Improving Student Performance in Programming Courses Through Unlimited Access to Computer and Software Resources

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Introduction

Computer programming is an integral part of the curriculum in Mechanical Engineering Department at New Mexico State University. Students in Mechanical Engineering are required to take two courses, a programming fundamentals course and a numerical methods course. The programming fundamentals course utilizes MATHCAD and MATLAB. The follow-on course covers basic numerical methods with MATLAB as the sole programming tool. Typically, students only have access to these programs via department computer labs. As a result of this, the students' time is limited to certain hours of the day and they compete with other students for the available computers. The authors felt that students' performance in the programming courses could be improved if the tools they needed were available all the time.

A mobility grant from Hewlett-Packard consisting of 40 laptop computers along with the recent building wide wireless networking in the department has provided an opportunity to test the merits of unlimited access to computers and software needed by students enrolled in the department programming courses. Although many students have computers of their own, only a very few have either MATHCAD or MATLAB installed. A random selection of students from each course received laptops with MATHCAD and MATLAB installed. The initial distribution of laptops occurred in the Spring 2004 semester, and a second distribution took place during the Fall 2004 semester. A further distribution is planned for the Spring 2005 semester.

Existing Computer Resources

Computing resources at New Mexico State University are made available to students through 11 campus computing labs. The campus currently has 11 general purpose computing labs. Through these labs, a total of 220 windows based personal computers and 29 Mac based machines are available for student use. The majority of the campus computing labs are open 6 days a week from 8:00 a.m. – 11:00 p.m. The only exception is the main computing lab, which is available to students 24 hours a day 7 days a week. The main computing lab contains 20 windows based machines and 20 Mac based machines.

The only computing software package that the campus computing labs support that is also used in ME 260 is MATHCAD. MATLAB is currently not available to students in any of the campus computing labs. In addition, the current version of MATHCAD that is available on the campus computing labs is the 2001 version. The Department of Mechanical Engineering

has 2 computer labs. One computer lab contains 18 windows based machines and is available from 8:00 a.m. to 5:00 p.m. and the other computer lab contains 52 windows machines and is available 6 days a week from 5:00 p.m. – 11:00 p.m.

Student Computers

The computers made available to students were obtained through a HP mobility grant written by the Computer Science and Mechanical Engineering Departments at New Mexico State University. The goals of the grant are to

- Make academic improvements at NMSU by influencing pedagogy and the learning process, especially as they relate to minority students and access to mobile technology
- Explore learning paradigms using mobile technologies
- Expose NMSU students to state-of-the art technologies and skills
- Advance the state of knowledge and practice in pedagogy in engineering and computer science and publication and dissemination of the results
- Provide more effective support to group-based educational activities, especially with regards to retention of a diverse student population
- Provide a rich environment for new hardware/software projects with wireless technology

At the same time the HP Mobility Grant was awarded to NMSU the Mechanical Engineering Department finished construction of a computer classroom which contained 52 windows based machines. This essentially reduced the demand for a wireless classroom because the resources were now available to students through the newly constructed computer classroom. At this time, it was decided to make the computers obtained through the Mobility Grant available to students through a loan program. Selected students enrolled in ME 260 and ME 329 would be loaned laptop computers for the semester they are enrolled in the course. The computers would contain all software needed for ME 260 and ME 329 as well as other software programs used by the department. In addition, the department installed a wireless network throughout the building housing the Mechanical Engineering Department.

A new goal was added to the Mobility Grant to take into account that selected students now had access to a computer on a full time bases. The new goal was to determine if unlimited access to the computer resources of the department had any influence on a student's performance in ME 260 and ME 329. The thought was that students now had access to MATLAB and MATHCAD on a full time bases and as a result of this more time could be spent on work related to ME 260 and ME 329.

In our analysis of the grades for ME 260 and ME 329 we are trying to determine if full time access to MATLAB and MATHCAD has an influence on a student's performance in these two courses. The loan program has only been available for 2 semesters and we are still in the initial phases of trying to determine all of the factors that influence a student's performance in these courses. Clearly, a more in-depth analysis would require a survey to determine student habits, existing resources available to all students in the courses, student performance in other course, etc. Thus, what we are presenting is only an initial look at the influence of having computer software and resources available to students on a full time bases.

Required Courses with MATHCAD and MATLAB

Students are first introduced to MATHCAD and MATLAB in the sophomore level course, ME 260 as mentioned above. This one semester course is three credit-hours. In this course students spend one hour in class and 2 hours in lab solving problems each week. ME 260 covers the following topics:

1. Engineering Problem Solving
2. MATLAB Environment
3. MATHCAD Environment
4. MATLAB Functions
5. Linear Algebra and Matrices
6. Solutions to Systems of Linear Equations
7. Interpolation and Curve Fitting
8. Ordinary Differential Equations
9. Symbolic Mathematics using MATHCAD
10. Integration and Differentiation using MATHCAD
11. Special Topics

Although traditional programming topics such as functions, control structures, arrays, input/output, etc. are not listed in the above topics they are still covered in the course. The emphasis of the course is problem solving and in the process of solving engineering problems students learn much of the material taught in a traditional programming course. The main difference is that students learn the material as the need arises. The course was taught for the first time using the high level software packages in the Fall 2003 semester. Since the course is taught every semester it will not be long before the course evolves into one that maximizes the benefits of the high level software packages and, at the same time, teaches students the basics of structured programming.

At the junior level the students take a required three credit-hour numerical methods course, ME 329. This course covers the following subjects while fostering good programming style.

1. Sources of error
2. Root of equations
3. Solution of linear system of equations
4. Solution of non-linear system of equations
5. Interpolation and curve fitting
6. Numerical differentiation and curve fitting
7. Solution of ordinary differential equations
8. Solution of partial differential equations

Both MATHCAD and MATLAB have been used for the course. Starting in the Fall 2003 semester the decision was made to use MATLAB exclusively. One reason is that MATLAB most closely resembles C or FORTRAN in how programs are written. Although not used in the course, MATLAB allows both C and FORTRAN to be imported, and for MATLAB m-files to be exported as stand alone C programs. Thus, it is quite powerful and, in fact, can be used as a program development tool. With MATLAB, it is straightforward to develop user-defined functions that can be used as modules in larger programs.

Data Collection and Analysis

Final grades for every student finishing the course, with one exception, were included in the analysis of the efficacy of the laptop distribution program. One student has habitually failed the ME 329 course, doing almost no work during four consecutive semesters. This student received a laptop in Fall 2004. It was deemed reasonable to remove this student from the analysis due their unusual behavior (most students would have dropped the course and then eventually passed it).

The initial method of assessing student performance with laptops versus those without, is based on the method of resampling[1,2]. This method does not depend on the underlying distribution. The basic method was to develop the probability distribution of all possible subgroup scores. Here the subgroup size is equal to the number of students receiving laptops.

Consider a class with a total of N students in which M laptops were distributed at random, M < N. From the final scores in the course all possible averages of M grades were desired. The number of possible combinations is $\frac{N!}{(N-M)!M!}$. This number can be very large for a typical class and sometimes exceeded the ability of a fast PC to enumerate in any sort of reasonable time. It was found that a random sampling method produced results essentially indistinguishable from complete enumeration. The basic idea is to see if the M laptop recipients did statistically better than a random group of M students.

All calculations and graph generation were done with MATLAB. For the results presented below10^7 random samples of size M were generated from the N students. For each of these samples the average score was calculated. From the 10^7 samples both a frequency and a cumulative probability distribution were developed in the form of histograms. The last step was to place the actual average score of the M laptop recipients in the cumulative probability distribution, and attempt to assess the significance of placement.

Results

Data for the Spring and Fall semesters of 2004 are presented in Figures 1 through 4. Figures 1 and 2 are for the ME 260, while Figures 3 and 4 are for ME 329. Laptops will be distributed during the Spring 2005 and findings for that semester will be included in the final paper.

Each figure includes the frequency distribution followed by the cumulative probability distribution. The bold vertical line in the cumulative distribution indicates the laptop group average. Note that the frequency distributions are reasonably well behaved in the sense of being uni-modal and fairly symmetric, although some skewing is evident. The present comparison method does not require any specific distribution function to proceed with the analysis.

Inspection of part (b) of Figures 1 and 2 shows that the laptop recipients in ME 260 of Spring 2004 did better than about 85% of all possible groups of 20 students. However, the results for

Fall 2004 indicate that the laptop group did no better than average, and perhaps a bit below. The laptop average falls in the middle of a bin so that exact placement is not clear. Nonetheless, it is clear that the laptops did not help this group.

For the numerical methods course, ME 329, inspection of part (b) of Figures 3 and 4 shows that the average score of the laptop recipients is above that of the class as a whole. For the Spring 2004 semester the laptop group did better than about 93% of all possible groups of M students. The results for Fall 2004, while not as dramatic, do show that the laptop group did better than about 83% of all possible groups of M students.

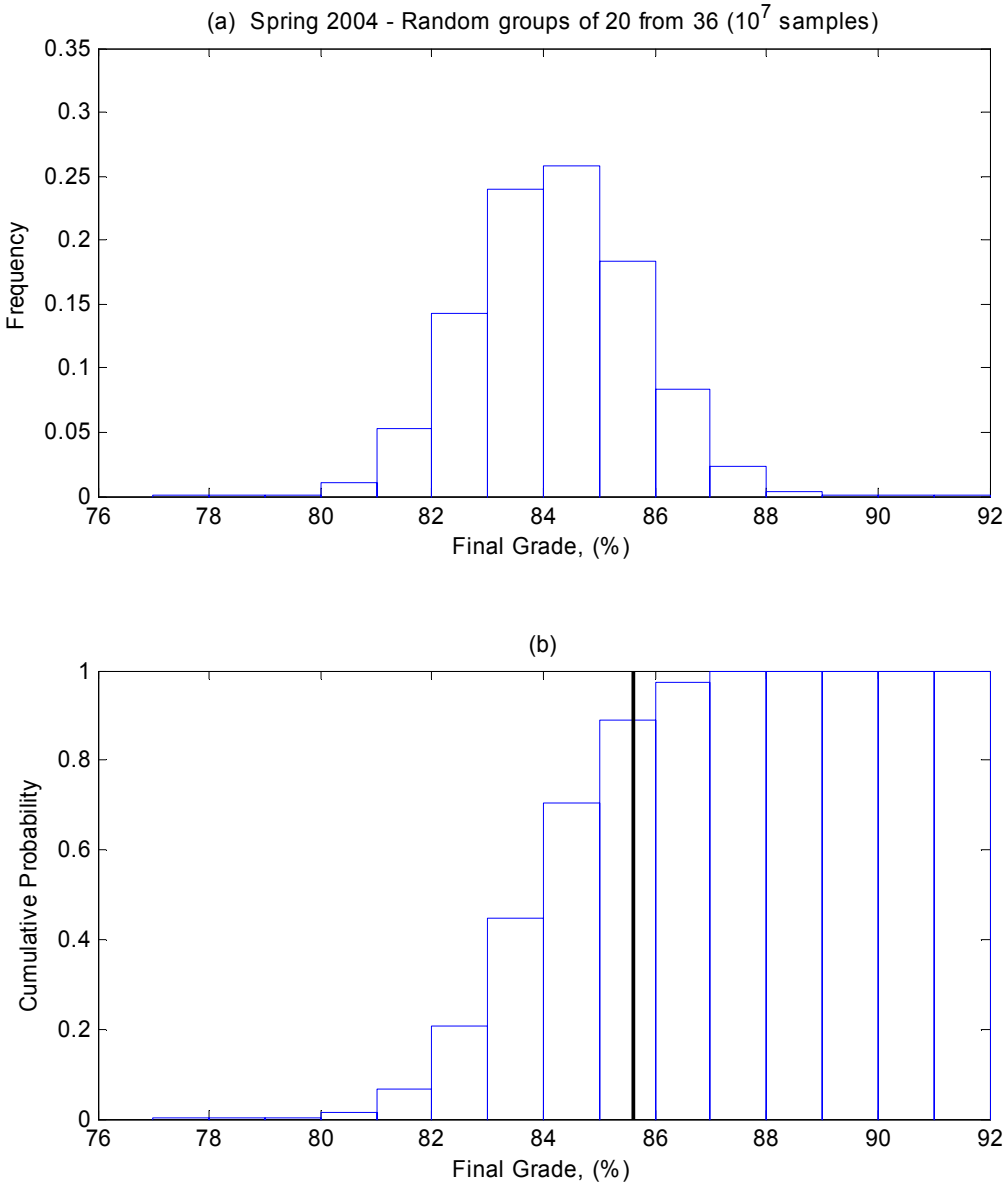

Figure 1. Distributions for ME 260 for Spring 2004 semester. Bold line in part (b) is laptop recipient average.

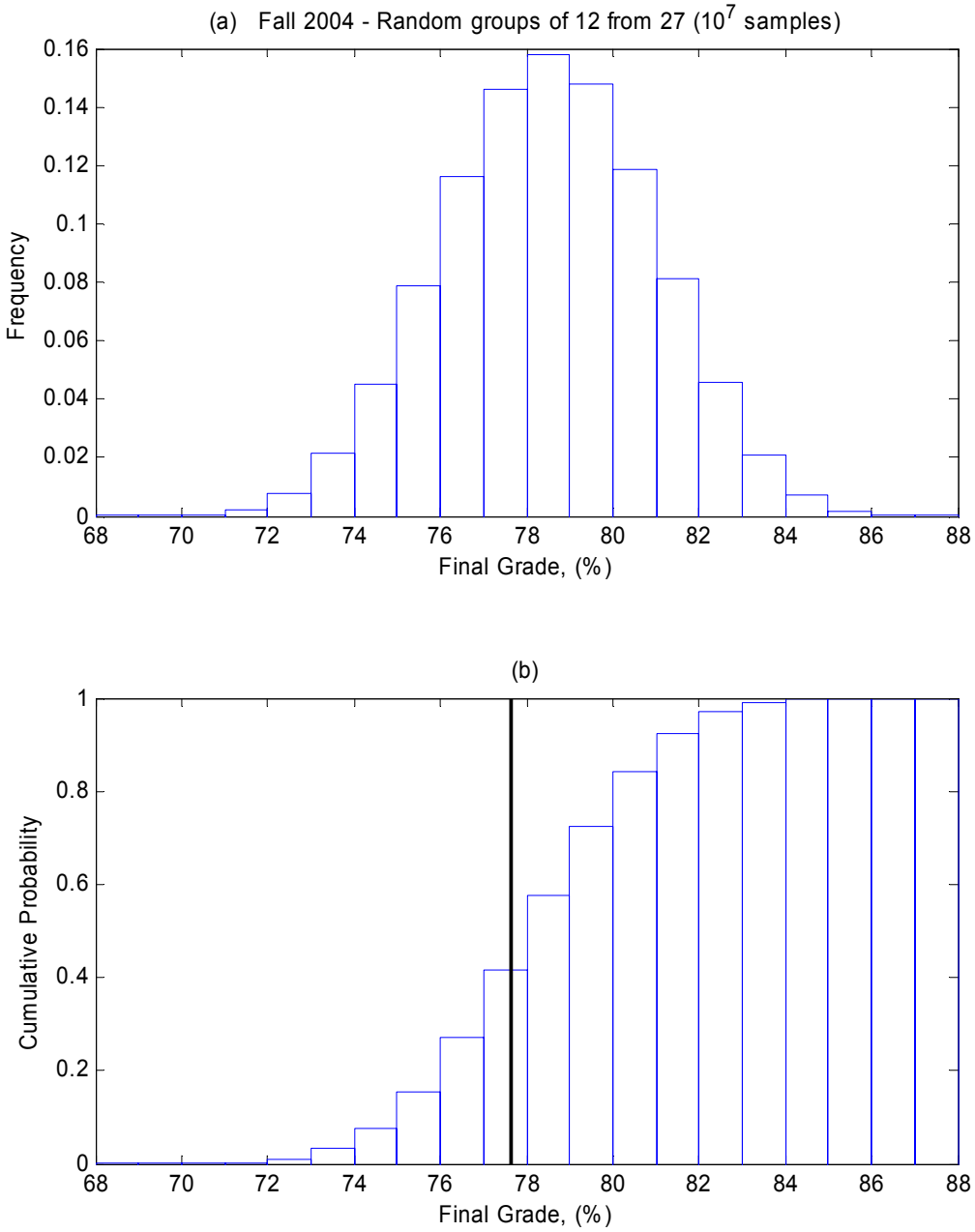

Figure 2. Distributions for ME 260 for Fall 2004 semester. Bold line in part (b) is laptop recipient average.

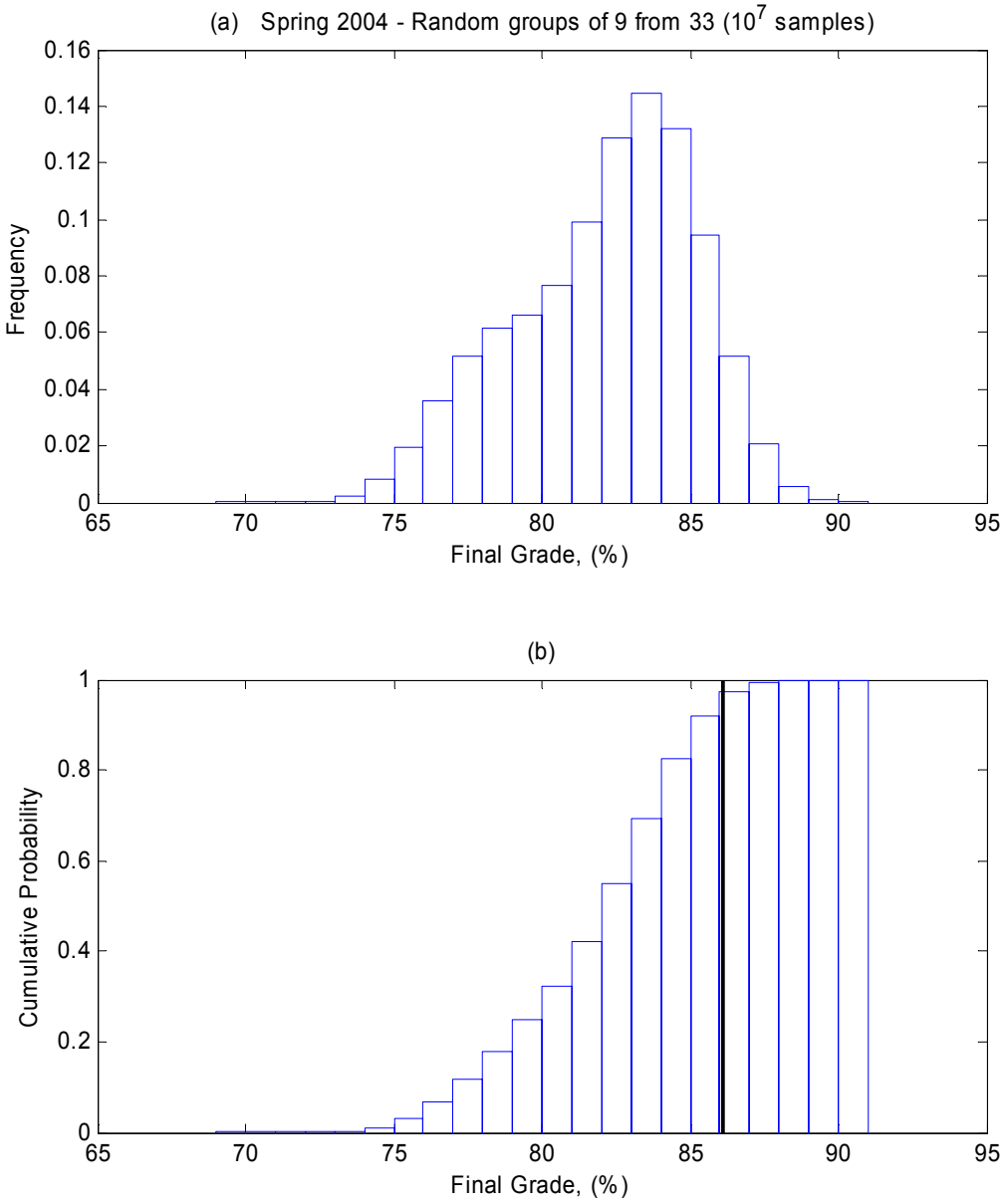

Figure 3. Distributions for ME 329 for Spring 2004 semester. Bold line in part (b) is laptop recipient average.

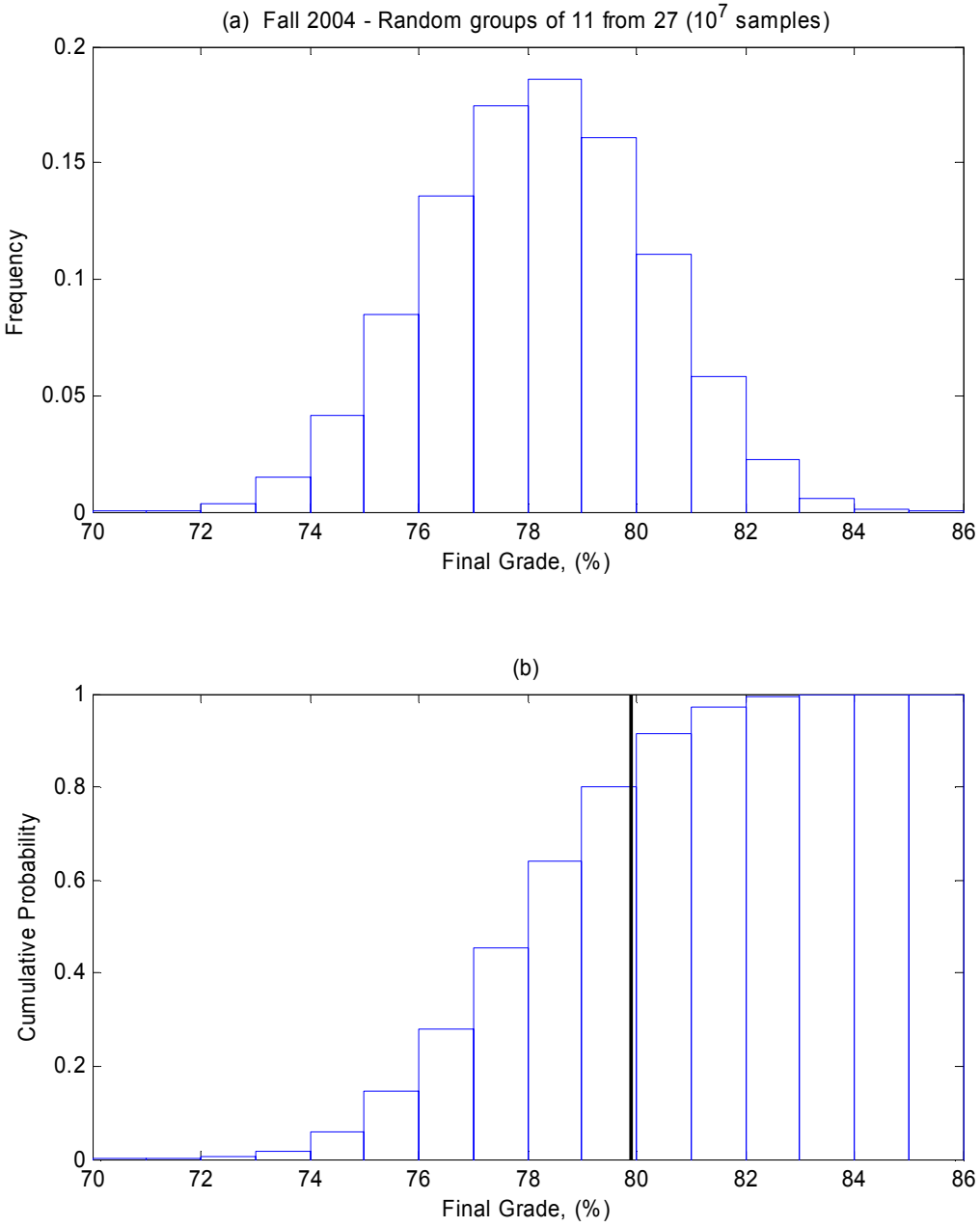

Figure 4. Distributions for ME 329 for Fall 2004 semester. Bold line in part (b) is laptop recipient average.

Discussion of Resampling Results

The typical standard for a statistical test is at the %5 confidence level. With our results, we cannot say that laptops improved a student's performance with this level of confidence. In the case of ME329 though, the results are suggestive. This was born out in a more detailed statistical analysis that will be touched on below and developed further for the June presentation. The ME260 results, averaged over the two semesters, do not suggest any improvement. This conclusion was also supported by the more detailed analysis.

The results presented above are based on the small sample of four classes and thus must be viewed with caution. In fact, the smallness of the samples (mainly number of students) is a major shortcoming. Data for one more semester (Spring 2005) will be available for the presentation in June. With a total of six data sets it is hoped that more reliable conclusions can be drawn. It would seem intuitive that the more resources that are available to a student then the better they should do. However, relatively small data sets, and lack of statistical balance for some categories may make definite conclusions difficult to reach.

Further Statistical Analysis

The authors are most grateful for the assistance of Dr. Leigh Murray of the Economics and International Business Department at NMSU for her assistance in performing a more detailed analysis of the data. These results were made available just before final submission of this paper so only the highlights will be given here. A more comprehensive presentation will be given in Portland in June.

The data provided to Dr. Murray was divided into the following categories: 1) students who had taken computer courses prior to taking ME 260 and ME 329; 2) students who had received a notebook computer in ME 260 and ME 329; 3) students who had taken ME 260 prior to the switch to MATLAB and MATHCAD; and 4) students who had taken the ME 260 after the switch to MATLAB and MATHCAD. From an Analysis of Variance performed on the data it was determined that the only comparison that generated a significant Pr > F value was the comparison between ME 260 students who had taken a computer course prior to taking ME 260. Here the analysis indicated that students who did not take a computer course prior to taking ME 260 performed better in the ME 260 course.

The analysis also showed that in ME 260 students who were provided with computers had an average grade of 80.58 in the course while students who were not given computers had an average grade of 79.28. In ME 329 students who were provided with computers had an average grade of 82.92 in the course while students who were not given computers had an average grade of 79.60. This supports the assumption that students who were given computers, with MATLAB and MATHCAD installed, performed better than students who were not given computers. However, the analysis in all cases indicated that the differences were not significantly different. The strongest effect was in ME329 for students receiving or nor receiving laptops

Conclusions

The present analysis suggest that laptops might improve students final grades, but not at a statistically significant level. One unavoidable shortcoming of the present study is the low number of student scores available for analysis. This is particularly true when trying to determine if affects such as previous experience play a role. Two additional sets of data for the Spring 2005 semester will be included in a final analysis. It has been suggested that the data may yield more meaningful information if a covariate, such as student GPA, is brought into the analysis. Fortunately, these data are available for each student when they started a particular course. The results of this more complete analysis will be presented in June.

References

1. Good, P. I., "Permutation Test: A practical Guide to Resampling Methods for Testing Hypotheses", Springer (2000)

2. Internet web site: www.resample.com . See "Class Evaluation" example at www.resmple.com/content/examples/clasevl.shtml