Student Engagement and Completion in Precalculus Precalculus Mega Section:

Efficiently Assisting Student Engagement and Completion with Communications and Information Technology

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Abstract

The Precalculus Mega Section project was developed with the main purpose of improving the overall performance of the student body in Precalculus, an important gatekeeper course that affects student engagement and completion, with typical drop/failure rates of over 50 percent. Strategies such as integration of technology and additional practice time with TA support, helped significantly reduce the withdraw and failure rates that prevail today in this course. Although it was carried out in a large group format (150 students), the experimental sections had better outcomes than current, traditional sections in smaller groups taking the same tests. Results show the design choices and underlying assumptions to be promising and cost-effective, and recommendations include testing the model as a substitute for current remedial coursework on campus and beyond.

Introduction

The University of Puerto Rico in Mayagüez is the second-largest and STEM flagship campus of the University of Puerto Rico system. The students in most of its majors have to take or test out of the introductory math course, Precalculus. Each semester, more than half of them fail to pass the course, either finishing with a D or an F, or withdrawing from the class altogether. In the fall of 2006, for example, a total of 1,298 students took the course, and 55.86 percent failed. These high failure rates represent a tremendous human, academic and administrative cost.

To date, before the intervention described in the present paper, high failure rates in this class have been addressed through remediation efforts formalized in a so-called "pre-basic," no-credit course that consumes a good amount of institutional time and resources. This remedial course aims at giving the students the content that, because of pre-college educational problems, they lack and need to successfully tackle entry level college mathematics. Remedial courses, however, have shown mixed results at UPRM (Bartolomei, 2006) and elsewhere (Armario, 2010;Redden, 2008.)

Because the budget situation in the public university translates into administrative demands for frugality, especially when advocating change, the idea behind the design and execution of the intervention described here was straightforward and relatively inexpensive. We wanted to design and implement a pilot, experimental section of the course that: 1) improved student learning and passing rates in the pre-calculus course, and 2) was cost-effective in terms of the allocation of institutional resources. To make the course cost-effective, we gave it a large lecture format. To make it more effective in promoting student learning and achievement, we implemented a set of technological supports, including the use of clicker technology in the classroom to provide instant feedback to the lecturer, and added an additional hour of TA-guided discussion and problem solving.

Research Design

Given the context and boundary conditions, the intervention had to engage students in the classroom, be gentle enough to prevent massive drops, be simple and cost-effective enough to be replicated if successful, and still provide tools to improve student learning. We wanted to test its impact relative to the other traditional sections. We also wanted to test whether such an intervention could have an effect on future learning, with the idea that the habits acquired in the section may carry over and increase the students' chances of sustaining success afterwards.

Because we were developing an intervention that, if effective, would hopefully turn into institutional policy, the design had to be amenable to comparison with other sections of the same course. The Academic Affairs Division on campus assigned a randomized, representative sample of incoming freshmen, stratified to include proportionate numbers of students per college (Arts, Sciences and Agriculture) and family income. To facilitate comparison, the students enrolled in this experimental course used the same textbook and syllabus and took the same departmental examinations (three midterms and one final) used for the traditional small-section course.

Regular, traditional sections had the following characteristics: 1) syllabus and content standards are centrally designed and were the same for all sections, 2) the most common section size is 30 students per classroom, although some large lectures are usually added to accommodate demand, and 3) there are a total of three contact hours per week.

Our pilot, experimental section had the following characteristics: 1) syllabus and content standards were the same as regular sections, 2) section size was 150 students, and this large-lecture format was reinforced with the use of technology (see below), 3) there was an additional hour of class per week, with groups averaging 25 students meeting with TA's to practice problem solving and study habits, and 4) departmental examinations (three midterms and one final) were the same as regular sections.

The technology to support lectures included lecture notes and problems projected for the students from the instructor's tablet computer. Notes were later uploaded to a course website for student use during individual study hours and also during the additional weekly hour with their TA's. In addition, each student was assigned a clicker. The clicker's role was to encourage student active participation, to prevent anonymity from dulling student engagement, and to provide feedback to the instructor about the students' level of understanding. It was also used to take attendance and so that students could interact with the instructor and obtain immediate feedback. The instructor could make use of this feedback in real time and alter the pace and content of the lecture as needed.

To incentivize engagement, an 8 percent bonus was offered for consistent participation with correct answers through clicker use. <u>This bonus, however, was not counted when tabulating grades for comparison with regular sections.</u> Congratulatory e-mails were sent to students who constantly provided right

Fall 2008-2009, Precalculus I

All		%	Others		%	Mega		%	Mega%-Others%
A	57	5.94	A	31	3.81	A	26	17.69	**13.87**
B	89	9.27	B	65	8.00	B	24	16.33	**8.33**
C	158	16.46	C	123	15.13	C	35	23.81	**8.68**
D	84	8.75	D	77	9.47	D	7	4.76	**-4.71**
F	311	32.40	F	287	35.30	F	24	16.33	-18.97
W	253	26.35	W	222	27.31	W	31	21.09	-6.22
Sub	952	99.17		805	99.02		147	100.00	
NR	8	0.83	NR	8	0.98	NR	0	0.00	-0.98
Total	960	100.00		813	100.00		147	100.00	

Table 1: Results for 2008-2009 Fall Semester

Spring 2008-2009, Precalculus I

All		%	Others		%	Mega		%	Mega%-Others%
A	42	3.63	A	37	3.67	A	5	3.33	**-0.34**
B	79	6.83	B	70	6.95	B	9	6.00	**-0.95**
C	217	18.76	C	179	17.78	C	38	25.33	**7.56**
D	86	7.43	D	75	7.45	D	11	7.33	**-0.11**
F	448	38.72	F	384	38.13	F	64	42.67	4.53
W	276	23.85	W	253	25.12	W	23	15.33	-9.79
Sub	1148	99.22		998	99.11		150	100.00	
NR	9	0.78	NR	9	0.89	NR	0	0.00	-0.89
Total	1157	100.00		1007	100.00		150	100.00	

Table 2: Results for 2008-2009 Spring Semester

Fall 2009-2010, Precalculus I

All		%	Others		%	Mega		%	Mega%-Others%
A	81	4.96	A	66	4.44	A	15	10.34	**5.91**
B	152	9.31	B	126	8.47	B	26	17.93	**9.46**
C	303	18.57	C	264	17.75	C	39	26.90	**9.14**
D	111	6.80	D	101	6.79	D	10	6.90	**0.10**
F	528	32.35	F	499	33.56	F	29	20.00	-13.56
W	457	28.00	W	431	28.98	W	26	17.93	-11.05
Total	1632	100		1487	100		145	100	

Table 3: Results for 2009-2010 Fall Semester

Spring 2009-2010, Precalculus II

All		%	Others		%	Mega		%	Mega%-Others%
A	63	6.90	A	44	5.76	A	19	12.75	**6.99**
B	98	10.73	B	70	9.16	B	28	18.79	**9.63**
C	283	31.00	C	231	30.24	C	52	34.90	**4.66**
D	88	9.64	D	73	9.55	D	15	10.07	**0.51**
F	269	29.46	F	243	31.81	F	26	17.45	-14.36
W	112	12.27	W	103	13.48	W	9	6.04	-7.44
Total	913	100		764	100.00		149	100.00	

Table 4: Results for 2009-2010 Spring Semester

responses in class, while those who consistently provided wrong answers received e-mails to alert them of their performance and suggest more practice of specific skills.

In addition, weekly electronic quizzes were required from the students, where the specific requirement was to pass (60 percent) every weekly quiz in order to gain access to the each partial exam. No points were awarded for the quizzes, passing them was required to take each partial exam; not passing one quiz resulted in automatically failing the corresponding partial exam.

Results of the Mega Section

This experimental Mega Section format was implemented for four consecutive semesters. During the first three, it was implemented in the Precalculus I course. The last semester it was implemented in the Precalculus II course. Only during the first semester were we able to obtain a randomized, stratified sample, but results were consistent throughout, as can be seen in the summaries (below and in Tables 1-4.) In all four semesters, the experimental section was significantly more effective ($p<0.05$) than the others when comparing grade distribution between all other sections (expected) and the Mega Section (observed) using a chi-squared test. Results were significant as well ($p<0.05$)comparing A, B or C (pass) vs. D, F, W (no pass), except for the second semester, where the significance level was 0.104. (see Tables 5-12.)

In the 2008-2009 fall semester, 960 total students took the course, 147 students were assigned, in a random sample, to the experimental section, and 26.18 percent more students passed the course in the Mega Section than in the traditional sections. Failure' includes drop (withdrawal) rates. This first Mega Section was a stratified, randomized sample taken from the incoming freshmen class, and all participating students were taking the course for the first time. This improvement in passing rates was not concentrated in the barely passing bracket, but well distributed among all grade brackets, that is, the experimental section helped all student levels. (See table 1)

In the 2008-2009 spring semester, 1,157 students took the course, and 150 students were assigned to a section replicating the format of the pilot. The instructor was the same and 6.15 percent more students passed the course than in the traditional sections. This section consisted mostly of people who were repeating the course after failing or withdrawing from it, and the students self-selected into the course, so we did not have a random sample. The diminished improvement in the passing rates suggests that although interventions should be designed to help students with a prior history of failing the course, this particular intervention is strongest when used in a student's first try. (see Table 2)

In the 2009-2010 fall semester, 1,632 students took the course, 145 students took the Mega Section, and 24.61 percent more students passed the course in the Mega Section than in the traditional sections. Although the students in this session were not randomly selected, most were first time takers, and this is evident from the impressive improvement in the passing rates. The instructor, again, remained the same. (see Table 3)

In the 2009-2010 spring semester, 913 students took the class, and the content was different, as the design was implemented in a Precalculus II course. One hundred forty-nine students signed up for the Mega Section and 21.80 percent more students passed the course

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The authors would like to thank Maira T. Rodríguez Pérez and Leonardo Vélez-Ramos at the Institutional Research Office at UPRM for her help in obtaining the data used here. The follow up was done using the three subsequent semesters, and monitoring math courses for those in the Mega Section vs other students who took Precalculus that semester. We also monitored subsequent performance for both groups in non-math courses.

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Building Engagement and Attainment for Minority Students (BEAMS) was a multi-year project, ending in 2008, which fostered data-driven campus change initiatives at the nation's minority-serving institutions (MSIs)—Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges and Universities—in order to increase student engagement and learning. BEAMS served more than 100 four-year MSIs.

	Others	Expected	Observed (MEGA)	CHITEST
A	31	5.66086957	26	6.88E-023
B	65	11.8695652	24	
C	123	22.4608696	35	
D	77	14.0608696	7	
F	287	52.4086957	24	
W	222	40.5391304	31	
Sub	805		147	
NR	8		0	
Total	813	147	147	

Table 5: Chi Test, Grade Distribution, Fall 2008

	Others	Expected	Observed (MEGA)	CHITEST
A	37	5.56112224	5	0.0426262
B	70	10.5210421	9	
C	179	26.9038076	38	
D	75	11.2725451	11	
F	384	57.7154309	64	
W	253	38.0260521	23	
Sub	998		150	
NR	9		0	
Total	1007	150	150	

Table 6: Chi Test, Grade Distribution, Spring 2009

	Others	Expected	Observed (MEGA)	CHITEST
A	66	6.43577673	15	4.31E-009
B	126	12.2864829	26	
C	264	25.7431069	39	
D	101	9.84868863	10	
F	499	48.6583726	29	
W	431	42.0275723	26	
Total	1487	145	145	

Table 7: Chi Test, Grade Distribution, Fall 2009

	Others	Expected	Observed (MEGA)	CHITEST
A	44	8.46596859	26	3.43E-013
B	70	13.4685864	24	
C	231	44.4463351	35	
D	73	14.0458115	7	
F	243	46.7552356	24	
W	103	19.8180628	31	
Total	764	147	147	

Table 8: Chi Test, Grade Distribution, Spring 2010

in the Mega Section than in the traditional sections. In this semester, the Mega Section was implemented in the Precalculus II course, which is the continuation of the Precalculus I course, where the Mega Section was implemented in the previous three semesters. Therefore, even though it was implemented in the spring semester of the school year, and the students were not selected randomly, most students were first time takers of the course, and this supported the idea that the intervention is most effective with first-time students. (See table 4)

We also carried out a follow-up study[4] to see if enrolling in the first, truly experimental' section had an impact on the passing rates in other courses. This study measured success in subsequent courses, and it revealed that 15.60 per-

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Downloaded in 8.8.10 from http://www.eddataexpress.ed.gov/.

	EXP	OBS	CHITEST
ABC	39.9913	85	7.31E-017
DFW	107.009	62	

Table 9: Chi Test, Pass/No Pass, Fall 2008

	EXP	OBS	CHITEST
ABC	42.986	52	0.1035834
DFW	107.014	98	

Table 10: Chi Test, Pass/No Pass, Spring 2009

	EXP	OBS	CHITEST
ABC	44.4654	80	1.56E-010
DFW	100.535	65	

Table 11: Chi Test, Pass/No Pass, Fall 2009

	EXP	OBS	CHITEST
ABC	66.3809	85	0.0020296
DFW	80.6191	62	

Table 12: Chi Test, Pass/No Pass, Spring 2010

cent more Mega Section participants passed their subsequent math courses than those participating in traditional sections. In fact, the students that participated in the first Mega Section (the only one where stratified random sampling was used to select the students), had a passing rate in their subsequent math courses of 22.57 percent more than those that participated in traditional sections. The Mega Section was significantly more effective than the others ($p<0.01$) when comparing A, B, C or P (pass) vs. D, F, W or NP(no pass). These results suggest that students in the Mega Section obtained skills or developed habits that were useful even beyond their math coursework. (see Tables 13-18)

The successful results, moreover, do not appear to be instructor-dependent. The instructor chosen for the task had the training and the experience for the job, but her performance prior to the experimental section in terms of student pass/fail rates was comparable to the average in the Mathematics department. The instructor was kept constant through all the interventions.

Discussion

The project described here originated as part of a campus-wide initiative to improve the student-professor relationship at the University of Puerto Rico at Mayagüez (UPRM), itself in turn part of the multi-campus BEAMS[5] (Building Engagement and Attainment for Minority Students.) At UPRM, the BEAMS initiative included several sub-projects in areas like student advising and faculty development. The sub-project described focused on the relationship between student engagement and student attainment, and had three important, data-based, underlying assumptions: 1) the resulting design had to incorporate tools to help students develop better study and problem solving habits, 2) it had to provide for a better student

MATH-MEGA	
92 A	18.969072165
81 B	16.701030928
91 C	18.762886598
28 D	5.7731958763
105 F	21.649484536
86 W	17.731958763
2 P	0.412371134
0 NP	0
485	100

Table 13: Grade distribution for Mega Section in subsequent math courses

MATH-OTHERS	
416 A	7.2880168185
543 B	9.5129642607
798 C	13.980378416
391 D	6.8500350385
1623 F	28.433777155
1267 W	22.196916608
441 P	7.7259985985
229 NP	4.0119131044
5708	100

Table 14: Grade distribution for others in subsequent math courses

NON-MATH-MEGA	
1056 A	38.054054054
771 B	27.783783784
445 C	16.036036036
156 D	5.6216216216
127 F	4.5765765766
207 W	7.4594594595
12 P	0.4324324324
1 NP	0.036036036
2775	100

Table 15: Grade distribution for Mega Section in subsequent non-math courses

NON-MATH-OTHERS	
7984 A	26.566399361
8172 B	27.191960869
6327 C	21.052806708
2284 D	7.5999068313
2152 F	7.1606827937
2644 W	8.79779057
474 P	1.5772135893
16 NP	0.0532392773
30053	100

Table 16: Grade distribution for others in subsequent non-math courses

	EXPECTED	OBSERVED	CHI
ABCP	186.76068676	266	1.42350E-013
DFWNP	298.23931324	219	
	485	485	

Table 17: Chi-squared test for Mega Section vs. others in subsequent math courses

	EXPECTED	OBSERVED	CHI
ABCP	2119.7775596	2284	2.12829E-013
DFWNP	655.22244036	491	
	2775	2775	

Table 18: Chi-squared test for Mega Section vs. others in subsequent non-math courses

engagement experience in the classroom and allow the instructor to know when students were falling behind or not understanding classroom material, and 3) in times of great fiscal crisis in the institution, it had to be cost-effective.

Preliminary institutional data showed that the introductory Mathematics course, Precalculus, had very high failure rates. The percentage of D's, F's and W's in the first semester of 2006 was 55.86 percent. Failure rates where even higher for low income students. In 2006 the failure rate for low income students was 63.6 percent. Because it is a part of almost every 4 year degree program at the institution, it is a pre-requisite for a large number of other courses, and because its failure rates are so high, the course is tremendously important for student retention and timely completion of graduation requirements. Recent qualitative research suggests failure in this course to be connected with the lower graduation rates experienced by low income students, and students' prior academic lacunae, as well as current lack of engagement with the class material through class participation and discussion of problems, to be critical components in failing and in the decision to withdraw from the course (Brusi, Díaz & González, 2010). The idea that students lack the necessary preparation to tackle the content of Precalculus in college is supported by recent reports on the state of Puerto Rican public schools, attended by 80 percent of the Puerto Rican population: 91.4 percent of students in Puerto Rican public schools live below the poverty level, 94 percent of Puerto Rican public schools did not make Adequate Yearly Progress (AYP) according to the Department of Education federal standards, and only 41.4 percent of fourth graders and 3.5 percent of eight graders were "proficient" in Math in 2007-2008 (Ladd, 2006; ED Data Express[6], 2010).

Our idea fit well with the BEAMS initiative because our underlying assumption was that student engagement (the main theme of the multi campus BEAMS initiatives) was a critical, missing component of the learning process, and because it addressed two important components of student engagement relevant to broader BEAMS goals but also local ones: the connection between engagement and educational attainment, and the connection between engagement and the enrichment of the academic experience (Kuh, 2010; Lipka, 2010.)

The results suggest the Mega Section to be effective in improving passing rates and reducing failing rates in the form of low grades and withdrawals. Course repetitions are particularly costly for UPRM, because it is a public, non-tuition-driven institution, where the average institutional cost of a three-credit course (around $1,300, according to the estimates provided by the Vice-Presidency of Academic Affairs at UPR) far exceeds the tuition paid for the course (currently an average of $135 for a three-credit course). This makes the added investment in equipment and TA salaries a very modest cost, relatively low when compared to the larger institutional and social costs of repetitions. A single experimental section of 150 students, where each student has a 25 pecent lower probability of repeating the course, represented savings amounting to $48,750 (more than enough to pay additional salaries and purchase the required supplies). Throughout time, and adding the increase in passing rates in subsequent courses, savings could be substantial.

Although the results do not appear to be instructor-dependent, the design of the course assumes certain characteristics for instructors. Because of the large class lecture format of this experimental section, we believe it is particularly important that the appointed instructor: 1) be able to communicate clearly and effectively, 2) use instant feedback from students' clickers to adjust content and pace of the course, and 3) ideally, model good teaching qualities beyond those described above so that the course can also serve as training ground for participating Teaching Assistants. The instructor chosen (one of the co-authors of this paper) did all of the above.

The Mega Section seems to be particularly effective in improving performance in students taking the course for the first time (25 percent more students pass the course in this setting). It does not seem equally effective improving performance in repeat course takers (where 6 percent more students pass the course). Moreover, the skills acquired in the Mega Section, be them related to the subject matter or to study habits, seem to continue serving first-time takers in subsequent Mathematics courses (15 percent more students pass these courses). All of the above suggest initial, larger scale efforts should be developed applying this format to incoming freshmen, to maximize future returns on investment.

The strategy implemented here had several strengths. The 24/7 availability of class notes helped students engage and learn, and it also liberated them from the note taking tasks and allowed for full attention during class. Technology enabling real-time interactions during class time allowed students to participate and get feedback immediately in class. The instructor can use the immediate feedback and can adapt the teaching strategy to the actual conditions in the class in real time. This technology, moreover, makes it difficult for students to become passive observers in response to the anonymity of a large section. Large sections are efficient in terms of resources, both human and financial. They can allow for the amplification of outcomes derived from the teaching of excellent instructors, and technology can make them more pedagogically efficient. The additional problem solving and discussion hour encourages a more distributed and intense studying regime, which may help form a continuing habit that helps students get better grades in this course and also furthers learning in subsequent courses. TA supervision and support during these sessions contributes to engagement.

We would also like to note some weaknesses and areas of subsequent research or improvement of the model. The strategy was adopted for two courses, taught by a single instructor, so subsequent research is needed to ascertain if the approach works for other courses and with other instructors. The class notes (a combination of Word and Powerpoint documents combined with handwritten notes added during the lecture using a Tablet PC) are useful, but unattractive in an era where multimedia is the preferred alternative to transfer information and knowledge, and their appearance could be improved or even made more interactive with annotation features once placed on-line. Large sections impose a restriction on face-to-face time with the instructor, for example, immediately after class or during office hours. And finally, the real time interactions require the acquisition of clickers, which are relatively expensive (although not more so than textbooks) and task specific, and in-person practice sessions may be impractical for students and expensive for the institution. This cost, however, is easily balanced by the much more significant savings derived from decreased course repetition.

In the near future, the authors would like to develop the strengths and address the weaknesses above by scaling-up the Mega Section initiative to include more sections and instructors and using screen casts of each lecture, providing a multimedia alternative to learning and review materials for students. The authors would also like to take advantage of the ubiquity of cell phones, developing an open-source SMS (text messaging) audience response system to replace clickers and develop a web-GUI (graphical user interface) for an open-source virtual classroom to enable virtual practice session and virtual office hours, thus facilitating contact between students and their instructor.

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