CONCEPTUALIZING APPLIED PROBABILITY THROUGH PROJECT-BASED LEARNING

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Several prominent educational institutions have recently increased their use of team-based projects to both enhance learning and aid in assessment. We present some of our ongoing research into the use of project-based learning for the instruction of applied probability and stochastic processes at the high school, undergraduate, and graduate levels. In particular, we will demonstrate how "real-world" multimedia modules may be integrated into the curriculum of existing educational programs to enhance learning. This includes the effective formation of teams, use of communication technologies, and the evaluation of various student reporting mechanisms. When implemented in a team-based setting, these modules have been shown to effectively aid students in conceptualizing key elements of probability and promote knowledge transfer beyond the presented contexts.

INTRODUCTION

The usefulness of applied probability and stochastic processes in several engineering and science applications has prompted the recent expansion of its instruction to students at various educational levels. Kao (2000) notes that this expansion has been spurred by the increase of readily available computational power, which increases the ability of this modeling approach to analyze real-world problems in greater depth. The curriculum of many introductory undergraduate collegiate courses, however, is frequently centered solely on the theoretical underpinnings of the topic. Students are introduced to the material in a mathematically rigorous fashion with limited exposure to the range of possible applications. In addition, the traditional curriculum does not promote the development of student "soft-skills" such as teaming and communication, which are essential in a global problem solving environment. In a high school setting, the topic is almost non-existent in the curriculum, thereby missing an opportunity to enhance the students' motivation to pursue engineering and science degrees of which it is an integral component.

In response, a set of multimedia educational modules that support the instruction of applied probability and stochastic processes at the secondary and tertiary education levels were recently produced by T. I. Matis and L.A. Riley under a grant from the U.S. National Science Foundation (2003). The pedagogy of this curricular approach is based on concepts recently published by the National Research Council in the research compilation How People Learn (2000). In particular, the real-world topic modules, each consisting of a self-contained DVD, create a knowledge-centered environment for student learning. When implemented in a team setting, this environment builds upon the prior knowledge that an individual possesses about a particular problem through an iterative process of multi-step corrective refinement. As this process progresses, erroneous concepts are replaced with correct ones towards the ultimate conversion of learned information to useful knowledge. In the following sections of this paper, we will give a brief overview of the modules, describe how these may be effectively implemented in a team setting, and present some of our findings from previous evaluations of this work.

MODULE DESCRIPTION

At the present time, a set of four multimedia modules have been produced through collaborative relationships with Fort Bliss Federal Credit Union, Sandia National Laboratories, the Celestica Corporation, and B. Weaver Apiaries. The first of these three are targeted towards tertiary education, and the last towards secondary education. The respective topics of these modules are the allocation of resources for the collection of past due loans, analyzing the reliability of the Z-machine (an extremely powerful X-ray generator), scheduling direct labor in a high-tech factory, and modeling the population dynamics of the Africanized honeybee. When implemented, they help students conceptualize a broad range of topics from probability modeling and stochastic processes, including basic probability theory, discrete and continuous time Markov chains, renewal theory, simulation, and non-linear modeling. In general, the presented problems are not trivial and require the specification of several assumptions by the students. In some of the modules, it is necessary for the students to limit the scope of the problem for tractability.

To illustrate the content of the modules, a description of the Fort Bliss Credit Union module will be given as an example. Upon inserting the DVD into a player, an introductory movie begins that displays clips related to the project set to music. Upon completion, the main menu of the DVD appears which is accompanied by an audio track that provides instructions to the viewer. The buttons on this main menu lead to a series of sub-menus that contain the movies, data, supporting documents, student resources, and production credits (Figure 1). This introductory piece spans a period of roughly one minute.

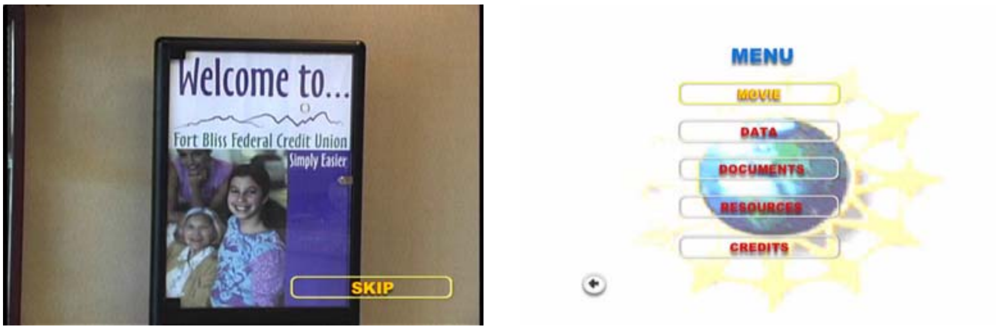

Figure 1: Still Images from the FBFCU Module

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 from the company. The movie is augmented with overlaid graphics and text to aid in the understanding of the material and to maintain viewer interest (Figure 2).

Figure 2: Still Images of Representatives from the FBFCU Module

The other sections of the DVD contain additional material that the student might find useful in solving the problem, including raw collected data and supporting documents. This material is stored in the ROM section of the DVD and may be downloaded to the computer. The DVD is enclosed in a case that displays attractive artwork relevant to the problem and credit to the production team.

TEAM IMPLEMENTATION

To maximize the benefits of the knowledge-based learning environment that the modules create, it is important that they be implemented in student teams that are functioning at a high productivity level. As an instructor, however, it is often difficult to effectively organize the teams and teach the student how to interact in this environment. Several common methods of team organization include allowing students to pick their own teams with the only constraint being on the number of team members, instructor organization of the teams based on past performance or grades, or the dual approach where each individual picks a partner and the instructor matches up the pairs. Each of these lay methods can be effective in particular situations, but it has been our experience that such teaming structures often have a long lead time before they operate efficiently. As the benefits of a knowledge-based learning environment will not be realized until the team functions efficiently, aspects of the team based implementation are critical to student learning through the modules.

The approach that we have taken consists of an active method for team selection and training. In particular, we use a functional-based approach, similar to that described by Sauer and Arce (2004). Each team consists of three individuals and four positions, those being *Team Leader*, *Team Engineer*, *Team Innovator*, and *Team Doubter*. The *Team Leader* is responsible for the overall management of the team, including calling meetings, structuring the discussion at meetings, and meeting deadlines. They are the sole person in the team who communicates with the instructor of the course about questions related to the module or assignment completion. The *Team Engineer* is responsible for performing all computations and technical research related to the project. The *Team Innovator* is responsible for generating new ideas and solution approaches to the problem. To mitigate the effects of "group-think" the *Team Leader* and *Team Engineer* should also jointly function in a fourth position, that being the *Team Doubter*. In this capacity, these individuals should be encouraged to constructively challenge the ideas brought forth by the *Team Innovator*. In general, we found that it is best to not have a fourth individual occupy the *Team Doubter* position as their constant focus on the negative often brings resentment from other group members, but an individual may fill this position if there is an imbalance in the total number of students.

The organization of the students into the teams occurs in a hybrid manner with both the students and instructors having input. To achieve this, a lecture presentation is provided prior to the start of the module(s) in which the instructor informs the students about the responsibilities of the different positions within the team. In this lecture, it is often useful to have a role-playing demonstration in which the responsibility of each position is highlighted in solving some trivial problem. It is important for the instructor to emphasize that each person within the team will receive the same grade, e.g., the *Team Leader* will not receive a higher grade than the *Team Innovator*. Following the lecture, the students are then given the opportunity to rank on a numeric scale, say 1 to 10, how effective they feel they would be in each position. Having collected this information, the instructor should then proceed to organize the teams trying as best as possible to adhere to the students responses for the different positions. Specific groupings of individuals by positions into the teams is left to the judgment of the instructor, yet it is noted that Bannerot (2004) comments on some common features (demographic, skill level, personality, etc.) of individuals that are, and are not, generally considered "good team players," which may be taken into consideration. Following the formation of teams, it is often good practice for the instructor to devote at least part of a following lecture to engage in team building exercises, such as trivial problem solving games, and it is essential that the instructor regularly inquire of the *Team Leader* concerning the functioning of the team and provide follow-on support if needed.

Another crucial aspect of the team implementation of the modules is the provision of an effective communication structure for the team members between themselves and with the instructor. Teams should be encouraged to meet regularly in a face-to-face environment. Whether these meeting happen during or after lecture depends largely on the educational level in which they are being implemented, but it is important that these happen several times a week. Each team should be encouraged to maintain a webpage on the project which clearly states their activities and findings, which is often one of the duties of the *Team Engineer*. The instructor may evaluate this webpage regularly as a grading mechanism, but its main purpose is for the student to regularly report their progress in a public setting, and for them to view the progress of other teams. Indirect information sharing between groups through the webpages should not be discouraged by the instructor, though this may require a shift in traditional evaluation methods.

MODULE EVALUATION

The efficacy of the modules in enhancing student learning in the concepts of probability modeling and stochastic processes has been thoroughly evaluated at the tertiary level, and those at the secondary level are forthcoming. The reviewers of the modules consisted of academic peers and student groups. The comprehensive set of data that was collected from each group of individuals is presently stored on the webpage http://engr.nmsu.edu/~csm/nsf-project and is available for download. This data consists of a quantitative scoring of each module individually, pre and post attitudinal surveys, pre and post performance evaluations, and numerous qualitative responses to short questions. A comprehensive summary of these findings, with statistical testing, may be found in the final report by Matis and Riley (2005). In this section, we simply comment on some of the key findings from these evaluations.

The student attitudinal surveys collected before and after module implementation in an introductory undergraduate stochastic processes course showed a statistically significant increase in the proportion of student who felt the course opened up new areas of scientific interest. This coincides with one the objective of the modules, i.e., increasing conceptualization of the material towards an increased interest in further application and related research. The performance evaluations were designed to test the students' ability transfer their knowledge to other applications outside those presented in the modules. The pre and post scored showed a demonstrable increase in the students' ability to identify stochastic methods and apply them correctly. There was, however, an increase in the standard deviation of students' scores on the performance evaluation following module implementation. Much of this is attributed to poor team development and training during the semester in which the evaluations were collected. The most interesting part of the student evaluation, however, was the qualitative responses. A sampling verbatim of these includes:

- *"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."*
- *"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."*
- *"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."*

The academic reviews of this work were all positive; though most felt that the scope of the modules was a bit too large for the suggested time allotted per module, i.e., three weeks. With this in mind, we now recommend that the instructor work closely with the *Team Leader* in helping to define the problem that needs to be solved.

CONCLUSION

In this paper, we have introduced a set of multimedia educational modules that may be used in the instruction of stochastic processes and probability modeling at the secondary and tertiary educational levels. They have been thoroughly evaluated at the tertiary level, and have shown a demonstrable increase in the student ability to conceptualize the fundamentals of stochastic processes. The formation of efficient student teams in implementing the modules has been shown to be a critical element, and suggested approaches for organizing and maintaining these have been given. These modules may be requested from the author of this paper through the e-mail address listed above, and they will be sent free of charge with no obligation or cost for subsequent classroom use.

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