A Program to Increase Undergraduate Physics Student Enrollment and Retention

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This paper describes recent efforts to improve the effectiveness of the undergraduate physics major program at Kent State University. Kent State is the premier public university in Northeast Ohio. It is an eight-campus institution with a total student population of 30,000 students. The Physics Department is a research-oriented department with 50 graduate students and 50 undergraduate students. Our efforts are in response to a decline in the numbers of B.S. degrees awarded by the Department from an average of 10 during the early 90's to an average of 4 several years ago. The same declining trend was present in all physics departments in the United States over the same period [1]. This trend, observed also in other science disciplines, has forced many national professional societies, and science, research and business boards or commissions to call for an increase in the number of science majors. A typical example of such a call is contained in the recommendations of the Ohio Governor's Commission on the Higher Education and the Economy [2], which calls explicitly for the increase in the number of Ohioans with mathematics and science knowledge, skills and degrees.

Several years ago our Department realized the need to increase undergraduate student enrollment and retention and initiated a series of steps in that direction. These steps include a change in the student advising structure, the reactivation and full support of the activities of the local chapter of the Society of Physics Students (SPS), the creation of an undergraduate lounge for student study and SPS activities, the restructuring of all undergraduate laboratories and an initiation to overhaul an undergraduate program and curriculum custom-made to prepare students just for the graduate school. At the same time, a study of many data on student enrollments and attendance, student evaluations on course instruction and laboratory instruction etc were studied to find out areas of weakness and take appropriate actions.

The first step in our efforts was to create a professional environment and a sense of community and belonging for the undergraduate students. The conversion of a research laboratory to a student lounge at a minimal cost proved to be a very successful investment that has resulted into a thriving place maximizing the student study efficiency, allowing group-study and discussion sessions, enabling showing of education films and videos (like Carl Sagan's Cosmos and Stephen Hawkings's Universe) etc. In addition to the undergraduate lounge, the physics majors have at their disposal the Department's Faculty conference room. The second step was a drastic change in the undergraduate student advising structure in the department by creating a small dedicated team of faculty advisers overseeing closely the progress of the students and by elevating advising/mentoring to a top programmatic priority.

At the same time, the need for an overhaul of the introductory physics laboratories (for both the Algebra-based and Calculus-based courses) became evident. The two labs had a largely overlapping curriculum and used a decades-old laboratory manual as well as antiquated experimental apparatus. The lecture and laboratory parts of the two courses were disconnected and out of synch, impairing the course learning effectiveness and generating many student complaints. The laboratory Teaching Assistants (TAs) were not adequately trained, and Faculty involvement in the laboratory operation and instruction was limited.

To remedy the situation, we introduced for the Algebra-based labs the curriculum of the RealTime Laboratory Manual [3] and replaced all lab experimental setups with new ones developed by Vernier or Pasco. Where it is appropriate or necessary, the setups are computer assisted or read. This effort was accompanied with an increased Faculty time devoted to the lab that included training and supervision of the instructor TAs. In the two years of the new curriculum and approach, the student complaints have diminished but their evaluations for the overall teaching of the instructors and the overall quality of the lab courses have been puzzling: they exhibit a similar degree of satisfaction, as compared to the previous curriculum and approach as can be seen in Figure 1, something that is presently not understood.

For the Calculus-based labs we introduced a new "home-made" curriculum based on recommendations of physics education research scholars. The lab instruction is complemented with hands-on demonstrations, Physlets [4] and simulations, and special emphasis is given in the extensive use of basic concepts of statistical analysis of experimental data and error analysis. Also, a pilot study is in progress aiming at the eventual integration of the lecture and laboratory parts of the course taught in a single classroom facility. The results of the study have been very positive with students demanding "more integration between lab and lecture". The instructors of the labs are either Faculty or TAs. Limited feedback (due to a small number of sections) from the instructors' teaching and lab quality evaluations by the students strongly suggest that the students would prefer that the lab instructors are Faculty, as can be seen in Figure 2.

The Faculty also realized the need to overhaul the entire undergraduate program and curriculum which had been tailored into educating and preparing students for graduate programs in physics. We have initiated the process to implement a new curriculum to prepare students for entry not only into the graduate school but into the industrial/high-technology sector and into high school education as well. Today's undergraduate physics programs should allow students to follow a curriculum leading not only to a research oriented track but also to a diverse professional track. This can be accomplished by, first, consolidating traditional existing physics and mathematics mandatory courses (thus making room for the introduction of new mandatory ones like scientific computing), and second, by giving students the option to take a number of elective courses based on their choice of professional orientation.

With the new curriculum, incoming students will take in their first semester a "preparatory" introductory course with emphasis in modern physics and problem solving using pre-calculus math. The two-semester Physics with Calculus sequence will start in the second semester and will be followed by a two semester sequence covering all of modern physics. In this scheme, at the beginning of the Physics with Calculus sequence the students would have already completed one semester of calculus. The Modern Physics sequence will expose the students not only to the theory of relativity and early quantum physics of the 20^{th} century but also to the basic concepts of quantum mechanics, solid state physics, nuclear-particle physics and cosmology.

Of crucial importance is the consolidation and streamlining of the mathematics courses taken by the physics majors. A critical look into the schedules of students and discussions with them indicated that by the time they take certain math courses "it's already too late", meaning that, frequently, they were not well prepared math-wise for upper level physics courses. A solution to this serious problem is the elimination of the four math courses taken by our majors: Calculus-

III, Linear Algebra, Ordinary Differential Equations, and Partial Differential Equations, and the introduction (in collaboration with the Mathematics Department) of a two-semester sequence on Math for Physical Science covering the essentials of the above four courses, to be taken in tandem with the standard two-semester sequence on Calculus.

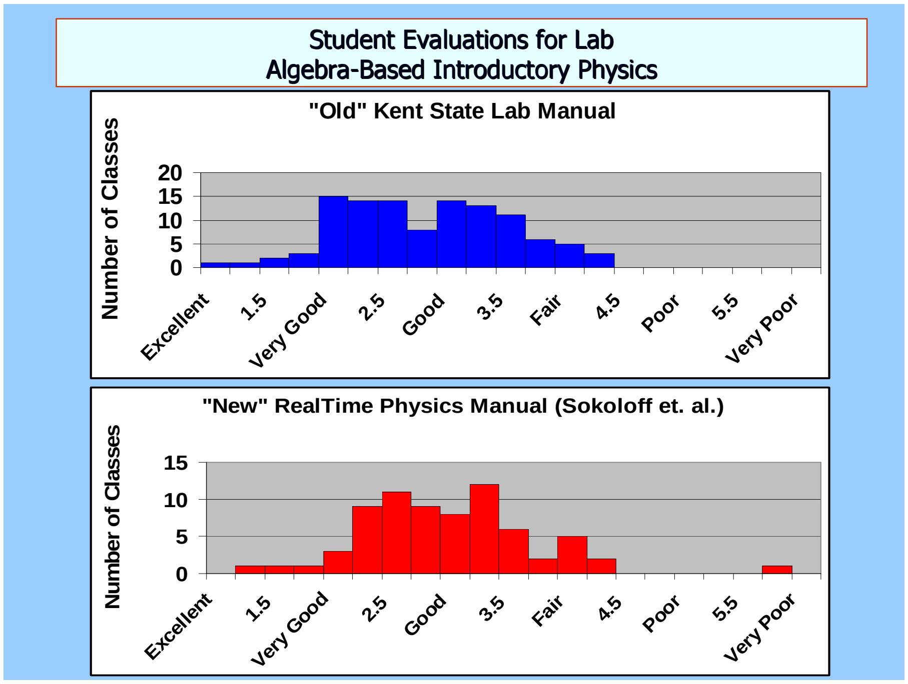

Fig. 1. *Student evaluation ratings for the Algebra-based labs before (3-year period, top) and after (2-year period, bottom) the introduction of the new curriculum and apparatus. The population for the laboratory classes was, on the average, 20 students.*

The above core of physics and math courses will be complemented by one semester courses in Classical Mechanics (instead of two), Electromagnetism (instead of two) and Thermal/Statistical Physics, as mandatory courses. The list of mandatory courses will include a course on Scientific Computing using the C/C++ programming language, and a course on Data Analysis and Simulation Techniques covering also the basic elements of probabilities and statistics. The latter two courses have not been traditionally part of physics undergraduate curricula, but are considered today essential for all physics majors no matter what their orientation and future plans may be. Another mandatory component of the curriculum will be Undergraduate Research for credit, performed either in house with our Faculty or through an external internship in the industrial sector, a national lab, another university with a National Science Foundation REU (Research Experiences for Undergraduates) program etc.

With the new curriculum students are offered the option to take a variety of elective courses, so that they can follow one of two tracks: research track (leading essentially to a physics graduate school) or a professional track (leading directly to the workforce). Students on the research track are mandated to take Quantum Mechanics, Solid State Physics, Nuclear-Particle Physics and Astrophysics/Cosmology. Students on the professional track are offered the availability of many elective courses in Physics, Mathematics, Computer Science, Chemical

Physics, Economics, Project Management and General Education. The list of the elective physics courses includes , in addition to the above four courses that are mandatory for the research track, Biophysics, Materials Physics, Modern Optics, and Electronics and Communications.

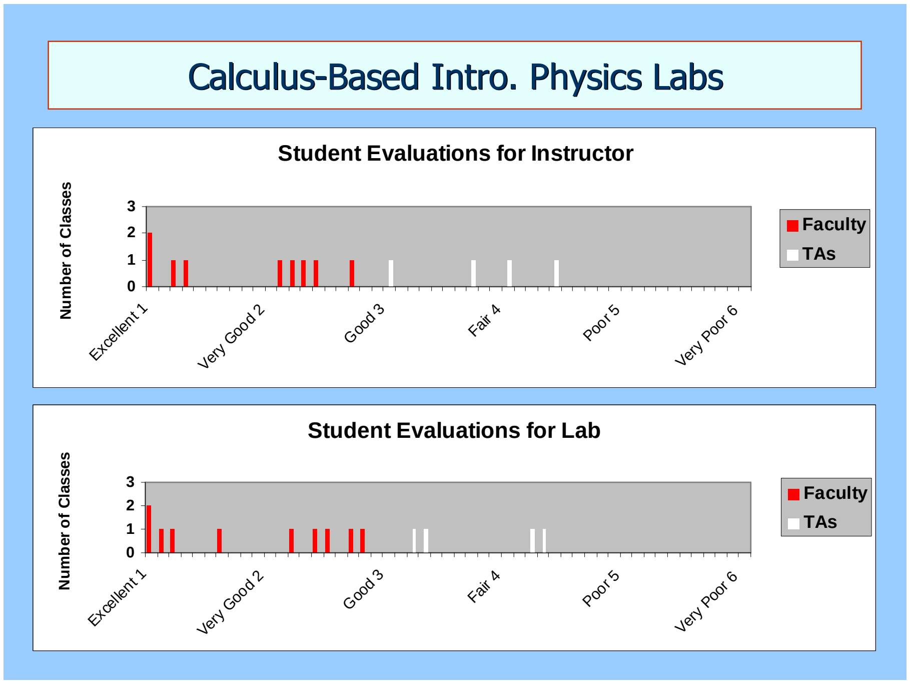

Fig. 2. *Student evaluation ratings for Calculus-based labs after the introduction of the new curriculum and apparatus. The population of the laboratory classes was, on the average, 10 students. The instructor group consisted of 3 Faculty and 3 graduate student Teaching Assistants (TAs) as individual instructors.*

In conclusion, in the few years since we started the effort to revitalize and improve the undergraduate program in our department, the number of majors graduating with a B.S. degree in Physics has doubled and all available indicators point to a further increase. We have found that several actions do make a difference in student retention: ensure that the undergraduate students receive quality advising and above all mentoring, offer them a pleasant work-study space and support their society and its activities, increase the Faculty time devoted to the professional development of undergraduate students and to instruction of undergraduate courses and laboratories, use Faculty as laboratory instructors for introductory courses for physics/science majors and above all, treat the undergraduate majors as colleagues in the making.

[1] "Enrollments and Degrees Report, 2003." American Institute of Physics Publication R-151.40 (2005)
[2] "Building on Knowledge, Investing in People: Higher Education and the Future of Ohio's Economy" Report by the Governor's Commission on Higher Education and the Economy (2004)
[3] D. R. Sokoloff, P. Laws and R. Thornton, "RealTime Physics", Wiley Higher Education, (1998)
[4] W. Christian and M. Belloni, "Physlet Physics", Pearson Education, Inc. (2004)