Motivation, Instruction, and Support of the Inadequately Prepared: Results from the 2012 SERU Math Module

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STEM completion is a major problem for virtually all U.S. four-year colleges and universities. Failure rates of 25% in introductory calculus courses (i.e. D, F, and NC grades) have been estimated for research universities (Bressoud, Carlson, Mesa, & Rasmussen 2012), and even pre-calculus courses generate large numbers of failing grades.[1] Students who are unable to master these introductory college mathematics courses face disappointment, unexpected changes in major plans, slow academic progress, and frequently enough become retention casualties. Nationally, STEM mastery and completion is a major national priority due to the perceived shortage of key personnel for national economic development. For students graduation in STEM fields leads to higher average pay and more secure employment than graduation from other majors (see Carnevale, Strohl, & Melton 2011).

Federal and state governments and individual donors have spent billions on programs to improve STEM mastery and completion, with some noteworthy successes at individual campuses (see, e.g., Maton, Sto. Domingo, Stolle-McAllister, Zimmerman, & Hrabowski 2009). However, a 2010 report of the President's Council of Advisers on Science and Technology (PCAST) concluded, "Over the past few decades, a diversity of Federal projects and approaches to K-12 STEM education across multiple agencies appears to have emerged largely without a coherent vision and without careful oversight of goals and outcomes and with limited overall impact" (PCAST 2010).

Some have suggested that calculus itself is the problem, and many experiments now exist to teach life sciences from algebra- or statistics-based mathematical foundations (Strother, van

Campen & Grunow 2013). For the time being, however, pre-calculus and calculus remain gateways into STEM careers in most colleges and universities.

Researchers have identified the following possible reasons for the difficulties science-oriented undergraduate students have in mastering college mathematics: (1) inadequate prior preparation, (2) unreliable placements, (3) low student motivation and effort, (4) weak confidence levels, (5) poor instructional practices, and (6) inadequate or inadequately utilized academic support services (Brint 2009).[2]

DATA AND METHODS

The SERU Consortium has developed a math module to allow researchers to investigate sources of mathematics difficulties on member campuses. This paper reports results from the three campuses that included the math module in the 2012 administration of the SERU Survey. These campuses are: Rutgers University, the University of California, Riverside (Riverside), and the University of Pittsburgh (Pitt). Altogether more than 2,000 students completed the math module; 1193 at Riverside, 557 at Rutgers, and 312 at Pitt. Some questions asked to Riverside and Rutgers students were left off the Pitt version of the module.

Our paper examines each of the main reasons that have been offered for student difficulties in mastering and completing gateway college math courses. We pay special attention to students who characterized their mathematics preparation as inadequate. To identify students who said they were inadequately prepared, we combine three variables: (1) students who reported that their high school math courses prepared them "not at all" or "not very well" for college mathematics; (2) students who reported that their community college math courses prepared them "not at all" or "not very well" for college mathematics; and (3) students who reported that mathematics at previous colleges prepared them "not at all" or "not very well" for

college mathematics at their current campus. The latter constituted only 10 percent of the students who said that their prior mathematics preparation was inadequate.

We compare campuses, where appropriate, both to show meaningful differences and as a way to help campuses identify specific issues that may be worthwhile to address. We also conduct a logistic regression to compare the influence of campus, social background, academic qualifications, and major disciplinary category on students who said they were inadequately prepared to succeed in college math.

Preparation

More than one-quarter of responding students said they were inadequately prepared to succeed in college mathematics. The SERU data show high levels of campus variation: Rutgers students were most likely to say they were inadequately prepared (30%), followed by Riverside students (27%). Pitt students were much less likely to say they were inadequately prepared (15%). The better preparation of Pitt students is a continuing theme in these analyses and will be discussed further below.

Among students who reported inadequate preparation, no single cause emerged as important across the campuses. Students on all three campuses were relatively likely to cite low innate ability, inadequate effort, poor instruction, teachers who failed to insist on mastery, time wasted in class, and being surrounded by students who did not care about math as sources of their inadequate preparation for college math. In each case one-quarter or more of the students who said they were inadequately prepared for college math cited these factors.[3] Scheduling of math classes at bad times during the day and incomplete grading of homework were only infrequently cited as sources of inadequate preparation – less than 15% of the time on any of the campuses.

Placement

Initial math placement did not appear to be a major problem on these campuses. Fewer than 10 percent of responding students on all three campuses said they were placed above their proper level. Most reported that they were placed at their proper level. However, about one quarter of students at Riverside and Rutgers said they were placed below their proper level (compared to 16 percent at Pitt). Conservative placements are prudent – students frequently over-estimate their readiness.

Nevertheless, we wondered whether they could be de-motivating for some students. Students who said they were placed below their proper level were, however, not more likely to indicate low levels of motivation to succeed. Instead, they indicated slightly higher levels of motivation to succeed than other students. By contrast, students who said they were placed above their proper level were much less likely to say they were highly motivated to succeed (25% compared to 48% for those who said they were placed properly). Clearly the danger of placing above their proper level is greater. This suggests that placement test be well-designed to be accurate, with error on the side of conservative placements.

Motivation

The plurality of students on every campus said they were "highly motivated" to succeed in math. Fifty-three percent of Pitt students characterized their motivation as high compared to 47% of Riverside students and 44% of Rutgers students. Students who said that they were "not very" or "not at all" motivated were relatively uncommon on all campuses – fewer than 20 percent on all three campuses and just 14% at Pitt.

At the same time, students seemed to us confused about what should be counted as success in math. Only 16% of Riverside and Rutgers students said that mastery of material was

the only thing that should count in grading. The others who answered this question – more than 80 percent of respondents – said that both mastery and effort should count. From the perspective of an instructor who is trying to prepare students for higher level mathematics courses or for success in science courses that require math, these student responses will likely sound off-key.

Self-reported effort itself did not always track students' generally high levels of expressed motivation. More than two out of five Riverside and Rutgers students said although they believed that math mastery required two hours study out of class for every hour in class, they did not spend that amount of time on math study. Another 15 percent said they did not believe math mastery required two hours of study out of class for every hour in class and did not spend that amount of time on study. Indeed, nearly two-thirds of Rutgers students said they were not spending two hours out of class for every hour in class studying. More than one-third of the 600 Riverside students who characterized themselves as highly motivated to succeed said that although they believed two hours of study out of class for every hour in class was required for success, they were not spending this amount of time on study. Similarly, about one-third of the more than 430 Rutgers students who claimed to be highly motivated to succeed fell into the same category.

Confidence

The math module does not allow us to measure confidence directly. However, it does ask students to discuss whether they felt too intimidated by professors or teaching assistants to attend office hours and whether the competition from other students was too much for them. More than one-third of students on all three campuses said that the statement "I felt too intimidated by professors to attend office hours" was at least "somewhat descriptive" of their experiences. Fewer students said feeling intimidated by TAs was at least "somewhat descriptive" of their

experiences, but nevertheless approximately one-quarter of Riverside and Rutgers said the statement fit their experiences. About one-third of students at Riverside and Rutgers said that the statement "Competition from other students was too much for me" was at least "somewhat descriptive" of their experiences (compared to fewer than one-quarter of Pitt students).

Those who said that feeling too intimidated to attend professors' office hours was "somewhat descriptive" of their experience showed roughly similar levels of motivation as other students. However, those who said feeling too intimidated was "very descriptive" of their experience were less likely to say they were highly motivated (approximately 34% compared to 47% of all students who said they were "highly motivated"). These students were few in number. By contrast, the de-motivating effects of feeling too intimidated by teaching assistants to attend their office hours were evident even among those who said this was only "somewhat descriptive" of their experiences.[4]

A similar pattern held for students who said that competition from other students was "too much for them"; their motivation suffered. Thirty-six percent of students who said this feeling was "somewhat" or "very descriptive" of their experience said they were highly motivated to succeed compared to 47% of all students. These students were not few in number (about one-third of the sample). To be sure, every hierarchical system creates feelings of being overmatched among those who are less successful. This is particularly true of hierarchical systems that lead to relatively high level rewards in society. Although professors and teaching assistants can cultivate a friendly persona to reduce students' feelings of intimidation, it is highly questionable whether math teachers can or should do anything to reduce the competitive drive of students.

The effects of the confidence variables on effort (willingness to put in two hours of study out of class for every hour in class) were marginal, but in the expected direction. Lower levels of confidence, as measured by feelings of being too intimidated to attend office hours or of being overmatched by the competition of other students, led to only slightly higher proportions of students saying that although they recognized that two hours of study out of class for every hour in class was necessary, they were unwilling to spend this amount of time on math study.[5]

Instruction

Instruction also emerged as a potential problem at the two schools where high proportions of students said they felt inadequately prepared to succeed in college math. A relatively high proportion of students at Riverside (44%) and Rutgers (32%) said discussion sections were conducted as second lectures (compared to fewer than 20% at Pitt). Two out of five students on both campuses said students never solved problems at the board during section meetings. Moreover, half of Rutgers students and 40% of Riverside students said professors provided too little feedback on errors (compared to 30% at Pitt students). These findings may suggest the need for more active learning opportunities and more feedback from professors and teaching assistants on the specific errors students have made.

Academic Support Services

Students at Rutgers were much less likely than students at Riverside to know about the existence of the campus learning resources center. One-third did not know about its existence, compared to 17% at Riverside and 10% at Pitt. In addition, fewer of those who knew about the campus resources center had used its services at Rutgers as compared to the other two campuses. Although most who knew about it and had used it found its services helpful, this amounted to less than a quarter of the Rutgers sample compared to one-third of the Riverside sample. Most

students at Rutgers and Pitt also did not know whether supplemental instruction sections were available on campus. On these campuses fewer students had interacted with peer mentors, though most who had interacted with them found the experience to be helpful, as was true at Riverside.

This set of questions shows the value of SERU for identifying potential campus issues. These findings suggest that academic support services need to be better marketed to students on the Rutgers campus and, if budget permits, that supplemental instruction and peer mentoring could be candidates for augmentation both at Rutgers and Pitt.

Who Are the Inadequately Prepared Students?

We conducted a logistic regression to identify the characteristics of students who characterized themselves as inadequately prepared to succeed in college math. In each analysis we controlled for campus. In the first analysis we entered only campus and socio-demographic variables. The latter included: gender, race-ethnicity (African American, Asian-Asian American, Hispanic, and European American), and self-reported social class. In the second analysis we included these variables and entered academic background characteristics. These included: SAT Math score, SAT Verbal score, and cumulative grade point average. In the final analysis, we included these variables and added major disciplinary category (STEM, social sciences and humanities, and missing or undeclared).

In each analysis, Pitt students were significantly less likely to be found in the inadequately prepared group. Pitt students had higher high school grades, better SAT Math scores, and were more likely to have taken calculus in high school than students at the other two campuses. In a logistic regression using only campus and socio-demographic predictors, Hispanic students were significantly more likely to be found in the inadequately prepared group.

However, when we entered academic background characteristics into the equation, Hispanic students were no longer significantly more likely to be found in the inadequately prepared group. Instead, students with lower SAT Math scores and lower cumulative GPAs were significantly more likely to be found in this group. Pseudo R-square was .12 in this analysis. Disciplinary major categories were insignificant and added no additional explanatory power.

It is heartening to see that gender is no longer associated with students' perceptions of adequate or inadequate preparation. Other socio-demographic variables were at best marginal influences and clearly much less important than academic qualifications. The bottom line is that academic qualifications and successes are the best predictors of whether students feel prepared to succeed in college math and nothing else matters very much.

DISCUSSION

Clearly, the quickest route to admitting prepared students is to select on SAT Math, calculus experience, and high school GPA.[6] Once on campus, well-designed placement tests, friendly professors and TAs who encourage active learning and give timely feedback, as well as well-advertised and fully-staffed academic support service centers can help students and perhaps – we emphasize perhaps -- thereby raise their likelihood of success.

The findings point up the importance of training teaching assistants to develop a welcoming manner. TAs are the front line contacts for most students and close in age to undergraduate students but nevertheless about one in five respondents said that feelings of being too intimidated to attend their TA's office hours were at least "somewhat descriptive" of their experiences. This is a relatively quick fix through well-designed TA training and one that campuses should make.

The data also indicate that colleges can do a much better job of emphasizing that mastery is ultimately what counts in college math and that effort, while essential for success, is no substitute for mastery. They can also point out the contradiction between students who say they are highly motivated to succeed but are not willing to spend two hours studying outside of class for every hour in class, even though they recognize that this amount of effort is typically required to master college math.

Our final observation is that the SERU Math Module is not yet in a finished state. In future versions of the module, we would recommend that students be asked specifically about their grades in gateway college mathematics courses. Additional questions on instructional practices would also be helpful, particularly those that delve into active learning opportunities and the use of instructional technologies. A revised math module may also wish to ask students to identify the class that most helped them to understand mathematics and to describe in an open-ended question what it was about the instruction that they found particularly valuable.

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Notes

[1] Failure rates are higher in master's granting universities and community colleges, approximately 38% in both types of institutions (Bressoud et al. 2012).

[2] The research literature is mixed on whether it is better for students to study alone or study in groups, and we consequently do not list individual or group study as a principle focus for research on student success in college math. Recent work by Arum and Roksa (2011) has questioned the conventional wisdom (see Treisman 1992) that students perform better when they

study in groups. These authors have emphasized the distractions associated with group study and the possibility that students can be misled by those who know as little or less than they do. In the SERU math module sample, students at all three campuses tended more often to study alone than to study with fellow students. Less than one-third of students said they "often" or "always" studied in groups. At Riverside and Rutgers, those who felt inadequately prepared to succeed in college math were only marginally more likely to study in groups as compared to those who said they were adequately prepared. At Pitt, however, the relatively few students who said they were not adequately prepared to succeed tended to say they "never" studied with other students (43%). These students may feel isolated on a campus where most students say they feel adequately prepared. However, at Pitt even students who said they were adequately prepared were more likely to say they never studied in groups (30%).

[3] Of the Riverside and Pitt students who said they were inadequately prepared, more than 40% stated that they were simply not good at math, compared to 30% of Rutgers students. In addition, Riverside students were relatively likely to cite poor instruction (39%) and time wasted in math classes (36%) as reasons for their inadequate preparation compared to students at the other campuses. Rutgers students were more likely to cite the failure of their teachers to insist on mastery (38%).

[4] Similarly, feeling intimidated of teaching assistants depresses motivation and this depressed motivation shows up at Riverside even for those who say that such feelings were only "somewhat descriptive" of their experiences.

[5] However, feeling intimidated of TAs seemed to reduce willingness to put in two hours of out-of-class study for every hour of in-class study.

[6] It is important to note that we do not include high school grade point average in these analyses, because it was not available in our data files. However, based on extensive research on admissions, we can assume that high school grades are a good predictor of college readiness, including math readiness.