N	54	54	54	54	54	54	54	54

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

Factor Analysis

Component Matrix

	Component 1
Q5	.789
Q14M	.744
Q20	-.805
Q29	.696
Q33	.833
Q37M	.676
Q43	.803
Q48M	.911

Extraction Method: Principal Component Analysis.
a 1 components extracted.

Section II Interview Data

Background

The second portion of this report is a summary of interviews we had with some of the students who had taken the online survey. We tried to select students from each of the four major engineering disciplines. These majors are electrical and computer engineering, mechanical engineering, civil engineering and chemical engineering. Of the fifty-four students who completed the on line survey, only eleven students, three electrical and computer engineers, four chemical engineers, three mechanical engineers, and one civil engineer agreed to be interviewed. Nine were men and two were women. All the students were interviewed during the month of May, 2002, before they graduated. The interviews lasted between thirty minutes and an hour, with most interviews taking less than forty-five minutes.

Interview Question Results

The students were asked about the usefulness of mathematics as it related to their upper division mathematics and engineering courses.

All of the students took our basic sequence of six mathematics courses: Calculus I, Calculus II, Calculus III, Differential Equations I, Differential Equations II and Statistics. Some of the students mentioned other courses that they felt used a significant amount of mathematics. These included: Linear Algebra, Discrete and Combinatorial Algebra, Boundary Value Problems, Dynamics, Physics, Analysis and Design of Engineering Systems, Electromagnetic Fields, Electromagnetic Waves, Error Correcting Codes, Econometrics, Elements of Electrical Engineering, Controls, Process Controls, and Heat

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Transfer. The mathematical concepts they used were integration, differentiation, plotting, and Laplace Transforms.

When asked about their experiences, the students said their engineering courses used a lot of calculus ideas from the freshman year. They said it was good to have the ideas of calculus reinforced and incorporated into other areas. The engineering classes made more sense and cemented the calculus ideas in their minds.

The students universally agreed they were prepared for upper division mathematics and engineering courses. They definitely understood derivatives and integrals. A typical comment was: "If anything stops me on a problem it is not the mathematics behind it."

Students could not think of any mathematical topics that they had needed in their engineering courses, but had not learned. Some typical comments were:
"I can't think of a specific time when that happened."
"Sometimes I need to review. There are things I don't remember. If you don't use the technique you forget it."
"Sometimes I'd have to review because we hadn't done it in a long time." A case in point is Laplace Transforms, which the students learn as sophomores but may not use again until they are seniors taking courses in Controls or Process Controls.

When asked about their knowledge of concepts, the students felt they were prepared. Comments tended to be of the form:
"I tend to forget stuff over time."
"I don't completely understand sometimes, but concepts I use every day I know."
"Definitely (knows concepts)."
"What I can't remember I know where to look up."
"If I have trouble I review."

The students felt the most useful concepts were: basic integration, ideas from differential equations, Laplace Transforms, differentiation, series, and vectors. One student said, "Statistics should be stressed more. Maybe a second course should be required." Another student summed it up this way, "The whole package. The biggest thing is learning how to think mathematically."

"Linear algebra should almost be required because of the many applications."

The students were asked how their attitude towards using mathematics had changed since they'd come to Rose. These comments were quite interesting.

"My upper division classes used math a lot. I now use it enough, now I'm indifferent."

"As (math) classes got more theoretical and more difficult, I didn't follow as well. It's not that I dislike it. I just don't feel it as much."

"When I started, I knew I'd be taking a lot of math, but until last year I didn't know why."

"I didn't think I was going to use much from calculus classes so I didn't realize that calculus is a base for everything you learn later on. You might not use everything, but you use all the main principles."

"I always thought math was just a subject to take…. I then realized it is not just a course. I use it as a tool to do other stuff I need to do. It's more of a fundaments type thing. You have to do the math before you can start doing Chemical Engineering problems."

"I see the applications more than I did. I never saw why we were doing math. But now, I see. It seems everything in engineering is based around math. That is where the answers come from. It 's (mathematics) the foundation of engineering."

Section III Conclusion

Conclusions from Survey

From the on-line survey it is clear that engineering students at Rose-Hulman felt that mathematics was more than memorizing formulas and that it was important to understand the underlying mathematical concepts of a problem. The students universally felt that mathematics was important, useful, and would be a tool that they would use when they leave college. Only a few students felt that mathematics would not be a tool they would use regularly during their careers. Some of these beliefs may have come from students who were going into the military after graduation, or were going to graduate school in fields other than engineering.

Conclusions from Interviews

The interviews supported what the survey told us. While students may enter Rose-Hulman with an attitude that mathematics is just a subject that needs to be taken, the seniors told us that their mathematics education was very important. We were continually told that the concepts learned in the calculus, differential equations, and statistics courses were regularly used by the students in their engineering courses. The students also stated that while they may not always remember a concept, they usually knew where they could go to review the material they had forgotten. We also learned that the engineering students at Rose-Hulman believe that mathematics is important and will be a tool they will use in the future.

The fact that virtually all the students felt mathematics was useful and in fact that mathematics was the basic tool of engineering should make all mathematics and

engineering educators glad. While we mathematicians try to make calculus and differential equations interesting to a group of students who "could seem to care less," it is nice to know that in the long run our efforts are rewarded. In the long run students do understand the concepts we are trying to present and do appreciate the usefulness and necessity of having a solid mathematics background.

Engineers should take heart in the knowledge that even though the students ma say "we never saw that mathematical concept before" if fact all the student needs to do is review the mathematical concepts the student learned.

As mathematics educators we need to continually emphasize that the topics we are teaching will be used in the engineering courses the students will take in the future. As educators of engineering students we need to continually remind students of the mathematical concepts we expect students to know when entering our classes. We must also remember, and maybe even remind the students, that we are not teaching the students how to do a series of isolated mathematical or engineering techniques. What we are doing is helping the students to learn how to think.

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.