Using Student Self-Concepts in Placement and Evaluation

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Abstract

For the past two decades, Purdue University has been using student self-reports to provide information that has proved to be invaluable in educational planning and development. These critical student inputs are used to help place students in beginning courses, to identify high-risk and honors students, to evaluate the quality of courses, services and resources, to initiate and evaluate existing and new programs, and to help students make career decisions.

This paper discusses the use of self-reports of beginning engineering students using the Mathematics Science Inventory (MSI). The MSI is used in placing students in beginning mathematics and chemistry courses and to evaluate their perceptions of their achievements in these courses.

Introduction

This paper reports on the mathematics and chemistry phases of a comprehensive research effort conducted at Purdue University to measure the background, achievements and self-perceptions of beginning engineering students. Initial efforts to examine the differential computer abilities of engineering, science and technology students demonstrated the feasibility of using self-reports to measure computer literacy, knowledge and competency[1]. Later studies using self-reports have focused on computers[2], self concepts, mathematics[3] and chemistry. Each of these student self-reports studies indicated that cognitive abilities could be reliably and validly measured and were especially valuable in measuring change. Baird[4] in his excellent ETC Research Monograph has pointed out, “self-reports can be believed, they can be made psychometrically adequate and useful, and often are more predictive of later creative accomplishments than grades and test scores”.

The *Mathematical Skills Self-Appraisal Survey* (MSSAS) was developed at Purdue as part of a comprehensive action-oriented research program to improve placement in beginning courses and to measure student achievement[5]. This research began in 1991 with a pilot study of approximately 400 students enrolled in beginning mathematics courses. Based on the results of this preliminary data, the study was extended to include virtually all the entering engineering students for 1992 and 1993 [6]. In 1993 we expanded our study to examine the potential of using self-reports in chemistry and found that self-reports could be effectively used in placement and in measuring change. In 1994 items from the two inventories were combined into the *Mathematics Science Inventory* (MSI). This paper summarizes the results of our research on the MSI.

Objectives

The research goal was to provide information to students, teachers and counselors that can be used to improve the academic achievement and retention of beginning engineering students. The specific objectives were: 1)to examine the overall and differential impact of beginning mathematics and chemistry courses on students' perceptions of their mathematics and chemistry knowledge, and 2) to examine the relationships of the student self-reports to achievements in mathematics and chemistry.

Method

The MSI is a 150 item self-report completed by virtually all 1500 Purdue beginning 1995 engineering students before Fall semester and readministered at the end of the first semester. The MSI includes 100 mathematics items and 50 chemistry items. To each item, the student responds

MATHEMATICS SCIENCE INVENTORY (1994)

The primary purpose of this survey is to provide information regarding your MATHEMATICS and CHEMISTRY background. Your individual responses will be kept confidential. Please respond on the optical scan sheet provided. Listed below are a number of topics in mathematics. Using the following response categories, MARK THE CORRESPONDING CIRCLES ON THE OPTICAL SCAN ANSWER SHEET.

Responses		*Weight*
Never Heard of it	A	*1*
Heard of it	B	*2*
General Knowledge	C	*3*
General & Detailed Knowledge	D	*4*
Extensive Knowledge	E	*5*

	ALGEBRA and LOGARITHMS		DIFFERENTIAL CALCULUS
4.	Factorial Notation	24.	Bounds of functions
11.	Laws of Logarithms	29.	One-sided limits
	STOICHIOMETRY		ACIDS and BASES
104.	Avogadro's Number	131.	Colligative Properties
109.	Mole	137.	pH and pOH

Figure 1 - Sample of items used in the *Mathematical Science Inventory* and the response categories and corresponding weights.

(A) "Never Heard of It", (B) "Heard of It", (C) "General Knowledge", (D) "General and Detailed Knowledge", or (E) "Extensive Knowledge". The 100 MSI mathematics items are organized into seven subscales: (1) Algebra and Logarithms, (2) Systems of Equations, (3) Differential Calculus, (4) Integral Calculus, (5) Plotting, (6) Vectors and Trigonometry, (7) Sequences and Series, as well as an Overall Mathematics Scale. The 50 chemistry items are organized into five subscales: (1) Stoichiometry, (2) Gases and Phase Changes, (3) Atomic Structure and Bonding, (4) Acids and Bases and Solutions, (5) Equilibrium and Reactions, as well as an Overall Chemistry Scale.

Figure 1 provides a specimen sample of the instructions, response categories, and weights used to compute the MSI scores. The research involved students enrolled in the seven different mathematics courses and four different chemistry courses that are offered in the Fall for the entering engineering students:

- MA 151 Algebra and Trigonometry Algebra and trigonometry for students with inadequate preparation for calculus. The students in MA 151 are the weakest students. They were not able to meet the entrance requirements for MA 161.
- MA 161 Calculus I Limits, derivatives and integration. MA 161 is for the typical first semester engineering student who has not had high school calculus.

- MA 161E Calculus I Limits, derivatives and integration. MA 161E is the same as MA161 except the course has two extra recitation hours per week. The course was designed for the higher risk students.
- MA 165 Calculus I Same content as MA 161, however the class meets one less period. The typical student in this course had calculus in high school.
- MA 162 Calculus II Continuation of MA 161. Calculus of one variable: derivatives, integrals, applications, infinite series. Minimal advanced placement test score for Calculus I or MA 161 required.
- MA 173 Calculus II Advanced standing. Same basic content as MA 162, however only first semester students with high advanced placement test score for Calculus I are admitted.
- MA 271 Multivariate Calculus Advance Standing. Solid analytic geometry, partial differentiation, multiple integrals. Only first semester students that pass the advanced placement test for Calculus I and Calculus II are admitted.

TABLE 1 - PRE-POST SURVEY RESULTS OF 1ST YEAR ENGINEERING STUDENTS ON THE MATHEMATICS SCIENCE INVENTORY (N=1106)

		MEAN	MEAN	MEAN	STD.	EFFECT	RELIABILITY	
NO.	SCALE	PRE	POST	DIFF	DEV.	SIZE	PRE	POST
1	ALGEBRA & LOGARITHMS	49.7	51.4	1.7	12.4	.16	.95	.97
2	SYSTEMS OF EQUATIONS	49.9	53.3	3.5	11.4	.34	.87	.84
3	DIFFERENTIAL CALCULUS	50.1	53.7	3.7	10.5	.38	.97	.98
4	INTEGRAL CALCULUS	50.1	54.1	4.0	9.1	.43	.97	.97
5	PLOTTING	50.1	52.1	2.0	11.8	.20	.94	.96
6	VECTORS & TRIGONOMETRY	49.6	50.6	1.0	11.3	.10	.92	.95
7	SEQUENCIES AND SERIES	49.6	53.1	3.5	12.3	.32	.97	.99
8	*MATH OVERALL*	*50.0*	*54.0*	*4.0*	*10.2*	*.39*	*.98*	*.99*
9	STOICHIOMETRY	49.6	55.2	5.6	12.0	.57	.94	.96
10	GASES & PHASE CHANGES	49.5	54.8	5.3	10.4	.55	.91	.91
11	ATOMIC STRUCTURE & BONDING	49.6	57.7	8.1	11.6	.83	.91	.95
12	ACIDS & BASES & SOLUTIONS	49.7	53.3	3.6	9.8	.38	.95	.94
13	EQUILIBRIUM & REACTIONS	49.9	53.3	3.4	9.7	.37	.95	.94
14	*CHEM OVERALL*	*50.0*	*55.5*	*5.5*	*10.1*	*.58*	*.98*	*.98*

All Differences Significant; p<.00001

- CHM 111 General Chemistry Beginning chemistry for non-engineering/science students.
- CHM 115 General Chemistry Regular chemistry for engineers and science students with lab.
- CHM 123 Chemical Science for Engineers Chemical Engineering oriented chemistry with lab.
- CHM 116 General Chemistry II Continuation of CHM 115.

To provide comparability between scales, the raw scores were converted to standard T scores where the Mean T score based on all students taking the pre-test was 50 and the Standard Deviation was 10. Cronbach's Alpha was used to measure internal consistency reliability. Effect Size (Ratio of Mean Difference to Standard Deviation) was used to compare the relative gains in each scale.

This paper is based on MSI data collected from beginning engineering students in 1995. The pre-data was collected before Fall classes began. The post-data was collected during the 14th week of the first semester. The data presented in this paper focuses on the students that completed both the pre and post surveys.

Results

The overall results are presented in Table 1. Statistically positive significant changes were observed between the pre-test and post-test mean T scores for each of the mathematics and chemistry subscales and for the two overall mathematics and chemistry scales as well. Table 1 also indicates high reliabilities for each of the subscales, ideal when measuring change. Note, every scale showed a significant gain with Student's t of $p<0.00001$

Mathematics Results

To examine the relationship of pre- and post-mathematics MSI scores the data were analyzed by the level of mathematics course taken. The results are presented in Figure 2 and Table 2. Figure 2 visually documents the differential validity of the MSI in measuring mathematics achievement. It should also be noted that changes in mathematics scores are differential; students in the lowest level math course (MA 151) had mean post-test scores similar to the mean pre-test scores of those at the next highest level (MA 161). Similar observations can be observed for the other mathematics courses (MA 165, 173 and 271).

TABLE 2 - MEAN PRE-POST MATH SCORES FOR DIFFERENT LEVEL COURSES

	Math 151 (N=103)					*Math 162 (N=103)*				
SCALE	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**
ALGEBRA & LOGARITHMS	45	50.2	4.9	.52	d	52	53	0.4	.04	
SYSTEMS OF EQUATIONS	44	50.5	6.7	.67	d	53	58	5.3	.54	d
DIFFERENTIAL CALCULUS	40	39.9	0.4	.05		56	56	-0.1	-.02	
INTEGRAL CALCULUS	39	40.9	1.8	.22		57	60	3.1	.44	c
PLOTTING	43	46.2	3.4	.38	c	54	53	-1.4	-.14	
VECTORS & TRIGONOMETRY	46	52.3	6.3	.67	d	50	57	7.3	.74	d
SEQUENCES AND SERIES	46	47.1	1.3	.17		51	67	15.8	1.75	d
MATH OVERALL	40	43.9	3.8	.49	d	55	61	5.8	.62	d
	Math161E (N=110)					*Math 173 (N=100)*				
SCALE	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**
ALGEBRA & LOGARITHMS	47	50.1	2.8	.28	a	55	56	0.5	.04	
SYSTEMS OF EQUATIONS	46	50.4	4.2	.44	c	56	59	3.5	.36	c
DIFFERENTIAL CALCULUS	39	52.7	13.8	1.84	d	58	58	0.4	.06	
INTEGRAL CALCULUS	38	50.8	12.4	1.93	d	58	62	3.3	.51	d
PLOTTING	44	51.5	7.2	.78	d	56	56	-0.3	-.04	
VECTORS & TRIGONOMETRY	50	47.3	-2.7	-.30	b	54	59	5.5	.55	d
SEQUENCES AND SERIES	47	47.8	0.7	.08		52	67	15.4	1.60	d
MATH OVERALL	41	50.4	9.0	1.23	d	58	63	5.7	.59	d
	Math 161 (N=218)					*Math 261 (N=18)*				
SCALE	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**
ALGEBRA & LOGARITHMS	48	50.1	2.1	.21	b	56	57	0.8	.08	
SYSTEMS OF EQUATIONS	48	50.5	3.0	.34	d	62	62	-0.4	-.04	
DIFFERENTIAL CALCULUS	47	53.2	6.2	.80	d	58	60	1.6	.22	
INTEGRAL CALCULUS	46	52.4	6.5	.85	d	61	62	1.5	.21	
PLOTTING	48	50.8	2.5	.27	c	57	58	0.6	.06	
VECTORS & TRIGONOMETRY	49	46.5	-1.9	-.20	a	58	62	3.3	.35	
SEQUENCES AND SERIES	49	49.6	0.9	.10		67	64	-2.9	-.32	
MATH OVERALL	47	51.1	4.4	.55	d	64	64	0.8	.08	

SCALE	***Math 165 (N=427)***					***Math 271 (N=27)***				
	PRE	**POST**	**DIFF**	**SIZE**	**SIG**	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**
ALGEBRA & LOGARITHMS	50	50.8	1.2	.11		58	57	-1.1	-.08	
SYSTEMS OF EQUATIONS	50	52.7	2.6	.27	d	64	65	1.6	.13	
DIFFERENTIAL CALCULUS	53	55.5	2.5	.33	d	60	61	0.8	.10	
INTEGRAL CALCULUS	53	55.3	1.8	.28	d	63	63	-0.3	-.05	
PLOTTING	51	52.9	1.7	.18	b	58	58	-0.9	-.09	
VECTORS & TRIGONOMETRY	49	48.4	-0.5	-.05		60	62	1.5	.14	
SEQUENCES AND SERIES	49	49.6	0.4	.04		68	71	2.7	.28	
MATH OVERALL	52	53.5	1.9	.23	d	66	67	0.9	.08	

Significance Levels (SIG): a=p<.05;b=p<.01;c=p<.001; d=p<.0001

Table 2 provides a more detailed documentation of the growth in understanding of mathematics by course level. The Effect Sizes (E.S. = Mean Difference/Standard Deviation) indicate very large but differential gains in self-reports of math knowledge as measured by the subscales. Students in MA 151 (College Algebra & Trig.) report the greatest gains in ALGEBRA & LOGARITHMS, SYSTEMS OF EQUATIONS and VECTORS & TRIGONOMETRY. This is a positive assessment of the course, in that these topics are discussed in great depth in MA151. In MA161 and MA165 (Calculus 1) the greatest gains are in DIFFERENTIAL CALCULUS and INTEGRAL CALCULUS and in MA 162 and MA 173 (Calculus 2) in SEQUENCES AND SERIES. Again,

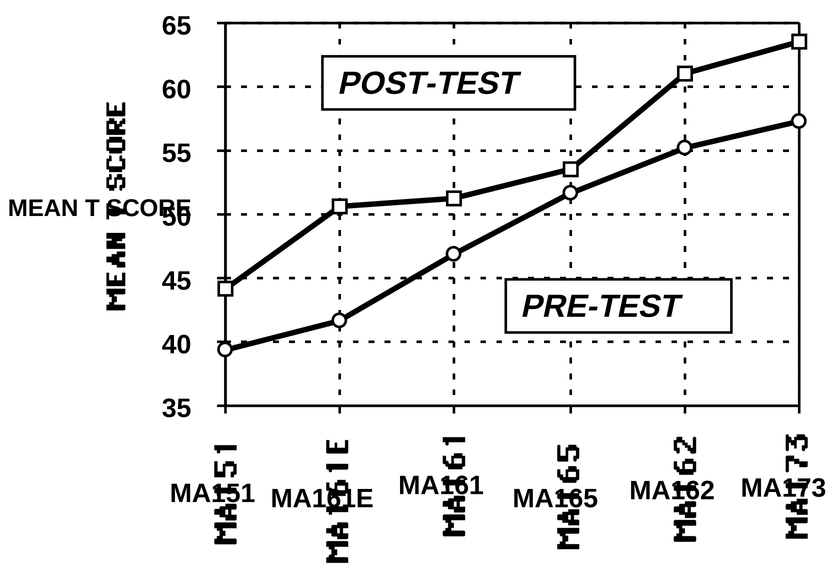

Figure 2 - Pre- and Post-MSI Overall Mathematics Mean T Scores by Math Course Level.

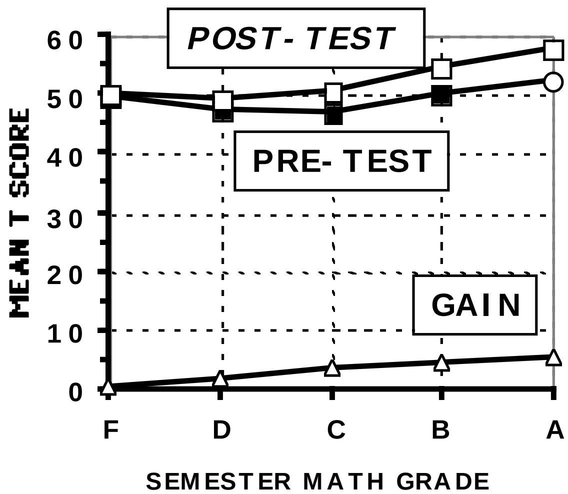

Figure 3 - Pre- and Post-Mean Scores by MATH grade in all courses combined.

the gains are directly related to the material taught in the courses. The same result can be verified for the material not covered in the courses. For example, 151 has little calculus, the difference as measured by the MSI confirms this fact. MA161 and 165 do not discuss vectors or sequences but MA162 and 173 do cover this material. Once again the MSI verifies this fact. It is also interesting and important to note that in Figure 3, small but curvilinear relationships were observed between pre-test and post-test scores and math course grades, and a highly significant linear relationship were observed between the Gains and math course grades. The individuals that received D's or F's did not show any gain. Thus, the students and the instructors came to the same conclusion, that no knowledge was gained, where the individuals that felt they gained the most are the same ones the instructors felt deserved an A.

Chemistry Results

To examine the relationship of pre-test and post-test chemistry MSI scores the data were analyzed by the level of chemistry course taken. The chemistry results are presented in Table 3 and Figures 4 and 5. They have a similar pattern to the math results. Table 3 provides a more detailed MSI

TABLE 3 - MEAN PRE-POST CHEMISTRY SCORES FOR DIFFERENT LEVEL COURSES

	Chem 111 (N=121)					*Chem 123 (N=172)*				
SCALE	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**
STOICHIOMETRY	40.7	55.7	15.0	2.0	d	58.8	58.4	-.5	.0	b
GASES & PHASE CHANGE	40.6	47.5	6.9	1.0	c	59.4	62.3	2.8	.3	d
ATOMIC STRUCTURE & BONDING	41.3	52.5	11.1	2.1	d	61.2	61.1	-.1	.0	d
ACIDS & BASES & REACTIONS	41.0	47.4	6.4	1.3	d	58.4	62.8	4.4	.4	d
EQUILIBRIUM & REACTIONS	41.1	49.0	8.0	1.3	d	60.4	63.3	2.9	.3	
CHEM OVERALL	40.1	50.2	10.2	2.1	d	60.6	63.0	2.3	.2	d

	Chem 115 (N=834)					*Chem 116 (N=27)*				
SCALE	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**	**PRE**	**POST**	**DIFF**	**SIZE**	**SIG**
STOICHIOMETRY	48.1	54.8	6.7	.7	d	54.1	56.5	2.4	.3	b
GASES & PHASE CHANGE	48.0	53.5	5.5	.6	d	53.0	59.6	6.6	.7	d
ATOMIC STRUCTURE & BONDING	48.0	57.3	9.3	1.0	d	53.3	59.2	5.8	.6	d

ACIDS & BASES & REACTIONS	48.2	52.1	3.9	.5 d	53.7	56.8	3.0	.3 d
EQUILIBRIUM & REACTIONS	48.3	52.2	3.9	.5 d	54.3	55.8	1.5	.2
CHEM OVERALL	48.0	54.1	6.2	.7 d	54.1	58.1	4.0	.4 d

Significance Levels (SIG): a=p<.05;b=p<.01;c=p<.001; d=p<.0001

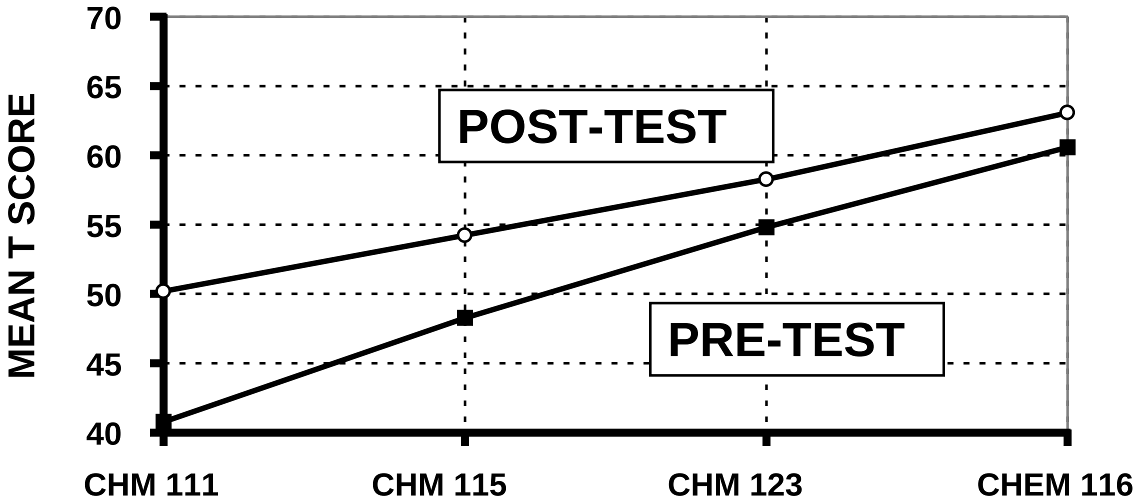

Figure 4 - Pre- and Post-MSI Overall CHEMISTRY Mean T Scores by CHEMISTRY Course Level.

documentation of the growth in understanding of chemistry by course level. The Effect Sizes indicate very large gains in chemistry knowledge on all scales for every chemistry course. The differential gains observed on the subscales in mathematics were also apparent in chemistry. It is also interesting and important to note that significant linear relationships were observed between pre-test, post-test and gain scores and chemistry course grades, as shown in Figure 5.

Placement

Our studies of the engineering education process have consistently shown that the best predictor of

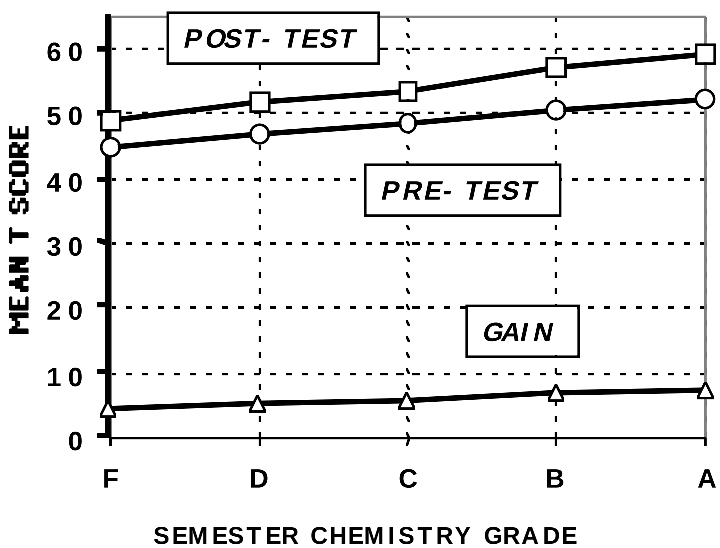

Figure 5 - Pre- and Post-Mean Scores by CHEMISTRY grade in all courses combined.

engineering retention is academic performance during the first year in college. To optimize academic performance, we have developed a broad database that includes not only admissions data, but high school credits and grades in chemistry, physics, pre-calculus, and calculus. We utilize discriminant analysis by using these data to make placement recommendations[7]. We have also found self-reports regarding understanding of topics in mathematics and chemistry can be especially helpful in the optimal placement of students in beginning courses. We utilize this information to create placement profiles for each beginning engineering student. The profile identifies student strengths and weaknesses and makes recommendations for course placement, advanced testing, and tutorial help. The student and counselor use these profiles not only in selecting key courses, but also in identifying special needs fur tutoring, career counseling and advanced placement testing. Each of these programs are also carefully monitored and evaluated to provide input on how these programs can be improved.

Figure 6 plots the Mathematics Science Profiles for students who participated in our Counselor Tutorial courses for high risk students, our regular courses and our advanced standing courses for Honors Students.

The MSI scales are effective and sensitive measures of students perceptions of their mathematics and chemistry backgrounds. These results confirm the potential value of utilizing student self-reports to provide highly significant and meaningful measures of student backgrounds at the college level. We are using this MSI data to assist in the optimal placement of beginning students
in their first year college courses.

Summary

Significant differences in mathematics and chemistry backgrounds were reported by students enrolling in beginning college level mathematics and chemistry courses. The *Mathematics Science Inventory* provides reliable and valid differential measures of change in student perceptions of their mathematics and chemistry pre-college backgrounds and college achievements. The MSI scales have discriminant validity (students in higher level courses have higher scores than peers in lower level courses). There is also statistical data using pre-test and post-test scores that indicate that the MSI scales can be used to provide important measures of changes in mathematics and chemistry achievement. *The Mathematics Science Inventory* provides engineering, chemistry and mathematics faculty with

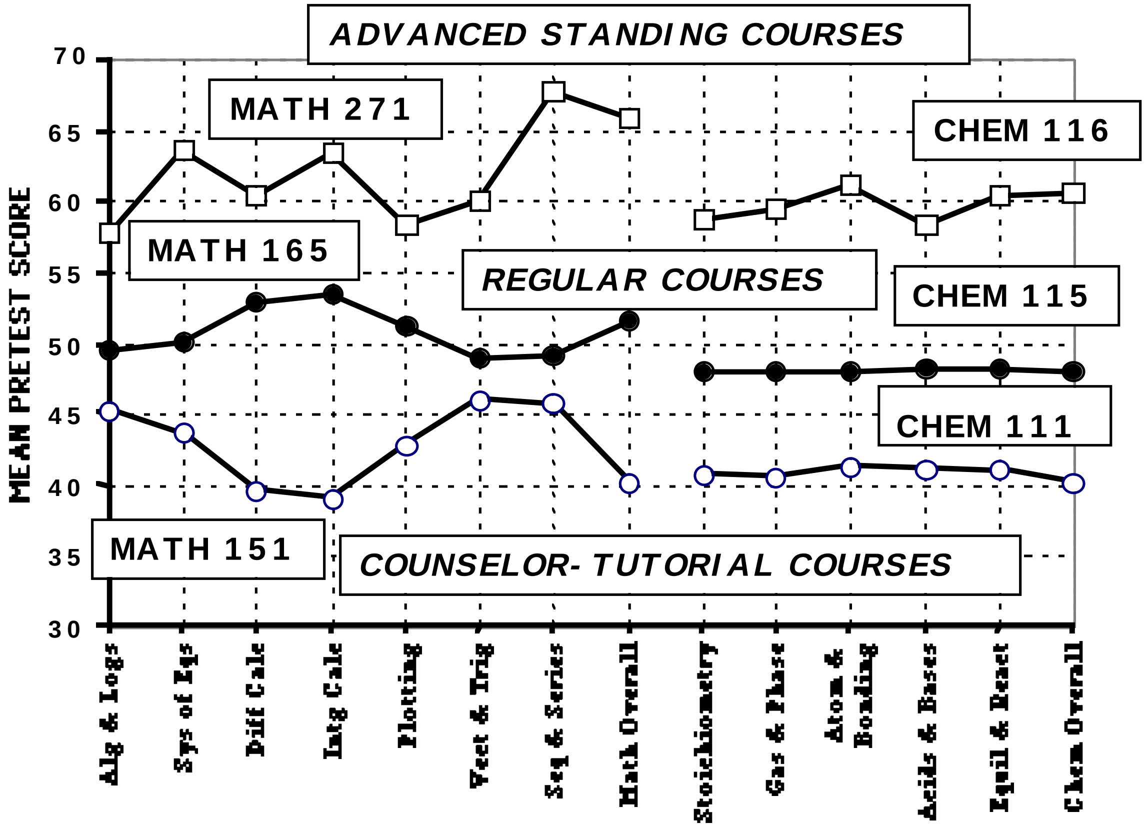

Figure 6 - Mean Mathematics MSI Pre-Test Scores by Programs

highly reliable and valid measure that can be used in placement, to document differences in the mathematics and chemistry backgrounds of incoming first year college students, and to measure changes in mathematics and chemistry achievement which are closely related to course level. This study indicates that the overall MSI scales is also related to college grades, but the relationships are complex.

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