Using the Internet to Support Active Learning

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Abstract

This paper describes an Internet based system we used to support Active Learning in a class taught to Industrial Engineering Seniors in the fall semester 2000. The system attempted to engage students in learning by presenting them with problems they perceive as more realistic than textbook problems and by requiring them to fill in gaps when presented with a situation they do not readily understand. An overview of the system implementation, problems and student reaction is presented.

I. Introduction

A difficulty in teaching subjects involving quantitative methodologies such as basic statistics and decision analysis is that students are not motivated to drill the homework problems required to cement the concepts taught in lectures. At the same time, while drills are important, it is widely accepted that students understand material better, retain it longer, and enjoy their classes most when they take the lead to think about what they are doing. In short, problems should not be cookbook; students should be made to think. With regard to motivation, research [1,2] has shown that positive influences are: (1) when students work on problems they perceive as meaningful or relevant; and (2) when students are placed in a competitive situation in the role of a problem solver confronted with an ill-structured problem.

In order to provide relevance, an instructor in quantitative courses often introduces anecdotal evidence concerning the application of the basic concepts. This may succeed in capturing interest during a class period, but it is not often possible to provide problems that piggyback on the anecdotes. Usually, if a synergistic exercise is provided, it is in the form of a project because simple homework problems do not permit the complexity required to truly stimulate deep thinking about relevant techniques, solution tradeoffs and their consequences. Textbooks are seldom of much help as they are usually filled with end of chapter exercises that are anything but ill structured. Many students typically do homework by perusing the relevant chapter until they find an example that looks like the current exercise. They then substitute data into the example framework and get an answer without appreciating any details of the method or its application. The downside of projects is the large amount of instructor time that is consumed in developing, managing and grading a realistic project. The effect of this, rightly or not, is that project type problems tend to be excluded from the realm of drill exercises. In an attempt to solve this dilemma of too little learning on the student side and too much tedious work on the instructor side, we implemented a web-based system to bridge the gap between drill exercises and term projects.

II. Basic System Operation

Generically, the operation of the system was as follows. Students accessed the web site using their normal browser and were required to login in the routine manner of entering a username and password. Once logged in, a problem was requested from the system. In response to the request, the system created and initialized a unique problem scenario. This problem scenario conformed to a problem template that consisted of a problem story, generated problem parameters, and a response/evaluation environment. The problem story was constant for each scenario generated from a particular template and described a problem to be solved. The problem parameters were pseudo-randomly generated for each problem using problem specific algorithms. Students used the response environment to obtain problem data. The environment contained the essence of real problem environment characteristics, most notably that data is subject to error and that data is acquired at a cost. Student interactions were not required to conclude in a single session. Students could login/logout any number of times before submitting a solution and were free to formulate a solution using any means available to them. Upon solution submission, results of the evaluation were returned as an economic score. Both solution accuracy as well as the resources used in achieving the solution, e.g., the number of data points requested, calendar time, etc. could influence the final score. The purpose of the economic score was to normalize outcomes among students it order to provide a mechanism by which students could compete since the normalized economic scores could be "fairly" compared. The system database stored all problem-related activities.

In order to implement a system as described, server-side processing is necessary. Because of the privileges required to do server-side processing it was most practical for us to implement a web server on one of our own computers rather than using one maintained by the university. We used a desktop PC running the Microsoft Windows NT Server operating system and Microsoft Internet Information Server for the web server. Since the number of users was small by web standards, Microsoft Access served as the database system. The use of Microsoft products was primarily because of convenience rather than any processing superiority. Freeware such as the Linux operating system and the Apache web server could also have been used.

In developing the problem to be used with the system there are two major problems: (1) how to generate the problem; and (2) how to evaluate the solutions. These are intertwined as the choice of one often affects the other. This will be illustrated by the two problems used during the semesters that are discussed below.

III. A Seasonal Forecasting Problem

The first problem was a fairly straightforward forecasting problem where students were given 24 periods of historical data and asked to forecast the next four. On the surface, this problem would seem to be the same as a textbook problem. However, with the web based system it becomes more interesting. When students requested a problem from the system, they were presented with the summary and action form shown in Figure 1. They were not given any other information and were told in lecture that they may use any method including divine inspiration to determine the forecasts; that the system was only interested in the forecast values not the method used to achieve them. It is very important to note, that each problem requested from the system was different so that a method of asking a friend "What's the answer to the homework?" was futile.

The template for this problem provided that the underlying phenomena would be a linear trend with seasonality and normal (Gaussian) random demand fluctuations. Thus, each problem was parameterized by the intercept and slope of the trend line; the number of seasons and values of the associated seasonality factors and the variance of the normal distribution used for the demand variation. The method used to generate the parameter values is shown in Table 1.

Table 1. Method of Generating Parameters

Parameter	Method of Generation
Slope	Uniform Random from interval [-2, 10]
Intercept	Uniform Random from interval [200, 300]
Number of Seasons	Uniform Random from {1,2,3,4,6,8}
Seasonal Factor for each season	Uniform Random from interval [0.5, 1.5]
Variance of Error Distribution	Constant value of 10, i.e. σ=10

Students could log off the system (by closing their browser) at any time and return at any time to resume the problem in progress. Thus they were not time pressured to submit a solution. However, they were always required to complete the current problem before starting another.

When a solution was submitted the system evaluated it and calculated an economic score. There are a number of ways in which an economic score could be calculated. The choice of evaluation methods usually involves a tradeoff between fairness and complexity of evaluation. The choice can be difficult. The difficulties are due to the same feature that makes the overall system useful, the fact that all problems are different. Because the forecasting problem was not complex, we found that a simple and yet reasonable way to normalize the result was to compare the student's forecasts to the expected values for period demands (which are known by the system and not the student) as a percentage ratio of total absolute errors. Thus the economic score is

$$EconomicScore = 100 * \frac{\sum_{period=25}^{28} \left|(ExpectedDemand - ActualDemand\right|}{\sum_{period=25}^{28} \left|(StudentForecast - ActualDemand\right|}$$

Again it must be emphasized that the most important test for an evaluation method is that students perceive the evaluations as being fair. Without justifying the fairness of the above method, we can say that it did appear to pass this test as few students complained that the evaluations were unfair.

IV. An Inventory Policy Problem

The second problem was an inventory policy problem where the students first saw the problem story and action form shown in Figure 2. The story described a continuous review inventory situation that included ordering costs, holding costs and shortage costs with stochastic demand and lead times. The problem required students to determine a reorder quantity and reorder point (Q, R) policy. Demand was required to be estimated from samples acquired at a cost.

In order to obtain demand data, the students filled in the number of demand samples desired on the action form and submitted the request. Data was randomly generated, based on the stored problem specific parameters, and displayed along with summary statistics. After digesting the sampled data, the student could (1) request more data, (2) enter a solution, or (3) exit the system to return later. Students could leave the system, in order to analyze and ponder, any number of times for any length of time without any negative impact on their score. Since all initial and generated information was retained for each individual student in a database, the system returned to the same state (as if the student had not left) when the student re-entered the system by logging in again. Students could review all data at any time.

Once students completed their analysis they entered values of Q and R and submitted the solution for evaluation. For this problem, a simulation over a one-year period was used for the evaluation. The re-order point was used as the initial inventory and daily demand was generated for one year with orders of size Q placed whenever the inventory position reached R. Over the course of the one-year simulation, ordering costs, holding costs, and penalty costs due to backlogged and/or lost orders were tallied. These costs, in addition to a cost for attaining sample data, were then totaled into a final cost value. A visual output of the simulation along with problem parameters and the final cost figures were presented on an evaluation page (see Figure 3).

The evaluation page also contained the economic score that was assigned to the solution and stored in the database. As stated previously, the development of a fair method of determining an economic score is both important and a non-trivial part of problem scenario development. Above all, students must perceive the system as evaluating them fairly. For this problem, we settled on the following evaluation method that provided a reasonable element of fairness and did not require an unreasonable amount of server processing time. To prepare for problem evaluation and scoring we developed a methodology to assure that generated problem parameters maintained reasonable pairwise relationships and did not cause very unusual optimum such as an order-on-demand solution. This was accomplished by using stochastic algorithms that bounded parameters to specific ranges and enforced reasonable relationships. For example, once item costs were generated, holding costs were generated as uniformly random 10 to 20 percent of item costs; time dependent stock out costs were generated as uniformly random 5 to 10 times item costs; and sampling costs were based on a percentage of total cost as calculated by a simple EOQ formula from previously generated values.

After student scores were evaluated, the scoring system calculated values of Q and R and the simulation was rerun using these values. Total costs were computed in a manner identical to the student evaluation with the exception that no sampling costs were included. The student economic score was calculated as (100)(*student score*)/(*system score*). In computing the system (Q, R) values, the system had the advantage of knowing the true probability distributions of demand and lead-time. However, an important constraint on the system was that the computation requirements of the solution method had to be kept to a minimum in order to produce rapid response to the student and more importantly not to bog down the server and influence overall system response. We used a variation of the heuristic treatment of the "fixed reorder quantity system with lost sales" model as developed in Johnson and Montgomery **[3]**.

The variation used a fixed three-step iteration and a fast executing polynomial approximation to the normal loss function. Since the system's solution did not include sampling cost, a score close to 100 was excellent. It should also be noted that as the system solution was obtained with a heuristic and that the solution was evaluated in a simulation, it was possible that a student could beat the "optimal" decision based on randomness in the system (emphasizing the real world nature of the problem and randomness).

IV. Implementation Issues and Discussion

Upon completion of at least two iterations of solving the prototype problem, students were required to fill out survey form containing the questions: (1) Provide your overall impression of the system. Did you enjoy using it? Did it challenge you? (2) Would you be interested in using a system like this to augment your learning experience in this or other courses? Why or why not? (3) Provide any other suggestions, complaints or comments that you feel would help improve the system for future use by students. Reaction to the system was overwhelmingly positive, as students cited numerous benefits to the system. Specifically, students noted that they were motivated to do the problems and the system was convenient and easy to use. Examination of the surveys suggested that the students were motivated to drill the problems because they were perceived as realistic and challenging and they were able to apply knowledge acquired in class. Also, the scoring rules drove them to continually improve. Here is a representative sampling of comments from students to that effect:

> "The system was user friendly and the problem was realistic"
>
> "I do enjoy using this system. You get addicted and can't stop. The problems were challenging and realistic"
>
> "I think it should continue to be used in this course, and start being used in other courses"
>
> "I really enjoyed using this program. It was challenging at first, but after some practice, the numbers just seemed to make more sense"
>
> "I really liked the immediate feedback"
>
> "I enjoyed the problem, it was challenging. The problem seemed realistic because of the not enough information factor"
>
> "The problems were more realistic than problems I faced in the book. It was challenging because I learned to use the formulas and see how they worked in a more realistic environment."
>
> "If I did not have to do this, I would not know that I knew nothing. Though its time consuming, its good for me."
>
> "I think it's a fun way to do a project"
>
> "The problem challenged me. At moments I was confused and had to rationalize my answers which made me understand the concepts better."
>
> "It challenged me because I had to decide what data was relevant to the problem."

"The problems were realistic as well as the way they were graded. Even if the exact answer wasn't determined, an effective economic score could be determined, which is close to realism."

"The problems did seem realistic and you have to weigh the option of how much you want to spend (on data sampling) compared to accuracy, as in real life."

"I think this system would be good for homework instead of doing problems from the text. Text problems just apply a few equations, and people don't have to think. However, these problems make people think."

"Taking notes, getting lectured and taking quizzes is such an unrealistic way of learning. Small projects like this are more in tune with reality because (a) I can work on it on my own time and (b) I can use any and every resource I can find."

"Being presented with different situations kept the assignment fresh and challenging."

"I would like a system like this because it involves competition. It would also motivate me to do more problems because if I did bad on a problem, I would want to try again and again to get better scores into my average."

"Its not the same boring out of the book problems"

A minority of students was less enthusiastic about the system. Some complained that they could guess answers as readily as compute answers. This was by design, as solution methodologies were not imposed on the students in this example. Here were some negative comments provided by students:

"I thought there was too much randomness involved in the whole process. It's tough to say if it challenged me or not because I felt that I did the second problem better than the first and I got a lower score on it"

"I feel the system is impersonal and provides no method for feedback that is not answer based. It does nothing to help a student improve his/her methodology. In other words, I still have no idea how to do the problems."

"I definitely did not enjoy using it because I didn't learn anything. The only thing that I was concerned about was to get my score up. It was more of a guessing game than a calculated result."

With these comments, students offered suggestions to improve the system for future implementations. These included:

1. Allowing a student to solve an "example" problem for practice;
2. Providing a "hints" function that would provide more insight to the problem at a cost, much like sampling;
3. Posting student scores (or an average) such that students would have a "target" to beat;
4. Providing links on the summary page to programs such as EXCEL;

5. Building integrated problem scenarios that build on each other.

V. Conclusions and Future Work

We examined the student scores to determine if we could draw any conclusions as to whether learning occurred. For each problem, students were required to solve 2 problems and permitted to do as many as they wanted with their grade dependent on their average score. The average number of problems, the average score on the first problem and the average score on the last problem done for each student are shown in Table 2.

Table 2. Average Statistics for Problems

	Forecasting Problem	Inventory Problem
Number of Problems Done	3.2	6.6
Average Score on First Problem	54	52
Average Score on Last Problem	56	79

It is interesting to note that while the first problem is much more straightforward than the second, students did three times as many of the second than the first. Not surprisingly, we also found that the there was a significant increase between the first and last score in the case of the second problem. Anecdotal evidence suggested that this was due to the fact that students found the second problem more interesting. Though minimal evidence, this implies that problem complexity is not a deterrent to drilling quantitative problems if a suitable vehicle is created to present them.

Although we are in our initial stages of testing the prototype system and integrating it as a learning tool into our undergraduate curriculum, we are encouraged by our initial results. This initial prototyping and testing is part of a larger goal of making a general problem based learning system available to all educators, without requiring that they have computer expertise.

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Figure 1. Problem Summary and Action Form for Forecasting Problem

Jane Smith

You are working on your 1st problem which was created 1/5/01 10:26:49 AM:

The scores for all class solutions submitted to date are available **HERE**

The plant manager has come to you in hopes of improving his forecasting ability for shipping a certain product line. He gives you the following data:

Period	Observation	Period	Observation	Period	Observation	Period	Observation
1	237.86	7	304.2	13	312.46	19	174.71
2	292.58	8	372.89	14	261.28	20	277.02
3	166.39	9	232.95	15	304.61	21	299.52
4	265.16	10	285.76	16	372.48	22	254.21
5	331.62	11	149.16	17	237.39	23	284.68
6	245.03	12	266.96	18	258.76	24	367.2

View the data in a single column

The manager is giving you four periods to prove you are capable of the task. Specifically, forecasts for the next four periods are requested.

Enter Your Forecasts, Then Submit

Period 25:

Period 26:

Period 27:

Period 28:

Submit for Evaluation

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Figure 2. Problem Summary and Action Form for Inventory Problem

Jane Smith

You are currently working on the following problem:

You have been placed in charge of a product line. Your vendor is fairly reliable and generally gets orders to you in 11 days time (+ / - 10%) after the order has been placed. According to a recently signed contract, they will be your sole supplier of product over the next year. Your agreed contract price is 11.72 per unit with a fixed cost of 161.71 per order.

Your task is to determine an ordering and inventory policy. Specifically, determine an order quantity Q and a reorder point R. Your company has a barcode system in place so your order is automatically placed when R is reached. As the lead time of your supplier is not always perfect, it is possible that more than one order may be outstanding at any given time. That is, you may place another order before the previous order(s) has arrived. For this reason, the inventory system will use **inventory position (i.e., current inventory plus all outstanding orders)** for the comparison to the reorder point R.

Your goal is to minimize the sum of all costs, namely sampling cost, the fixed cost of ordering, holding, backlog and all penalty costs. **Please note: your sampling costs are included.** Holding costs are 1.83 per unit per year. If customers wait for their product, a backlog cost of 15.21 per unit per year is paid. However, not all customers will wait for your product, but rather, go to your competition. For each of these customers, you pay a loss of goodwill penalty cost of 15.78 for each sale lost. Historical data shows that out of 100 customers that request a product when there is no inventory, 75 will wait and 25 will go to the competition. Your end of year bonus is tied to how you save money over the next year.

As expected, demand is uncertain. However, for a processing cost of 241.92 per request and a per-unit sample cost of 24.19, the marketing department will supply you with historical data (daily demand). You may request the number of daily observations below. Your may request data more than once but will pay a fixed cost each time. Upon completion of your analysis, enter your values of Q and R.

Request Demand History

Num of Obs [ ]

[Submit Request]

[Review Data Already Obtained]

Enter your solution for this problem and submit

Order Quantity (Q) [ ]

Reorder Point (R) [ ]

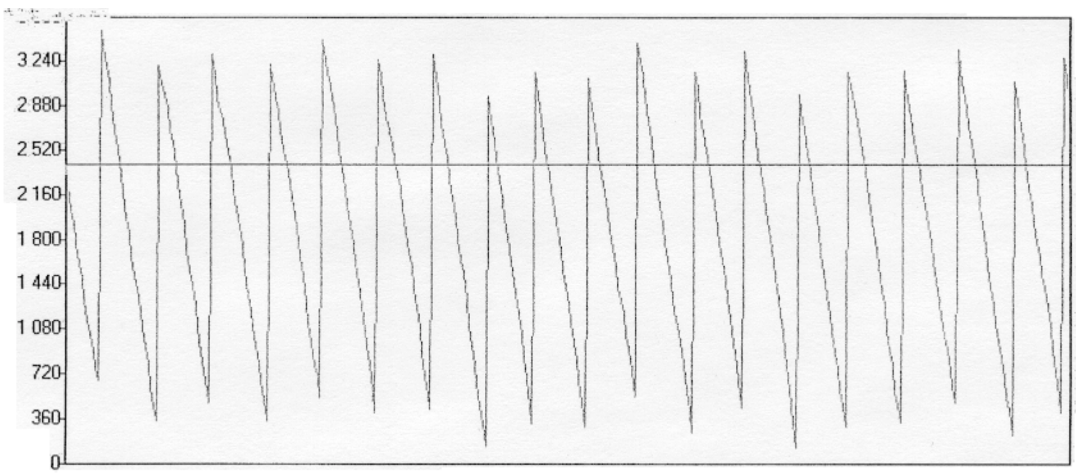
[Submit Your Solution for]

Figure 3. Inventory Problem Evaluation

Order Quantity = 3000 Reorder Point = 2400 Unit Cost = 15.39 Sampling Cost = 867.94

Fixed Cost = 233.87 Holding Cost = 2.8 Penalty Cost(/Unit) = 19.16 Penalty Cost(/Time) = 20.47

Stock History



Number of Orders = 19 Sales Lost = 0 Total Order Cost = 4209.57

Total Holding Cost = 5050.34 Total Penalty Cost/Unit = 0 Total Penalty Cost/Time = 0

Your Grand Total Cost = 10127

I solved this same problem using a (Q,R) policy of (3281, 2393). My total cost was **9652**. Therefore, I will give you a score of

(mine/yours)*100 = **95.3**

Continue