Bringing Linear Programming to Life for Business Students – An Interactive tool to Improve Understanding

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I. Motivation.

At Rhode Island College, we teach a sequence of three mathematics courses to all of our business majors. In the first course, Quantitative Business Analysis I, one of the major topics is linear programming. Students often struggle with these problems for a variety of reasons. The students feel problems are often long, with many tedious steps necessary to solve the problem. Also, many of them do not thoroughly understand the reasons behind each of these steps. Our goal was to bring the process of solving linear programming problems to life by designing a software tool with which the student could interact. We hoped to improve a student's ability to solve such problems on his/her own.

II. Linear Programming and the Student.

By the end of the chapter on linear programming, a student is expected to be able to solve a problem like the one below.

$$\begin{aligned} \text{Maximize: } & 10x+5y \\ \text{Subject to: } & 2x-y \geq 0 \\ & -x+3y \geq 5 \\ & x+2y \leq 10 \end{aligned}$$

In the step-by-step process used to solve these linear programming (LP) problems, students have little trouble graphing the constraints (a system of linear inequalities). If they are given the corner points, they can find the solution to the LP problem, but they do not understand why only the corner points are important, nor do they understand that in the case of an unbounded feasible region, there may not even be a solution to the problem.

It has seemed that despite being able to handle the individual steps of the solution process, many could not look at the LP problem and successfully put all the steps together in a single package. We wished to pursue this issue.

III. The Goal.

Our goal was to develop a tool that would walk the student through the steps of the problem without it also doing all of the work. We wanted some element of "crudeness"

in order to force the student to stay active and think about what was happening in the solution process. Furthermore, since we wanted the tool to work as a guide, it was our intent to expect the student to be doing the problem with pencil and paper while working at the computer. In addition, we wanted a tool that would more easily "show by example" why the corner points were the interesting places in a feasible region when looking for the optimal solution to the LP problem. By design, this would also show why an unbounded feasible region may not allow for a solution to a given LP problem.

IV. Development of the Tool.

We took our ideas to an MAA PREP workshop during the summer of 2003. With the help of the workshop leaders, we developed the basic structure of our linear programming applet.

The main goal of the applet is to get a student to solve a linear programming problem. As described in our goals, the student is expected to work with pencil and paper, along with interaction with the computer, to keep track of the stages of the solution process. The first page the student sees is the problem that is to be solved. The student is then prompted to first look at the constraints of the problem. As shown in Figure 1, the applet displays the graph of the line $ax+by=c$. There's a red ball that can be dragged around the xy-plane. In addition, if the ball is located at (x_1,y_1) there's a location to the right of the graph which gives the value of ax_1+by_1. As the student moves the ball, s/he can see how the value of $ax+by$ changes.

Testing the Linear Inequality

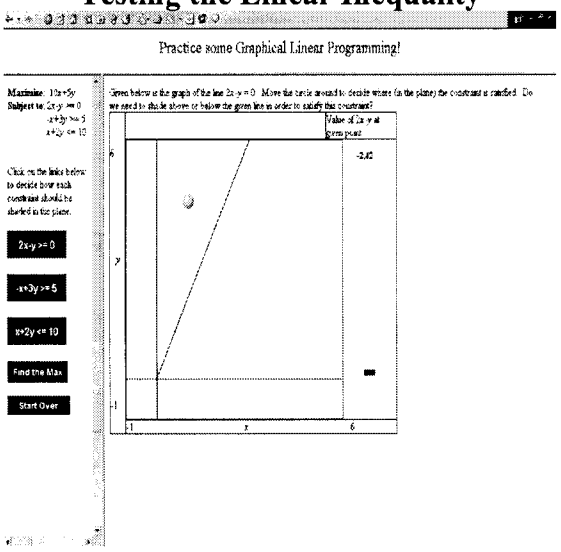

Figure 1

Testing the Feasible Region

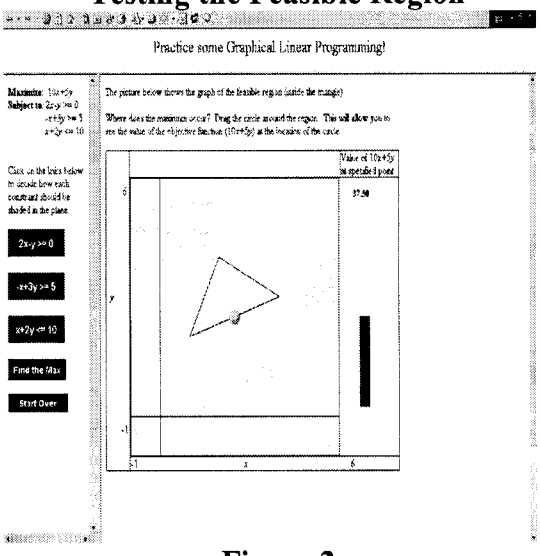

Figure 2

Once the student decides what the solution region is for each inequality, s/he is expected to decide what the solution (feasible) region for the LP problem is. In the next step, the feasible region is drawn (Figure 2) and the student must now decide where the solution to the problem is. This time the red ball is moved to experiment with values of the objective function in the feasible region.

We must emphasize that the program should under no circumstances replace the student's ability to solve the problem on his/her own. We are aware of lots of other applets that solve the problem immediately. Our purpose is to act as a "workbook" to give the student a chance to work out a problem with some help, but also without giving away the whole problem.

V. Implementation.

Students are introduced to linear programming in the classroom (routine chalk and talk). They are given a chance to do the homework and ask questions the next day. Usually, the instructor is met with many confused students. Students can handle each task individually, (1. graph feasible region, or 2. if given a feasible region with corner points find the appropriate corner point which maximizes or minimizes the objective function) but when put together in one problem, they often cannot organize their work.

Next, they are brought into the computer lab. The instructor introduces how the applet works (with some time; actually solve a problem with applet and chalkboard). Now, students are given a chance to work out some other problems written for use with the applet, then go back and re-try the homework. Even if the homework problems do not have an associated "applet" students could still go back to the webpage and see how each problem was organized. Our hope was that a student was now in a habit of setting up and working new problems appropriately. That is, the blueprint for solving would become innate, as opposed to nonexistent.

VI. Classroom Results and Future Work.

Preliminary work was in fall 2003. The overall response was quite positive. Emotionally, the students were happier and more confident. They felt that the problems were tractable, whereas before they felt these were insurmountable. Figure 3 is a copy of the questionnaire that was given to the students to fill out, with a summary of their responses in Table 1.

There are several limitations to the current condition of the software. Though we emphasize that the software should not solve the problem for the student, we feel that once the feasible region is on the screen, and the student is trying to find the optimal solution, that the ball should not be allowed to move out of the feasible region on the screen. Secondly, the size of the ball that the student moves around is much larger than we would like. Due to our programming limitations, at this stage we have not been able to correct this problem. We intend to continue to address these issues and others as our programming sophistication improves.

In addition to correcting some crude aspects of the applet, we next intend to study the change (if any) in grades students achieve on such problems. We would like to know if the student response to the applet is merely emotional, or if it does correlate into improved ability to solve such problems.

Student Questionnaire

Please answer these few brief questions about the Linear Programming Applets you just saw.

I. Circle one answer in each question that best fits your opinion.

1. This helped improve my understanding of how to find feasible regions to linear programming problems.

Strongly Agree *Agree* *Undecided* *Disagree* *Strongly Disagree*

2. This helped improve my understanding of how to find graphical solutions to linear inequalities.

Strongly Agree *Agree* *Undecided* *Disagree* *Strongly Disagree*

3. This helped improve my understanding of why solutions (if they exist) to linear programming problems are located at the corner points of the feasible region.

Strongly Agree *Agree* *Undecided* *Disagree* *Strongly Disagree*

4. I would use this program again.

Strongly Agree *Agree* *Undecided* *Disagree* *Strongly Disagree*

II. Give a brief answer to each of the following questions. (If you need more room, you may use the back of this sheet.)

5. What did you like about these applets?

6. What did you dislike about these applets?

7. What suggestions do you have to improve these applets?

Figure 3

Results of Student Questionnaire

Question\Response	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	11%	61%	29%	0%	0%
2	7%	63%	22%	7%	0%
3	18%	57%	25%	0%	0%
4	14%	43%	39%	4%	0%

Table 1