Mathematics Across the Community College Curriculum

Evaluation Report

Student Survey Results
2005 – 2008

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This report is the penultimate review of student outcomes in courses developed under the auspices of the Mathematics Across the Community College Curriculum initiative. Since 2005, 160 community college faculty comprising 59 interdisciplinary teams from 36 colleges in 19 states have participated in five MAC^3 institutes where they were provided the time and resources to create curricular materials linking mathematics with another discipline. Through these courses "community college students throughout the nation [are] offered opportunities to deepen and reinforce the mathematics they have learned in their math classes, apply it in context, and understand its greater importance and application in their lives." The goal of this effort is "to create a mathematically literate society that ensures a workforce equipped to compete in a technologically advanced global economy."[1]

The teams who created and taught these courses represent the full range of disciplinary offerings; the resulting courses thus link mathematics with topics in science, social science, humanities, vocational and study skills courses. Table 1 below summarizes the project activity to date. Note that although the courses offered in the 2005-06 academic year were necessarily the result of work done at the 2005 Summer Institute, some courses offered in later terms represent work that was done in earlier years. A number of faculty members attended more than one institute and/or taught their course more than one time.

[1] This goal statement is taken from the MAC^3 website, http://www.mac3.amatyc.org/

TABLE 1. MAC[3] Project Activity, 2005 - 2008

		SUMMER	FALL	WINTER/SPRING
2005-2006	Institute	Summer Institute, WA 48 participants *from* 11 colleges *in* 7 states		
	Courses		5 courses 87 students	10 courses 174 students
2006-2007	Institute	Summer Institute, WA 39 participants *from* 14 colleges *in* 11 states		Winter Institute, FL 31 participants *from* 10 colleges *in* 7 states
	Courses		10 courses 181 students	7 courses 79 students
2007-2008	Institute	Summer Institute, WA 40 participants *from* 12 colleges *in* 9 states		Winter Institute, FL 40 participants *from* 14 colleges *in* 9 states
	Courses		12 courses 166 students	13 courses 170 students
2008-2009	Institute	Writing Workshop 12 participants *from* 6 colleges *in* 6 states		
	Courses		(14 courses presently scheduled to run.)	

The Evaluation Process

The results reported here are based on matched pre- and post-survey responses provided by 850 students in 57 fully evaluated MAC[3] courses that have run since Fall 2005.[2] (Because not all MAC[3] courses were fully evaluated, the number of students who participated in all MAC[3] courses is larger than the sample represented by the evaluation results, perhaps by as much as a factor of two.[3]) The MAC[3] student survey, developed by the MAC[3] Steering Committee in 2005, includes 21 pre-post items about mathematics

[2] To be included in the overall analysis, a course had to be represented by at least four matched surveys. Some courses that returned both pre- and post-surveys failed to meet this number, apparently because students did not include their identification numbers correctly on both surveys. Some courses returned only a pre- or a post-survey for the entire class and could not be included in the analysis for that reason. Some courses have been taught more than once and are counted as a course for each evaluated iteration.

[3] Estimating from the number of unmatched surveys, the number of courses with who returned only pre-or post-surveys and the number of courses that ran but returned no surveys.

attitudes. The post-survey also includes student self-evaluations of content learning and math skills gains. The pre-post attitude items are rated on a five-point continuous response scale with options ranging from "1 = strongly disagree" to "5 = strongly agree." These items measure change in students' interest and confidence in doing mathematics, their concept of mathematics, their awareness of the role of mathematics in society, and their attitude toward interdisciplinary teaching. (The survey is included as Appendix 1 of this report.) On the post-survey, students also assess how well they understand main topics in the course and how much they gained in math skills using similar continuous five-point scales, where "1 = Not at all" and "5 = A great deal." Questions about course content are created by each interdisciplinary team and are thus specific to each course; the pre-post attitude questions and the self-assessed skills gains common to all courses.

To simplify analysis and reporting, four constructs were extracted from the 21 attitude questions. These constructs combine questions that reference a shared underlying theme (as evidenced by strong correlation of responses across the items) into a single measurement. Thus, for example, students who agreed with item 2, "I am good at math" also tended to agree with items 9 ("I enjoy doing math"), 14 ("I am comfortable talking about math"), and with six other items that indicated interest and confidence in doing math. Students who disagreed with one of those items also were likely to disagree with all. We conclude that, taken together, these eight items all reference the theme "I like math," and can be combined in the "interest/confidence" construct, which is then treated as a single variable. Similarly, items 1, 4, 15 and 17 all refer to an "awareness" of the role of math in everyday life. Items 7, 8, 11 and 16, the "concept" construct, do not at first glance suggest a single theme, although they are highly correlated statistically. Items 7 and 16 ask about perseverance and taking multiple approaches in attacking math problems, while items 8 and 11 ask whether students use (or plan to use) math outside school. We have chosen the term "concept" because these items all query whether mathematics is rigid system and hence not applicable to unstructured (real life) applications or a flexible one with uses outside the classroom. The "interdisciplinary" factor includes two items (6 and 12) that refer to the efficacy of interdisciplinary learning.

The constructs[4] are listed in Table 2 below. Responses to Item 3 ("If one way of solving a problem doesn't work, I try another method."), Item 5 ("Mathematics is facts, rules and formulas to be memorized,") and Item 10 (Estimating is part of doing mathematics.") did not correlate closely enough with any of the constructs—or with each other—to be included. This does not mean that those questions are unimportant or uninteresting, only that they do not appear to reference directly any of the themes expressed in the four constructs extracted.

TABLE 2. Survey Constructs[5]

INTEREST/CONFIDENCE 2. I am good at math. 9. I enjoy doing mathematics. 13. I want to learn more math. 14. I am comfortable talking about mathematics. 18. I feel comfortable asking questions in my classes when I don't understand things about math. 19. I am going to study more math. 20. In mathematics I can be creative and discover things for myself. 21. After I've forgotten all the formulas, I'll still be able to use the ideas I've learned
MATH AWARENESS 1. Many things I use every day were designed using math. 4. Sometimes I see things outside of school that make me think of math. 15. Sometimes I think about math without meaning to. 17. Lots of things I do every day involve math.
CONCEPT OF MATH[6] 7. If I can't get the idea of a problem right away, I probably can't get it. 8. I don't need a good understanding of math to achieve my career goals. 11. I rarely use math outside school. 16. Math problems can be done correctly in only one way.

[4] The validity of a construct is based on the strength of the correlation among the constituent items. Perfect correlation among the items would result in an alpha measurement of "1.0," total independence in a measurement of "0." An alpha of .7 or greater is considered a strong association. The alphas for the constructs here are: pre-interest = .86, post-interest = .89; pre-awareness = .75, post=awareness = .77; pre-concept = .76, post-concept = .81; pre-interdisciplinary = .73, post-interdisciplinary = .79.

[6] The "Concept of Math" factor has been redefined this year, excluding two items that were previously included (items 3 and 10). Although the six-item factor had acceptable reliability (pre- alpha = .68), the four-item factor is both more cohesive and more explanatory. In the six-item factor, items 3 and 10 showed almost no pre-post change, while the other four items showed very significant changes in the undesirable direction. The new factor includes only the four items—7, 8, 11, and 16—that posted large declines.

INTERDISCIPLINARY LEARNING

6. Doing math in another subject makes the other subject easier to learn.
12. Doing math in another subject makes the math easier to learn.

In creating the constructs, and for all other analyses, all statements have been scored so that the desired response is "5" and the undesired response is "1." For most items, this means that "strongly agree" is given the value of "5" and "strongly disagree" the value of "1." But for items that are negatively phrased—5, 7, 8, 11 and 16—where the desired answer is "strongly disagree," that scale is reversed, and "strongly disagree" is scored as "5." This means that in this analysis ***higher values always indicate a more desirable outcome.***

Survey analysis is based on the comparison of pre-post attitude change for individual students. Students' pre- and post-surveys were matched using their student identification numbers. Surveys from students who were not present on both days or who did not enter their identification number correctly on both surveys could not be utilized in the analysis. A high percentage of surveys from most courses were matched, so we can be confident that the comparative results are representative.

Survey Demographics

850 students in 57 MAC^3 courses completed both the pre- and post-survey. This analysis is based upon results from those 850 sets matched surveys completed over the course of three academic years. Over 60% of the students in these courses were women and two-thirds were under the age of 22. The majority—62%—identified themselves as "Caucasian/white." Table 3 below presents the demographic data for students in the sample.

TABLE 3. Gender, Age and Ethnicity of MAC^3 Students

GENDER	N = 850 %
Male	37
Female	63
AGE	
18 – 22	67
23 – 30	20
31 – 58	13
ETHNICITY	
African American/Black	8
Asian/Pacific Islander	7
Latino/Hispanic	17
Native American	2
Caucasian/White	62
Other	4

Survey Results

The goal of the MAC^3 project is to improve student learning in mathematics, an outcome that depends in some large part on achieving favorable student attitudes toward mathematics.[7] The survey results reported here about attitude change and self-assessed skills and learning gains thus address this goal directly, measuring improvement in these areas in the student population. In addition to this "summative" function, information about change in students' math attitudes and skills and about learning gains also serve a "formative" evaluation role: they help us identify circumstances that seem to promote success in these interdisciplinary courses and those that do not. By comparing the demographic and instructional characteristics of courses where students did very well

[7] This overarching goal is also advanced when MAC^3 principles are disseminated, either through MAC^3 faculty participants applying those principles to other courses they give or through their recruiting other faculty members at their colleges to try these strategies. This aspect of the project will be addressed in the final report.

with those where they did less well, we can identify conditions that correlate with—and those that appear to be irrelevant to— stronger student results.

The discussion of survey results thus has two parts. The first, Student Outcomes**,** presents overall student attitude, skills and learning results. The second, Indicators of Success, compares results among courses to identify factors that appear to lead to more effective interdisciplinary teaching. It is important to be aware that factors which are correlated with lower performance in this sample are not necessarily barriers to successful interdisciplinary teaching, but they may require compensatory thought and strategies in order to mitigate their impact.

Survey Results: Student Outcomes

Pre-post attitude changes. After completing a MAC^3 course, surveyed students showed statistically significant gains in their interest and confidence in mathematics, their awareness of math in their lives, and their appreciation for interdisciplinary learning. They posted a significant decline, however, in the "concept" factor, which indexes their understanding that math is not rote procedures to be used in the classroom but a flexible strategy for solving problems in many arenas. Figure 1 displays the pre-post change in the four major factors graphically. Table 4 presents the same results in tabular form.

FIGURE 1

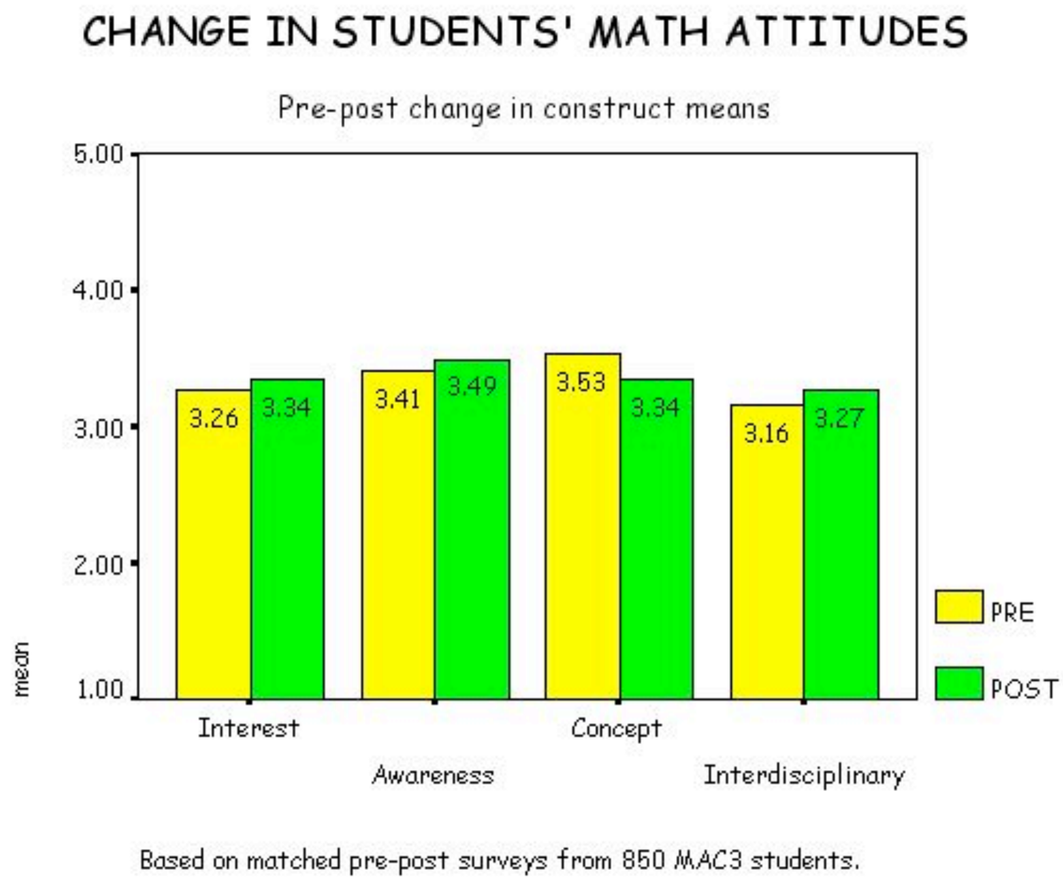

TABLE 4: Change in Math Attitudes
(N = 850)
Pre-post change in construct means

CONSTRUCT	MEAN	STANDARD DEVIATION	MEAN PRE-POST CHANGE
Interest/confidence pre	3.26	.79	+.08
Interest/confidence post	3.34	.85	
Math awareness pre	3.41	.81	+.08
Math awareness post	3.49	.86	
Interdisciplinary learning pre	3.16	.89	+.11
Interdisciplinary learning post	3.27	.97	
Concept of math pre	3.53	.57	-.19
Concept of math post	3.34	.70	

These results are strong and consistent—survey outcomes have varied little since the first round of courses in 2005-2006. Significant gains in interest in mathematics, awareness of mathematics in the world around them, and an understanding that math is connected to other disciplines provide solid evidence that the main goals of the MAC^3 project are being met. It is telling that the two survey items showing the greatest gains were those that directly reference interest and confidence in math, arguably the attitudes that more than any others lead students to continue to study and use mathematics. Item 2, "I am good at math," posted an overall gain of .15, and Item 9, "I enjoy doing mathematics," showed a .14 increase. (Pre-post values for all 21 items are found in Appendix 2.) We can conclude that student participation in MAC^3 courses appears to promote interest in mathematics and deepen mathematical understanding in ways that will contribute to a more mathematically literate workforce and society.

The fourth factor, "concept," has shown a significant pre-post decline population-wide with every survey iteration. A closer look at the results, however, reveals that courses where math or science was the primary discipline (accounting for 58% of the MAC^3 population) post a small overall increase on this factor, while courses where social science, humanities, professional/vocational skills or study skills was the primary discipline posted overall declines.[8] These latter were *all* courses where the math component comprised less than 25% of the course. Under these circumstances, where the mathematics infusion was modest and tightly focused, it is not surprising that students did not acquire the deeper understanding of mathematical process queried by items 7 and 16 (the fact that there are multiple approaches to math problems and one should keep trying to find them). But it is surprising that students' awareness of the importance of math in future careers seems to diminish. The MAC^3 initiative is motivated by the belief that mathematics is important to all contemporary occupations—indeed, the point of including mathematics in disciplines not conventionally linked to math is precisely to show that all fields, and by implication all careers, require mathematical competence. It is disappointing, therefore, to find that this realization appears less strong after students

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[8] The difference between the pre-post difference in the concept factor scores of courses where math or science was the primary discipline and that score for all other courses is statistically significant.

have completed MAC^3 courses in social science, humanities, vocational/professional and study skills. Another explanation for the pre-post decline in these items among this group is that after an interdisciplinary math course students change their career aspirations in a direction that they believe avoids exposure to math. Neither is a desirable scenario.

It is possible that when math is inserted into a course in a time-limited and tightly focused way, instructors tend to emphasize formulaic ways of problem-solving. This could have the unintended consequence of undermining the notion that math is open-ended and widely applicable in careers and real life. Faculty members should be aware of this possible interaction and take pains to remind students about the widespread requirement for mathematical abilities in the workplace.

Self-assessed skills gains. Students are asked on the post-survey to assess their gains in understanding, problem-solving, and attitudes toward math as a result of their work in the MAC^3 course. Following the question, "To what extent did you MAKE GAINS in any of the following as a result of what you did in this class," students are asked to rate seven items on a five-point scale where 1 = "not at all" and 5 = "a great deal." If we assume that the psychologically salient midpoint of the scale is "3," so that a response of "3" represents the expected gain in any course, then responses above "3" would indicate a greater than standard gain, while a response less than "3" would reflect less than expected progress. As Figure 2 and Table 5 show in graphic and tabular form respectively, MAC^3 students believe that they made notable gains in all areas except enthusiasm for math. They recorded the strongest results in mathematical comprehension—understanding concepts, thinking through and solving problems and being comfortable with complex ideas. Students in learning communities posted significantly better scores overall on skills gains, with a mean score of 3.4, compared to 3.1 for courses with modules of any size. There were also significant differences according to the primary discipline in the interdisciplinary pair, with students in math courses scoring significantly better than those in study/life skills courses. Taken as a whole, these are commendable results, reinforcing the conclusion that the MAC^3 initiative is achieving its goals.

FIGURE 2

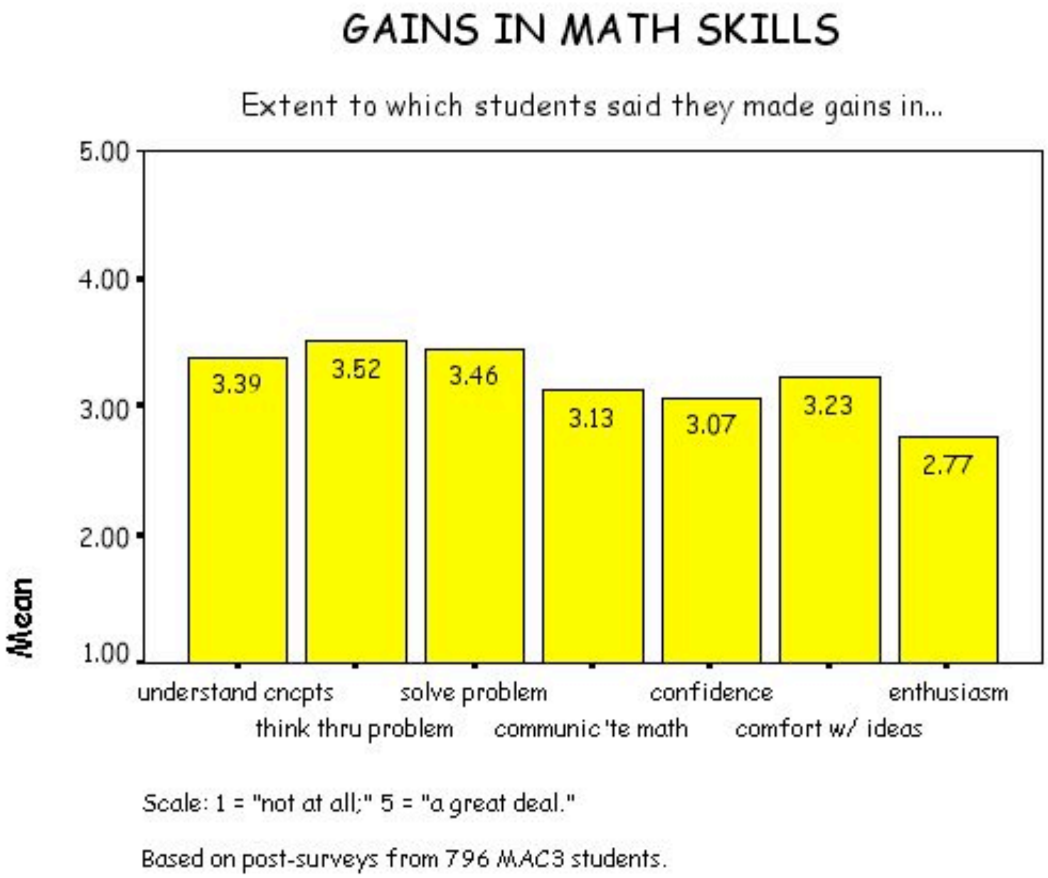

TABLE 5. GAINS IN MATH SKILLS: ALL STUDENTS
N = 796
Extent to which students said the made gains in…

MATH SKILL	Survey mean (on a 1 – 5 scale)	Standard deviation
Understanding concepts	3.39	.92
Thinking through a problem	3.52	.95
Solving problems	3.45	.94
Communicating about math	3.12	1.06
Confidence in math ability	3.08	1.18
Comfort with complex ideas	3.22	1.04
Enthusiasm for math	2.77	1.25

Course specific content learning. To measure actual content learning, course instructors identified three to six major mathematical concepts[9] they hoped their students would understand after taking their MAC[3] course. Students were asked to rate their content learning on the same five-point scale as their skills gains (from "not at all" to "a great deal") in response to the question, "As a result of your work in this class, how well do you think you now UNDERSTAND each of the following?" [10] Like the courses themselves, these content items ranged widely, from items like fractions and place value in some developmental courses to manipulating vectors in an advanced calculus course. Although the content items ranged from elementary math concepts to sophisticated ones, they are comparable across courses because in every case the challenge they represented for the students was the same.

Again assuming that "3" is the psychologically salient middle of the scale, so that values above "3" represent greater-than-expected gain, we find that the mean content score across all courses was 3.7, suggesting that students felt they learned "a lot" about the material they were presented. There was no difference between courses where math was paired with a science and those where it was combined with a non-science; the content score was 3.73 in both categories. Nor was there a statistical difference among the three teaching formats (learning communities, modules constituting less than 25% of the course, modules constituting more than 25% of the course) in terms of content learning. The only statistically significant difference was between courses whose primary discipline was categorized as "professional/vocational," whose scores were as a group the lowest (3.4) and the courses whose primary discipline was math, science or social science (whose scores were 3.8, 3.8 and 3.9, respectively).[11] It is important to note that although the math, science and social science courses scored higher than the vocational/professional courses, *all* courses posted means above the scale midpoint, indicating that students in all categories of courses felt their learning gains in the interdisciplinary MAC[3] courses were solid.

[9] Where appropriate to the course content, a few instructors also included some non-mathematical concepts, but all courses measured the mathematical learning goals of their courses.
[10] "Learned elsewhere" was also an option.
[11] Courses where the primary discipline was humanities had the highest scores—4.0—but the small number of students involved (15) prevents this comparison from being statistically significant.

Conclusions: Student Outcomes. In a time when technology and globalization insure a rapidly changing work environment, a mathematically competent workforce not only requires individuals with the math skills needed for their present jobs, it also requires individuals who are willing and able to acquire new skills as needed. To determine whether MAC^3 courses were preparing students for this future, we measured changes in attitudes toward math and gains in fundamental math skills as well as actual content learning gains among MAC^3 students. In every case, the findings suggest that the kind of interdisciplinary approach promoted by MAC^3 leads to significant improvement in these areas.

After a MAC^3 course students showed increased interest and confidence in math, a greater awareness of its role in their lives and a greater appreciation for the interdisciplinary learning environment. All of these attitude changes increase the likelihood that these students will continue to learn math in new and different situations. Students in courses where the primary discipline was math or science, a scant majority of MAC^3 students, also gained a deeper understanding of mathematics as a process and showed a greater appreciation of its role in future careers. Courses where other disciplines were primary—and where coincidently much less math was included—showed declines in processual understanding and in awareness of the role of math in the workplace. While it is easy to understand how these concepts are sidestepped in short and tightly focused math infusions, and while deepening understanding of them may be difficult in such circumstances, instructors would be advised to emphasize these ideas, editorially if necessary.

MAC^3 students also showed strong gains in basic math skills such as the ability to think through and solve problems, to understand the relationships among concepts and to feel comfortable with complex ideas. In all but their enthusiasm for math,[12] they showed growth in the skills that will help them continue to learn and use mathematics.

Finally, students in all courses made solid gains in understanding the mathematical material of the course, whether that involved, for example, place values and fractions for developmental students, unit conversions for science courses, slope for

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[12] In the many four-year colleges where this survey has been given, this item has also always posted the lowest score of the seven items. It may be that "enthusiasm" is not an emotion that many students, even those who like math, associate with mathematics.

economics courses or vectors for calculus students. Courses in all disciplines and in all teaching formats posted means above the midpoint for content learning.

The fact that all three measures of student outcomes—attitudes, skills and content—showed gains and that these gains were, for the most part, found in all interdisciplinary combinations and with all teaching formats suggests that the interdisciplinary, student-centered approach promoted and supported by MAC^3 institutes and workshops contributes effectively to creating a mathematically competent workforce.

Survey Results: Indicators of Success

Student outcomes data not only help us understand the impact of teaching mathematics in an interdisciplinary context on student attitudes and knowledge, they also help us understand how to do this better. Comparing survey outcomes by the demographic and pedagogical variables that might be expected to impact student results, we can identify conditions that appear to affect student performance—and those which do not appear to influence outcomes. The comparison is complicated, however, by the fact that MAC^3 courses vary greatly in size (from 3 to 70 surveyed students) and there is an inverse correlation between size and survey results, so that smaller courses post significantly higher scores than larger courses. When the courses are divided into equal categories by size, we see that students in the smallest courses (12 or fewer students) perform significantly better than students in larger courses (13-16 students, 17-30 students and more than 30 students). This means that neither analysis of survey results by student nor by course yields a fair representation of the impact of the MAC^3 approach. Analysis by student tends to over-weight large courses that perform less well than smaller ones (e.g., a course of 70 students contributes ten times as much to the outcome as a course of 7 students), while analysis by course over-weights the better-performing smaller courses where sampling error is likely to be higher.

Therefore two analyses were conducted to identify conditions that influence survey outcomes, one analysis by student and another analysis by ranked courses. In the first, outcomes were calculated over the entire student population (850 matched individual pre-post surveys). In the second, courses were ranked into three groups according to their survey results—top, middle, lower—and these groups were tested to determine if they were alike or different in terms of the variables we believe may influence survey performance. Both analyses consider variables that might reasonably be expected to influence students' performance in a mathematics course. Some are characteristics of the students themselves: gender, age, ethnicity and the attitudes about math they bring to the course (represented here by their attitude survey pre-score). Some are characteristics of the course: the format of the course (learning community, a course where the math infusion comprises more than 25% of the course, a course where the math comprises less than 25% of the course), the nature of the faculty collaboration (both collaborators are present for most/all classes, both collaborators are sometimes present, one of the collaborators teaches the course alone) and the disciplines involved (which discipline is paired with math, which of the two disciplines is primary,[13] and whether a science is involved).

To facilitate comparison across students and courses, a single index of survey outcomes, called the "change" index, was created by combining results from the attitude and skills measures in a way that takes these two aspects of change into account with about equal weighting.[14] The mean change index score over the entire population was .24, comprising a mean attitude gain of .03 and a mean skills gain of .21. Only factors that were statistically significant at the 95% confidence level by the appropriate statistical test *in both the by-student and the by-course analyses* are considered to impact the success of the MAC^3 interdisciplinary approach.[15] These are discussed below and tabulated in Appendices 3 and 4.

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[13] In learning communities where a math course is paired with another course, math is considered the primary discipline for purposes of this analysis on the grounds that this represents a 100% math infusion.

[14] Since the attitude survey has a mid-point of 3 and the skills self-assessment has an implied referential mid-point of 3, the index was constructed by summing the actual and implied pre-post differences of the two. Thus "change" = [post-survey attitude mean – pre-survey attitude mean] + [skills mean – 3]. Since higher scores on the attitude survey indicate more desirable attitudes, a positive difference between the post- and pre-survey scores indicates desirable change, while a negative difference indicates change in the undesired direction. Similarly, a skills score greater than 3 indicates a desirable outcome while a score of less than 3 indicates an undesirable outcome. These attitude and skills difference scores tend to be of about the same magnitude and thus when summed represent these two important aspects of change about equally. The content measure was not included because, although roughly comparable, the items are not identical across the entire population.

[15] The by-student analysis considered the 850 matched student surveys returned thus far from 56 MAC^3 courses. A few courses did not return the student self-assessment section of the post-survey and thus did not contribute data to the analysis of those items. The student data were analyzed for differences by gender, age, ethnicity, class content and style, and class size using a t-test for independent variables or ANOVA, as appropriate. The by-course analysis considered the 52 courses that returned both attitude and skills gain

Class size. Among the conditions that impact student results, as measured by the MAC[3] survey, class size is primary. The quarter of theMAC[3] student population enrolled in the smallest courses (3-12 students) did significantly better than the quarter enrolled in the largest courses (more than 30 students), although they entered with significantly less favorable attitudes toward math than students in the large courses. This finding is not surprising. The interdisciplinary, student-centered MAC[3] approach requires the kind of individualization of instruction and hands-on activities that are more difficult to organize with a large number of students. The approach is also unfamiliar to many students and thus may require the additional explanation and support that is, again, easier to provide when the class is small.

Gender. There is no difference in outcomes by gender. There is no significant difference in men's and women's change score, or in its attitude and skills components, in the by-student analysis. Similarly, there is no difference in the gender composition of more and less successful courses. These results suggest that linking mathematics to other disciplines is an equally effective pedagogical strategy for both men and women students.

Age. There is no difference in outcomes by age. Students were divided into three age groups—18-22 years old, 23-29 years old and 30 years old and over. There is no significant difference in the change scores of these three groups in the by-student analysis, nor is there any significant difference in the age composition of the high, middle and low scoring courses (about 65% of students in all three categories of courses were 18 to 22 year-olds).

Ethnicity. Students from different ethnic groups perform differently in MAC[3] courses, but like everything else concerning ethnicity in American society, the picture is both complicated and unclear. Although there is no significant difference among the ethnic groups in the attitudes they bring to the MAC[3] course (their mean attitude pre-score), there is a difference in outcomes. In the by-student analysis Latino/Hispanic students (change score = .72) significantly outperform white students (change score = .09), who post the lowest change score of any group. African-American and Asian

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data. The courses were ranked according to the change index and were then divided more or less equally into top, middle and bottom groups. These groups of courses, ordered by level of success, were compared to determine if they were alike or different in terms of the distribution of these same variables (gender, age, ethnicity, class content and style, class size), using the chi-square test as a measure of heterogeneity.

students also score well (with change scores of .49 and .43, respectively), but because their numbers are small, the difference between them and white students is not significant. Latino/Hispanic and African American students are over-represented in the most successful courses, while white students are over-represented in the least successful courses. The performance of white students does not differ by either gender or age: white men and women of all ages posted less desirable survey results than students from other ethnic groups.

Although we do not yet have complete data about the ethnic identification of MAC^3 faculty, preliminary analysis of the effect of the interaction between the ethnicity of the student and the instructor,[16] suggests a more complicated picture. Consistent with the student analysis, African American and Asian students post above-average scores with faculty of all ethnicities. Latino students score above the average with Latino instructors but score below average in courses taught by white faculty members. Indeed, students of all ethnicities (including white students) score above average in courses taught by Latino instructors, whose students overall recorded the highest change scores. But 94% of all white students were taught by white instructors or teams, and in these classes white students scored substantially lower than any other ethnic group. Although additional data may clarify some relationships, they are not likely to change the primary conclusions of this analysis: Latino instructors appear to be especially effective and white students appear to perform poorly, relative to members of other ethnic groups.

The survey data provide no reason *why* students of different ethnicities should perform differently, of course. We do not know, for example, whether white students' poor performance is math-specific or typical of their academic performance in general. Perhaps math is a place where students with limited English language skills can excel. Perhaps non-white students are more likely to be highly motivated first-time college-goers in their families. Perhaps there are differences in study strategies, in preparation or in career aspirations of the different groups that make the interdisciplinary, student-centered approach more effective with non-white students. Whatever the reason, it is heartening to know that the MAC^3 approach is particularly effective with populations who are often characterized as underserved and who may especially need improved math

[16] This analysis includes the 726 students for whom the ethnicity of the instructor is known.

skills. It is dismaying, however, to realize that although white students still post gains in these courses, they are weak compared to those of other groups.

Attitude pre-score. Students who entered the MAC[3] course more favorably disposed to math (i.e., those whose pre-score on the attitude survey was at or above the mean) had better outcomes, overall, than students whose initial attitudes about math were less salutary.[17] However, in this case combining the attitude and skills measures into a single index masks important differences. The half of the student population with more favorable entering attitudes (a mean of 3.83 on the five-point scale) posted high skills gains (+.42), but recorded a significant decline in math attitudes (-.04). Students with less favorable initial attitudes (a mean of 2.90 on the five-point scale) showed the opposite outcome: they recorded significantly more desirable attitudes about math at the end of the course (+.08, nearly three times the population mean gain) , but experienced less than expected skills gains (-.02). The large attitude improvement among students with less favorable initial math attitudes—they posted significant gains on ten individual survey items—is a very strong outcome. We know that positive attitudes toward math are critical in determining whether students continue to learn and use mathematics.

It is important to note, however, that although students with more favorable entering attitudes posted an overall pre-post attitude decline, they did not experience a loss of *interest* in mathematics. The overall decline in the math attitude score of those students is due *entirely* to highly significant declines in the four items about doing math and using it in a job that comprise the "concept" scale (see above, page 9),[18] once again raising the question of why participation in MAC[3] courses seems to erode attitudes that reference the multiplicity of approaches to, and applications for, mathematics. Reinforcing this concern is the fact that the only item on which the lower pre-score group showed a significant decline was Item 16, "Math problems can be done correctly in only one way."

Primary discipline. Students whose MAC[3] experience was in the context of a math course, either as one course in a learning community or a math course with non-math interdisciplinary infusions, scored significantly better on every index than students

[17] In this case the by-student comparison is highly significant, while the comparison across courses falls just shy of significance (p = .06).
[18] The only other significant change for this group was a significant increase in item 2, "I am good at math."

enrolled in non-math courses to which math applications or exercises were added. There was no difference in the gender composition of these two categories of courses, but there was difference by age (math courses enrolled significantly more young students, non-math more older ones) and by ethnicity (Latino students were over-represented in math courses, students who identified as white were over-represented in courses with a non-math primary discipline). It would appear that when it comes to improving math attitudes and abilities, more math is better. The pervasiveness of this effect is shown clearly in Table 6 below, which compares the change across these indices for students in "math plus X" courses and those in "X plus math."

TABLE 6. Pre-post change by primary discipline of the interdisciplinary collaboration

Index	Math + X infusions N = 577	X + Math infusions N = 273
Change (combined index)	.42	-.12
Skills change	.33	-.02
Attitude change (overall)	.09	-.10
"Like" construct change	.12	-01
"Awareness" construct change	.13	-.04
" Concept" construct change	-.06	-.45
"Interdisciplinary" construct change	.20	-.07

On the other hand, there was no significant difference between students in courses where math was the primary discipline and those where it was not in terms of self-assessed content leaning. Students in both situations posted solid content gains, suggesting that even if the math exposure in non-math courses was not sufficient to change long-held attitudes, students mastered the mathematics they were presented.

Interdisciplinary pairing. Certain disciplinary combinations produced stronger results than others. Science courses that added a math component and math courses that added a humanities component had significantly better results than other combinations (several other pairings that produced good results involved too few students to achieve statistical significance). It seems likely that these pairings would be productive: a science context clarifies the usefulness of math; adding art, music or literature to a math course uses intrinsically interesting material to stretch students' ideas about the nature of math. On the other hand, certain pairings were less successful, at least in terms of promoting the mathematical goals of MAC[3]. Professional/vocational courses and study/life skills courses that added math had significantly less desirable results in both analyses than other pairings.

The study/life skills courses represent a special case that deserves closer attention. Three courses fall into this category. Two of them, between them enrolling 18 students, posted change indices above the population average of .24. The third, enrolling 136 students (88% of students in this category) in eight sections of a single course, produced a change index score of -.26. Unlike every other course evaluated—most of which were electives, some of which were required courses in a major sequence—this course was a graduation requirement for every student in the college. Most students were thus not in the course itself by choice; they were not likely to welcome the further addition of mathematics. Under these circumstances, it is not surprising that the survey results are not positive. On the other hand, the course instructor felt that the students were interested in the math they employed and saw its value in the context of the host discipline. She felt the use of math improved student work in the course and she continues to offer the mathematical infusion every term. This example suggests that although captive audiences may not be the best candidates to benefit from a math infusion, the activity is not without value.

Course format. Students in learning communities performed significantly better than students in single courses with interdisciplinary infusions. However, this effect may be attributable in some large part to the fact that all learning communities except one (a physics-English pairing) included a whole math course, itself a strong predictor of desirable survey results. A comparison of results for all courses where math was the primary discipline tends to support the importance of "more math." Math courses that were part of a learning community posted higher change scores (.75) than math courses with interdisciplinary additions that were less than 25% of the course (change score = .50) and significantly higher scores than math courses where the other discipline accounted for more than 25% of the course (change score = -.12). Courses that were

100% math thus yield the best results, courses with over 75% math the second best and courses with less than 75% math yield the least good results.

Another method for assessing the relative importance of teaching format and amount of math is to compare the same math course as part of a learning community and as a free-standing offering. One MAC^3 instructor taught one section of his introductory algebra course as part of a learning community and two sections of the same course as free-standing math classes. Students in all three courses completed the pre-post attitude survey.[19] The learning community and one of the standard courses posted solid attitude gains; the other standard course showed a small attitude decline. There was, however, no significant difference among the survey results of the three courses. Both this case study and the comparison of the amount of math in the course raise the possibility that the strong performance of learning communities on the math survey results more from the amount of math presented in that format than from the format itself.

Pairings that include a science are another good example of the impact of format on results. Although math is an essential tool of science, and the two are often seen as a "natural" combination, the inclusion of a science in a course combination was not enough, in itself, to significantly effect results. For MAC^3 courses, at least, it matters how they are connected. As noted above, science courses with a math infusion produced strong results across the board. However, in situations where mathematics was the primary discipline and science the "added" one, learning communities and courses where the science activities constituted less than 25% of the course posted very strong results (change scores of .79 and .57, respectively), but courses where the science constituted more than 25% of the course had a mean change score of -.50. Again, the "more math" dictum applies.

Collaborative style. It does not appear to matter, in terms of survey results, whether courses are taught by a single instructor (who might or might not be part of a learning community), by a team who are both in the classroom for all classes, or by a team where one instructor is present only occasionally to offer activities. Although the by-course analysis shows a statistically significant difference among the three styles, this

[19] The freestanding classes did not compete the skills gain portion of the post-survey, so attitude changes are the only comparative data available.

derives from differences in the proportional contribution to the middle range of courses, a distinction which is not particularly important in understanding success.

Conclusions: Indicators of Success. This analysis took two approaches to identifying the demographic and pedagogical conditions that are correlated with desirable student survey results: a comparison of survey results across the entire MAC^3 student population of 850 students and a comparison of courses whose survey results put them in the top third with those whose results ranked them in the two lower tiers. The course-based analysis was included to avoid the large-course bias inherent in the student results, where large courses, which perform significantly less well than smaller ones, are more heavily weighted.

While the overall outcomes for MAC^3 courses were strongly positive, certain circumstances tended to produce even better results. Among pedagogical factors that dispose to greater success in these interdisciplinary, hands-on courses is *small class size*. It makes sense that student-centered approaches work best when there are more opportunities for direct student-teacher interaction. Students also posted better math attitude and skills gains in courses where *mathematics was the primary subject*. Indeed, the more math students were exposed to, the stronger their attitude and skills gains. This finding may also account for the success of students in learning communities, who (with a single exception) were all enrolled in a full-time mathematics course. Math courses with humanities infusions had particularly good results, perhaps because the material was interesting and unusual in that context. Students in non-mathematics courses with added math activities performed significantly less well, with the important exception of *science courses that included math exercises*. Including relevant math that helps students advance their understanding of a science is a successful approach, even when the amount of mathematics added is modest. While these factors enhanced success, it is well to remember that all interdisciplinary combinations produced positive results except for study/life skills courses, where one very large college-wide required course illustrated the challenges of bringing hands-on mathematics to a captive audience. It is important to note that there was no difference between courses where math was primary and those where another discipline was primary in terms of achieving the course math content goals.

Among student characteristics that influence outcomes it is noteworthy that gender and age had no discernable effect—and that ethnicity did. Latino students (especially when paired with Latino instructors) posted the strongest gains and white students (in almost all circumstances) performed significantly less well than others. It is not clear whether these findings reflect motivational or preparation differences among different student groups or whether there are cultural circumstances that make the inquiry-based, student-centered MAC^3 approach a better fit with certain students than others. Whatever the reason, it is important to know that while MAC^3 courses were successful with all students, they were particularly successful with women and non-white students, groups that have been under-represented in math and the SMET disciplines.

MATHEMATICS ACROSS THE COMMUNITY COLLEGE SURVEY

This course is part of a project funded by the National Science Foundation to measure the impact of different instructional approaches. Please answer honestly and thoughtfully and remember, there are no right or wrong answers. Your responses are very important to the research and will be treated with great respect and confidentiality.

Please circle the number that best describes your position on the scale where 1= "strongly DISAGREE" and 5 = "strongly AGREE." THANK YOU.

Please fill in the last 5 digits of your Student Identification Number ☐☐☐☐☐

(This information enables us to match surveys from the beginning and end of the course. it does not enable us to identify you.)

	Strongly Disagree				Strongly Agree
1. Many things I use every day were designed using math.	1	2	3	4	5
2. I am good at math.	1	2	3	4	5
3. If one way of solving a problem doesn't work, I try another method.	1	2	3	4	5
4. Sometimes I see things outside of school that make me think of math..	1	2	3	4	5
5. Mathematics is facts, rules, and formulas to be memorized.	1	2	3	4	5
6. Doing math in another subject makes the other subject easier to learn.	1	2	3	4	5
7. If I can't get the idea of a problem right away, I probably can't get it.	1	2	3	4	5
8. I don't need a good understanding of math to achieve my career goals.	1	2	3	4	5
9. I enjoy doing mathematics.	1	2	3	4	5
10. Estimating is a part of doing mathematics.	1	2	3	4	5
11. I rarely use math outside of school	1	2	3	4	5
12. Doing math in another subject makes the math easier to learn.	1	2	3	4	5
13. I want to learn more math.	1	2	3	4	5
14. I am comfortable talking about mathematics.	1	2	3	4	5
15. Sometimes I think about math without meaning to.	1	2	3	4	5
16. Math problems can be done correctly in only one way.	1	2	3	4	5
17. Lots of things I do every day involve math.	1	2	3	4	5
18. I feel comfortable asking questions in my classes when I don't understand things about math.	1	2	3	4	5
19. I am going to study more math.	1	2	3	4	5
20. In mathematics I can be creative and discover things for myself.	1	2	3	4	5
21. After I've forgotten all the formulas, I'll still be able to use ideas I've learned .	1	2	3	4	5

APPENDIX 1 ***STUDENT LEARNING SELF-ASSESSMENT***

Course Name

College and Date

Instructions: Please circle the number on the scale that most closely describes your situation.

1. As a result of your work in this class, how well do you think you now **UNDERSTAND** each of the following?

	Not at all	Just a little	Some-what	A lot	A great deal	Learned elsewhere
•	1	2	3	4	5	0
•	1	2	3	4	5	0
•	1	2	3	4	5	0
•	1	2	3	4	5	0

2. To what extent did you **MAKE GAINS** in any of the following as a result of what you did in this class?

	Not at all	Just a little	Some-what	A lot	A great deal
• Understanding the relationships among concepts.	1	2	3	4	5
• Ability to think through a problem.	1	2	3	4	5
• Ability to solve problems.	1	2	3	4	5
• Ability to communicate mathematical ideas.	1	2	3	4	5
• Confidence in your ability to do mathematics	1	2	3	4	5
• Feeling comfortable with complex ideas.	1	2	3	4	5
• Enthusiasm for mathematics.	1	2	3	4	5

3. Please tell us your

SEX: _______ Male

_______ Female

AGE: _______

4. With which of the following groups do you self-identify?

_______ African American/Black

_______ Asian/Pacific Islander

_______ Latino/Hispanic

_______ Native American

_______ Caucasian/White

_______ Other

5. Please tell us the most important thing you learned in this class

Appendix 2. Pre-post student attitude survey means, Pre-post changes in the total population that are significant at the 95% confidence level are shaded yellow for desirable change and blue for undesirable change. Significant differences in individual MAC^3 courses are not indicated because small (and varying) class sizes render this data less useful. **Questions have been coded so that higher post-survey scores always indicate change in the desired direction.**

ITEM	Pre-survey mean ALL N = 850	Post-survey mean ALL N = 850	Change
1. Many things I use every day were designed using math.	3.93	4.02	.09
2. I am good at math.	3.22	3.37	.15
3. If one way of solving a problem doesn't work, I try another method.	3.98	4.00	.02
4. Sometimes I see things outside of school that make me think of math.	3.40	3.50	.10
5. Mathematics is facts, rules, and formulas to be memorized.	2.96	3.05	.09
6. Doing math in another subject makes the other subject easier to learn.	3.07	3.20	.13
7. If I can't get the idea of a problem right away, I probably can't get it.	3.50	3.32	-.18
8. I don't need a good understanding of math to achieve my career goals.	3.53	3.35	-.18
9. I enjoy doing mathematics.	2.97	3.11	.14
10. Estimating is a part of doing mathematics.	3.78	3.81	.03
11. I rarely use math outside of school	3.45	3.33	-.12
12. Doing math in another subject makes the math easier to learn.	3.25	3.35	.10
13. I want to learn more math.	3.31	3.31	.00
14. I am comfortable talking about mathematics.	3.21	3.25	.04
15. Sometimes I think about math without meaning to.	2.83	2.94	.11
16. Math problems can be done correctly in only one way.	3.65	3.37	-.28
17. Lots of things I do every day involve math.	3.49	3.51	.02
18. I feel comfortable asking questions in my classes when I don't understand things about math.	3.52	3.62	.10
19. I am going to study more math.	3.39	3.41	.02
20. In mathematics I can be creative and discover things for myself.	3.06	3.14	.08
21. After I've forgotten all the formulas, I'll still be able to use ideas I've learned .	3.38	3.50	.12

Appendix 3. Overall comparison of survey change index by student.[20]

FACTOR	STUDENT N	CHANGE INDEX	SIG.[21]
GENDER			.67
Male	294	.22	
Female	489	.26	
AGE GROUP			.94
18-22	512	.24	
23-29	161	.24	
>30	107	.28	
ETHNICITY			.00
African-American	59	.49	
Asian/Pacific Islander	59	.43	
Latino/Hispanic*	134	.55[D]	
Native American	18	.17	
White*	486	.09[U]	
Other	34	.37	

[20] "Sig." indicates statistical significance, likelihood that the expressions of each variable are alike (drawn from a homogeneous population). A significance value of less than .05 indicates that we can say at the 95% confidence level that there is a significant difference among the categories comprising that variable. Note, however, that when there are more than two categories, not all categories under the variable heading may be significantly different from each other. Those individual categories that are significantly different from each other are indicated by a superscript, red for those comprising the desirable end of the difference, blue for those comprising the undesirable end. Thus when the courses are divided according to "Interdisciplinary Pairs," we see that scores for students in "math + humanities" courses were significantly higher than scores for students in "math+ science," "social studies + math," "vocational studies + math" and "study/life skills + math." Scores for students in "math + vocational studies" were significantly higher than scores for students in "study/life skills + math," but they were not significantly better than scores for any other category. Also note that because the determination of statistical significance depends in part on sample size, large differences between small samples may not be significant, while somewhat smaller differences between larger populations are significant.

[21] Significance determined by t-test for independent variables for paired variables and by oneway ANOVA for categories of three or more variables.

ATTITUDE PRE-SCORE			.00
Combined pre-score => mean (72) *	400	$.37^{D}$	
Combined pre-score < mean (72) *	360	$.06^{U}$	
PRIMARY DISCIPLINE			.00
Math *	299	$.51^{D}$	
Non-math *	501	$.08^{U}$	
INTERDISCIPLINARY PAIRING [Primary course + secondary course/applications][22]			.00
Math + science	111	.14	
Math + social science	10	.70	
Math + humanities*	117	$.65^{D1}$	
Math + professional/vocational studies	0	0	
Math + study/life skills*	42	$.45^{D2}$	
Science + math	136	$.43^{D3}$	
Social science + math	69	.15	
Humanities + math	29	.43	
Professional/vocational studies + math*	108	$.03^{U1, U3}$	
Study/life skills + math*	154	$-.18^{U1, U2, U3}$	
MATH-SCIENCE PAIRING			.28
Pairing includes science	277	.27	
Pairing does not include science	494	.18	
INSTRUCTIONAL FORMAT			.00
Learning community/linked course*	170	$.57^{D}$	
Interdisciplinary applications >25% of course*	110	$.03^{U}$	
Interdisciplinary applications <25% of course*	466	$.09^{U}$	

[22] Wherever a full math course is involved (e.g., in a learning community format or a linked course format) the math course was treated as the primary course. Thus instances where math is the primary course include learning communities, linked courses and single courses with non-math applications. All cases where a non-math course is primary are single courses with math applications.

CLASSROOM COLLABORATION			.17
Taught alone	391	.28[D]	
Collaborator present for occasional class	221	.04[U]	
Collaborator present for most classes	133	.10	

Appendix 4. Overall comparison of change index by course ranking[23]

FACTOR	PERCENT IN TOP 18 COURSES N = 200	PERCENT IN MIDDLE 17 COURSES N = 273	PERCENT IN LOW 17 COURSES N = 349	PERCENT IN TOTAL STUDENT POPULA-TION	TOTAL NUMBER OF STU-DENTS	SIG.[24]
GENDER						.80
Male	35.9	37.7	38.8	37.7	300	
Female	64.1	62.3	61.2	62.3	495	
AGE GROUP						.68
18-22	67.9	67.5	63.1	65.7	520	
23-29	18.4	19.4	23.1	20.7	164	
>30	13.7	13.1	13.8	13.5	107	
ETHNICITY						.00
African-American	11.5	6.8	5.9	7.5	60	
Asian/Pacific Islander	5.8	8.3	7.6	7.4	59	
Latino/ Hispanic	22.0	27.2	6.2	16.9	135	
Native American	2.1	1.9	2.6	2.3	18	
White	56.0	49.1	74.5	61.6	491	
Other	2.6	6.8	3.2	4.3	34	

[23] This table shows how each variable is distributed across the three categories of courses—the TOP, MIDDLE and LOW scoring. A chi-square statistic of less than .05 indicates that the distribution is heterogeneous, that is, the variable is distributed differently in the three groups.
[24] Significance determined using X^2 statistic.

FACTOR	PERCENT IN TOP 18 COURSES N = 200	PERCENT IN MIDDLE 17 COURSES N = 273	PERCENT IN LOW 17 COURSES N = 349	PERCENT IN TOTAL STUDENT POPULA-TION	TOTAL NUMBER OF STU-DENTS	SIG.[25]
ATTITUDE PRE-SCORE						.06
Combined pre-score =>72	54.3	56.6	47.3	52.0	407	
Combined pre-score <72	45.7	43.4	52.7	48.0	375	
PRIMARY COURSE						.00
Math	64.5	48.0	14.6	37.8	311	
Non-math	35.5	62.0	85.4	62.2	511	
INTERDISCIPLINARY PAIRING [Primary course + secondary course/applications][26]						.00
Math + science	24.7	8.8	14.6	14.8	117	
Math + social science	5.9			1.3	10	
Math + humanities	27.6	14.7	8.6	14.8	117	
Math + vocational studies						
Math + study/life skills		15.4		5.3	42	
Science + math	37.6	18.3	6.9	17.4	138	
Social science + math		19.0	4.9	8.7	69	

[25] Significance determined using X^2 statistic.

[26] Wherever a full math course is involved (e.g., in a learning community format or a linked course format) the math course was treated as the primary course. Thus instances where math is the primary course include learning communities, linked courses and single courses with non-math applications. All cases where a non-math course is primary are single courses with math applications.

FACTOR	PERCENT IN TOP 18 COURSES N = 200	PERCENT IN MIDDLE 17 COURSES N = 273	PERCENT IN LOW 17 COURSES N = 349	PERCENT IN TOTAL STUDENT POPULA-TION	TOTAL NUMBER OF STU-DENTS	SIG.[27]
INTERDISCIPLINARY PAIRING (continued) [Primary course + secondary course/applications][28]						.00
Humanities + math	4.1	4.8	3.4	4.0	32	
Vocational studies + math		4.0	28.7	14.0	111	
Study/life skills + math		15.0	33.0	19.7	156	
MATH-SCIENCE PAIRING						.00
Pairing includes science	62.4	27.1	30.1	36.0	285	
Pairing does not include science	37.6	72.9	69.9	64.0	507	
INSTRUCTIONAL FORMAT						.00
Learning community/linked course	44.3	25.8	11.5	23.1	177	
Interdisciplinary applications >25% of course	13.9	16.2	14.6	15.0	115	
Interdisciplinary	41.8	58.1	73.9	61.9	475	

[27] Significance determined using X^2 statistic.

[28] Wherever a full math course is involved (e.g., in a learning community format or a linked course format) the math course was treated as the primary course. Thus instances where math is the primary course include learning communities, linked courses and single courses with non-math applications. All cases where a non-math course is primary are single courses with math applications.

applications <25% of course						
CLASS-ROOM COLLABOR-ATION						.00
Taught alone	52.2	71.2	39.0	53.6	403	
Collabora-tor present for occasional class	31.8	10.8	43.0	29.8	228	
Collabora-tor present for most classes	15.9	18.1	18.1	17.6	135	

Change Index by Course Ranking and Disciplinary Pairing

INTERDIS-CIPLINARY PAIRS [Primary course + secondary course/applications][29]	TOP 18 COURSES N = 167	MIDDLE 17 COURSES N = 267	LOWER 17 COURSES N = 337	TOTAL STUDENT POPULA-TION N = 771
Math + science	.87	.38	-.62	.14
Math + social science	.70			.70
Math + humanities	1.24	.42	.-.01	.65
Math + vocational studies				
Math + study/life skills		.45		.45
Science + math	.89	.25	-.35	.43
Social science + math		.23	-.08	.15
Humanities + math	.74	.55	.01	.43
Vocational studies + math		.57	-.32	-.03
Study/life skills + math		.18	-.32	-.18
TOTAL	.96	.33	-.25	.21

Comparison of factors with and without required all-school course

CONSTRUCT	ALL STU-DENTS PRE N = 850	ALL STU-DENTS POST N = 850	ALL STU-DENTS CHANGE	W/OUT SCHOOL -WIDE REQUIR-ED COURSE [30] PRE N = 714	W/OUT SCHOOL -WIDE REQUIR-ED COURSE POST N = 714	W/OUT SCHOOL -WIDE REQUIR-ED COURSE CHANGE
LIKE	3.26	3.34	.08	3.29	3.40	.10
AWARENESS	3.41	3.49	.08	3.44	3.54	,10
CONCEPT	3.65	3.53	-.12	3.74	3.68	-.06
INTERDISC'Y	3.16	3.27	.11	3.20	3.36	.16

[29] Wherever a full math course is involved (e.g., in a learning community format or a linked course format) the math course was treated as the primary course. Thus instances where math is the primary course include learning communities, linked courses and single courses with non-math applications. All cases where a non-math course is primary are single courses with math applications.

[30] This course is required for graduation for all students matriculated at the school. The median course size is 16, the mean 22.