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IML - Institutional Change in Lower Division Mathematics

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II. Description of West Virginia University and its Students

West Virginia University (WVU) is located in Morgantown, West Virginia, resting in the Appalachian Mountains approximately 70 miles south of Pittsburgh. WVU is an extensive four year, public doctoral/research university, as classified by the Carnegie Foundation. Enrollment is 26,051 as of Fall 2005, with students from all 55 counties in West Virginia, all 50 states, the District of Columbia, and 89 other nations. The students are 59% state residents and 41% nonresidents, with 6,541 graduate and professional students. All college freshmen are required to live on-campus. WVU enrollment is on the rise, with 19,510 FTE undergraduate students, of which 5,647 are first-year students. The gender balance is 51% male and 49% female. There are 1,043 students over 25 years of age, accounting for a low percentage of only 5%. The racial/ethnic makeup at WVU is 7% minorities, with 4% Black, 2% Asian, and 1% Hispanic. At WVU first generation college students are defined as those whose parents do not have college degrees. The percent of first generation college students at WVU is considerable at 25%. WVU ranks nationally in the number of students who have garnered prestigious scholarships, including 25 Rhodes Scholars, 17 Truman Scholars, and 29 Goldwater Scholars.

III. Program/Initiative Description

The Institute for Math Learning (IML) was established at WVU in 2000, spurred by the efforts of Dr. James Miller and Dr. Laura Pyzdrowski to incorporate computer laboratories into the Precalculus course. A year of planning and recruiting led to the IML launch with Dr. Robert Mayes as Director, and a new dedicated instructional computer laboratory. The primary objective of the IML is to reform all before calculus courses, including Liberal Arts Mathematics, Applied College Algebra, College Algebra, College Trigonometry, Precalculus, and Applied Calculus. Currently the IML has seven tenured or tenure-track faculty, a visiting assistant professor, six instructors, a lab manager, an administrative assistant, and a computer scientist, along with graduate students and undergraduate lab mentors. First year freshmen and sophomore students are the primary audience for IML courses.

The IML has three core missions (1-3) and three supporting missions (4-6):

1. Improve curriculum, instruction, and assessment in before calculus classes through innovative and effective math learning models
2. Provide outreach to K-12 students and teachers
3. Restructure math education courses for K-12 teachers
4. Conduct research to support change in instruction, curriculum development, and assessment
5. Secure grant awards supporting IML initiatives
6. Provide national leadership in innovative and effective math learning models

The 6 IML courses share the following traits.

1. All courses include a minimum of 8 computer ***laboratories***, which focus on conceptual understanding and application of mathematics.
2. The courses measure skill acquisition, conceptual understanding and problem solving via a variety of ***assessments*** including:
    - weekly on-line WebCT homework quizzes;
    - 5 on-line WebCT exams, one of which is a comprehensive final; and
    - conceptual and application based labs.
3. A goal of the courses is to improve student learning, conceptual understanding, and ability to apply mathematics to solve problems via ***technology***, including:
    - pervasive graphing technology (applets, software, or graphing calculators);
    - WebCT course management; and
    - Personal Response Systems (PRS).
4. The courses emphasize ***Quantitative Literacy*** by demonstrating the utility of mathematics in the students' world.
5. The large lectures incorporate ***active student learning*** with PRS serving as a delivery mechanism
6. An increase in ***student accountability*** is achieved with
    - tracking daily attendance and posting on-line;
    - class participation as part of attendance; and
    - consistent, frequent feedback on progress via WebCT.
7. Instructors report the ***current grade status*** for students in WebCT.

All IML courses have common elements, including course specific variations of the components above and four general outcomes. First, the courses incorporate multiple representations of mathematical concepts, including algebraic, graphic, and numeric perspectives. Second, the courses focus on communication of ideas, requiring students to explain in written or oral form key mathematical concepts. Third, the courses are built around problem solving, providing opportunities for students to gain experience in analyzing real world problems. Finally, the courses incorporate an element of history of mathematics so that students can understand mathematics as a human endeavor.

However, coordinators in specific IML courses bring their own innovation to implementing the IML components and outcomes. The following highlight specific innovations from each of the courses.

Personal Response System: Liberal Arts Mathematics (Math 121) is typically taken by students in non-science disciplines. Currently, the topics covered include set theory, logic, number theory, geometry, probability, and statistics. One general goal of the course is to stress to these students, who are often disinterested in math, the utility of mathematics in everyday life. Another goal is the development of basic quantitative literacy. In Liberal Arts Math there are typically two to four PRS questions posed per class, creating a dynamic component to the usually passive activity of listening to a

lecture. Students respond to an interactive Power Point question using a hand held input device, then formative data is displayed live to promote class discussion.

Mathematical Modeling: Applied College Algebra (Math 124) has restructured the course from skills development to modeling real world problems. Learning mathematics in context provides a motivation for students to engage in the course. Poor student preparation in mathematics can be overcome if students view the subject as having utility. So students examine real world data and determine a function model that allows them to make future predictions. They are engaged in using the model to answer questions, motivating the need to solve equations, interpret graphs, and read tables.

Study Guide: College Algebra (Math 126) has as specific goals stressing an algebraic, graphic, and numeric approach to functions, graphing, and equations. One course component that is currently unique to College Algebra is a study guide. The study guide helps students follow the lecture by leaving spaces for students to complete already written out problems and blanks for students to complete definitions. The study guide is especially useful to students with learning disabilities.

Java Applets: College Trigonometry (Math 128) is the course taken after College Algebra and has many of the same goals. One innovation in this course is the use of interactive Java based on-line applets, which allow students to explore and discover mathematical concepts. The laboratory applets in trigonometry were developed with NSF support using the Mathematical Java Toolkit and Java Sketchpad, and have been adapted for use in Math 121, 126, and 129.

Collaborative Laboratories: Precalculus (Math 129) combines College Algebra and College Trigonometry for better prepared students. The laboratory assignments, done in pairs or triads, engage students in activities and are technology intensive. The activities emphasize writing, collaboration and discourse. In addition to earning points for showing evidence of understanding and doing mathematics, up to 10% of the points are awarded for the ability to work collaboratively, communicate about mathematics in a clear manner, and follow directions and a schedule.

Software Tools: Applied Calculus (Math 150) stresses an algebraic, graphic, and numeric approach to the study of the concept of function, using functions as models and modeling techniques used in solving real world problems; using the derivative as a tool to solve problems; and using the definite integral and area to solve problems. Its laboratories incorporate Excel worksheets among other interactive tools, providing College of Business and Economics student's exposure to a software tool used in future classes.

IV. Research Plan

Preliminary findings, based on research currently being conducted, indicate that the IML at West Virginia University is having a positive impact. Within the IML, all courses have adopted laboratory activities and online assessments as part of the revised course curriculum for first-year students. The impetus for this change has been a need to improve student success in these courses, so the baseline measure for the success of these efforts has been to monitor student grades. Students who receive an A, B or C are considered to have succeeded in the course. The remaining grades of D, F, and withdrawal are aggregated for each course (called the DFW rate), and the resulting statistics are analyzed for changes in distribution and correlation with any underlying changes in a course's curriculum. To ensure course quality is maintained, success in subsequent courses is also measured. For example, a student taking College Algebra often goes on to take College Trigonometry, so student performance in this subsequent course is tracked as well. Success in a subsequent course is also defined as earning an A, B, or C.

Several courses have implemented other research programs that attempt to assess the effectiveness of various changes more specifically. An Applied College Algebra research project is studying the effect of the course on students' ability in and attitudes towards mathematics, as well as the effect of supplemental instruction on student success. Supplemental instruction provides students with an additional day of instruction with a focus on skill development. A retired math ACT test is given as a pretest and posttest to measure cognitive change. A Likert scale attitude survey is given as a pre-assessment and post-assessment to measure affective change.

In addition to considering DFW rates, the College Algebra and Precalculus courses co-coordinators have studied the effects of the course restructuring more carefully through several research studies. Since Fall 2004, College Algebra students have taken a retired version of the math ACT test. Precalculus students started taking the test in Spring 2006. The math ACT test, used as both a pretest and posttest, is considered an established instrument to measure change in student scores.

The Applied Calculus course has been studying the effects of stratified assessments, which offer students with a wider variety of learning styles an opportunity to demonstrate their knowledge and understanding of calculus. These assessments include individualized semester and gateway exams, online homework quizzes, and group laboratory activities. Students are offered multiple attempts on quizzes and gateways in order to decrease the impact of test anxiety on their performance.

In addition to analyzing student performance on assessments, several other research studies are being conducted. For example, various surveys have been given out in Liberal Arts Math, College Algebra, and Precalculus. One finding from these surveys is that in general, students react very positively to the computer laboratory component of IML courses. Research into Personal Response System use in Liberal Arts Math, College Algebra, Trigonometry, and Precalculus, including course comparisons and survey data, is also being conducted.

V. Findings

Before the creation of the IML, the DFW rates in the courses served were as high as 70%. The long term goal of the IML is to hold DFW rates below 30%. For the 2004-2005 academic year the Liberal Arts Math, Trigonometry, Precalculus, and Applied Calculus courses held DFW rates to an average 37%, while the Applied College Algebra and College Algebra courses held the DFW rates to an average of 44%. Success in subsequent courses after completing the IML courses has been exceptional, with success rates averaging 80% for those receiving an A or B in an IML course and 50% for those receiving a C.

ACT scores are currently used to place students into appropriate mathematics courses at WVU. One interesting finding is that students in Applied College Algebra, College Algebra, and Precalculus are not achieving on the pretest the required ACT score to enter the course. For example, the required score to be placed into Precalculus is 24, while the average pretest score is 23. This fact highlights one difficulty facing the IML – a lack of student preparedness. However, comparisons of pretest and posttest scores show a statistically significant gain in ACT scores for students in Applied College Algebra and College Algebra. Data from Precalculus will be available next year.

Preliminary data also shows that use of a Personal Response System is having a positive effect. For example the course coordinator taught two sections of Trigonometry in the Fall 2005 semester, one using PRS and one not. The average number of recorded days absent in the non-PRS section was 6.24, while in the PRS section it was 5.50. The DFW rate in the PRS section was 3.8% lower than in the non-PRS section. Further analysis is needed to determine if these differences are statistically significant.

Liberal Arts Math is currently the only IML course without a weekly meeting in the computer lab. Instead, students complete lab assignments on their own. Survey data indicates that students in Liberal Arts Math react less positively to the laboratory component, and have a difficult time connecting the material covered in lecture with the topics on the labs. This data suggests that a weekly meeting, in which students can ask questions and receive help when completing labs, is an essential element in the success of IML courses.

Based on the experiences of IML faculty members, support from the Provost, Dean, and Department Chair in the implementation of significant course changes is a prerequisite for success. In addition, it is important to realize that coordination of these courses uses an immense amount of time. In order to enhance the effort by faculty on curricular change, the IML plans to implement a system, starting in the Fall 2006 semester, in which each course will have a lead instructor. It will be the job of the lead instructor to handle general course coordination tasks (tracking attendance, posting grades, uploading and downloading spreadsheets, etc.), freeing faculty members to focus more on development and improvement of the courses.

VI. Recommendations

In these days of limited resources, competition, and striving for efficiencies, many schools seek economy of scale by enlarging section sizes. The IML has achieved success in this environment, but with a significant commitment of the higher administration as shown by
1) investment in laboratory resources, including space, equipment, and staff,
2) promotion of educational technology to make the classroom an active learning environment, and
3) hiring directed towards new faculty predisposed to bring energy and enthusiasm to scholarly work connected with the teaching aspect of the department's mission, and faculty evaluation policies designed to encourage and value such work by all faculty.

The best argument to make for this approach is that everyone benefits. The administration gets consistency, improved student success, and engaged instructors. Instructors share experience, course management duties, and structure such as common syllabi and testing. Students have classroom and laboratory activities to provide a varied instructional environment