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# Teaching Theoretical Stochastic Modeling Courses Using Industrial Partners and Their Applied Problems

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This paper describes a pilot project funded by the National Science Foundation's Course Curriculum and Laboratory Improvement program that addresses the common learning challenges of engineering students enrolled in an undergraduate stochastic processes course. In particular, these students often have difficulty transferring this basic knowledge to solving real industrial problems. The traditional curriculum of this course is typically focused on theoretical development of the subject matter and not the implementation of such. Thus, the objective of this project is to introduce "real-world" applications into the curriculum through the development of technology-based laboratory modules in conjunction with several industrial partners to support the development of student problem solving skill using stochastic processes. Each module consists of a self-contained DVD which contains a description of a particular problem, unfiltered data, supporting documents, and student resources. The problem description portion of the DVD consists of one or more videos in which several industrial representatives describe the problem to the students in their own setting. They provide background information about the company, a description of the process under study, a focused description of the problem, and expected deliverables. The modules are presented to teams of students in a laboratory setting, and they will collectively use their knowledge of stochastic processes acquired through lecture to model the problem, parameterize the model, and perform the appropriate analysis. The time frame for each module spans a period of approximately 3-4 weeks at the end of which the students are asked to generate a written and oral report that is to be addressed to the head of the company, i.e. often a non-technical audience. Initial feedback from students, industrial representatives, and peer academic reviewers about the modules has been highly favorable.

In the remaining sections of this paper, we justify the need for this work in the context of engineering disciplines, describe one of the modules as an example, describe research activities and findings to this date, and discuss future work. It is important to note that the activities and findings of this paper span the 2003 calendar year, which corresponds to the first year of this project.

## Project Motivation

The stochastic processes subject is one that spans many disciplines within engineering. There are numerous applications within communications and power systems (Electrical Engineering), water management and transportation (Civil Engineering), and materials (Mechanical Engineering) to name a few. In particular, this subject is an integral part of the Operations Research component of many Industrial Engineering programs and is often regularly taught as either an elective or core course to undergraduate students. The need for the modern-day undergraduate curriculum of Industrial Engineering programs to emphasize applications and "real" problems is well documented in recent literature. This new problem-based curriculum is in contrast to the traditional tool-oriented approach of Roy[1]. Kuo and Deuermeyer[2] remark that the focus of effective modern curriculum should be on the application of the tools rather than the development of the mechanics of the tools. Buzacott[3] suggests that the Industrial Engineering discipline as a whole should be focused on applications rather than theory. He further remarks that the interdisciplinary spirit of the profession should be enhanced. Kuo[4] comments on the need for Industrial Engineering programs of the 21st century to partner with industry. He notes that the undergraduate curriculum of these programs should be focused on and responsive to industry needs.

As for the subject itself, Nelson[5] remarks that students often learn many of the basic concepts of probability modeling in an introductory stochastic processes course, but they frequently have trouble making these concepts "fit" together. For example, students typically understand that probability models may be used to describe real-world events and that they may be parameterized using collected data. They also understand that these models may be analyzed using analytical methods or simulation. The confusion arises in properly connecting the modeling, parameterizing, and analyzing phases of the process. This confusion is only enhanced when the students are asked to consider large-scale "non-academic" type problems where the objective of the analysis is not trivial, the assumptions are not clearly stated, and modern computational support is required.

Feedback from our own assessment processes at New Mexico State University developed under ABET 2000 criteria show the same pattern as observed in this literature. Industry, students, and alumni desire more focus on stochastic modeling applications using advanced technological tools applied to real world problems. These collective observations justify the need for this project and the production of these modules. To the best of our knowledge, this approach to the instruction of this subject has not been preformed elsewhere previously.

## Module Production

The production of each module involves many activities and stages of work. These include problem specification, filming, editing, and testing. The problem specification stage often requires several weeks of discussion as the problem should be realistic, yet manageable given the knowledge level and time constrains of the ultimate implementation to undergraduate students in an introductory stochastic processes course. Once the problem is fully specified, film is collected at the company's physical facility. At this stage, it is important to get as many individuals as possible on camera discussing their role within the company, background information about the company, and/or the problem itself. Additional footage of the surrounding environment should also be collected for future incorporation. The third stage of editing is the most time consuming and technically challenging part of the project. A storyboard for the video portion of the DVD is initially drafted, which provides structure for the editing process. Using Adobe Premier®, the film of the industrial representatives, additional environmental footage, and created text slides are merged together to produce a professional end product. Once produced, the video is tested using a pool of student workers to ensure completeness and aesthetic appeal. These evaluations are combined with that of the industrial representatives and peer academic reviewers and incorporated into the module.

We describe the second module produced with the Celestica Corporation as an example of a finished product. Celestica is a world-wide leader in electronics assembly. Their facility located in Fort Collins, Colorado is one that specializes in the production of high-mix and low-volume specialty products. Hence, their production process must be highly flexible and staffed by well-trained workers. One of the challenges faced in such a production environment is the optimal scheduling of direct labor. Due to the large variability of input materials and product demand, it is often difficult to project the number of workers that will be needed in upcoming two-week scheduling periods. This is the problem that was selected for consideration in the module. The video portion of the DVD for this project contains upwards of 10 individuals at Celestica explaining the company, their mission, and the problem to the students. In particular, the video is divided into three parts titled introduction, problem, and tour of facility. Through these, the student will become fully acquainted with the problem as if they were visiting the facility themselves. Other parts of the DVD include a data portion with the vendor supplies, bill of materials, and product deliveries for the past 3 months, additional documents with the quarterly and year end reports for the past several years, and student resource materials consisting of sample Mathematica® programs for large stochastic methods.

The Celestica module is one of three that has been produced at this time. The others were produced with Fort Bliss Federal Credit Union and Sandia National Labs. Each of the modules present problems that are challenging, not defined in the language of stochastic processes, and not easily solved. We attempt to replicate the "real-world" problem solving environment that the students will face as close as possible.

**Module Implementation**

The modules should be introduced in a laboratory setting as early as possible in the semester. This laboratory period may replace some of the existing lecture periods if additional laboratory time is not available. In particular, it may replace those periods previously spent for working through example problems. The time span for each module in meant to encompass a period of about 3 to 4 weeks. The students will need to spend a considerable amount of outside class/lab time in completing this work, possibly upwards of 20 hours per person in the group. The student teams should receive minimal general guidance from the instructor in fulfilling this work as they are to use their creativity in model building and problem solving. The instructor should respond to direct questions when asked given that they are related to the preliminary work performed by the group. Any assumptions that need to be made about the problem should be done by the individual groups and justified if possible. At the end of the allotted time period, the groups should present an oral and written report as if it were to be given to the chief executive of the company. The importance of comprehensive reporting should be stressed by the instruction in that only if their work is interpretable by the ultimate customer will be of any practical use.

**Preliminary Module Evaluation**

The Fort Bliss Federal Credit Union and Celestica modules were implemented in the Industrial Engineering 415/515 stochastic processes modeling courses and the IE 630 Engineering Logistics course in the spring 2003 semester at New Mexico State University. These courses consisted of 12 undergraduate students and 29 graduate students from various engineering departments including Industrial, Electrical, and Civil Engineering. Attitudinal surveys were collected from the students in which they were asked to evaluate each module. This led to several key preliminary findings related to module timing, length, reporting, and support which are qualitatively summarized in this paper. A comparison of performance evaluations prior to and following module incorporation has not yet been completed due to the ongoing establishment of rubrics. These may be obtained from the authors of this paper upon completion by request.

In general, the student teams liked working on "real" problems in a group setting. This was something that was exciting and gave a sense of purpose to them. From evaluations of the module, students reported these comments: *"The Celestica problem was excellent. It was great to deal with a real world complex problem."* And this comment: *"The module was worthwhile. It lends a far more realistic approach to the theory we covered, a definite improvement over the imaginary scenarios normally used to present concepts."*

The students also felt DVD delivery medium was effective, enjoyable, and generally of high quality. *"The video and audio was easy to watch, the content was good and the supporting files gave a lot of pertinent information."* The alternative teaching approach to stochastic processes also received high marks from the students. *"I felt the module was a very good teaching method. Projects help an individual get a better grasp of material and a project that is a real world example is even better. Also in the module, a student gets to see if his way of solving the problem compares to an IE in the workforce."*

An unintended positive consequence of the module was the new found sense of confidence some students realized when working with real-world "noisy" problems. *"It was eye-opening to realize how little some companies know about process improvement and logistics philosophies. That realization made me feel much more confident in my own newly acquired skills."* Also, as stated earlier, a great deal of Celestica information was contained on the DVD, some of which was not at all necessary to formulate a solution to the problem at hand. By having a number of different individuals present aspects of the problem, contradictions of perspective normally occurred. *"I felt that the gentleman that was the main presenter of the video had a lot of good information and was able to convey his information very well. However some of the others that spoke in the video seemed at times to contradict one another and also some seemed to give wrong information."*

Most students had some level of access to a DVD player outside of the laboratory classroom that allowed them to work on the project at times that were convenient for the group. The evaluations were mixed yet generally positive on whether the students felt that they learned more using the modules than they would have otherwise. Again, a sampling of verbatim comments follow. *"I think the module was a useful tool to discuss how problems actually arise and are perceived inside of a factory. I didn't find the supporting documentation useful, more distracting than anything, but if we'd had longer to work on the problem, it may have been useful. Again, however, from a real world perspective, that also occurs, having information available that isn't really useful in solving the problem."*

Students' main dislikes centered around the pace of the modules and the lack of a clear definition on how to apply stochastic processes in solving the problem. There were also several comments with regard how students ultimately presented their deliverables related to the modules. *"I felt that the only downside was the time allotted to do the work on this module. I feel if it could have given earlier, it wouldn't have been so rushed or we could have done a better job of analyzing."* Some students proposed alternative methods for deliverables and discussion of solutions. "*Distribute the module early in the course and leave time at the end to discuss each of the logistics philosophies presented as solutions to the Celestica problem. If time allows, go through a second iteration of solutions using the material discussed after the first round. Allow the class to evolve in a direction indicated by the solutions presented. Overall, the module was excellent, but there is still more potential."*

We are looking into possible ways to narrow the scope of the problems presented in the modules without loosing realistic interest. A possible alternative would be to use the module projects as homework and/or test grades to alleviate some of the students existing time constraints. The problem of solution uncertainty is one aspect that was actually built into the modules. The student are generally used to receiving case studies with clean solutions in most of their other courses for project assignments, which the modules are not and are not supposed to be. A greater level of instructor involvement with the groups, possibly scheduled meeting to review progress, might help the student groups resolve this concern.

Overall however, one of the primary goals of this pilot project is to heavily focus on internal and external evaluation of the modules and use the lessons learned in applying for a second round of NSF funding. We feel that we have sufficient feedback at this point to move in this direction.

**Future Developments**

Through the course of this pilot project, we have amassed a great level of knowledge into the difficulties and requirement for producing instructional modules using digital video media. We plan on continuing these efforts towards the production of a suite of 10-12 modules that span multiple disciplines by applying for the next round of NSF funding. We are considering expanding this work to include problems centered on interesting research based problems from academia, i.e. spread of AIDS, etc., and developing basic modules for the inclusion in an Advanced Placement Statistics course in K-12 high school education.

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