# *Integrating Technologically-Based Laboratory Modules into the Stochastic Processes Curriculum*

Timothy I. Matis
New Mexico State University
USA

Linda Ann Riley
New Mexico State University
USA

James H. Matis
Texas A&M University
USA

## Abstract

*This paper describes a new and innovative approach to the instruction of applied stochastic processes at institutions of higher education and a method for introducing this topic to K-12 students for pre-course motivation. This approach consists of incorporating laboratory modules via digital video media that present real-world applications of stochastic processes into coursework. The modules engage the students in problem solving, thereby creating a conceptual framework for learning the subject. The pedagogy behind this instructional approach and module content is described in this paper. Preliminary evaluations are presented for assessment purposes from a pilot implementation of the modules at the collegiate level.*

## Introduction

The usefulness of stochastic processes in the modeling and analysis of many science and engineering applications has prompted the recent instructional expansion of this topic. Kao (1997) notes that this expansion has been spurred by the increase of readily available computational power, which increases the ability of this modeling approach to more fully analyze real-world problems. Though the subject is rich in mathematical theory, the learning objective of many students exposed to stochastic processes is to develop knowledge in the subject for application to their own areas of interests. The curriculum of many introductory courses at the collegiate level, however, is frequently centered solely on the theoretical underpinnings of the subject. The topic is typically introduced in a mathematically rigorous fashion, with limited exposure to its use as a modeling and analysis tool. At the K-12 level, stochastic modeling is an advanced topic that is rarely introduced to the students. In those rare cases that it is introduced, the subject is illustrated with simple mathematical exercises that have no practical application or with projects that the students do not actively work on. Hence, the aforementioned learning objectives are frequently not addressed by the curriculum of related courses at either level.

This paper describes materials being developed for the instruction of stochastic processes that promote the development of understanding skills and knowledge-transfer ability by the students. This work is being funded by the National Science Foundation and consists of technologically-based laboratory modules that describe real-world problems whose solution involves stochastic modeling and analysis. Each module consists of a self-contained DVD that is produced through multidisciplinary collaboration with industry, government, and academia. The students work together in teams to solve the presented problem using standard concepts covered either in lecture or on the DVD itself. The stochastic methods addressed by the full set of modules include properties of expectation, Markov chains, Markov processes, and Markov-renewal theory. Each module spans a period of roughly three weeks of normal coursework and requires considerable effort by each team. The students are expected to deliver upon completing each module a comprehensive oral and written report that is directed towards a non-technical audience. This report should clearly describe the chosen model, justify its assumptions, and describe the result of their analysis.

The remaining sections of this paper present: the pedagogy behind the modules; a module targeted to K-12 students for pre-course motivation; modules targeted to higher education; and the evaluation of a pilot implementation of the modules in a collegiate setting.

## Module Pedagogy

The pedagogy behind the laboratory modules presented in this paper is based on concepts that were recently reported by the National Research Council (2000) in the *How People Learn* (HPL) research compilation. Though not referenced directly, the remaining discussion in this section draws upon ideas and research findings presented in this HPL compilation. Clearly there are numerous other learning theories, however, the HPL concepts seem particularly relevant to the present effort.

The laboratory modules create a knowledge-centered learning environment for the students. This provides a structure on which they are able to organize and expand their knowledge of stochastic processes. An open problem is described through the use of digital visual media by industrial representatives in their own setting. The students start with a preconceived notion of the presented problem and possible solution methods to the problem. These initial ideas form a base of knowledge upon which new information is added as models are built, statistical tests performed, and analysis completed. Erroneous concepts are replaced with correct knowledge as the iterative modeling, testing, and analysis procedure progresses, thereby encouraging the development of conceptual understanding rather than factual knowledge.

In particular, as the students begin modeling the problem, they will draw on the material that they have learned in lecture up to that point. The instructor should help the students organize previously learned information about stochastic processes in the context of the model. This guidance should be performed cautiously, however, as the students should not be directed to any particular modeling approach. The students should be encouraged to "find their way" around the module by using their own perceived knowledge in creating various models. These initial models may be flawed or not reflective of the process, yet as the students attempt to parameterize and analyze these flawed models, the shortcomings of their approach will often be apparent to themselves and the group. This self-correction process aids in the ultimate conversion of learned material to useful knowledge.

Upon completion, the modules create a context for the conceptualization of future information acquired in the subject. In a sense, the students become "experts" in the topics of the completed modules, and mimicking the conceptualization process of "experts", the students will tend to place new information acquired about stochastic processes in this established context. Thus, the process of knowledge building is transformed and expanded gradually in a structured and contextualized manner towards the ultimate goal of understanding concepts within the discipline.

The creation of the problem contexts by the modules, however, presents the potential risk of over-contextualization of the subject by the students. This would actually hinder the ability of the students to transfer their knowledge to the solution of other problems outside the realm of the modules. The steps that we have taken to minimize this risk are two-fold. First, several modules should be introduced to the students throughout the course of the semester. These modules are not used as semester projects but rather span a limited time period of only three-four weeks. As such, the students are exposed to several different contexts throughout the semester, each of which adds to their conceptual framework. The second step is the reuse of a module topic in multiple contexts. A module may be presented to the students several times throughout the semester, as they are asked to expand upon a previous problem that was presented. For example, the instructor may ask the students to relax assumptions made previously or engage in "what-if" scenarios. Both of these measures will assist in the generalization of the concepts by the students beyond the specific context of the modules.

## Description of K-12 Modules

A DVD with the objective of introducing stochastic processes to students at the K-12 level with only a first course in statistics is being developed as part of this project. Some materials which introduce stochastic processes in week-long research workshops for high school Advanced Placement (AP) students are described in Matis, Kiffe, Renshaw, and Hassan (2003). The participating students at these workshops are required to have coursework in statistics and calculus, but have little or no exposure to stochastic processes. Several days of basic lectures on the topic are followed by the presentation of some realistic application. Applications have included problems dealing with stochastic system modeling of ruminant nutrition, human physiology, and insect population dynamics.

The modules prepared for this broad target audience will be framed by subject-matter experts in their real-world settings, and each DVD will contain an abundance of data and background resource material. The DVDs for this audience will also contain a complete solution to the problem, with references to the scientific literature which address the problem. The learning challenge for the students will be to integrate the methodology presented in the DVD with the published scientific papers on the specific example, and then transfer that knowledge to solve similar, closely related examples.

The first part of the initial DVD addresses predicting the arrival time of the Africanized honey bee (AHB) at a given location. Entomologists at Texas A&M University (TAMU) describe methods for AHB trapping, and data on the movement of the leading edge of the invasion through Mexico are provided. Descriptive statistics are discussed and a probability model is developed for predicting future movements. These predictions are shown to be successful until the arrival of the varroa mite parasite. The impact of the varroa mite on bee colonies is described by a commercial beekeeper (at B. Weaver Apiaries).

The second part of the DVD introduces the logistic population growth model, a fundamental concept in ecology, and its fixed ‘carrying capacity’ parameter. The concept of a more general, equilibrium population-size distribution, which can be approximated using simple algebraic equations for its moments, is also presented. The DVD shows a study area at the Welder Wildlife Refuge in south Texas, with a TAMU entomologist pointing out active AHB colonies at a distance. Data on AHB density at this site over a 12-year period are presented, and used to parameterize the stochastic model. Students are challenged to apply the new methodology to predict fox and badger population densities in England from data given in the literature.

The DVD will be widely disseminated among AP students, as well as first course statistics students at TAMU, to test its effectiveness. The application to bee and mite population dynamics is developed extensively in Matis and Kiffe (2000), which illustrates how relaxing certain assumptions, such as single births and exponential waiting times, can introduce the student to cutting-edge research problems in stochastic processes.

## *Description of Higher Education Modules*

At the present time, a set of three pilot modules targeted toward the instruction of stochastic processes at the undergraduate level in a collegiate setting have been produced with Fort Bliss Federal Credit Union, Sandia National Laboratories, and the Celestica Corporation. The respective topics of these modules are the allocation of finite resources for the collection of past due loans, reliability and failure modeling of the Z-machine (an extremely powerful X-ray generator), and the scheduling of direct labor. These three examples illustrate, respectively, the concepts of Markov chains, Markov processes, and Markov-renewal theory. The problems presented in each of the modules are not trivial and require the specification of several assumptions by the students. In many modules, it is necessary for the students to limit the scope of the problem to facilitate a tractable analysis in terms of project time. The format of the modules will be described in this section in a general setting and supported with still images from the Fort Bliss Credit Union module as an example. Following this, a sample implementation of the modules with pedagogical reference is given.

As previously noted, each module consists of a self-contained DVD that is presented to a team of students. Upon inserting the DVD into a player, an introductory movie begins that displays clips related to the project set to music. This introductory piece spans a period of roughly one minute with the student given the option to skip at any time (Figure 1).

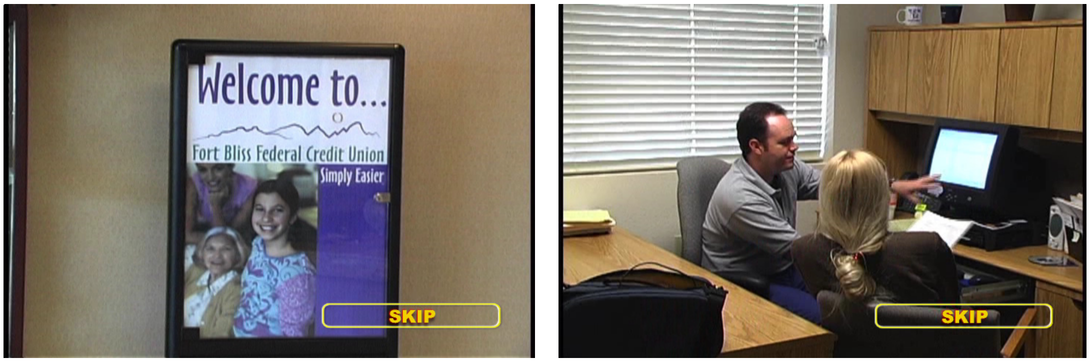


**Figure 1: Still Images from the Introductory Movie of the FBFCU Module**

The main menu of the DVD is presented upon either completion or termination of the introductory movie. This menu is accompanied by an audio track in which navigation instructions are given to the viewer. The buttons lead to a series of sub-menus that contain the movies, data, supporting documents, student resources, and production credits (Figure 2).

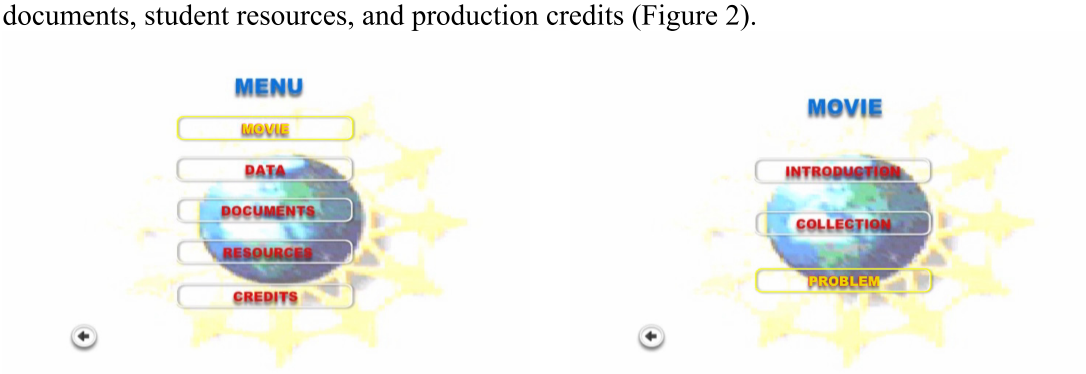


**Figure 2: Still Images of the Navigational Menus of the FBFCU Module**

The movie section of the DVD contains a visual introduction to the company, description of the problem, and statement of expected deliverables. The movies collectively span a time period of approximately 1 hour and contain several representatives of the company addressing the students (Figure 3).


**Figure 3: Still Images of Representatives from the FBFCU Module**

The movies are significantly augmented with overlaid graphics and text to aid in the understanding of the material and maintain the interest of the viewer in the movie. These rotate in and out of the presentation approximately every 30 seconds on average (Figure 4).

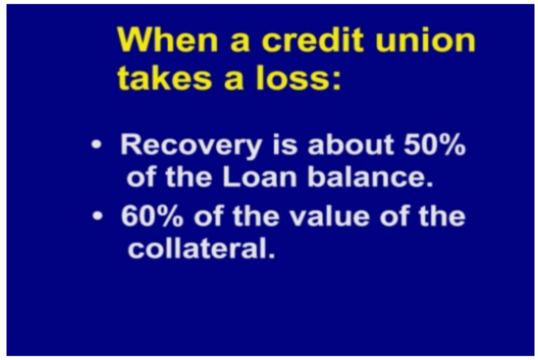


**Figure 4: Still Images of Graphic and Text Overlays from the FBFCU Module**

The other sections of the DVD contain additional material that the student might find useful in solving the problem. These materials are stored in the ROM section of the DVD and may be downloaded to their computer. The data section is typically divided into two parts. The first contains a description of the data in Microsoft Word® format and the second contains the data itself as either a Microsoft Excel® or text file. The supporting documents section contains additional company information, i.e. mission statements, standard operating procedures, financial reports, etc, in PDF format. The student resources section contains Mathematica® programs that demonstrate the computer implementation of common methods used in stochastic processes. The DVD is enclosed in a case that displays artwork relevant to the problem and credit to the production team.

As an example, consider the following module implementation plan for an introductory stochastic processes course. When the instructor is near completion of his/her lectures on Markov chains, the instructor organizes teams of 3-4 students and assigns them the FBFCU module. To support the students with this assignment, the instructor may want to set aside one lecture a week as a laboratory period in which he/she meets with the teams to monitor their progress. The students view the DVD either as a team or individually and meet to discuss the problem. A preliminary conceptual framework is established by the each student through their initial insights into the problem and ideas of possible solution methods. This framework is subsequently reshaped as the students meet as a team to discuss the problem. At this stage, a preliminary model will be built by the team, which may or may not involve Markov chains. As the students attempt to parameterize and perform statistical tests on the model they created, they may discover that the model originally created needs to be modified. For example, states may need to be added, removed, or reclassified, the model may need to be modified for the Markov property to be reasonable, the order of the Markov chain may need to be increased, etc. Their conceptual framework is continually updated with this new information throughout this process and their knowledge base corrected. Once justified, the model will be modified and analyzed repetitively to optimize the performance of the system, whereupon a written and oral report will be generated. The students' base of knowledge is now at the level at which the final model was created. To avoid over-contextualization, the instructor may ask the students to vary some assumptions of the problem or assign another problem whose solution involves Markov Chains. As the lectures progress through the next topic, say Markov Processes, the instructor will repeat the same exercise with the Celestica module and the process starts over.

Some common comments received by the laboratory instructor (teaching assistant) of the 415/515 introductory stochastic processes course at New Mexico State University related to the fall 2003 implementation of the FBFCU module were: *1) Do we use all observations when calculating the transition probabilities of an absorbing Markov Chain or only those in which the process was absorbed, 2) I went ahead and assumed the chain was of first order since that is what we covered primarily in class, that is not a big a deal, is it?, 3) The steady state distribution ends up with everything in the two absorbing states, how do I get steady state probabilities for the other states?, 4) What is the state space of the process?,* and *5) What do I do with the model now that I solved it?*. These common questions came out of student attempts to solve this problem and each exposes a deficiency in the student's current knowledge base, i.e. 1) correctly interpreting data, 2) understanding the Markov property, 3) interpreting transient states, 4) creating models reflective of the process that answer desired questions, and 5) using the model to optimize a process. It is important to note that the students discovered this knowledge deficiency themselves and corrected it through limited intervention by the instructor. In addition, this range of questions spans all phases of the stochastic modeling process, i.e. model formulation, parameterization, and analysis. Some groups went through several model building iterations and raised several similar types of questions before creating a model that performed acceptably for them. This information correction process expands and refines the base of knowledge possessed by the students, towards the development of fundamental understanding in the subject.

## *Module Evaluation*

At the present time, evaluations have been collected for the Fort Bliss Credit Union and Celestica higher education modules from pilot implementations in the Industrial Engineering (IE) 415/515 introductory stochastic processes course and the IE 630 Engineering Logistics course at New Mexico State University in the fall 2003 semester. The purpose of these evaluations is to assess the efficacy of the modules in achieving the desired outcomes of: 1) an improved learning environment for students enrolled in introductory stochastic processes courses, 2) higher levels of understanding of the course material among students, and 3) higher levels of knowledge transfer from this course to others where the theory is applied. In establishing the universal principles of utility, feasibility, propriety, and accuracy in the evaluation, this evaluation plan incorporates the assessment methods of Lewis and Seymour (www.wcer.wisc.edu/nise/CL1/flag/cat/attitude/attitude1.htm) and of Slater (www.wcer.wisc.edu/nise/CL1/flag/cat/perfass/perfass1.htm), along with the statistical techniques of Jaeger (1983), and the program evaluation standards of the Joint Committee on Standards for Educational Evaluation (JCSEE, 1994).

The evaluations presented in this paper are only a part of those that have been and will be collected. The full assessment plan additionally includes faculty peer-review of the modules and student performance evaluations, which are in the process of being collected and organized. However, the evaluations currently available and presented in this section provide preliminary evidence to the efficacy of this educational approach. A copy of the attitudinal survey is contained in the appendix of this paper and should be consulted for the full interpretation of stated findings.

### <u>*Qualitative Response*</u>

The qualitative response section of the attitudinal survey administered to the IE 630 course in fall 2003 for the Celestica module is summarized below. Selected comments were extracted from the surveys and are reported verbatim.

In general, the student teams liked working on "real" problems in a group setting. 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 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."*

The evaluations were mixed yet generally positive on whether the students felt that they learned more using the modules than they would have otherwise. *"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. *"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."*

## Quantitative Response

The quantitative response sections of the attitudinal survey given in Appendix A which was administered to the IE 415/515 course in fall 2003 for the FBFCU and Celestica modules are summarized below in Figures 6 and 7 respectively. There were at total of 12 respondents to the FBFCU survey and 14 respondents for the Celestica module, which is a subset of the 18 people to which the modules were assigned.

Attitudinal Survey for Fort Bliss Credit Union Module
IE 415/515 Fall 2003

| Question # | | | | | | | | | | | | | Average | Median | Variance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | 1 | 4 | 2 | 1 | 1 | 4 | 3 | 1 | 1 | 2 | 2 | 1 | 1.92 | 1.5 | 1.36 |
| 1.2 | 1 | 4 | 2 | 1 | 3 | 4 | 3 | 1 | 2 | 2 | 2 | 1 | 2.17 | 2 | 1.24 |
| 1.3 | 1 | 3 | 3 | 1 | 3 | 4 | 2 | 1 | 3 | 2 | 3 | 2 | 2.33 | 2.5 | 0.97 |
| 1.4 | 1 | 4 | 3 | 1 | 1 | 3 | 2 | 1 | 1 | 2 | 3 | 2 | 2.00 | 2 | 1.09 |
| 1.5 | 1 | 4 | 4 | 1 | 3 | 3 | 2 | 1 | 1 | | 3 | 2 | 2.27 | 2 | 1.42 |
| 1.6 | 1 | 3 | 4 | 1 | 5 | 4 | 3 | 2 | 2 | 3 | 3 | 1 | 2.67 | 3 | 1.70 |
| 1.7 | 1 | 3 | 4 | 1 | 2 | 3 | 2 | 1 | 1 | 3 | 2 | 1 | 2.00 | 2 | 1.09 |
| 2.1 | 1 | 3 | 4 | 1 | 2 | 5 | 1 | 3 | 1 | 2 | 2 | 1 | 2.17 | 2 | 1.79 |
| 2.2 | 1 | 3 | 4 | 1 | 3 | 5 | 1 | 3 | 2 | 2 | 2 | 2 | 2.42 | 2 | 1.54 |
| 2.3 | 1 | 4 | 3 | 1 | 2 | 4 | 1 | 2 | 2 | 2 | 2 | 1 | 2.08 | 2 | 1.17 |
| 2.4 | 1 | 3 | 1 | 1 | | 3 | 1 | 1 | | 2 | 2 | 1 | 1.60 | 1 | 0.71 |
| 2.5 | 1 | 4 | 4 | 1 | 5 | 3 | 2 | 3 | 1 | 2 | 2 | 1 | 2.42 | 2 | 1.90 |
| 2.6 | 1 | 4 | 5 | 1 | 5 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 2.67 | 2 | 1.88 |
| 2.7 | 1 | 3 | 4 | 2 | 5 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 2.42 | 2 | 1.36 |
| 2.8 | 1 | 3 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 2.25 | 2 | 0.57 |
| 2.9 | 1 | 3 | 4 | 1 | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 1.92 | 1.5 | 1.17 |

**Figure 6: Quantitative Response to the IE 415/515 Implementation of the FBFCU Module**

Attitudinal Survey for Celestica Module
IE 415/515 Fall 2003

| Question # | | | | | | | | | | | | | | | Average | Median | Variance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | 3 | 2 | 2 | 1 | 5 | 3 | 2 | 4 | 2 | 4 | 5 | 4 | 2 | 1 | 2.86 | 2.5 | 1.82 |
| 1.2 | 3 | 2 | 3 | 1 | 5 | 3 | 2 | 4 | 2 | 4 | 5 | 4 | 4 | 2 | 3.14 | 3 | 1.52 |
| 1.3 | 4 | 2 | 2 | 1 | 4 | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 3 | 2 | 2.93 | 3 | 0.99 |
| 1.4 | 4 | 2 | 2 | 1 | 3 | 2 | 2 | 2 | 3 | 4 | 3 | 2 | 3 | 1 | 2.43 | 2 | 0.88 |
| 1.5 | 3 | 2 | 3 | 4 | 3 | 2 | 2 | 2 | 3 | 4 | 3 | 1 | 3 | 1 | 2.57 | 3 | 0.88 |
| 1.6 | 5 | 2 | 4 | 1 | 5 | 4 | 4 | 4 | 3 | 4 | 5 | 4 | 4 | 3 | 3.71 | 4 | 1.30 |
| 1.7 | 4 | 2 | 3 | 1 | 3 | 4 | 3 | 2 | 2 | 4 | 2 | 1 | 2 | 1 | 2.43 | 2 | 1.19 |
| 2.1 | 5 | 2 | 4 | 1 | 5 | 5 | 2 | 4 | 2 | 3 | 2 | 3 | 2 | 3 | 3.07 | 3 | 1.76 |
| 2.2 | 5 | 3 | 4 | 1 | 5 | 5 | 2 | 4 | 2 | 3 | 4 | 3 | 2 | 3 | 3.29 | 3 | 1.60 |
| 2.3 | 4 | 3 | 4 | 1 | 1 | 5 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 4 | 2.79 | 3 | 1.41 |
| 2.4 | 3 | 3 | 2 | 1 | | 5 | 1 | | 2 | 3 | | 3 | 2 | | 2.50 | 2.5 | 1.39 |
| 2.5 | 5 | 3 | 4 | 1 | 5 | 5 | 2 | 4 | 2 | 3 | 4 | 3 | 4 | 4 | 3.50 | 4 | 1.50 |
| 2.6 | 5 | 1 | 2 | 1 | 5 | 5 | 2 | 2 | 2 | 3 | 2 | 1 | 3 | 3 | 2.64 | 2 | 2.09 |
| 2.7 | 4 | 2 | 3 | 2 | 5 | 5 | 2 | 4 | 2 | 3 | 4 | 2 | 4 | 5 | 3.36 | 3.5 | 1.48 |
| 2.8 | 1 | 2 | 1 | 2 | 3 | 1 | 1 | 1 | 5 | 4 | 2 | 2 | 3 | 3 | 2.21 | 2 | 1.57 |
| 2.9 | 5 | 1 | 3 | 2 | 5 | 5 | 3 | 4 | 1 | 4 | 5 | 1 | 4 | 5 | 3.43 | 4 | 2.57 |

**Figure 7: Quantitative Response to the IE 415/515 Implementation of the Celestica Module**

A general comparison of these quantitative results reveal that 1) the students liked the FBFCU module more than the Celestica module, 2) the students felt the modules were implemented in too short a time frame, and 3) the students were mixed on their thoughts of the modules efficacy as a learning tool. It is important to note that the Celestica module was implemented in the final three weeks of the semester during final examinations. The majority of students expressed verbal disapproval for this timing.

## Conclusion

Materials developed for the instruction of stochastic processes at the K-12 and higher education levels have been described in this paper. These materials were developed based on the pedagogy presented in the *How People Learn* research compilation, and they create a knowledge-centered learning environment. Preliminary evaluations are presented from pilot implementations of the modules to assess the adequacy of this educational approach.

## Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 0230643. A copy of the DVD laboratory modules described in this paper may be obtained free of charge by request. Please visit the website http://engr.nmsu.edu/~csm/nsf-project/ and follow the "request evaluation copy" link.

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# *Paper Appendix: NSF Pilot Project Evaluation*
# *Teaching Theoretical Stochastic Modeling Courses Using Industrial Partners and Their Applied Problems*

*Background*

The goal of this NSF pilot project is to create an innovative learning environment that incorporates "real-world" applications into Industrial Engineering courses that include (IE) the study of stochastic processes. This is accomplished through the development of a set of technology-based modules developed in conjunction with several industrial partners. Therefore, the purpose of this evaluation is to determine:

1. To what extent were the goals met;
2. How might this pilot project be improved for further development in the future;
3. What were the strengths and weaknesses of the multimedia modules associated with the course; and
4. Your opinion on how this approach supports the overall program of study in industrial engineering.

Ultimately, this evaluation will assist the project principal investigators with refining the content and delivery of the modules for future offerings.

*Part 1*

As relayed in class with the introduction of the modules, the outcomes of this project include an improved learning environment, higher levels of student transferal of knowledge, the exposure of students to a number of different technological tools, the integration of advanced technology in the design and creation of the modules, and a curriculum package that is highly transferable to other programs and universities offering stochastic modeling courses.

Therefore, for each of the following topics, please circle the number that best describes your response on a scale of 1 to 5, where 1 means your strongly agree and 5 means that you strongly disagree.

| What module are you evaluating in this survey?<br>☐ Fort Bliss<br>☐ Celestica<br>☐ Sandia National Laboratories | **Strongly Agree** | | | | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1.1 The use of a multimedia module for **understanding** industrial engineering problems was helpful. | 1 | 2 | 3 | 4 | 5 |
| 1.2 The use of a multimedia module for **solving** industrial engineering problems was helpful | 1 | 2 | 3 | 4 | 5 |
| 1.3 The video portion of the module was effective. | 1 | 2 | 3 | 4 | 5 |
| 1.4 The video portion of the module was well-produced. | 1 | 2 | 3 | 4 | 5 |
| 1.5 The overall quality of the video was excellent. | 1 | 2 | 3 | 4 | 5 |
| 1.6 The additional resources portion of the module helped me understand the problem better. | 1 | 2 | 3 | 4 | 5 |
| 1.7 The audio quality of the DVD was effective? | 1 | 2 | 3 | 4 | 5 |

*Part 2*
The second set of questions investigates specifics about the integration of the modules into the course design and the instructor's knowledge level and methods with respect to the module. Please answer the following questions by placing an X in a box corresponding to 1 to 5.

| | | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|---|
| 2.1 Instructor's apparent familiarity with the material presented on the module. | Extensive | | | | | | Limited |
| 2.2 Instructor's ability to convey knowledge about the subject matter on the module. | Excellent | | | | | | Poor |
| 2.3 Instructor's attitude toward using the module. | Enthusiastic | | | | | | Bored |
| 2.4 Instructor's impartiality in grading module work. | Fair | | | | | | Biased |
| 2.5 Organization of the module integration into the course. | Excellent | | | | | | Poor |
| 2.6 The instructor motivated me to do my best on the module. | Strongly agree | | | | | | Strongly disagree |
| 2.7 I have learned....because of using the module. | More than expected | | | | | | Less than expected |
| 2.8 The pace of the module presentation was... | Too fast | | | | | | Too slow |
| 2.9 Would you recommend that the instructor use this module again? | Definitely yes | | | | | | Definitely no |

*Part 3*
This section of the evaluation asks you to comment on the instructor's strengths and areas for improvement with respect to teaching this module as a component of this course. It also asks you to comment on how the module could be better developed for the future.

3.1 How could the instructor improve the integration of this module into course material with regard to content, presentation, utilization of class time, balance between book, modules and lecture? What would you change for future offerings of this course using this module? Please explain your answers below. Use additional paper if necessary.

3.2 How might the module be improved? Please comment on video, audio, content, supporting files, etc. Use additional paper if necessary.

*Part 4*

4.1 In your opinion, do you feel that this module was a worthwhile addition to the course material? Why or why not?

4.2 Is there anything else you would like to add to this module evaluation that hasn't been covered thus far?