

USING MAPLE, MAPLE TA, MATHLYNX AND THE TABLET PC TO TEACH UNDERGRADUATE CALCULUS.

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ABSTRACT. The emergence of the iPADS, e-Books, Tablet PC's, Computer Algebra Systems and other digital tools for the teaching and learning of mathematics have intensified the need to rigorously assess the potential that these tools possess for educational use. This paper describes the use of the Tablet PC, the MathLynx Electronic Calculus Text, Maple TA and the Maple Computer Algebra System to conduct Single and Multivariable Calculus Courses at Medgar Evers College from the Fall of 2009 through the Summer 2012. Two questions are explored: Do these tools positively affect student engagement in the classroom? and; Do they aid in the long term development of a deep conceptual understanding of mathematics?

1. MEDGAR EVERS COLLEGE

Medgar Evers College(MEC), named for the late civil rights leader, Medgar Wiley Evers (1925-1963), was established in 1969 with a charge to meet the educational and social needs of the Central Brooklyn community. A senior college within the City University of New York system, MEC is a center for the development of innovative educational initiatives in the metropolitan New York City region.

1.1. Department of Mathematics. The Mathematics Department of Medgar Evers College has gained considerable experience in terms of pedagogy and practices in teaching undergraduate mathematics as well as in the design of broad instructional programs that meet the needs of a student population that is at once non-traditional and very diverse but, at the same time, highly motivated and talented. In general, the challenges that face the Mathematics Department are not unlike those facing other academic departments: specifically, the problem is to design and implement a complete instructional program that is capable of successfully meeting the students with the mathematical skills and knowledge that they bring to the institution as entering freshmen and, subsequently, developing within them the knowledge and confidence in mathematics that they will need to negotiate, successfully, the constantly increasing technological and quantitative requirements that the society imposes.

1.2. The Context. Medgar Evers College is a Predominantly Black Institution(PBI¹). We describe below the fall of 2007 MEC student body profile²: A little more than 98% of its students come from minority groups. Specifically, 93.9 % are African American and 4.5 % are Hispanic. Women

Date: March 22, 2014.

1991 Mathematics Subject Classification. Primary 97U20 , 97U50, 97U70 ; Secondary 97U60 .

Key words and phrases. e-books, Tablet-PC, MAPLE, MAPLE-TA, MathLynx, Calculus, African Americans, Underrepresented Minorities.

This work was supported by the Medgar Evers College Mathematics Department.

¹www2.ed.gov/programs/pbihea/pbi-statute.pdf

²The student population has experienced significant growth(currently approximately 7000 students) since the fall of 2007 but the percentages reflected below are still quite accurate

constitute 75.3 % of the student body and 62.5 % of all students were employed in a full-time capacity. The average age of a student was 28.6 years and ages ranged from 16 to 60.

Based on CUNY Placement Test³ results, 20.1 % of the entering students needed developmental courses in all three of the basic skills areas: reading, writing and mathematics; 50.7% needed the basic skills course in writing; 63.6% needed the basic skills course in math and 29.6% need the basic skills course in reading. The data indicated that 45% of students did not continue from semester to semester; and around 50% of the freshmen did not return. This state of affairs has had a profound effect on student enrollment in School of Science. Around 18.5% of the student body is enrolled in the school of science. A majority of these students seek to participate in the Nursing Program. Non-nursing students (45/760) represented just 5.9% of total MEC student body enrolled in the school of science. Around one thousand four hundred students were enrolled in math courses and only 181 (12.6%) were taking courses in Calculus or higher. This data is evidence of very real gaps in the broad understanding of the fundamental ideas of arithmetic, algebra and trigonometry that are necessary for success in college level math courses. To better appreciate the context we note below in Table I and Table II the data on the performance of students in Pre-Algebra, Elementary Algebra (non-credit, developmental) and credit bearing Algebra courses in the Fall of 2007 and Spring of 2008⁴:

TABLE 1. Performance of students in Pre-Algebra and Elementary Algebra (non-credit, developmental) courses in the Fall of 2007 and Spring of 2008. Dropouts includes D, WU, W, INC grades.

	Fall 2007		Spring 2008	
	Pre-Algebra	Elem-Algebra	Pre-Algebra	Elem-Algebra
Pass	287(50%)	226(33%)	155(37%)	151(26%)
R/Dropout	289(50%)	470(67%)	264(63%)	435(74%)
Enrolled	576	696	419	586

TABLE 2. Performance of students in credit bearing algebra courses in the Fall of 2007 and the Spring of 2008. Dropouts includes D, WU, W, INC grades.

	Fall 2007		Spring 2008	
	Interm Algebra	College Algebra	Interm Algebra	College Algebra
Pass	230(50%)	44(52%)	176(48%)	35(49%)
R/Dropout	229(50%)	41(48%)	188(52%)	37(51%)
Enrolled	459	85	364	72

Since all students are required to take 6 to 8 credits in mathematics to meet B.A./B.S. requirements the College needed to establish a uniform pedagogical and assessment infrastructure that could in a timely manner fill these gaps. This continues to be an ongoing challenge. The mathematics department also offers more than forty courses and two undergraduate degree programs: Bachelor of Science in the Mathematical Sciences and Associate of Science with a Mathematics Concentration. Evidently, the long term viability of these endeavors is inextricably linked with the capacity to

³All Students admitted to the college must take the CUNY Placement Tests before enrolling in the college, regardless of New York State Regents, SAT, ACT, and/or AP scores in Mathematics. Test results are used for placement purposes in the appropriate mathematics course. www.cuny.edu/academics/testing/cuny-assessment-tests.html

⁴MEC Office of Institutional Research, 2008

meaningfully engage this student body in the study of Pre-Calculus and Calculus, which, as is well known, is the cornerstone in the foundation for almost all students in science, technology, engineering and mathematics (STEM) degree programs. Also well known, is that success in mathematics, particularly in Calculus, involves a subtle balance of a conceptual understanding of the fundamental ideas and a mastery of the algebraic manipulations needed to use these ideas in discipline-specific situations. Mastery in both of these areas is typically achieved through practice and repetition and while this practice is important, its full utility is not realized without appropriate feedback. So in the Department's assessment what was needed were tools to complement instructors that could efficiently deliver an individualized blend of conceptual understanding, practice and repetition with appropriate assessment so as to facilitate a rapid mathematical growth on the part of the students. These concerns drove the Department's search for innovative solutions to these evident challenges and it was within this context that the Mathematics Department approved the use of the MathLynx tools in one section of its PreCalculus offerings in the Fall of 2009. This was followed by a second Pre-Calculus section and one section of Calculus I in spring of 2010 and one section of Calculus I and one section of Calculus II in the Fall of 2010. In the Spring 2011, MathLynx was used in one section of Calculus II and one section of Calculus III. In the Fall 2011 one section of Calculus III and one section of Calculus I was offered using the MathLynx Text. In the Spring 2012 two sections of Calculus I were offered in this manner and finally in the Summer of 2012 one section of Calculus II was offered using the MathLynx electronic text. The goals were to

- (1) Determine it's effect on increasing student engagement;
- (2) Assess it's impact on student learning; and
- (3) Disseminate ideas and observations as best as could be discerned on the challenges and opportunities of the implementation of these tools in our department to other faculty members

2. WHAT IS MATHLYNX?

MathLynx⁵ is a series of intelligent, interactive undergraduate mathematics texts created at Brooklyn College by John Velling⁶. That is, it a full set of resources for the learning and teaching of mathematics for the student, the instructor, and the institution for a standard college or university courses in precalculus, calculus of one variable, and multivariable calculus. In its current iteration it is an online interactive text, containing walk-through tutorials which illustrate and guide the user through standard approaches to common problems. It allows the user to randomly generate practice problems based primarily on the walk-through tutorials and provides instant feedback to problem solving attempts. In its original incarnation The MathLynx Environment was written in the Computer Algebra System MAPLE. The Problem-solving tools aid in standard tasks and facilitate the development of problem solving acumen. Some Examples:

- List candidate rational solutions to a polynomial equation;
- Easily change parameters in optimization problems like curve fitting or finding distance between geometric objects;
- Finding equations of lines from standard data;
- Finding equation of circle determined by three non-collinear points; and
- Optimizing functions with respect to constraints using Lagrange multipliers.

Another very important feature is the way that MathLynx can be used by instructors. There is no single way to explain or understand any aspect of mathematics. MathLynx offers the flexibility for instructors to:

- Design their own class text from the written material; and to
- Produce and incorporate their own textual material when they find that what is written does not suit their liking.

⁵www.mathlynx.com/online/welcome

⁶John A. Velling is a professor of mathematics at Brooklyn College and faculty member of the City University of New York doctoral program in mathematics.

3. TABLET PC'S

A Tablet PC is a portable computer which looks much like an iPad, a Tablet, or perhaps a detached screen from a conventional notebook computer. A hybrid of laptop and earlier palmtop computers, the Tablet PC owes much to those earlier technologies. The key distinction is that one can write on the LCD screen using a stylus. The user interacts with the computer by drawing directly on the screen with the stylus. Like a notebook, the Tablet PC features a full-sized color screen, an internal hard drive, and other features associated with a standard computer. This greatly enhances the use of a Tablet for public presentations and for teaching mathematics using a Computer Algebra System [1]. In our classes we used Microsoft OneNote⁷ on the Tablet PC and combined it with a Digital Projector in the place of a Whiteboard. We note below a few general advantages of this method [3].

- There was no need to erase the “blackboard” in order to keep going. It possesses infinite digital space.
- We can go back, to any place, during the lecture to deal with any unresolved questions.
- We can archive and share our lecture notes in their entirety after class. This, in my experience, profoundly changes student note-taking – our students mover from being “transcribers” to “thinkers”.
- We can easily incorporate rich media and diverse source material into each lecture.
- We can more easily overlay annotations on images and prepared slides.
- We can easily manipulate the sizes of images, fonts etc. Experience suggests that this have a very positive effect on student engagement.
- We face our students. It is well know that learning is social, and eye contact tells us a lot about the learning in the classroom.

4. COMPUTER ALGEBRA SYSTEMS

A computer algebra system (CAS) is a software program that allows symbolic computation of mathematical expressions in a manner similar to the traditional manual, i.e., “by hand”, computations of mathematicians and scientists. Using these systems one can do complicated arithmetic, algebraic and graphical mathematical operations quickly and precisely. Computer algebra systems are divided in two classes: specialized ones and general purpose ones. The specialized systems are devoted to a specific part of mathematics, such as number theory, group theory, or teaching of elementary mathematics. General purpose CASs aim to be useful to users working in any scientific field in which we have to manipulate mathematical expressions. The main ones in use in undergraduate mathematics classrooms are Matlab, Maple, Mathematica and Sage.[2]

Over the past decade, researchers have carried out extensive studies on the use of computer algebra systems (CASs) in mathematics classrooms. CASs have proven to be beneficial, and many studies demonstrate that the conceptual understanding of mathematics rises as a result of their utilization. Our observations, in part, support these findings. Studies of university-level, undergraduate mathematics courses support the claim that the effective use of a CAS can “free” students from manipulation errors and thus allow them to quickly generate both exact and approximate results. Furthermore, CASs allow students to handle mathematical questions more complicated than most students could do with only pencil and paper. Students not only obtain the answer but also are able to reflect on it and see its structure and reasoning. In other words, they are able to interpret the answer in a symbolic form, rather than just producing it. However, to accomplish such positive outcomes is not so simple. The very presence of a CAS in a classroom does not automatically produce positive results. Teachers must know how to efficiently integrate the technology into the learning process, because not all students adapt well to this type of learning. [2] Traditionally, mathematics departments tend to incorporate a mathematics computer lab into its curriculum and require that all precalculus and calculus students take the course. The lab is usually a co-requisite for the pre-

⁷a note-taking and information-management program which allows you to capture ideas and information in electronic form, insert files or Web content in full-color, searchable format or as icons that you can click to access.

calculus class and a prerequisite for calculus. It is often a one-credit course that is taught separately from the precalculus and calculus classes and its function is to introduce students to a computer algebra system. The lab course introduces basic functions of the system (such as performing calculations, graphing, and solving equations) and explores their uses in relation to various precalculus topics but it is often disconnected from the lecture. It is precisely on this point that we believe that our study and the tools it describes contribute to the understanding of the use of CASs in undergraduate mathematics. We argue that it is through integrating the computer algebra system with the text that we can best realize the full pedagogical potential of the CAS.

4.1. **Maple TA.** Maple T.A. is a web-based system for generating questions and exercises, and automatically assessing a student's response via the Maple computer algebra system ⁸.

5. THE BASIC SETUP

Our classes ranged from 25 to 32 students. We meet in a computer lab. Each student was assigned to a computer on which the MathLynx e-book and the Maple CAS was installed. Students were required to mirror this installation on their personal computer. Maple is available freely to all registered students across the various CUNY campuses and the MathLynx electronic text was made available to each student on a CD. In a typical lecture, the relevant sections of the text was projected to the white board and each student was then able to mirror that section of the text on their classroom machine and discussions ensued. As described before, the instructor used Microsoft OneNote on a TabletPC combined with MathLynx electronic text. In this way he was able to integrate the use of the CAS, the MathLynx text and any other material into the lecture notes. Class notes were converted to PDF files and posted to the web upon completion of the class. A MapleTA site established for the class. At times, this site was directly linked in the electronic text.

6. STUDENT ASSESSMENTS

What follows are some insights gleaned during conversations with students and written student assessments solicited in order to gauge sentiment/perceptions of the courses. This sample was typical of the responses in both Pre-Calculus and Calculus I, II & III.

- (1) The use of the MathLynx Maple embedded text in teaching this course is excellent. It gives me more opportunity to focus on the class work and I do not have to worry about taking notes. It makes math accessible from any computer and takes away the burden of paying for and carrying a very high priced math book. I appreciate the clarity of the lectures and the facility to quickly view problems from numerical, algebraic and geometric perspective.
- (2) Calculus is fun. It is good that we take the time to explain the principles and the steps of doing a math problem during the class. On the other hand, using Maple requires that you have some knowledge about using a computer. If not, this is a hard class. So for the older generation, I do not recommend using Maple. There should be an age limit for this class or a pre-survey given about computers before folks register for this class. Maple is good for visual learners. I am a visual learner. I feel the younger generation coming up will benefit from this program of instruction. Although the introduction to and learning how to use the Maple book is a bit time consuming it helps to visualize things better. I was learning just the formulas but now I understand the physical meanings of these formulas.
- (3) The biggest advantage for using MathLynx Maple is having the option to navigate between the text and the worksheet and being able to enter my personal notes directly into both places. I also like I am able to put in my personal notes in a different color and store it on a flash drive that I can take anywhere. Finally in the past I've found Math textbooks to contain so much information and I'm not sure what I need to zero in on. With MathLynx it's already condensed and you can do everything at the same time. Read the concepts see the examples and practice it by putting the function into Maple and seeing graph. I think the biggest drawback for me is that it requires some computer technical expertise.

⁸<http://www.maplesoft.com/products/mapleta/>

- (4) I think that MathLynx text is very helpful and convenient. I normally spend more time on the PC than reading my textbooks and by having this portable math textbook that I can just read on my PC, is great for me. I spend more time learning and practicing math on my own. This increases my interest because it creates the desire for me to know more and attempt to solve more complex math problems. It also builds my confidence when I acquire the correct answer. I am aware of what I can do because MathLynx provides effective feedback very quickly. The textbook CD costs a lot less than the traditional textbook. This is great because the textbook will be available to those who want to save and for those who cannot afford a traditional textbook. I think that MathLynx Maple benefits me more than a traditional textbook.

7. CONCLUSIONS

In the initial fall 2009 section of Pre-Calculus offered using the MathLynx tools and Maple twenty eight students attended the class. Of those who started in Pre-Calculus in the fall of 2009 at least eighteen took Calculus I in the Spring of 2010, and of those, at least ten indicated that they were strongly motivated as a result of the Pre-Calculus experience to take the MathLynx “designated” section of Calculus I with the same instructor. In the spring of 2010, the second phase of this project, a number of new students joined the MathLynx sections because of the student conversations surrounding the use of the Maple embedded electronic book and its minimal cost. Twenty-nine students regularly attended class during this semester. This is a very positive outcome in MEC context. In the fall of 2010 the MathLynx designated Calculus I and Calculus II courses were oversubscribed. This pattern has been repeated throughout the semesters for the classes in which these tools were used.

It is yet too early to judge whether this method of presenting the text and the material will lead to a sustained rise in student achievement and engagement over the long term but the anecdotal evidence at Medgar Evers College suggests that this is an endeavor that offers much promise in this direction. The MathLynx electronic text effectively facilitates a dynamic weaving together of theory and practice that has deepened student engagement in the targeted Pre-Calculus and Calculus sections. This level of student engagement is, in our view, greater (It is certainly no worse) than the level of engagement that exists when one uses the traditional lecture format and texts. It has lead to the development of a more broadly shared understanding of the material and most importantly, it is our sense, that it better facilitates the communication of the spirit of inquiry that characterizes the mathematical endeavor. Here are the key advantages, relative to the traditional text, as we have observed them:

- (1) Interactivity: Instructors are able to quickly and effectively illustrate key points, and students can at the same time experiment with the ideas that instructors are trying to
- (2) Timely feedback: Understanding at this level is a function of repeated practice. There is a rich set of tutorials, problem-solving walk-throughs, and practice problems, which, we believe, more effectively communicates the process of learning to manage mathematical tasks. Because these tasks all include randomly generated parameters, users can see an infinite variety of examples of a given mathematical idea.
- (3) Portability: The ability to “carry the course” on a flash drive in a pocket or on a mini laptop computer was a facility that students enthusiastically embraced.
- (4) Cost: The advantages here are evident and need no explication.
- (5) Leveraging of Expertise: In some ways, the text acted like a tutor and in so doing it enabled students to work in a more effective manner independently.
- (6) Syncing the instructor-student interaction during the lecture: Having the class in computer lab enabled us to install the text on all of the machines in the class. This in turn allowed for a much more focused conversation between the instructor and the student during the lectures.
- (7) The instructor can integrate/juxtapose algebraic, numerical, geometric and conceptual ideas in a easy and effective manner during the lecture.

- (8) There is a definite layer of complexity involved in putting the computer at the center of the mathematics classroom. As we have observed, older students, in particular are at some relative disadvantage.
- (9) There are some, still unresolved, issues concerning students who, for economic reasons, do not have access to personal computers and the internet, to access the web based assignments, at home. However there are resources within the campus community that can aid in diminishing the negative impact of this fact on student learning.

This method of presenting the course is challenging but it offers many opportunities for genuine learning on the part of the students and the instructors. A Pre-Calculus or Calculus course that intentionally seeks to incorporate the development of a technological capacity in our students as a means to achieving the course objectives will inevitably promote a spirit inquiry which can only aid in the development of the mathematical culture at Medgar Evers College. Given our experience over the course of the last three academic years we strongly recommend that this mode of teaching be continued and subjected to ongoing analysis.

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