PROJECT BASED LEARNING IN AN INTERDISCIPLINARY ECONOMCS AND MATHEMATICS SERVICE COURSE

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ABSTRACT

In this paper, we describe the advantages of using real-world projects and the types of real-world projects that are successful in teaching a project based interdisciplinary finite mathematics course. This paper illustrates the value a project-based approach has to beginning mathematics students with respect to relevance of course material and their perceptions of the value of mathematics to their own disciplines. Projects used in teaching the course over five years are briefly described along with the mathematical techniques applied in each project. The paper also discusses the issues involved in selecting successful projects and presents a case study demonstrating how a project evolves from its inception to its completion.

INTRODUCTION

The traditional approach to teaching and learning quantitative methods such as those in mathematics and statistics has several inherent weaknesses: data are artificial, problem statements look artificial, and students see no connection between the data, problem, and the real-world. Therefore, students may not participate in the learning process and students are not stakeholders in the learning outcomes. Mathematics in Action [Shafii-Mousavi, M. and Kochanowski, P. 1998a]- an interdisciplinary, freshman level finite math course - has been developed to overcome these weaknesses and develop other skills such as modeling, computer proficiency, and writing. This course is part of the NSF sponsored project entitled "Mathematics Throughout the Undergraduate Curriculum" which has as its primary goal changing students' attitudes about mathematics. In this service course, students not majoring in mathematics work on real world business projects. The project-based learning approach provides students with hands-on real-world projects using actual data that illustrate the power of finite mathematics tools in solving actual business and social problems. Students in the course develop teamwork skills, data gathering experience, and methods of parametric analysis.

Examples of projects used in the course include, inter-alia, the traveling sales person problem, the keep versus replacement decision, linear and nonlinear inventory economic order quantity problems, hotel market analysis, geographical incidence of diabetes, and optimal policy for replacing absent workers. Each of these projects requires specific finite mathematics tools such as linear programming, network analysis, inventory analysis, matrices, probability, statistics, etc. The authors' article [Kochanowski, P. and Shafii-Mousavi, M. 2000] describes how to design and teach a finite mathematics project-based course. Other articles [1998, 1998a,1999] describe the development of these projects and the role an interdisciplinary approach plays in designing projects

This paper illustrates the value a project-based approach has to beginning mathematics students with respect to relevance of course material and their perceptions of the value of mathematics to their own disciplines. Projects used in teaching the course over five years are briefly described along with the mathematical techniques applied in each project. The paper also discusses the issues involved in selecting successful projects and presents a case study demonstrating how a project evolves from its inception to its completion.

WEAKNESSES OF THE TRADITIONAL APPROACH

The traditional approach fails to convince students that mathematics, and indeed, even basic mathematics, can provide a powerful set of tools to solve a wide variety of interesting real world problems. Textbook writers have attempted to overcome this lack of relevance problem by designing problems that show the applied nature of mathematics. The problems span such diverse disciplines as health care public administration, economics, finance, marketing, and criminal justice and often are based on actual situations. For example, the finite mathematics textbook used on our campus [Barnett, Ziegler, Byleen, 1999] provides many interesting problems. The weakness in all of these attempts stems from the artificiality such problems have in the eyes of the student. We discuss a couple of problems used in this textbook for the Linear Programming method (section 5-4) to illustrate the weaknesses of the traditional approach.

Example 1 - Investment. An investor has at most \$100,000 to invest in government bonds, mutual funds, and money market funds. The average yields for government bonds, mutual funds, and money market funds are 8%, 13%, and 15%, respectively. The investor's policy requires that the total amount invested in mutual and money funds not exceed the amount invested in government bonds.

(A) How much should be invested in each type of investment in order to maximize the return? What is the maximum return?

(B) Repeat this problem under the additional assumption that no more than $30,000 can be invested in money market funds.

Example 2 - Construction–resource allocation. A contractor is planning to build a new housing development consisting of colonial, split-level, and ranch-style houses. A colonial house requires ½ acre of land, $60,000 capital, and 4,000 labor-hours to construct, and returns a profit of $20,000. A split-level house requires ½ acre of land, $60,000 capital, and 3,000 labor-hours to construct, and returns a profit of $18,000. A ranch house requires 1 acre of land, $80,000 capital, and 4,000 labor-hours to construct, and returns a profit of $24,000. The contractor has available 30 acres of land, $3,200,000 capital, and 180,000 labor-hours.

(A) How many houses of each type should be constructed to maximize the contractor's profit? What is the maximum profit?
(B) A decrease in demand for colonial houses causes the profit on a colonial house to drop from $20,000 to $17,000. Discuss the effect of this change on the number of houses built and on the maximum profit.
(C) An increase in demand for colonial houses causes the profit on a colonial house to rise from $20,000 to $25,000. Discuss the effect of this change on the number of houses built and maximum profit.

These typical textbook problems provide the student with a statement of the problem, the data necessary to solve the problem, and the appropriate technique to use to solve the problem. As a consequence, the student has little reason to think much about defining the problem, the importance of the problem and its solution to those needing to solve the problem, the difficulties in determining the appropriate tool(s) needed to solve the problem, the data requirements necessary to solve the problem, or where the data will be obtained. The stake the student has in solving the problem is not the value his/her solution has to the organization individual that requires a solution but rather the grade he/she will earn. The student sees the problem, tools, and data as artificial and consequently down plays the real world importance of finding a solution to the problem. The relevance and power of the tools needed to solve the problem become diminished in the eyes of the student. Indeed, the above textbook problems provide much of the analysis and all of the data necessary to solve the problem. In an actual real world situation, the problem in example 1 might be posed as: "An investor has $100,000 to invest. What is the best way to use this money?" Similarly, the second example might be given as:
"A contractor has 30 acres of land. The contractor plans to build homes on this land. What should he do?"

These more realistic ways of formulating the problems, which are typical of what one finds in actual situations, require much more effort and thought on the part of the student. Much of the information needed to solve the problem must be acquired. For instance, in the first example the possible investment options available, their respective returns, their relative risks, and the like must be obtained. Various constraints on the problems must also be determined. Perhaps the investor in the first example requires a certain level of liquidity to make some upcoming purchase. Moreover, the techniques needed to solve the problems must also be resolved. It will not be obvious to most students that linear programming naturally solves problems like those in examples 1 and 2 so that the student will need to discover the appropriate set of tools. In short, the traditional textbook problem, regardless of how well conceived, has little chance of capturing the imagination of the student or instilling in the student a sense of value for the tools needed to find its solution.

HOW TO OVERCOME THE WEAKNESSES

The course we designed to overcome these shortcomings is called "Mathematics in Action: Social and Industrial Problems" and is part of the National Science Foundation grant of Indiana University*, Mathematics Throughout the undergraduate Curriculum*. Under this grant, Indiana University has developed about 22 interdisciplinary courses including this course. Developed courses include Business and Mathematics, Arts and Mathematics, Biology and Mathematics, History and Mathematics, Mathematics of Finance, Hearing and Mathematics, etc. For a complete list of courses and the MTC refer to web site www.math.iupui.edu/mtc/. Mathematics in Action is

- Interdisciplinary for freshmen students of Business, Economics, Education, Liberal Arts and Sciences, Nursing, and School of Public and Environmental Affairs. The course replaces three introductory mathematics courses Finite Mathematics, Excursion in Mathematics, and Mathematics for Elementary Teachers II.

- Co-taught by the two professors from two different disciplines. Authors experiences regarding the co-teaching of the course are found in [Kochanowski, P. and Shafii-Mousavi, M.1998].

- Project based. Students learn mathematics by modeling and solving actual real-world problems in business, industry, social and governmental agencies.

Mathematics in Action attempts to overcome the relevance weakness of the traditional freshman level finite mathematics course by using real world actual projects as vehicles to show the importance of mathematical and statistical tools. In this course, students work in teams as consultants for participating real organizations. A team designs a mathematical model for a real project for an organization, solves the model, gives solution(s), and makes recommendations to the organization. Organizations instill in students a sense of the project's worth. The relevance issue is largely overcome as students involve themselves in narrowing the problem, struggling to find the relevant data, attempting to discover, learn, and apply those tools that will lead towards a solution. Students see themselves as major stakeholders in finding a solution for an actual project. The motivation to solve the problem no longer involves simply a grade but instead finding a solution to a problem deemed essential to an actual organization. The time and effort that students put into solving an organization's problem go far beyond anything we have experienced in the traditional type of course. Even less motivated students appear to be excited by working on actual real world projects. This alone, in our opinion, attests to the pedagogical value of a project based approach.

SELECTING PROJECTS

Over the past four years, our student teams have completed 27 projects for eight participating organizations. Table 1 provides information regarding these projects by the organizational name, the year project completed, and the primary quantitative technique used. Integrating actual organizational projects into a course requires many decisions prior to offering the class, as well as during the class. Real world projects are in a word "messy." Organizations often are not clear on exactly what the problem is, the type of answers that would be useful, or the availability of the necessary information to solve the problem. Different personnel in the organization will often view the problem from their own perspective. Student teams working on problems often try to define the problems in ways that make problems more manageable or more meaningful thereby restating problems in ways that are at odds with the needs of the organizations. Course requirements also play a role in that key elements of organizational problems must mesh with course concepts. To maximize the chance that a project will provide a successful learning experience for the students, adequately incorporate course materials, and provide useful information for an organization, several issues must be addressed.

<u>Structured vs. Unstructured Projects</u> - The use of actual organization projects in a course such as Mathematics in Action requires some critical up-front decisions about how much leeway students will have in defining the problems they will solve. This is a decision that has to be made prior to soliciting the cooperation of organizations. Two extremes exist, though, in general, the final outcome is a mixture of these two. At one extreme, the *organization and faculty* define the problem that students will tackle. Alternatively, the *organization and students*, within broad parameters, define the problems the students will work on. The decision on whether the projects will be structured or non-structured largely depends on the level of student and perhaps the risk one is willing to take. Totally non-structured problem based learning approaches allow the students to entirely define the problem. Most examples of such courses are found at the graduate level. The Price College of Business at the University of Oklahoma, for instance, teaches business principles to Masters of Business Administration (MBA) students through student generated and run businesses. *An Experienced Based Approach* [L. Michaelsen 1999] describes how student teams select the products they will sell, the relevant markets they will target, the competitive strategies they will pursue, the financing policies they will need, write business plans, etc. and make all of the relevant decisions. Students draw whatever they need from course material and from the faculty who act as consultants. The Price College of Business MBAs are evaluated on the success of their entrepreneurial efforts (i.e., the profitability of their respective businesses). Relatively less structured approaches also have had success with upper level undergraduate students. Professors Dan Maki and Wayne Winston of Indiana University's Mathematics Department and School of Business, respectively have designed such a course taught as part of the Liberal Arts Management Program (LAMP). Students in the course are junior or senior honors students with high grade point averages (>=3.5) who have all taken at least a freshman level mathematics course. The faculty in this course select participating organizations as sources of projects. Student teams and the selected organizations decide on the projects within guidelines that projects make use of broadly defined mathematical and statistical tools. The mathematical needs of the student team projects entirely drive the course curriculum. Teams are evaluated on the quality of their written reports and their presentations to the organizations.

The course Mathematics in Action takes a structured approach to defining the student-organization projects. Prior to the semester when the course is to be taught the faculty work with organizations to identify suitable projects. Project abstracts based on these discussions then are written and sent to the organizations. The project abstracts insure that those teaching the course and those in the participating organizations have the same concept of what the projects will entail. Student teams in the class are then assigned projects and organizations.

This high level of structure results from both the nature of the students and the curriculum needs of Mathematics in Action. Students in the class are mostly first-year students who have had no other classes in finite mathematics and whose majors cut across all majors offered by Indiana University South Bend. The risk that on their own students at this level will fail to work with organizations to define suitable projects is very high. The course also substitutes for other finite classes that students would ordinarily take. Thus, the projects used in the course need to touch on the core curriculum covered in a traditionally taught freshman level finite mathematics course.

<u>Necessary finite mathematics tools</u> - Over the five times Mathematics in Action has been taught, student teams have carried out twenty seven different projects for organizations as diverse as a social organization, school corporations, a university, a financial institution, a manufacturer, a newspaper, and a shopping mall. Most of these projects are outlined in our course web site (www.iusb.edu/~mshafii/math-in-action.html). The projects that work well for our purposes use substantial amounts of finite mathematical tools (descriptive statistics, combinatorial and permutations, probabilities (simple, conditional, Bayesian), solutions to systems of linear equations and inequalities, and linear optimization such as a linear programming). Some projects lend themselves naturally to this requirement. A local school corporation, for example, had a truck delivery routing problem analogous to the well-known traveling salesperson problem. A financial institution had a loan delinquency problem that fitted nicely into a conditional probability analysis; the delinquencies and amounts conditioned on loan products and borrower characteristics.

Sometimes it takes creativeness, insightfulness, imagination, and lots of discussion and thinking to work with an organization to find a suitable project and to figure out the appropriate tools that might be applied. A good example of this is a project the course students did for the local office of the American Diabetes Association (ADA). The local ADA office has two main functions: 1) to educate people about diabetes and 2) to raise money that can be used for education, research, prevention, etc. Unfortunately, the local organization has neither the knowledge of where undiagnosed diabetics might be located nor where potential donors to the association might be found. Two projects used Center for Disease Control data on conditional probabilities of diabetes that were coupled with census information to identify potential pockets of diabetics in the local area and in the broader state of Indiana.

<u>Time requirements</u> - That the projects make use of the tools covered by the course is critical, but other project characteristics are also of import. Instructors look for projects that are doable in an eight to ten week time frame. This generally means that prior to using the project we have a reasonably good idea of the availability of necessary data. Sometimes the organization supplying the project will have the required data in easily accessible form. A financial institution we worked with, for instance, had computerized records on loan payments by customer, product type, and month for several years. A manufacturer had printouts of late part shipments. Although it was time consuming, students could, nonetheless, enter the data into work files and analyze them. More often than not, the data needed for the project are not so readily available and in some instances a major part of the project might entail obtaining primary data. The traveling salesperson truck routing problem, mentioned above, required students to estimate distances between origin-destination pairs for schools within a school corporation's service area. Initially, students suggested driving these routes to estimate times and distances. This proved unworkable because of the time demand it would have placed on them. Ultimately students used a city map, decided, based on their knowledge of the city, which routes would be optimal, and measured the map distances that were then converted to miles. Grappling with these data problems is an important part of learning to tackle problems and cannot be replicated in the traditional lecture, textbook type of course.

<u>Real world data and technology</u> - The use of real data for the projects and the ability to find a solution necessitate the use of computer technology and modern software. *The Use of Computer Technology in a First-year Finite Mathematics Course* [Shafii-Mousavi and Kochanowski 1999] discusses this necessity. Many real world projects involve large data sets or large numbers of calculations that simply cannot be done on a hand held calculator. A delinquency loan rate project for a financial institution, for example, had approximately 140,000 loan accounts for each of twelve months (longer periods were also available). The routing problem using the traveling salesperson algorithm was too large even for the computer and had to be broken into parts and then reconstructed to obtain solutions. This unexpected need for technology turned out to be a blessing in disguise (though this is not necessarily the way we thought about it that first year). Indeed, the last time the course was taught it was linked to a technology course so that students acquired not only the quantitative tools needed to undertake the projects but also the technology required to implement those tools.

<u>Organizational commitment</u> - The nature of the project, its data needs, and its use of technology all are extremely important ingredients of what makes a "good project."

Perhaps of equal consequence are qualitative dimensions largely related to the organization providing the project. The qualitative aspect of most significance is that the project be of high priority to the organization, the higher the priority the better. The organization's commitment to working with the students in helping them understand the nature of the problem, uncover the necessary data, connect with necessary personnel, convince those personnel that the project is of value largely rest on the organization wanting to find a solution to a critical problem.

THE ANATOMY OF A COURSE PROJECT

Projects used in the course proceed through a series of steps that illustrate many of the issues described above. For example, in the spring semester of 2000, a student team completed a project for the South Bend regional office of the American Diabetes Association dealing with how the organization might best allocate its resources to maximize its net fund raising revenues.

0) Preliminary Steps: A semester before the course was offered, the faculty made the following efforts.

- Request for project
- Initial contact
- Exploration of potential projects
- Narrowed the project, and modeling

1) Teams are formed (3rd week of semester).
2) Team meets with organizational personnel (4th week of semester).
3) Team investigates the history of the ADA and its fund raising activities (after meeting with organization personnel)
4) Team defines problem: "How should the director allocate her time, volunteers' time, and financial resources to maximize the net revenues from the organization's fund raising events?" and attempts to put problem into its own terms (4th or 5th week of semester).
5) Team focuses on fund raising events (6th or 7th week of semester).
6) Team narrows problem to those events in the upcoming year (8th to 10th week of semester).
7) Team and instructors investigate necessary modeling and technological tools (8th to 11th week of semester):

- Constrained optimization problem using integer programming
- Technology: Excel's "Solver" module

8) Team starts gather information on potential fund raising events (from initial meeting with organization to 12th week).

9) Team works with organization Director to collect data about resources and event revenues (starting in 9th week):

- Revenues and variable cost for each event
- Financial resources required for each event
- Volunteers' time required for each event
- Director's time required for each event
- Limitations on the availability of financial and time resources
- Team also makes assumptions: 1) Limitations on the number of times a particular event could be held; 2) The role of weather conditions to the success of an event

10) Team interprets computer results and discusses these with instructors (11th and 12th weeks of semester)
11) Team makes recommendations and does sensitivity analysis (12th and 13th weeks of semester)
12) Team completes technical report (5th week through 13th week).
13) Team presents findings to organization (14th week).
14) Instructors work with team to finalize technical report (15th week)

Each of these steps requires decisions that influence how successful the project will be for both the students and the organization. In this particular case, **step 0** involved extended discussion between the faculty and the director of the association about the type of project she might find valuable. Initially, discussions centered on looking at the success and failure of fund raising activities throughout the United States and from that information portfolios of projects the director might pursue locally. Each portfolio would have its own expected return and risk. As discussion progressed, it became obvious that the data requirements for the project made it extremely risky, since the Association's computer system did not allow easy access to the necessary data, even though such data were available. As an aside the Director said, "What I really needs is for you to tell me the mix of events that I should put on in the next year. For example, how many walks should I have, how many wine tasking parties should I have, etc.?" After further discussion, it became apparent that this could be framed as a straightforward constrained optimization problem solvable using linear programming. This had a lot of appeal given that linear programming is one of the core topics covered in the course.

Once the project has been agreed upon the instructors write a short abstract describing the project, which is sent to the organization and later given to the student team working on the project. This insures that the organization, instructors, and team have the same vision of what will be done and accomplished. Clearly defined projects that all parties embrace generally work the best since little or no time is lost defining the project. The instructors at this point also start working out modeling options, data needs, technological requirements, and the like.

The next major step, **step 1**, in a project is the formation of the student team that will work on the ADA project Teams are formed according to performance on the first examination, disciplinary interest, and in some cases geographical proximity to the project's organization. An attempt is made to promote member diversity with respect to abilities and disciplines.

The initial meeting of the team with organization personnel, **step 2,** provides students with a history of the organization, its functions, its budget, and its goals. Further, the Director expands on her view of the problem and her expectations about the project. It is at this stage that it is critical that everyone is clear on the goal of the project and what needs to be accomplished. It is also critical at this stage to make sure that the organization commits itself to working with the students to gather necessary information. Though not in this case but often in other projects, the organization personnel who have decided on the project are different from the organization personnel who will be helping the team carryout the project. If these different levels in the organization have not communicated effectively, problems can, and often do, occur.

The information the team obtains from the Director allows the team to start on the historical part of the technical report. Each technical report has a brief history of the organization and a history of the problem the team is investigating. **Step 3** forces the team to start thinking about the final technical report early in the semester and to write those parts that can be written prior to actually carrying out the project. This step helps offset the natural pushing off writing to some time later that often occurs in a project covering several weeks. For whatever reasons, many students view writing the technical report as something that can be done in a few hours or in a day at the most. Anyone who has ever written a consulting type technical report knows that, unfortunately, this simply is not true. Such reports often take considerable time to write and rewrite.

As stated earlier, prior to meeting with the Director the team is given an abstract of the project based on the instructors' earlier discussion with the Director. This is how the instructors in the course structure the project to make it doable with entry level undergraduates. The team's meeting with the Director provides another view from that given by the instructors. The team at this point attempts to reconcile these views of the problem and arrive at the problem that will be attacked (**step 4**). This is an extremely important step to monitor closely. Lack of clarity about what needs to be done often results in a team redefining a project in ways at odds with what was initially agreed upon, what the organization actually wants done, and what the course content requires. Problems are more likely to arise if the team works with organization personnel other than those who initially decided on the project. At this point in the ADA project, the team focused its attention on fund raising events and narrowed those to events in the upcoming year (**steps 5 and 6**). The instructors work closely with the team at this stage, to minimize the chances that the team's efforts will go astray.

By this stage in the project the team is ready to start thinking about the mathematics that will be used to solve the problem and the technology that will go along with the mathematics. **Step 7** often requires the instructors providing out of class tutorials to bring students up to speed on the techniques required. In this case the mathematical tool, linear programming, and the technological tool, Excel's "Solver Module", are obvious choices for optimization problem involving constraints. Nonetheless, linear programming occurs towards the end of the Mathematics in Action course and must be explained to the team earlier. The same is the case for the "Solver Module", which is demonstrated at the very end of the course. Much of the risk at this stage is related to how well the students comprehend the mathematics they are using. For beginning students, linear programming is a complex technique that probably raises much math anxiety. Instructors try to alleviate some of these fears by working with the team on writing the objective function and the equations for the necessary constraints. Instructors also try to convey through intuitive examples what the technique intends to accomplish.

Investigation of the mathematical tool required to accomplish the project also leads to investigation of the data necessities of the technique. Collection of data, **step 9**, is ongoing from the initial meeting of the Director until the 9th or 10th week of the semester. A linear programming problem of the sort used for the ADA project necessitates information on the gains from the various events that might be offered, the resource requirements of those events, and resource capacities. It moreover requires assumptions on how many times a particular event can be offered (i.e., a fund raising walk cannot be held every weekend), as well as the role of random factors such as the weather. The team communicates its data request to the Director. It is at this point where potential problems can arise from the use of real world data. For example, the ADA Director argued she had unlimited time, financial resources, volunteer time, etc. In other words, she had no constraints. This obviously was not the case, however. This led the instructors to work with the team to show the Director that there were only so many hours of her time available and that volunteer time and financial resources were not unlimited. Real world projects often have data deficiencies that need to be creatively addressed. Sometimes this entails treating lacking data values parametrically and testing the results to the sensitivity of the assumptions made. Other times data unavailable from the organization can be gathered elsewhere.

Once the data have been obtained, the instructors attempt to aid the students in determining whether the results are reasonable (**step 10**). Potential problems at this point often involve one or more of the following: misunderstanding or misinterpreting the model; incorrect data; incorrect assumptions; and incorrect use of the technology. Instructors must monitor students closely at this point. It is also useful to allow enough time for the team to go back and show the organization what it has found. This preliminary view of the findings by the organization often points out incorrect data values or assumptions. Unfortunately for most projects, constraints on student and/or organization personnel time make this difficult to do.

In **step 11**, the team translates its results into recommendations. It is obviously important that the recommendations are based on the mathematical analysis and computations the team has performed. The results also must be practical and feasible. Instructors encourage the team to think of possible problems in implementing its recommendations.

The final steps in the project, **steps 12 and 13**, deal with finalizing the technical report and preparing the presentation the team will make to the organization personnel. As noted previously, the instructors encourage the students to continually work on the technical report, periodically requesting drafts that can be reviewed. This approach works well. Entry-level students generally have never done any written project as large as the required technical report and are not accustomed to rewriting material. Instructors help the team correct various writing problems, stressing to the team that the university's reputation hinges on the quality of its report Instructors also work with the team on its presentation to organization personnel. This involves instructing the team that each member most participate equally in the presentation and providing the team with possible presentation formats that will allow this to happen. Problems at this stage of the project often involve the panic and frustration a team may feel, as many things need to be done with little time left. Instructors try to help by keeping students calm and insuring them that every team undergoes the same trauma and comes out of it successfully.

The very last step, **step 14,** works to finalize the technical report so that it can be transmitted to the organization. The team provides the instructors with a complete draft of the report, which after reading and editing is returned to the students for necessary changes. In some instances, these changes are simply rewriting, correcting misspellings and grammatical errors, adding additional information, etc. In other cases, incorrect mathematical computations are redone

CONCLUSIONS

It is pretty obvious from the above description that the team-teaching of an interdisciplinary project-based course such as Mathematics in Action: Social and Industrial Problems, is a very time consuming and labor intensive endeavor. This is probably the most common objection to such a course. Offsetting this disadvantage is the quality of the learning experience, which is much higher than in a traditional lecture type course. This is true for the faculty involved, but it is even truer for the students. Students in the class learn both about mathematics and about the principles of another discipline. They work as quasi-consultants for real organizations, using real data, and solving real world problems. They acquire technological expertise and become proficient enough at using spreadsheets such as EXCEL to manipulate, describe, and analyze large data bases. They learn how to work together as a team. They learn to communicate their findings by writing a professional type report and making a presentation to key personnel of their organization. Much of what students receive from an interdisciplinary team-taught course cannot be replicated in the traditional lecture type course. In short, the costs of an interdisciplinary team-taught course are high, but so too is its value-added. We believe after having taught the course five times (and currently teaching it the sixth time) that the rewards to us as faculty and to our students are well worth the price we have paid in terms of additional effort. We thus encourage others to investigate the possibility of undertaking similar interdisciplinary team-taught, project-based enterprises.

Table 1: Course Projects and Primary Quantitative Technique

Project	Year	Organization*	Quantitative Techniques
Truck Keep v. Replacement	1997	PHM	Shortest Path Analysis

Optimal Maintenance Worker Pool	1998	PHM	Linear Programming
Cost of Periodic v. on Demand Light Bulb Replacement	1999	PHM	Sampling-simulation
Cost Analysis of Lunch Program Alternatives	2000	PHM	Statistical Analysis
Cost Analysis of Duplicating Options	2002	PHM	Sampling-Simulation
Loan Default and Customer Characteristics	1997	TCU	Conditional Probability
Loan Process Control	1998	TCU	Pert Scheduling Analysis
Service Transaction Time Analysis	1999	TCU	Time study-statistical Inference
New Products and Deposit Shifting	2000	TCU	Non-linear Modeling
Factors Influencing Loan Defaults: Direct Loans	2002	TCU	Bayesian Probability
Locating Potential Diabetics – South Bend	1997	ADA	Cond. Probability-forecasting
Locating Potential Diabetics – Indiana	1998	ADA	Cond. Probability-forecasting
Fundraising for Diabetes	1999	ADA	Desc. Statistics-inference
Optimal Mix of Fundraising Activities	2000	ADA	Linear Programming
Optimal Lunch Routing Pattern	1997	SBCSC	Traveling Salesperson Prob.
Optimal Textbook Inventory Policy	1998	SBCSC	Dynamic Inventory Model
Optimal Science Kit Purchase Policy	1999	SBCSC	Simulation Techniques
Impacts of Lower Grade Enhancement Programs	2000	SBCSC	Hypothesis testing
Late Machine Part Shipments	1997	Ward	Conditional Probability
Parking Requirements for a New Store	1998	NVM	Sampling-stat. Inference
Viability of a New 4-start Hotel	1999	NVM	Market Forecast-Sampling
Optimal Utilization of Mall Land	2000	NVM	Linear Programming
Security Personnel Scheduling Needs	2002	IUSB	Bayesian Probability
Optimal Mail Routes	2002	IUSB	Traveling Salesperson Prob.
Factors Influencing Retention Rates	2002	IUSB	Bayesian Probability
Analysis of Advertising Effectiveness	1997	Times	Hypothesis Testing
Inventory Control for Purchasing Paper	1998	Times	Optimal Reorder Point

** PHM= Penn-Harris-Madison School Corporation; TCU=Teachers Credit Union; ADA=American Diabetes Association; SBCSC=South Bend Community School Corporation; Ward=Ashley Ward, Inc.; NVM=North Village Mall; IUSB=Indiana University South Bend*

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