A RE-EXAMINATION OF RETAINED MATHEMATICS SKILLS AMONG BUSINESS STATISTICS STUDENTS

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ABSTRACT

This paper reports some of the findings from the follow-up of an assessment of basic mathematic skills among business students. The apparent lack of retention of material from arithmetic and elementary algebra is still of concern, even though recommended prerequisites were increased.

BACKGROUND

Weak quantitative reasoning skills have been of concern for many years. In 1999, the Moser Report in the United Kingdom [13] stated that one-third of adults cannot calculate 21 x 14 even with the aid of an electronic calculator. This problem affects not only the general adult population as "almost all jobs require at least some understanding of basic mathematics [21]"; it is having serious impact of tertiary studies in many fields. Standing [22] gave undergraduates a test consisting of 10 simple items taken directly from a third-grade curriculum in 1932; the hardest test item, 92 x 34, had a 32% error rate. Hunt and Lawson [12] found a significant decline in the mathematical skills of undergraduate engineering students as early as the mid 1990's. More recently, Robert Mann has found that current college students are stronger when compared with those of a decade ago at grasping mathematical concepts but weaker at applying them, a possible consequence of the National Council of Teachers of Mathematics (NCTM) reform shifting math pedagogy to emphasize conceptual thinking rather than computation skills [14]. These poor skills have beein implicated as a contributing factor in the loss of academic standing among undergraduate students [8]. Noser, Tanner and Shah [17] noted that deficiencies in fundamental skill areas had serious negative impacts on effective university level teaching and hindered students' ability to succeed. They furthermore commented that "when it comes to basic math skills for college students, deficiencies remain." Sherry Mantyka found that students struggling with basic numerical facts and processes were disadvantaged when faced with more complex math problems [14]. Sutherland and Pozzl [23] found that even the most mathematically able students were having difficulty with routine calculations. Boise State University found that discouragement due to poor math performance was an important factor in freshmen dropping out [20]. A number of reasons have been suggested for poor performance in business statistics classes, including anxiety [18], inadequate math preparation before matriculation [15, 24], and inadequate math prerequisites [10]. Armstrong and Croft [1] recommended that universities may need to make adaptations to their courses to counter the apparent shortfall in basic math skills. Standing [22] suggests that "the major cause of the observed deficit is that the teaching and practice of basic arithmetic skills in North American school and university systems has declined greatly in the last seven decades: no other interpretation appears plausible." Faculty at the University of Washington indicated in a public statement in 2008 that the declining level of math competency had forced a reduction in the math level of couses in science and engineering over a ten year period [4]. Is reducing the level of content in our discipline-based courses a reasonable adaptation to counter this shortfall?

The ongoing assessment reported in this paper began in 2003 as an attempt to isolate which basic math skills were not being retained by current undergraduate business students. As all of the courses being assessed required clearance of the university mathematics proficiency requirement prior to enrollment, only material at or below this level was included [3]. Arithmetic and elementary algebra were especially emphasized as they are considered basic skills for entry-level undergraduate students [6, 9]. After the first assessment was performed and evaluated, the prereqs were changed slightly to recommend a higher course (finite math or higher), while still allowing the same minimal level (math reasoning). This second assessment was done to examine the efficacy of that change

All students enrolled in the one of the basic business statistics courses at either the main residential campus or the downtown commuter campus at Eastern Washington University were given the same anonymous assessment at the beginning of the first class meeting either in January of 2004 or in September of 2010. These five courses were:

A. First quarter statistics at the main campus
    a. Winter 2004 – 70 undergraduates with a mean age of 23.8
    b. Fall 2010 – 59 undergraduates with a mean age of 21.9, 38.5% recommended prereq or higher
B. Second quarter statistics at the main campus
    a. Winter 2004 – 56 undergraduates with a mean age of 23.3
    b. Fall 2010 – 61 undergraduates with a mean age of 22.5, 61.7% with recommended prereq or higher
C. First quarter statistics at the downtown campus
    a. Winter 2004 – 52 undergraduates with a mean age of 26.5
    b. Fall 2010 – 38 undergraduates with a mean age of 24.6, 43.6% with recommended prereq or higher
D. Second quarter statistics at the downtown campus
    a. Winter 2004 – 60 undergraduates with a mean age of 27.4
    b. Fall 2010 – 49 undergraduates with a mean age of 24.9, 54.2% with recommended prereq or higher
E. PreMBA statistics at the downtown campus
    a. Winter 2004 – 23 post-bachelors students with a mean age of 31.8
    b. Fall 2010 – 15 post-bachelors students with a mean age of 31.8, 71.4% with recommended prereq or higher

Calculators were allowed and the time for completion was 30 minutes. As the initial purpose of this assessment was to determine which basic mathematical skills were not being retained, the students were not informed in advance to prevent review and preparation.

The actual assessment items, along with the proportion of students by quarter and by course who were unable to correctly respond, are found at the beginning of the discussion. Equivalent answers, such as -22/3 for -7.333…, were accepted as correct. Although, questions designed to isolate pertinent mathematical misconceptions [2] were considered for the reassessment, changes to the instrument were not made as comparability was determined to be of utmost importance.

For those assessed in Winter 2004, mean ages for each course were obtained for the entire class roster through the student information system at a later date. Age, time and level of last math class, and self-rated math skill were added to the Fall 2010 assessment to examine some issues noted previously in more detail.

DISCUSSION

The instrument and results are in table 1 below and on the next page. A graph of the proportion that missing each particular question for all students by quarter assessed is in figure 1. The bar on the left in each pair is for the more recent assessment. The significantly sharp significant changes noted between the bars for questions 2 through 5 is of particular concern.

Directions for 1 through 11 – Solve for y		Proportion of students answering incorrectly in Winter 2004 Proportion of students answering incorrectly in Fall 2010 (P-value for test of H_1: F2010 > W2004)*					
Problems	Answers	Overall	Course A	Course B	Course C	Course D	Course E
1. $y = 1 + 2 \times 3$	7	0.1533 0.1471 (0.625)	0.1000 0.1333 (0.374)	0.0357 0.1538 **(0.028)**	0.2115 0.1591 (0.820)	0.1500 0.1321 (0.705)	0.4783 0.1880 (0.988)
2. $y = -5 \times \frac{4}{6} - \frac{6+10}{3+1}$	-7.333…	0.4444 0.6092 **(<0.0005)**	0.4286 0.6500 **(0.009)**	0.3571 0.4923 (0.094)	0.4423 0.7500 **(0.002)**	0.4333 0.6226 **(0.034)**	0.7391 0.5000 (0.969)
3. $y = (3 \times 10^{-3})(4 \times 10^{5})$	1200	0.3678 0.5042 **(0.001)**	0.3143 0.6333 **(<0.0005)**	0.1964 0.3077 (0.117)	0.4423 0.6136 (0.071)	0.4000 0.5094 (0.164)	0.6957 0.5000 (0.942)
4. $y = 3(-4m^2 + 7) - (5m^2 - 6)$	$-17m^2+27$	0.5211 0.6092 **(0.029)**	0.5714 0.6167 (0.366)	0.2857 0.5846 **(0.001)**	0.5385 0.6818 (0.111)	0.5833 0.4906 (0.880)	0.7391 0.8750 (0.269)
5. $4y - (y-2) = 7 - 2(3y-4)$	13/9	0.5172 0.6050 **(0.030)**	0.6143 0.6500 (0.406)	0.4643 0.5846 (0.127)	0.3846 0.6136 **(0.021)**	0.5000 0.5283 (0.456)	0.6957 0.7500 (0.500)
6. $z = \frac{1}{2}(x + y)$	2z-x	0.6552 0.6134 (0.855)	0.7000 0.7500 (0.331)	0.5357 0.5692 (0.426)	0.6538 0.6364 (0.653)	0.6500 0.4906 (0.972)	0.8261 0.6250 (0.963)
7. $\frac{8}{y-2} - \frac{13}{2} = \frac{3}{2y-4}$	3	0.8812 0.8866 (0.482)	0.8286 0.9500 **(0.027)**	0.8571 0.8308 (0.740)	0.9423 0.8636 (0.953)	0.9167 0.8868 (0.803)	0.8696 0.9375 (0.452)
8. $15 - \frac{2}{3}y > -5$	y < 30	0.7280 0.7479 (0.344)	0.7000 0.7167 (0.495)	0.6607 0.6923 (0.430)	0.7308 0.7273 (0.607)	0.8167 0.8113 (0.624)	0.7391 0.9375 (0.121)
9. $\lvert 2y-5 \rvert < 7$	-1 < y < 6	0.9234 0.9538 (0.111)	0.9286 0.9833 (0.144)	0.9286 0.9077 (0.770)	0.9231 0.9318 (0.593)	0.9167 0.9811 (0.134)	0.9130 1.0000 (0.341)
10. $2\sqrt{y-8} = -3$	none	0.9732 0.9706 (0.673)	0.9571 0.9833 (0.370)	0.9821 0.9538 (0.920)	0.9808 0.9773 (0.793)	0.9833 0.9623 (0.900)	0.9565 1.0000 (0.590)
11. $\begin{cases} 3x - 5y = 19 \\ 2x - 4y = 16 \end{cases}$	y = -5 (x = -2)	0.6667 0.7941 **(0.001)**	0.6143 0.8833 **(<0.0005)**	0.5536 0.6615 (0.152)	0.7308 0.9091 **(0.023)**	0.7167 0.7358 (0.494)	0.8261 0.8750 (0.522)
12. If you can travel 25 miles in 35 minutes, at what speed in miles per hour (correct to three decimal places) are you driving?	42.857 mph	0.6054 0.6008 (0.577)	0.5143 0.7000 **(0.024)**	0.5893 0.5385 (0.772)	0.6154 0.6818 (0.322)	0.6833 0.4906 (0.989)	0.6957 0.6250 (0.790)
13. If a recipe requires 2¼ cups of flour to make 36 cookies, how much flour is needed to make 60 cookies?	3¾ cups	0.3831 0.3697 (0.656)	0.3000 0.4667 **(0.038)**	0.4107 0.2769 (0.959)	0.4423 0.3636 (0.839)	0.4000 0.3962 (0.592)	0.3913 0.3130 (0.800)

Problems	Answers	Overall	Course A	Course B	Course C	Course D	Course E
14. Sue bought a coat on sale at 15% off the regular price and paid $71.40 for it. What was the regular price of the coat?	$84	0.5594 0.5672 (0.466)	0.5571 0.6667 (0.137)	0.4821 0.4615 (0.659)	0.6346 0.5909 (0.742)	0.5667 0.5472 (0.655)	0.5652 0.6250 (0.485)
15. Catherine works two part time jobs: one pays $7 per hour and the other pays $10 per hour. Last week, she worked a total of 32 hours and made a total of $278. How many hours did she work at each job?	14 hr @ $7/hr 18 hr @ $10/hr	0.5326 0.4958 (0.819)	0.4714 0.5667 (0.182)	0.4464 0.4462 (0.574)	0.6346 0.5000 (0.938)	0.6167 0.4151 (0.990)	0.4783 0.6880 (0.167)
MEAN NUMBER INCORRECT (MEAN ERROR SCORE)	Maximum 15	8.912 9.475 **(0.025)**	8.600 10.350 **(<0.0005)**	7.786 8.462 (0.111)	9.308 10.000 (0.146)	9.333 9.000 (0.705)	10.609 10.438 (0.565)

Table 1: The assessment instrument and composite results

* Proportions tested using Fisher's Exact Test; means tested using Unpooled two-sample t-tests

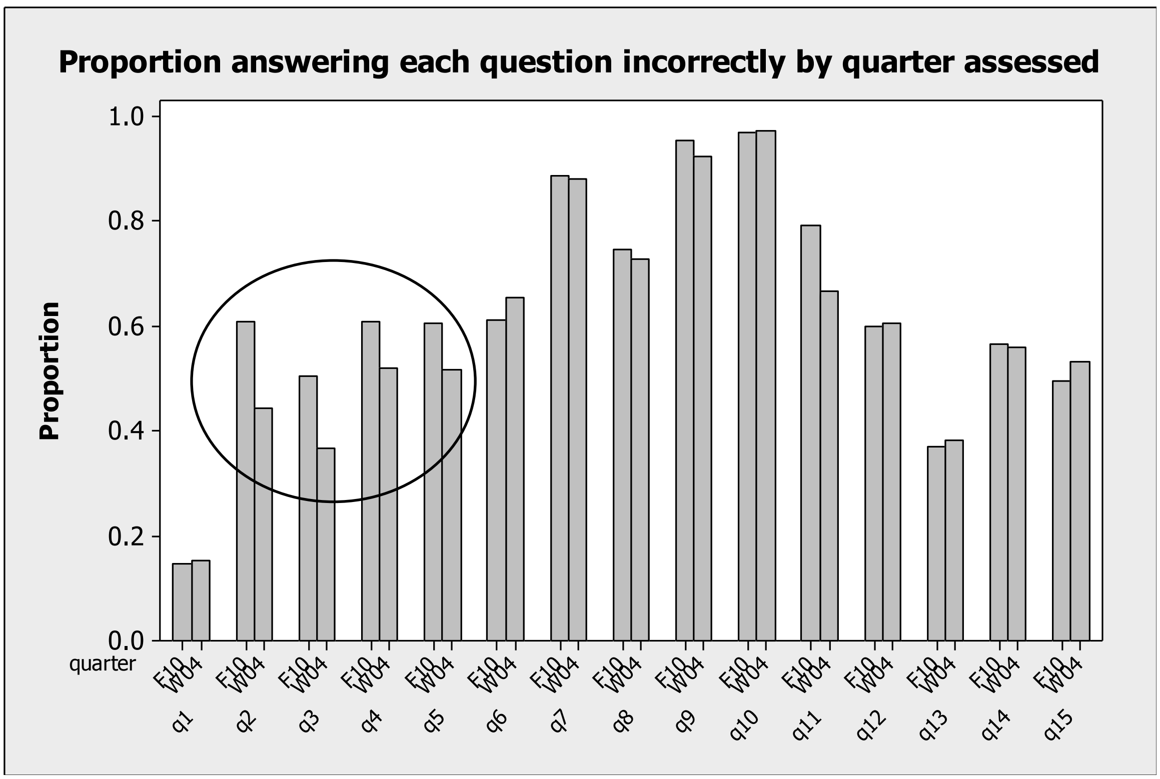

Figure 1: Proportion answering each question incorrectly by quarter assessed

(Note: The recent assessment is the bar on the left in each pair)

A similar proportion (about 15%) of students on the second assessment was unable to handle the simplest of order of operations in question 1. As about 15% <u>more</u> were in trouble mathematically by question 2 during the second assessment as noted in figure 2, it appears that the proportion of students reluctant to multiply fractions [16] has increased. The significant increase in inablity to do more advanced arithmetic and basic algebra in questions 3 through 5 is quite alarming as it indicates that math skills have slipped even among our weaker college students during the last six years.

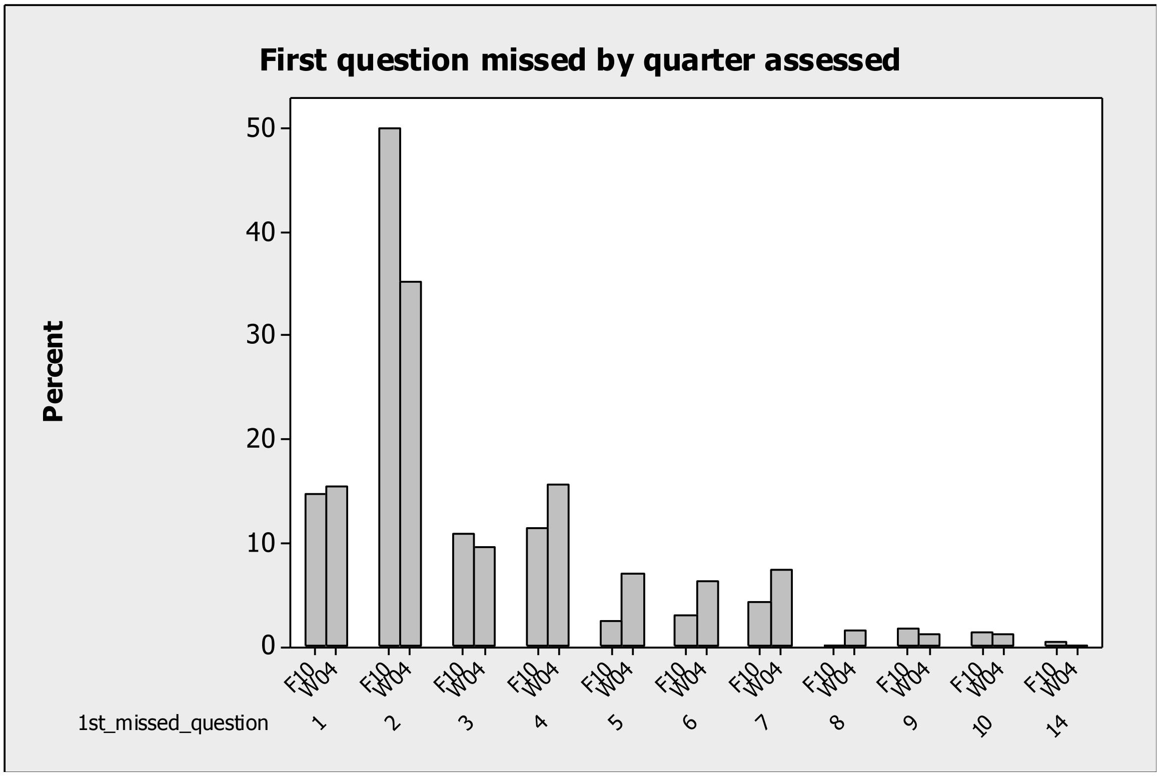

Figure 2: First missed question by quarter assessed
(Note: The recent assessment is the bar on the left in each pair)

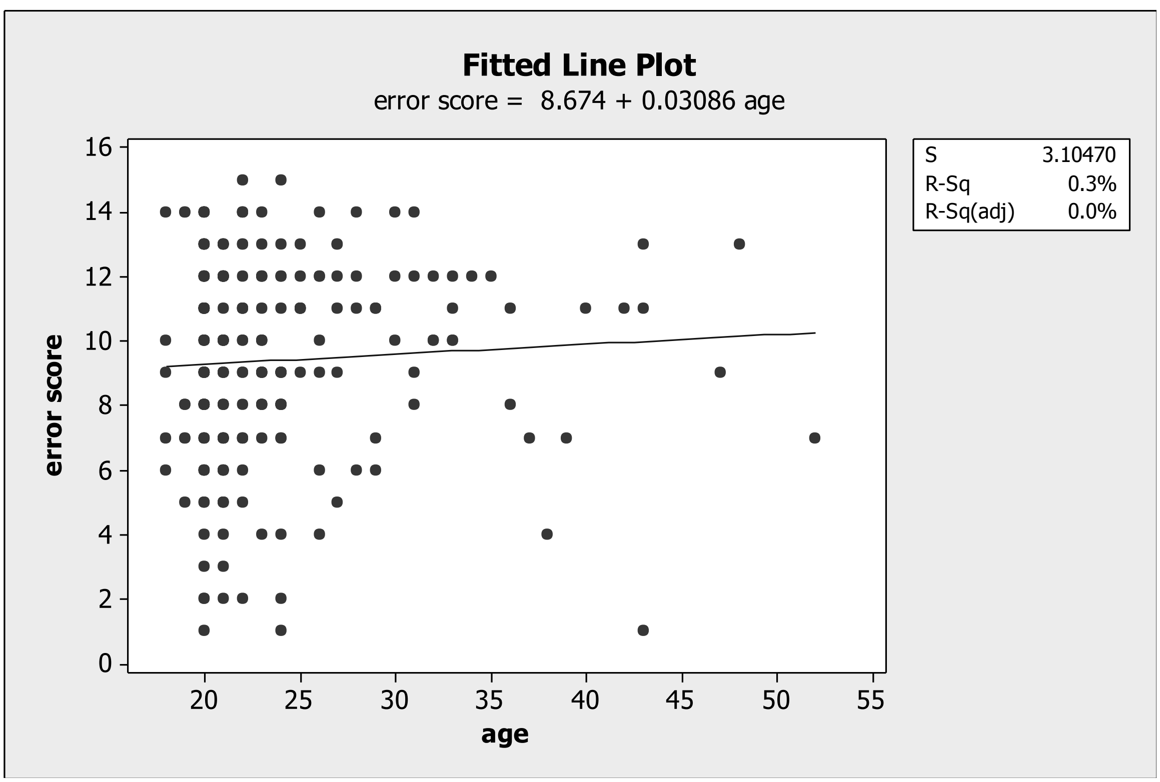

Figure 3: No significant relationship seen between number incorrect (error score) and self-reported age
(Note: These are Fall 2010 results only as age data was only available in aggregate for Winter 2004

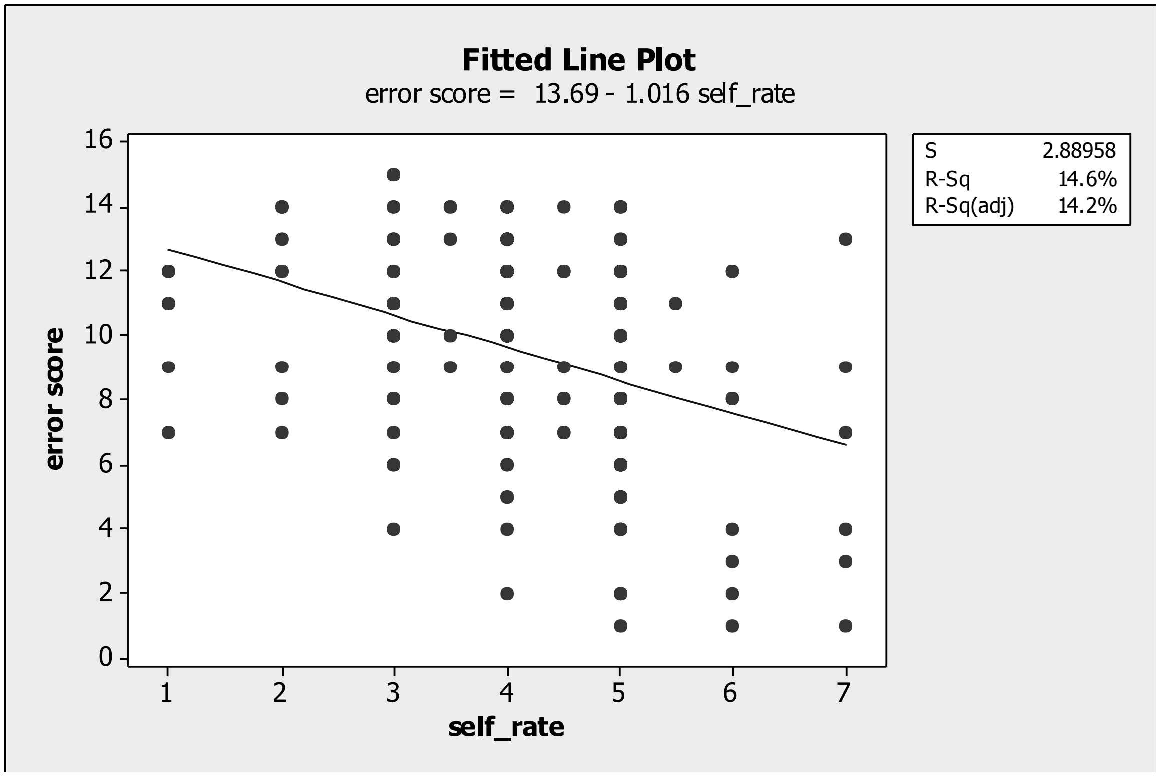

Figure 4: A significant relationship seen between error score and self-reported math ability
(Note: These are Fall 2010 results only as age data was only available in aggregate for Winter 2004)

The older returning post-bachelors students performed worse than the undergraduate students on the basic material (questions 1 through 5) during the first assessment; this difference was not noted during the second run. As the proportion unable to answer correctly increased as the mean age of the class increased during the first assessment, students were asked to self-report age during the second assessment. An error score for each student was calculated as the number of questions missed and these scores were then regressed against age as seen in figure 3 on the previous page. The result was not significant ($p = 0.392$), suggesting that the loss of retained math skills with age is not a viable hypothesis.

As mathematical notation past simple order of operations was beyond most students during the second assessment, the repeat of the poor performance previously seen on questions 6 through 11 was not surprising. The fact that the proportion unable to correctly answer these questions did not generally increase suggests that the student population is becoming more segmented with respect to math skills rather than an overall decrease in math skills is occuring. The proportion of “good” students is stable; the marginal students are slipping into “bad”.

Armstrong and Croft [1] indicated that even although many students do not believe they need considerable help, they also lack basic ability and knowledge in mathematics. With this in mind, students were asked to self-assess their math skills using a 7-point Likert scale during the second assessment. The results are in figure 4 above. A significant ($p<0.0005$) reduction in error score occurred as students rated their ability higher. This suggests that students are generally aware when they need help. However, it is worth noting the wide range of error scores among those rating themselves highest. This suggests that self-rating is not always sufficient in itself for identifying those individuals likely to struggle in quantitatively oriented courses.

Students still struggled with applying ratios as about one-third still could not answer the cooking problem correctly and more than half were unable to answer the unit change and discount problems correctly. As most college students in remedial math courses have the misconception that multiplication is used for computing increases and subtraction is used for computing decreases [16], these results suggest that the slightly increased prereq did not overcome this mathematical misconception. This substantiates the idea that students who overcome a mathematical misconception will often return to it shortly after the end of ordinary instruction [7].

Ratcliff and Yaeger [19] noted that quantitative reasoning is not developed only mathematics classes. This seemed to be supported by the fact that context was important for the older returning post-bachelors students during the first assessment; however this effect also seems to be lessening. The dramatic difference in the proportion of students unable to answer the simultaneous equation problems (questions 11 and 15) correctly in course E during the first assessment approximately halved during the second assessment. This suggests that there may have been a cohort for which reasoning skills were intact but the formal notation was lost. These students appear to be moving out of tertiary education, hence the shift seen.

For both assessments, all of the students in the courses studied had the material on the assessment instrument as a prerequisite to enrollment. The failure of many to retain it was suspected to be due to the very minimal prereq used at that time. While there were factors preventing raising it absolutely, it was possible to introduce a strong recommendation for a higher level course. During the second assessment, students were asked to indicate the level of their last math course. While the error score reduced for those clearing the recommended rather than the minimal prereq by a significant 0.779 questions ($p=0.017$), this is realistically only a minimal improvement. This suggests that further effort is needed to help our mathematically weaker students. The question is whether simply increasing the prereq in line with Green et. al.'s need for more extensive prerequisite math course sequences as preparation for statistics courses [11] will be enough.

CONCLUSION

There is national recognition of this dilemma. Deficits in American students' learning of math may be compounded by discrepancies between high stakes secondary math tests and college standards for mathematics success [5, 25]. Educational policy makers are focusing increasingly on aligning college readiness with high school math assessments, on communicating to high school students that success in college depends not only on gaining access to college but also on bringing to the college experience the requisite knowledge to succeed in university level courses, and on ensuring that educators at the secondary and tertiary levels work together to address these deficits from both ends [26].

The minimal intervention taken after the first assessment was insufficient to compensate for continuing loss of math skills among these business students. A stronger response is needed to prevent a reduction of the math content in quantitative business courses. The discussion of possible corrective measures is ongoing as of this writing and will form the core of this presentation at WDSI 2011.

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