Spreadsheets in Education (eJSiE)

Volume 5 | Issue 2 Article 3

May 2012

Teaching quantitative methods to business and soft science students by using interactive workbook courseware

Dan DuPort
European Business Schools, mail@duport.com

Follow this and additional works at: http://epublications.bond.edu.au/ejsie

This work is licensed under a Creative Commons Attribution-Noncommercial-No Derivative Works 4.0 License.

Recommended Citation
DuPort, Dan (2012) Teaching quantitative methods to business and soft science students by using interactive workbook courseware, *Spreadsheets in Education (eJSiE)*: Vol. 5: Iss. 2, Article 3.
Available at: http://epublications.bond.edu.au/ejsie/vol5/iss2/3

This Regular Article is brought to you by the Bond Business School at ePublications@bond. It has been accepted for inclusion in Spreadsheets in Education (eJSiE) by an authorized administrator of ePublications@bond. For more information, please contact Bond University's Repository Coordinator.

Teaching quantitative methods to business and soft science students by using interactive workbook courseware

Abstract
The article discusses the use of self-contained interactive, self-paced courseware for teaching quantitative methods to business and soft science students. The courseware can be created in Excel workbooks by interlacing text with embeddable interactive tools in a way that provides continuous binding of theory and exercise. When the workbooks are built around certain types of tools, a best courseware is created for learners who are non-quantitative. Exemplary Excel workbook chapters which have been created and used for teaching linear programming to business students are used to illustrate the special types of tool required for best courseware. Examples are given of interesting subjects ripe for treatment with quantitative interactive workbooks. Best practices for using interactive workbook courseware are discussed. The article concludes with a brief account of statistical studies relative to the efficacy of computer assisted instruction, and a study using the author's workbooks is outlined and proposed. Within the article a good sized exposition of linear programming courseware is presented. Chapter1i.xls, consisting of 28 worksheets, is downloadable and can be used for a course. Custom worksheets are constructable within its framework, so instructors can also use it as a starting point for creating their own variation of the courseware.

Keywords
interactive Excel courseware, linear programming, visual learning

Distribution License

This work is licensed under a Creative Commons Attribution-Noncommercial-No Derivative Works 4.0 License.

Spreadsheets in Education (eJSiE)

Volume 5 | Issue 2 Article 3

May 2012

Teaching quantitative methods to business and soft science students by using interactive workbook courseware

Dan DuPort
European Business Schools, mail@duport.com

Follow this and additional works at: http://epublications.bond.edu.au/ejsie

Recommended Citation
DuPort, Dan (2012) "Teaching quantitative methods to business and soft science students by using interactive workbook courseware," *Spreadsheets in Education (eJSiE)*: Vol. 5: Iss. 2, Article 3.
Available at: http://epublications.bond.edu.au/ejsie/vol5/iss2/3

This Regular Article is brought to you by the Faculty of Business at ePublications@bond. It has been accepted for inclusion in Spreadsheets in Education (eJSiE) by an authorized administrator of ePublications@bond. For more information, please contact Bond University's Repository Coordinator.

Teaching quantitative methods to business and soft science students by using interactive workbook courseware

Abstract
The article discusses the use of self-contained interactive, self-paced courseware for teaching quantitative methods to business and soft science students. The courseware can be created in Excel workbooks by interlacing text with embeddable interactive tools in a way that provides continuous binding of theory and exercise. When the workbooks are built around certain types of tools, a best courseware is created for learners who are non-quantitative. Exemplary Excel workbook chapters which have been created and used for teaching linear programming to business students are used to illustrate the special types of tool required for best courseware. Examples are given of interesting subjects ripe for treatment with quantitative interactive workbooks. Best practices for using interactive workbook courseware are discussed. The article concludes with a brief account of statistical studies relative to the efficacy of computer assisted instruction, and a study using the author's workbooks is outlined and proposed. Within the article a good sized exposition of linear programming courseware is presented. Chapter1i.xls, consisting of 28 worksheets, is downloadable and can be used for a course. Custom worksheets are constructable within its framework, so instructors can also use it as a starting point for creating their own variation of the courseware.

Keywords
interactive Excel courseware, linear programming, visual learning

This regular article is available in Spreadsheets in Education (eJSiE): http://epublications.bond.edu.au/ejsie/vol5/iss2/3

Teaching quantitative methods to business and soft science students by using interactive workbook courseware

Abstract

The article discusses the use of self-contained interactive, self-paced courseware for teaching quantitative methods to business and soft science students. The courseware can be created in Excel workbooks by interlacing text with embeddable interactive tools in a way that provides continuous binding of theory and exercise. When the workbooks are built around certain types of tools, a best courseware is created for learners who are non-quantitative. Exemplary Excel workbook chapters which have been created and used for teaching linear programming to business students are used to illustrate the special types of tool required for best courseware. Examples are given of interesting subjects ripe for treatment with quantitative interactive workbooks. Best practices for using interactive workbook courseware are discussed. The article concludes with a brief account of statistical studies relative to the efficacy of computer assisted instruction, and a study using the author's workbooks is outlined and proposed. Within the article a good sized exposition of linear programming courseware is presented. Chapter1i.xls, consisting of 28 worksheets, is downloadable and can be used for a course. Custom worksheets are constructable within its framework, so instructors can also use it as a starting point for creating their own variation of the courseware.

1 Interactive courseware and TEL

Interactive courseware, software generally provided on a desktop or laptop computer for teaching a course is self-paced eLearning material which has its roots in the 1980s when technology enhanced learning, TEL, was used almost exclusively for computer based training, CBT. CBT was expensive, custom, and generally applied to learning computer languages, operating systems, or application packages. CBT was performed in small labs and so served the small population of those interested in computers and literate in the 1980s and 1990s. The small labs of those decades have become a giant maze of laptop computers, and the small population of those working with computers has become the literate world. CBT has evolved into what is today called TEL. While on the macro level TEL is usually thought of as eLearning, electronic white boards, and online school learning centers, it encompasses CBT, and its cousin, computer assisted instruction, CAI, including the use of interactive courseware.

Dror points out in [1] that learning materials constructed via TEL are less taxing on the cognitive system than tradition lecture / text. Furthermore, from [1]

> "When considering the learners, we need to note that when the learning material is simply presented to the learners, they are passive and so learning is minimal. In contrast, when learners are active and motivated, when they are involved, participating, engaged, and interacting with the material, then learning is maximised."

Thus interactive courseware, which requires engagement and interacting, is less cognitively taxing and provides more learning than traditional lecture / text.

Surprisingly, Anderson's equivalency theorem [2],

> **a**. Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student–student; student–content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience.
>
> **b.** High levels of more than one of these three modes will likely provide a more satisfying educational experience, although these experiences may not be as cost - or – time effective as less interactive learning sequences.

implies that student-content interaction provided by interactive courseware can yield deep and meaningful formal learning by using it along with other interactions at minimal levels. The truth of the theorem, at least **a**., has been verified by statistical evidence (see Miyazoe & Anderson [3]).

While it is an open question of how much of the each interaction, student–teacher; student–student; student–content, is appropriate in a course [4], one thing is clear: teacher presence sets the tone of the course. Sims and Bovard in [5] question what it means for a teacher to have presence or to be effectively present. They conclude that positive teaching presence is an important component in learning that must exhibit a balance of cognitive and social activity. This gives the impression that interactive courseware alone cannot be a sufficient teaching method without some teacher interaction. But how does interactive courseware affect teacher

interaction? It minimizes the conveyance of knowledge thru verbal language; interactive courseware does not have to audibly talk to the student, instead it provides an activity that the student performs.

Does the teacher lose anything by having the text and illustrations in an electronic media, instead of in a classical book? Perhaps the comfort of teaching the way he/she was taught is the only loss. What is gained is in the switch from teacher-centered learning to student-centered learning, which again might represent a loss to the teacher. Instead of writing on a board or presenting slides, the computer can be used to project the lesson directly from it, with local copies on the students' desktops or laptops where notes can be taken and incorporated, if necessary. The instructor becomes a guide, directing, but giving the student maximum participation, class interaction, and **engagement** by yielding the course to the student learning self-paced via interaction with the courseware on computer.

By allowing more and more passive relationship with the instructor, the student becomes motivated to learn in a new way, interacting without much instructor intervention, just direction and support; more able to control the learning process. Surely, as opposed to the words that are often missed during a lecture, courseware does not disappear into the air; if something is not understood, it can be bookmarked for later revision, instead of being lost.

Putting all this together, we see that interactive courseware delivering the "right" amount of student-content interaction can maximize learning, as well as make it more convenient, both mentally, and temporally.

2 QIWs and QIWC

A "quantitative" interactive (Excel) workbook, QIW, is an interactive workbook that can be used to train a student to solve a mathematical problem by performing a quantitative method, that is, by performing an algorithm that terminates with the solution of the problem. That it is fundamental that training provides a best source of concept learning in quantitative subjects is given to us by theorist Jerome Bruner. For example, in [6]

"The concept of prime numbers appears to be more readily grasped when the child, through construction, discovers that certain handfuls of beans cannot be laid out in completed rows and columns. Such quantities have either to be laid out in a single file or in an incomplete row-column design in which there is always one extra or one too few to fill the pattern. These patterns, the child learns, happen to be called prime. It is easy for the child to go from this step to the recognition that a multiple table, so called, is a record sheet of quantities in completed mutiple rows and columns. Here is factoring, multiplication and primes in a construction that can be visualized."

An analogous example is that the concept of a solution point of a linear model appears to be more readily grasped when the student, through construction, discovers by moving an objective function iso-line out of a feasibility region, and while observing the corner points of the region and slope of the iso-line, that if the iso-line were slanted differently it would leave the region at

different corner point and yield a different optimal solution. The astute student would be able grasp for the picture of the plane in three-space associated with the objective function, as well.

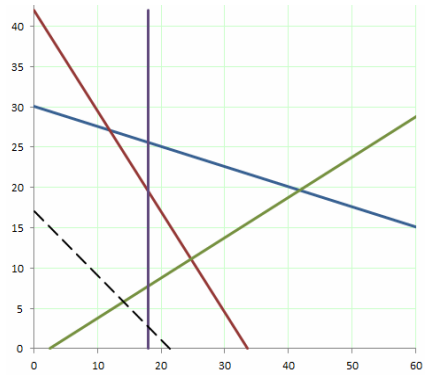

Figure 1: Polygons and iso-line (dotted line) involved in the solution of a linear model

The construction of the feasible region and movement of the iso-line can be performed by a tool in Excel; an interactive tool that can be used to both perform and illustrate the geometric solution method for linear models of two variables. Such a tool is talked about in (3 Tools and the TVLP tool) and is a cornerstone to binding theory and exercise in interactive workbooks. Note here that the Excel solver can be used to solve linear models of two variables, but it is a black box that accepts data, and returns solution(s); the solver is not illustrative.

By a tool, it is meant a quantitative tool, an interactive object with user interface that can be used to perform a quantitative method. By an illustrative tool it is meant a tool that can be used to both illustrate the method as well as perform it. The Excel solver is not an illustrative tool. It is possible to assure Bruner's constructive learning of concepts in a QIW by endowing the workbook with tools that are illustrative; using non illustrative tools provides essentially no concept learning.

An illustrative QIW is a workbook that is built around illustrative tools that embed in and integrate into the workbook. A series of QIWs is called quantitative interactive workbook courseware, QIWC, best to be enunciated QIW courseware. QIWC composed of only non-illustrative QIWs are inferior to "good" QIWC that is composed of illustrative QIWs and that is a (complete) exposé of a quantitative theory -- for example, the theory of two variable linear models, or the theory of quantitative risk.

3 Tools and the TVLP tool

There are many illustrative tools available for use in teaching quantitative methods. Many are stand-alone, and as many embed and integrate into Excel. Since QIWC is composed solely of workbooks, standalone tools will only be discussed relative to equivalent ones that are workbook embeddable. Excel is used in this article as the workbook software. However, generality should not be limited by its use, and any equivalent or better spreadsheet software can be considered as a base for QIWC.

While any illustrative tool will help maximize learning engagement and interactivity, an easy to use illustrative one will maximize the learner's acceptance of using it, thus enhance the learner's motivation, and commitment.

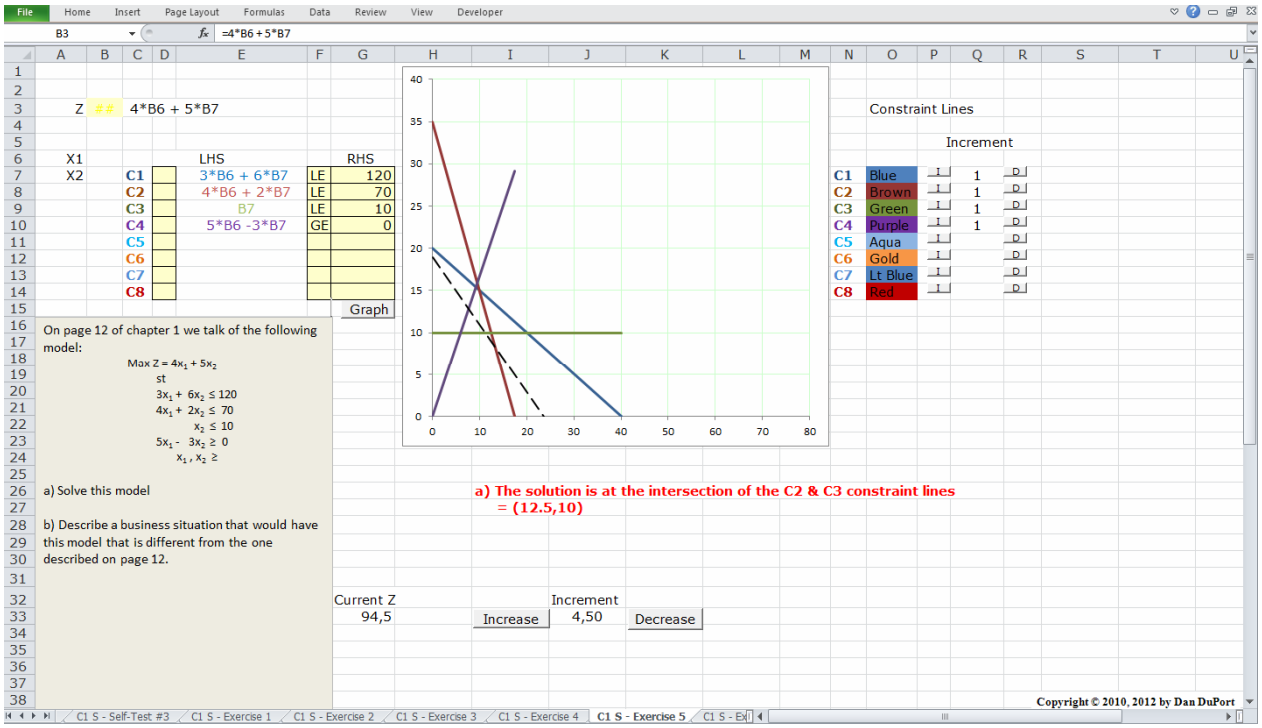

Figure 2: The TVLP tool from chapter1i.xls

The illustrative, easy to use TVLP tool is used in chapter1i, an interactive workbook that is part of good QIWC developed for teaching linear programming, LP, to business students. It is called the TVLP tool because it can be used to illustrate the geometric method of solving two variable LP problems. It was built entirely in Excel using VBA, taking advantage of Excel's chart object. The linear model in Figure 2 is solved by the using the TVLP tool first to create the graph and then to move the iso-profit line (dotted line), which is the projection of the Z function onto the Cartesian plane, through and out of the feasible region, which is defined by the constraints. That (12.5, 10) is the solution is easily arguable since the function, Z, because of its linearity, forms a smooth plane in three-space, and increases continuously. Since all the Z values along the iso-profit line are equal and the coefficients of Z are all positive, they are all *greater*, equal values when Z is evaluated at points further from the origin.

The TVLP tool is easy to use because it circumvents algebra and arithmetic data manipulation – as it only involves putting in the parameters of the model, hitting a graph button, and moving the object function away from, or toward, the origin to find the solution(s) visually. There are software packages, usually distributed on CD or downloadable from the web, which perform in an analogous manner to the TVLP tool, but these do not embed nor integrate into workbooks so they cannot be used in QIWC. The software package called POM-QM [7] is a good example.

That QIWC be self-contained and provide continuity and binding of theory and exercise thru common tools is essential to the interactive student-centered learning it provides.

Good examples of tools that embed and integrate into Excel are the statistical ones made by Palisade Software and risk modeling tools found in Crystal Ball and Vose Model Risk. While these are commercial products written by professional software developers, amateurs can, within Excel and VBA, and in conjunction with the use of available Excel add-ons, develop tools that can be used in building QIWC. There is an abundance of subjects ripe for QIWC, and these will be talked about in (7 Developing QIWC).

A categorical tool is a tool that can be used to solve all problems within a quantitative theory, or at least a large meaningful sub-class of problems within one. For example, the tool offered by Crystal Ball that displays a density distribution so that one can easily see probability densities and read their accumulative per cents is (illustrative and) categorical on a large class of quantitative problems arising in the theory of quantitative risk. Many tools available for solving linear models are categorical but not illustrative, such as the Excel solver. The TVLP tool is illustrative and categorical on the class of two variable linear models. That it is restricted to eight constraints for educational purposes has no bearing on this categoricity. The best QIWC is built using tools that are both illustrative and categorical, as non-categorical tools limit the binding of theory and exercise, and exposition of the theory.

A snippet is an illustrative tool that illustrates a quantitative method on only a small class of problems. It is a non-categorical tool. Examples of snippets are obtained by limiting the TVLP tool to only changes in coefficients of the objective function of a model, or limiting the TVLP tool to the change of parameters of only a particular model. A similar example appears in a popular new book by Ragsdale [8]. It's a snippet loadable from the books accompanying CD and is used to illustrate the geometric solution(s) and sensitivity analysis for a lone example of a particular model (Blue Ridge Hot Tub sales). As pointed out above, best QIWC cannot contain only snippets; however, QIWC can be built around them. See the suggestion in (7 Developing QIWC) for a particularly interesting one.

A popular tool used in LP, which is categorical on the whole theory and illustrative, is the tool that performs the Simplex quantitative method for solving linear models. See Chinneck [9] for one of the gentlest introductions. To think of the Simplex method as a tool, think of the user interface being a series of empty tableaus that can be filled, one after the other, by applying certain successive manipulations to the model's parametric data and to its so manipulated successors. A final tableau is then eventually filled that exposes the solution. However, unlike the TVLP tool, it involves cumbersome data manipulation which can deter the weaker student's view of the method at hand, encumbering the binding of theory with exercise. It uses a method of solution that is different from the one used by the TVLP tool; one more suitable for the eyes of a computer or those interested in working in an algometric, but non-geometric way. It is not easy to use. For linear models involving more than two variables, the Simplex method, or equivalent, however cumbersome, is necessary since methods analogous to the geometric method for two variable linear models that work with three variable linear models are complex and not practically extendable to models of more than three variables. Even so, the geometric

method is presented in most LP teaching materials, simply because it provides insight into the concept of the solution of two variable models.

4 QIWC as core course material

My QIWC on linear programming presents two variable LP, sensitivity analysis, and transition to the Excel solver and report interpretation.

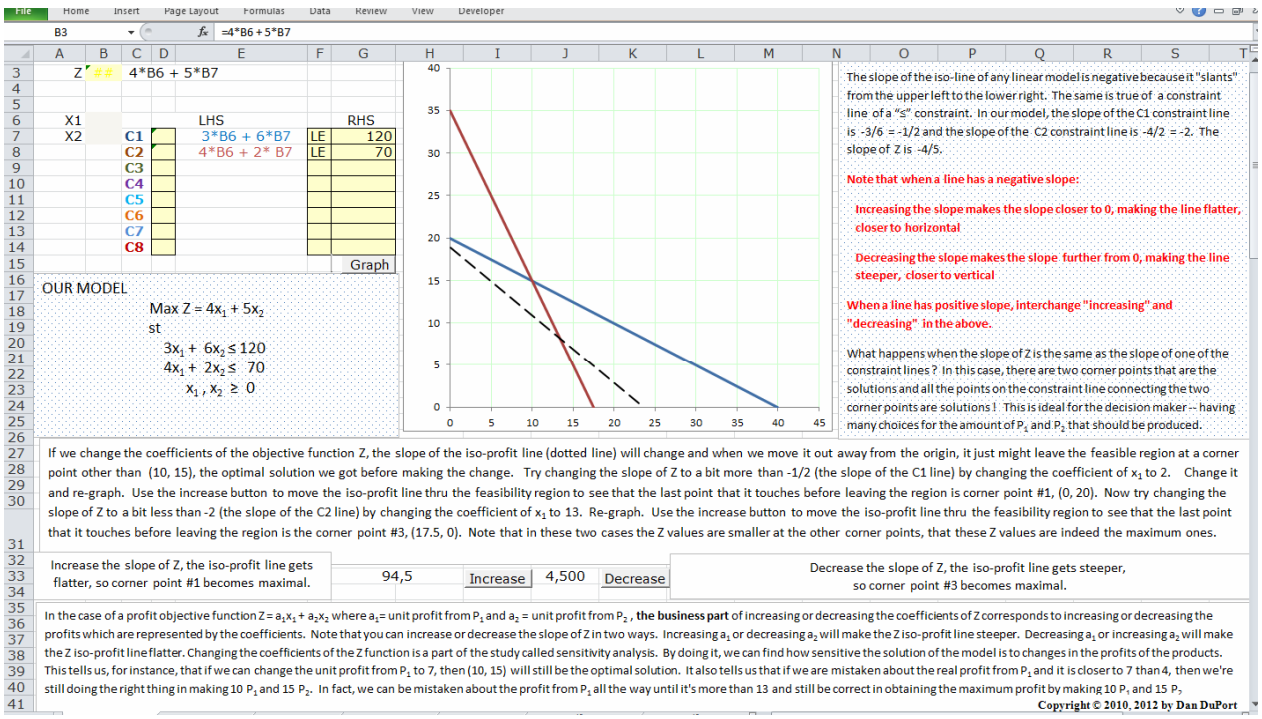

Figure 3: Sample page from chapter1i.xls showing illustration of methodology

In chapter1i, the first workbook belonging to it, the TVLP tool is used as a basis to expose theory. The learner is guided by the tool thru the content. However, every concept need not be expressed by activity with the tool. In Figure 3, the text in rows 35 thru 40 is not supported by interaction with the TVLP tool. This text is auxiliary, making a finer point or an aside to the text involved in the interactivity of the page. However, in chapter2i, the next workbook in the QIWC, the point is presented again and covered interactively. Generally speaking, QIWC needs a little supplemental handholding by the teacher. However, it can be written for autonomous use; see (7 Developing QIWC).

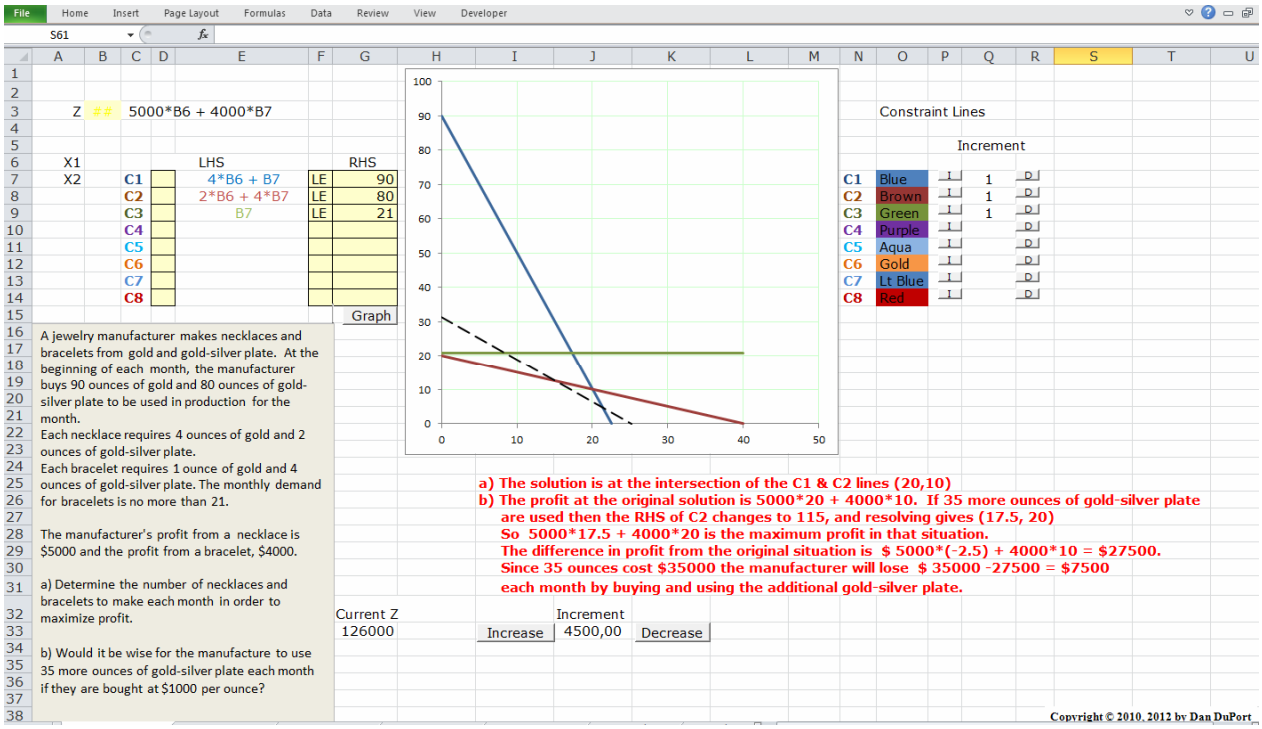

Figure 4: Sample page from chapter1i.xls showing problem solving

Best QIWC uses illustrative and categorical tools to bind the theory with the exercises. If the tools are not categorical, then a full range of exercises in the theory being exposed cannot be offered using only the tools. Ideally, the student will be able to continue using the tools used in the QIWC in latter, more advanced topics on the same or similar subjects.

As was verified in the first part of this article, QIWC has many distinct advantages over other course presentations. It provides engagement, involvement, participation, and interaction. Easy to use, illustrative QIWC provides motivation and commitment; easy bookmarking and hyperlinking. And the best QIWC, which is categorical as well as illustrative, provides smoothness of presentation and learning continuity via binding the theory with exercise.

Best QIWC compared with core course material composed of a coarse macro blend of lectures, text, and external snippets or tools, offers not only better student learning, but also less work for the teacher. Core course material that presents a subject in a piecemeal and disjointed fashion presents the student with inconsistent learning methods and distraction by switching from among them. For example, during a macro blended course, lectures might be used to talk about a quantitative method, a tool on a CD might be used to illustrate the method, and the student might perform exercises from a text. The worst case would be if the student couldn't use the tool for the exercises. Even if the student could use the tool, there are three separate elements in play, the lectures, the tool, and the text; and these have almost always been created by different authors, so that each was designed with a particular type of exposition in mind. Left for the student is the task of putting together the pieces, often to ignore one or more piece to get along with the study, and perhaps not get a clear picture of the course. As pointed out in [10], a study involving blending, students thought that a blended course structure was too fragmented and

that it was difficult to get the big, complete idea of the course because of this. With QIWC there are no gaps between talks, or illustrations, or exercises; these are all seamlessly one. Furthermore, seeing the big picture is easy, the pieces of the course are presented continuously, and also at any time the student wants to view them. This is analogous to a film being broadcast at only a particular time and with many (commercial) interruptions vs. the film without the interruptions and a presentation that is controllable by the viewer. Which is more attractive?

All the components of core course material should have appropriate weighting, as well as seamlessly fit together. The best way to do this is to have woven them into one piece, having a prior weighed the value of each component. Thorough presentation of the entire course content must be delivered. That the teacher should not blend materials on top of such content, or use blended materials solely as core material, depends on the type of course. Clearly, in advanced courses, blending of materials is appropriate, and sometimes necessitated by a lack of available material which thoroughly presents the entire course content. But what is most important in introductory and fundamental quantitative courses, and often makes the difference between student success and failure and retaking of the course, is that the core material is in one piece. This is where the best QIWC is needed most. See [4] for a further discussion of different learning modes and content orientations.

5 The divide

Many educators assume that materials used for the teaching of applied math are, or should be, designed for science, engineering and math majors and those in other fields, like the social sciences, business management, and economics can just adapt to what is produced. A one size fits all approach. However, most students not in the science, engineering or math fields are math nulls, and to give them the same materials that are given to those in these technical fields is being ignorant to education, and sometimes done only to self-fulfill the mind-set of the teacher. In [11] it is pointed out that less than 12%-18% of the population learns aurally and that less than 20% of the population has the logical-mathematical intelligence needed to succeed in traditional lecture style quantitative courses. Couple this with the observation that these non-critical thinkers drift away from courses that are rigorous and into business and soft science courses made by Arum [12]. To cater to this problem, materials that are illustrative and that the student feels are easy to use, with minimal use of algebra and data manipulation, are the best for the majority of business and soft science students.

Some important questions are posed by Dror in [1]

"the questions we ask in TEL should not focus on the technologies, but on the learners: For example, what does the learner take from the learning? What knowledge will be acquired? What will be remembered? And what will be used?"

The answers to these questions point out a quantitative divide, a prime example of which stems from the learning of LP across different student audiences at the university level. LP can be thought of as planning with linear models. For a business, the planning doesn't stop with finding the solution(s) to a model of a situation (business problem); the planning starts there and

finishes with the sensitivity analysis performed with the parameters of the model. The sensitivity analysis involves determining ranges of variability of the model parameters in which the solutions do not change. So for a business, this aspect of LP is equally important as finding the model solution, as ranges of parameters are used to determine inventory re-stocking, production planning, etc. Thus, for the business student, the gist of the study of LP is often the sensitivity analysis and so that is what must be presented thoroughly. The Simplex method is often presented in brief, or in an appendix, and/or in brief as the application working underneath the solver tool. However, a science, engineering or mathematics course in LP might spend a great deal of time on the Simplex method, how it works, and why; and pay little attention to sensitivity analysis.

For the business and soft science student, QIWC is a valuable bridge spanning logical-mathematical intelligence and linking the two quite different types of course expositions, one type for the business and soft science students, the other type for the science, engineering, and math students, each on one side of a quantitative divide. It is because of this divide that the measurement of the efficacy of QIWC is cumbersome – and in trying to measure it, the separate and distinct course expositions must be observed, as well as the teaching methods involved.

6 Bridging the divide: Sensitivity analysis and transition to the Excel solver

Careful observation of the content of Chapter1i will reveal that it hints at sensitivity analysis. For instance the bottom of page C1 -- Page10 (See figure 3):

In the case of a profit objective function $Z = a_1x_1 + a_2x_2$ where a_1 = unit profit from P_1 and a_2 = unit profit from P_2 , **the business part** of increasing or decreasing the coefficients of Z corresponds to increasing or decreasing the profits which are represented by the coefficients. Note that you can increase or decrease the slope of Z in two ways. Increasing a_1 or decreasing a_2 will make the Z iso-profit line steeper. Decreasing a_1 or increasing a_2 will make the Z iso-profit line flatter. Changing the coefficients of the Z function is a part of the study called sensitivity analysis. By doing it, we can find how sensitive the solution of the model is to changes in the profits of the products. This tells us, for instance, that if we can change the unit profit from P_1 to 7, then (10, 15) will still be the optimal solution. It also tells us that if we are mistaken about the real profit from P_1 and it is closer to 7 than 4, then we're still doing the right thing in making 10 P_1 and 15 P_2. In fact, we can be mistaken about the profit from P_1 all the way until it's more than 13 and still be correct in obtaining the maximum profit by making 10 P_1 and 15 P_2.

And some of the exercises in Chapter1i provide the same sort of stretch, for instance the second part of Exercise 3 (See figure 4):

b) Would it be wise for the manufacture to use 35 more ounces of gold-silver plate each month if they are bought at $1000 per ounce?

Here the student works with the idea of shadow price, and consequences of knowing it, before it is formally introduced.

In Chapter2i ranging is presented, starting with optimality. The idea is to present ranging with the TVLP to give the students a good foundation so that they can visualize the ideas involved. Then, when it comes time to learn the N variable LP counterparts, the student can hold on to the two variable ideas as a frame of reference. It's sort of training wheels for handling LP in general business situations.

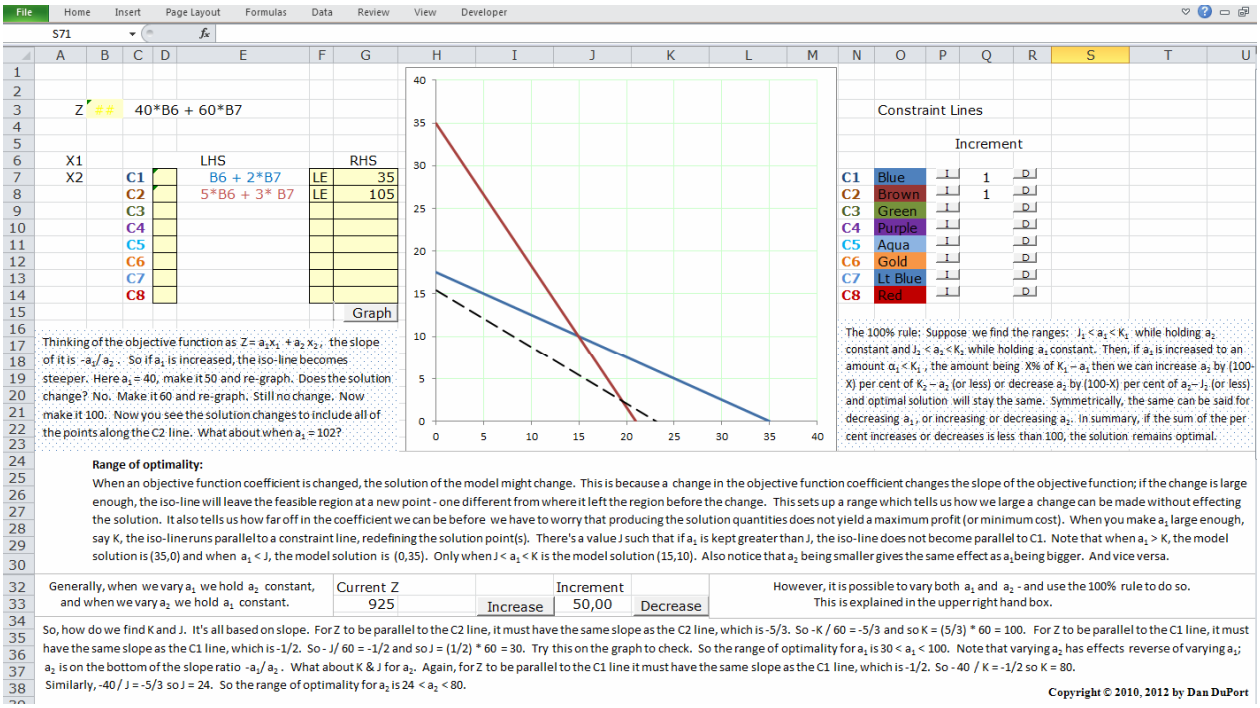

Figure 5: Sample page from chapter2i.xls showing illustration of range of optimality

And then we move on to shadow price and range of feasibility.

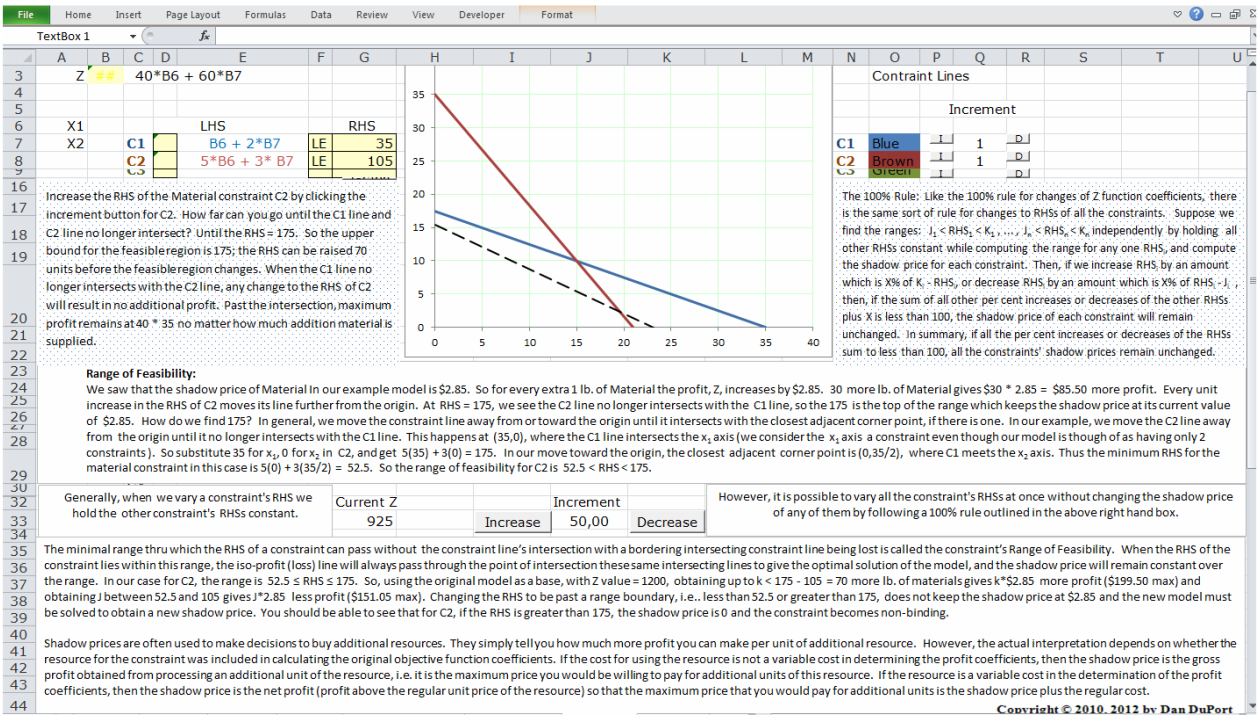

Figure 6: Sample page from chapter2i.xls showing illustration of range of feasibility

Sensitivity analysis finishes with a discussion of reduced costs, and how the theory of the dual ties everything together.

The TVLP is put to good use in determining and verifying the answers to standard exercises, like the following (borrowed from Taylor [13]):

> 7. The Smith family owns 410 acres of farmland in North Carolina on which they grow corn and tobacco. Each acre of corn costs $105 to plant, cultivate, and harvest; each acre of tobacco costs $210. The Smiths have a budget of $52,500 for next year. The government limits the number of acres of tobacco that can be planted to 100. The profit from each acre of corn is $300; the profit from each acre of tobacco is $520. The Smiths want to know **a)** how many acres of each crop to plant in order to maximize their profit, how many acres of farmland will not be cultivated at the optimal solution and do the Smiths use the entire 100-acre tobacco allotment? They also want to know things like: b) What would the profit for corn have to be for the Smiths to plant only corn? c) If the Smiths can obtain an additional 100 acres of land, will the number of acres of corn and tobacco they plan to grow change? d) If the Smiths decide not to cultivate a 50-acre section as part of a crop recovery program, how will it affect their crop plans? e) The Smiths have an opportunity to lease some extra land from a neighbor. The neighbor is offering the land to them for $110 per acre. Should the Smiths lease the land at that price? What is the maximum price the Smiths should pay their neighbor for the land, and how much land should they lease at that price? f) The Smiths are considering taking out a loan to increase their budget. For each dollar they borrow, how much additional profit would they make? If they borrowed an additional $1,000, would the number of acres of corn and tobacco they plant change?

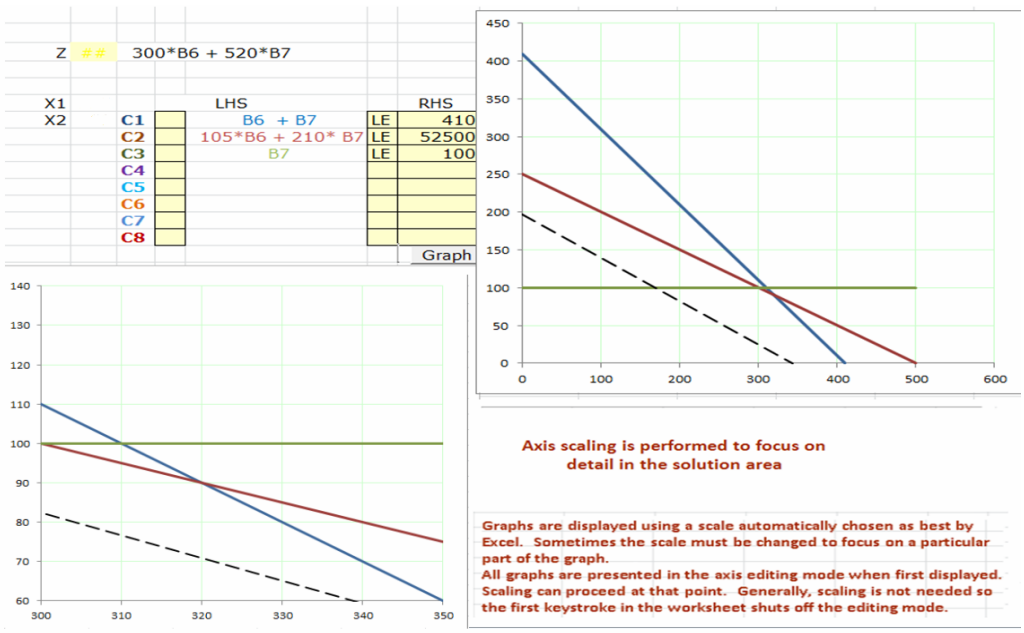

Figure 7: Sample page from chapter2i.xls showing part of the solution of exercise 7

Solutions:

a) Inspect the graph to see that $x_1 = 320$, $x_2 = 90$
Substitute the solution point in the constraints and solve for slack: $320 + 90 + s_1 = 410$ so $s_1 = 0$ acres uncultivated; $90 + s_3 = 100$ so $s_2 = 10$ acres of tobacco allotment unused

b) Corn is represented on the x_1 axis, so when $x_2 = 0$ only corn will be produced. Thus (410,0) needs to be the optimal solution. This happens when the slope of $Z = a_1x_1 + a_2x_2$ is less than the slope of the C1 line, which is -1. Hold a_2 fixed at 520 to find the new a_1. $-a_1/520 = -1$, $a_1 = 520$. If the profit from corn is more than 520, only corn should be produced. Remember that the steeper the slope, the less the value of the slope, and vice versa. Making a_1 more than 520 decreases the value of the slope, and makes the Z line steep enough to leave the feasibility region at (410,0)

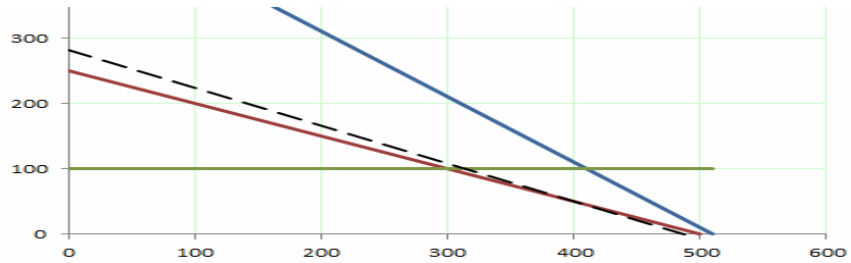

Figure 8: Graph for exercise 7c solution

c) Getting an additional 100 acres of land means that the RHS of C1 changes to 510 (410 + 100). The C1 line will move outward to a location which changes the solution to the point where the C2 line intersects with the x_1 axis. This new point is $x_1 = 500$, $x_2 = 0$. That's 500 acres of corn and no tobacco.

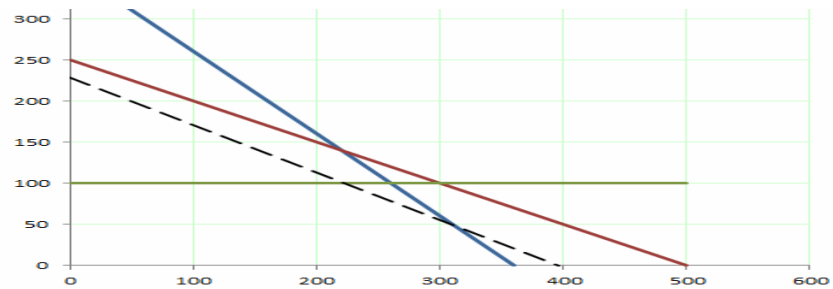

Figure 9: Graph for exercise 7d solution

d) Decreasing the land used by 50 means decreasing the RHS of C1 to 360 (410 - 50). The C1 line will move inward to a location which changes the solution to the point where C1 intersects C3. At this point $x_1 = 260$, $x_2 = 100$.

e) No, the shadow price for land is $80 per acre indicating that profit will increase by $80 for each additional acre obtained. To get the shadow price for land solve the model with the RHS of C1 equal to 411, and subtract the resulting Z value from the original Z value of 142,800, the value when the RHS of C1 is 410.

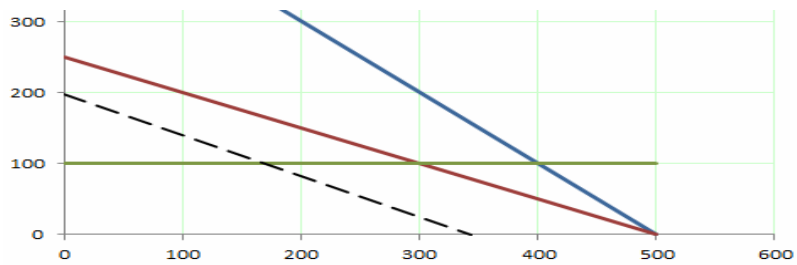

Figure 10: Graph for exercise 7f solution

f) The maximum price the Smiths should pay is $80 and the most they should obtain is at the upper limit of the feasibility range of C1. This limit is 500 acres, or 90 additional acres. Beyond 90 acres the shadow price would change to 0. See this by incrementing C1 (use 5 or 10 unit increments) until it no longer intersects with C2.

g) Look at constraint C2. The shadow price for the budget is $2.095. Thus, for every $1 dollar borrowed they could expect a profit increase of $2.095. Check that 1000 does not exceed the upper bound of the C2 range of feasibility, so that borrowing $1000 will give them $2095 more profit. Borrowing $1,000 would change the amount of corn and tobacco they plant to $x_1 = 310.5$ acres of corn and $x_2 = 99.5$ acres of tobacco. You must resolve the problem to get this new optimal point.

At this point, the student hasn't yet been exposed to N variable LP but they are presented with a few N variable LP sensitivity report exercises. The reports are not labeled as to where (what solver) they come from, nor are the business situations for which they were formulated discussed in detail. I've found this a turning point for the course, where those that have learned from the preceding material will readily come up with the answers, while those that haven't learned will become more aware of their lack of knowledge, and perhaps start to do more work from this point onward.

For example, the students are presented with generic exercises like the following:

> The LP model whose output follows determines how many necklaces, bracelets, rings, and earrings a jewelry store should stock. The objective function measures profit; it is assumed that every piece stocked will be sold. Constraint 1 measures display space in units, constraint 2 measures time to set up the display in minutes. Constraints 3 and 4 are marketing restrictions.
>
> MAX $100x_1+120x_2+150x_3+125x_4$
> S.T.
> 1) $x_1+2x_2+2x_3+2x_4 \leq 108$
> 2) $3x_1+5x_2+x_4 \leq 120$
> 3) $x_1+x_3 \leq 25$
> 4) $x_2+x_3+x_4 \geq 50$
>
> OPTIMAL SOLUTION
> Objective Function Value = 7475.000

Variable	Value	Reduced Cost
x_1	8.000	0.000
x_2	0.000	5.000
x_3	17.000	0.000
x_4	33.000	0.000

Constraint	Slack/Surplus	Dual Price
1	0.000	75.000
2	63.000	0.000
3	0.000	25.000
4	0.000	-25.000

OBJECTIVE COEFFICIENT RANGES

Variable	Lower Limit	Current Value	Upper Limit
x_1	87.500	100.000	No Upper Limit
x_2	No Lower Limit	120.000	125.000
x_3	125.000	150.000	162.500
x_4	120.000	125.000	150.000

RIGHT HAND SIDE RANGES

Constraint	Lower Limit	Current Value	Upper Limit
1	100.000	108.000	123.750
2	57.000	120.000	No Upper Limit
3	8.000	25.000	58.000
4	41.500	50.000	54.000

Use this output to answer the following questions:

a. How many necklaces should be stocked?
b. Now many bracelets should be stocked?
c. How many rings should be stocked?
d. How many earrings should be stocked?
e. How much space will be left unused?
f. How much time will be used?

g. By how much will the second marketing restriction be exceeded?
h. What is the profit?
i. To what value can the profit on necklaces drop before the solution would change?
j. By how much can the profit on rings increase before the solution would change?
k. By how much can the amount of space decrease before there is a change in the profit?
l. You are offered the chance to obtain more space. The offer is for 15 units and the total price is 1500. What should you do?

Answers: 8,0,17,33,0,57,0,7475,87.5,12.5,0, Say no. The shadow price for the space constraint is $75 and an increase of 15 is within range, so the increase in profit from obtaining 15 more units is 15*$75 = $1125, which is less than the cost of 1500.

Let me point out that this generic exercise requires using no LP solving methodology and thus is an unbiased indicator of students' knowledge of the application of LP in a business situation. It can therefore be used in studies to provide a correct measure of the successfulness of the methodology used to teach the student, whether it be computer aided, student centered, classical lecture, etc.

All this sets the stage for the general solution to the N variable linear programming problem and the Excel solver is introduced. It is actually overlaid on the same area as the TVLP tool so that the input area that has been used all along is preserved. And so Chapter2i finishes up with the transition to the Excel solver.

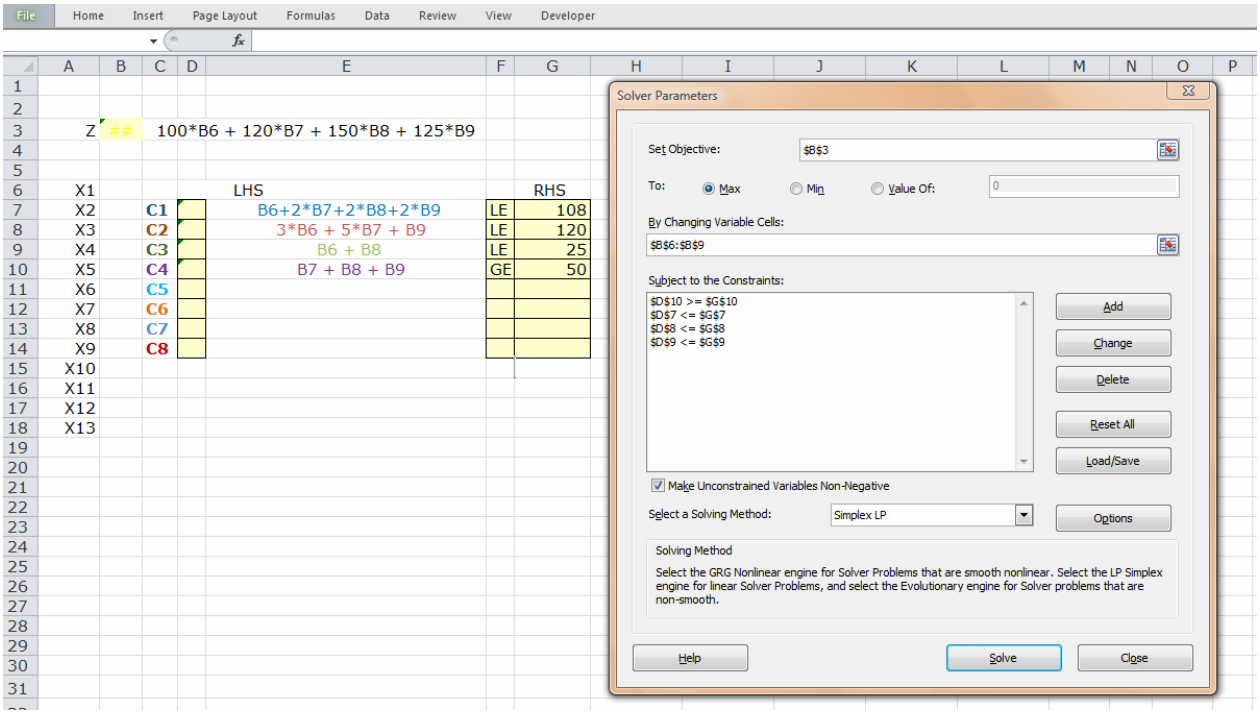

Figure 11: Sample page from chapter2i.xls showing illustration of the application of the Excel solver

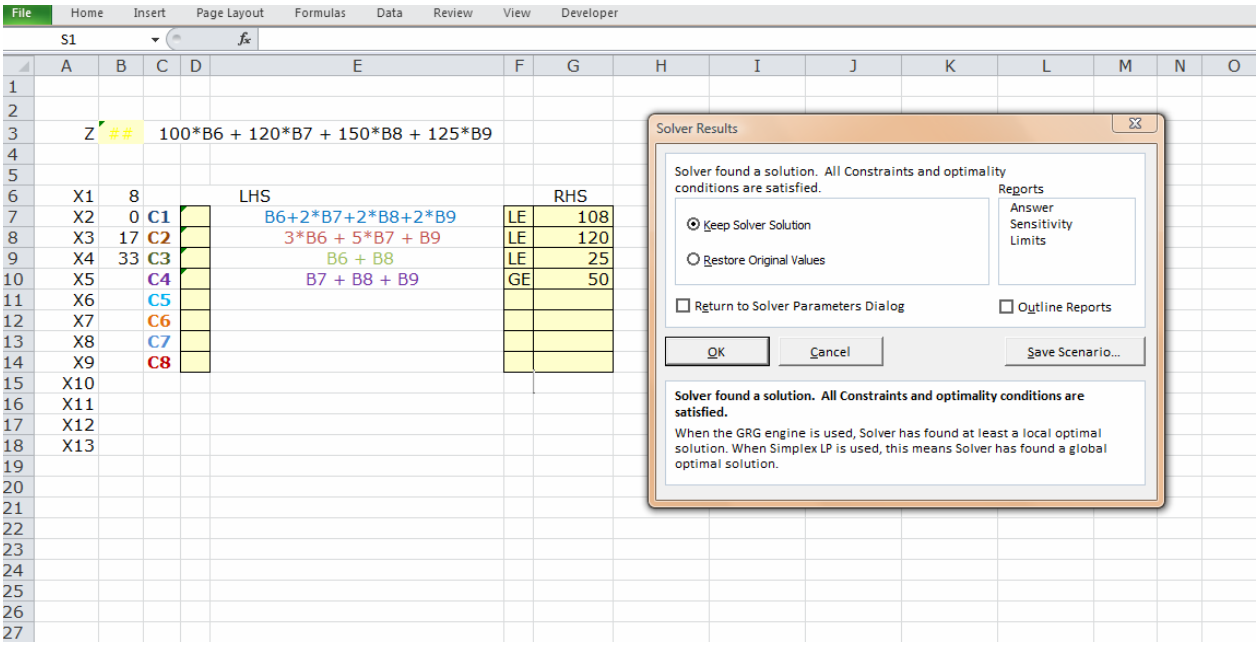

Figure 12: Sample page from chapter2i.xls showing illustration of the application of the Excel solver

7 Developing QIWC

It should be easy to see by looking at chapter1i that interactive workbooks are not difficult to create, but may require a good deal of work. They start by conception and construction of illustrative tools, categorical ones if possible. Once the tools are decided upon, the text is created by using them to get from one place in the theory to another, and having the tools illustrate the quantitative methods involved. The best QIWC uses illustrative, categorical tools to bind the quantitative theory with exercise.

Regarding specific candidate quantitative subjects, a substantial project would be to produce a good elementary QIWC on risk analysis. This would involve producing tools like those already developed by Palisade, Crystal Ball, and Vose Software, or involve embedding them into the workbooks. There are substantial costs associated with using others' tools, so it's better to make your own instead of embedding others, provided you are adventuresome and handy at coding. Many of the current quantitative texts which use commercially developed tools are very advanced and require that the student have a strong background in statistics; they are clearly not written as introductory material for business or soft science students. A big hole in the current text lineup could be filled by QIWC designed for students with a weak background in statistics, and that could lead the inquiring student to a firmer pasture. Along these lines, precursor or first QIWC would involve a treatment of families of distributions.

Also, I think elementary QIWC on plane analytical geometry would be easy to produce and fit well into the high school mathematics curriculum. Since plane analytical geometry is not a quantitative theory, per se, snippets would be used in the exposition.

Chapter1i is the first of two chapters which geometrically expose the theory of two variable LP, using the TVLP tool. Chapter2i covers sensitivity analysis and transition to the Excel solver and N variable LP. It includes a review of Chapter1i, so for advanced students, a course could start with it. Content is written in a foundational manner, and covers the content of many standard recently written textbooks like the works of ([8], [13], and [14]). However, it is self-paced, interactive, illustrative, and avoids algebra and data manipulation. The idea for the courseware came while, using the standard texts, I repeatedly found business students giving up on the concepts involved because of the drudgery of drawing graphs and solving sets of linear equations. The QIWC was designed with the university business student in mind. It was helpful to address this small segment, and to have first worked in it for several years using standard, popular texts.

After creating the tool(s), first version workbooks can be constructed. After a while, you might find that certain attributes need to be added to a tool, or that it might need a slightly different interface to blend in with the whole courseware. In my case, I had to look ahead to the chapter2i workbook to adjust the TVLP interface to match the Excel solver interface. This was done to provide a seamless transition from the use of TVLP to the use of the solver.

It helps to be very familiar with the subject, but even so, you will find that many revisions will be necessary to get the workbooks just right. Deciding on which parts of text are left stand alone providing no interactivity is the hardest part. And in being so, it is the key to the effectiveness of the workbooks and resulting courseware. A hint is that these stand-alone parts are almost always auxiliary parts, perhaps the finer points that only the good student will pick up. However, there may also be parts that will be covered interactively in subsequent sections of the courseware, but are convenient to be placed stand-alone to give the better student a broader view of the current concept, as was discussed in (4 QIWC as core course material).

Only after using the QIWC for several courses will it come to pass how much more interaction is needed if it is to be used autonomously, as would occur in an unattended eLearning environment. Chapter1i is only in its early stages; more interactivities need to be added before I would consider it ready for autonomous use. However, when used with instructor intervention it works quite well. I have received many compliments from students and overall higher exam scores, over 30% higher on average, using it as core courseware.

Another feature you may want to consider is to allow your QIWC content to be augmentable or even changeable. You can see that Chapter1i is augmentable in two ways. The unprotected template can be used not only to create exercises but also to create new content pages. While copying the template is simply a matter of using the Excel worksheet copy function (right click on the sheet's name), positioning your content to work with the TVLP tool requires a little explanation, so a brief explanation on that is included as the last two worksheets of the chapter. However, in allowing changeability the author is releasing part of his/her copyright. It is important to place a proper copyright notice on your work, along with a disclaimer (see mine on the bottom margin of C1 -- Page 0 in Chapter1i). It is equally important to keep your design unique by fixing a signature that cannot be removed. This has been done in Chapter1i with the

positioning of the TVLP tool, which cannot by changed. Thus it is unquestionable whether or not the work has been copied; if the situation arises that requires this analysis.

8 Best practices in using IWC

Perhaps an outstanding question on the reader's mind is the level of Excel needed by the student in working with the IWC. I've found that the student with little or no background in Excel has a learning curve to climb before becoming comfortable with the IWC. If you find many students have a lack of background, then a first class in basic Excel will do the trick for most. Hopefully, the IWC has been designed so that expertise in Excel is not a requirement of the student.

The lab classroom environment is the very best place to use the IWC. This is mostly because the students can work together, the instructor can walk around and help, and advanced students can walk around and help as well. You can still lecture in this environment, in an introduction, in asides, and in review, but you must remember that the students have another lecturer at their side, one on their laptop that travels with them when they leave. Thus your classes might be "flipped" - the students working ahead in a workbook at home to absorb new content before the next class, and then in the next class, working on exercises and clarification of the concepts studied in the homework.

You may also present whiteboard augmentations to the workbook material during class and the students can use the margins to record these; however, the vast majority of the time spent by the student in class should be spent working in the workbooks, asking questions, and getting a helping hand; not taking lecture notes.

When I first started using chapter1i in the lab classroom, I'd try to lecture on top of it. After all, there's a class in front of me, and I wanted them to hear me talk to get used to how I talk. It's tempting, but incorrect. The correct posture is to have the students read the first page, and then after everyone has, you can talk about it. Your IWC talks just like you do. The object is to give the student enough time to become familiar with using the courseware, while at the same time assuring the student you are there to help. Your utterances will be complimentarily to the text and you'll find the combination more than enough to have the students fall in love with your classes.

The next best place to use the IWC is the e-learning center, where the students download the workbooks and forge ahead on their own. If this is the place your work will end up, then you should be very careful, in the first few pages, that you identify how one goes about working in the workbooks. You will also have to assure that your IWC is complete in the sense that every question the student may have that might block his/her progress can be answered within the workbook, or via a help system. For most complex subjects, this will require more development than most authors would want to do, and the completeness of it would be difficult to verify. A way of proceeding in this direction is to use the IWC in several lab courses, using each course as sort of a beta site for the autonomous version by taking good note on what should be added to

avoid the lab students from asking questions. Each lab course will give you an iteration that is closer to IWC which can be used autonomously.

Even the best done autonomous version will require a help line, either email or instant messaging will do, but the best method would be to use an online chat system, were calls for help could be received by a good number of students whom have completed the course previously. Having previous course participants randomly available for the receipt of the chat calls would benefit all involved.

In either of the above cases, homework is submitted via email and easily corrected en masse by browsing through the students' workbooks. Exams take place in the course workbooks as well, or with separate workbooks that don't include the course content or past exercises – whatever your students warrant. I've found that in complex subjects, the student won't gain by looking back on previous exercises or content during exams. So for LP, I distribute the exams on worksheets and let the students append these into their workbooks and solve the problems there. Their workbooks are emailed to me at the end of the exam period. In the case of an internet outage, or no internet, in a lab setting, a USB key can be used to collect the workbooks, one by one, as the students finish. Exams in the autonomous setting can require the student to show up at a testing site, or be in an "honors environment" where the exams are emailed to the student, and solutions emailed back. Perhaps in this case, individualized clone exams should be produced by varying problem parameters.

Since today seems to be the day of the e-book, students will feel that Excel interactive learning is up the same alley, and should embrace any well done IWC. The actual learning that will take place will depend on the quality of the IWC and support by the instructor(s). More and more universities are offering on-line learning centers. Having slick IWC that the student can work with autonomously is a large plus for the institution. IWC does not involve relying on external learning management system establishments, which are costly and can be unreliable. IWC is local to your institution, and can be seen to set yours a step above others that haven't the staff that can develop and easily maintain and enhance materials for their students' use, without relying on external sources and the internet. The internet is a great place to share information and collaborate; however, it is not the place to be working on, or studying problem solving. The desktop or laptop, with the proper software, or courseware, is the best place for it. Some things will never change.

9 Suggested research and concluding remarks

It would be nice to talk here about the efficacy of QIWC. In doing so, it is convenient to think of QIWC as belonging to the class of online learning materials, as it can be stored on-line and brought onto the learner's computer at appropriate study times. That is, we can view the use of interactive workbooks as a form of interactive on-line learning and infer from [15] that there is a significant challenge in providing this kind of courseware and teaching methodology that can cater to large and varying disciplinary classes of individual learning preferences and styles.

In answering the efficacy question, it is important to note, as pointed out in [16], that it is still hard to distinguish between effects of technology and effects of other factors that may be present in CAI; that confounding is ever present in the analysis and separation. However, in the fields of mathematics and science, increasing of concept acquisition has occurred with the aid of microcomputer-based laboratories [16]. Several studies do establish superior efficacy of lecture plus CAI, but of course are limited to certain subjects. For instance, Basturk in [17] shows a large gap between Lecture-only and Lecture-plus-CAI in college introductory statistics courses.

On the other hand, a dissertation by Spradlin [18] points out that statistically there was no significant difference in the mathematics performance of students in a developmental mathematics course using traditional lecture vs. lecture plus CAI. However, the mathematics presented was algebra, the study of which is different from the study of quantitative methods. Spradlin in [18] also concedes along the lines of Kinney and Robertson [19] that CAI research gives non uniform results because often software that is used in the studies has been designed for teacher-centered instruction instead of designed to provide learner-centered instruction and deliver thorough presentation of the entire course content, like QIWC. This awareness gives rise to more QIWC being produced, and used. Even though, there are still apparent misconceptions in the academic community today. In a current article by Kydd [20], a study that used a TVLP type java applet in a teacher-centered environment concludes that the benefit of using the interactive applet in the lecture setting is unclear. So the Kinney-Robertson dilemma is still with us.

A study must be performed that skirts the Kinney-Robertson dilemma, and it should compare CAI only with lecture plus CAI. Such a study can be done by using my workbooks, since they are elementally designed to provide pure CAI. To make the study even fairer, the TVLP tool should be used during lectures by the instructor in the lecture based group and also offered to that group as a standalone tool to use. The lecture content should also be more or less the same as the content written in the courseware workbooks. In this way, a non-biased study will compare only the idea that the student can self-study the material, interactively via the computer, and a true CAI vs. conventional lecture efficacy will be provided. My intention is to do such a study Fall 2012, and teach both groups, in an unbiased way, thus providing even one more control, as my lectures will present the exact same content in the same manner as it is presented in the workbooks. No lectures will be provided the CAI only group, but the classes will be held in a lab setting. A meaningful measure of the ability of a student to apply LP to business situations will be chosen. As pointed out in (6 Bridging the divide: Sensitivity analysis and transition to the Excel solver), a set of generic exercises involving solver reports would be a good choice. The results of this study will be submitted to ijSiE in 2013 for a follow-up article.

In summary, I have shown that QIWC is a fundamental, attractive way of performing CAI. I have argued that CAI is the best method of teaching quantitative subjects and have committed to statistically verify this. More importantly, I argue that the actual flavor of course content and instruction is dependent on what the student wants and needs to get from the course, and that these wants and needs are different across level, including major, sex, culture, etc.; yet standard textbook content and teaching methodology is generally constant across these levels. The

solution is the construction of QIWCs by teachers specific to the particular types of students they teach. There can be many QIWCs on LP used for the teaching of it, depending on who's doing the learning. These can certainly be shared by schools and instructors teaching the same level, and combination of levels.

In conclusion, educators should perform more pure CAI and QIWC is an ideal media to use. Excel has been and will remain ubiquitous, even in today's world of the X-PAD. With the recent Excel update for Apple to version 2011 which accepts ***all*** VBA code, QIWC enjoys a wide base of potential users, essentially every one owning a laptop or desktop. Once again, it is not difficult to develop QIWC, but it does require some thought and a bit of work. However, the end result can provide the instructor, and the school, with easy to administer teaching tools which can grow with them, and become a part of their pedagogy. In this sense we can view the student, instructor, and school as a family that grows and learns together, that provides CAI that evolves year over year, and forms an expert knowledge base. And each school's QIWC might be quite different, as their students might be of one sort or the other. Thus a vibrant community of QIWC could someday provide a wondrous locker containing all aspects and forms of quantitative learning. A vibrant community of QIWC can be created as a legacy for those to come.

10 References

[1] Dror, Itiel E. 2008. Technology enhanced learning: The good, the bad, and the ugly. *Pragmatics & Cognition* 16:2, 215–223.

[2] Anderson, T. 2003. Getting the mix right again: An updated and theoretical rationale for interaction. *The International Review of Research in Open and Distance Learning.*

[3] Miyazoe & Anderson. 2010. The Interaction Equivalency Theorem. *Journal of Interactive Online Learning*, Volume 9, Number 2, Summer 2010.

[4] Miyazoe, T. 2009. LMS-based EFL blended instructional design: Empirical research on the sense of class community, learning styles, and online interaction written interaction. *(Unpublished doctoral dissertation).* International Christian University, Tokyo.

[5] Sims, R. & Bovard, B. 2004. Interacting with online learners: How new elaborations of online presence can foster critical thinking and reflection. *Proceedings of the 21st ASCILITE Conference*. R. Atkinson, C. McBeath, D. Jonas-Dwyer & R. Phillips (Eds)

[6] Bruner, J. 1973. *Going Beyond the Information Given*. New York: Norton.

[7] Weiss, Howard, J. 2006. *POM-QM v 3 for Windows Manual and CD POM, 3/E*. Temple University Prentice Hall, 2006

[8] Ragsdale, C. 2011. *Managerial Decision Modelling*. Cengage Learning, Sixth Addition, p. 34

[9] Chinneck, John W. 2001. *Practical Optimization: A Gentle Introduction*. Available: http://www.sce.carleton.ca /faculty/chinneck/po.html. Last accessed 5 May 2012.

[10] Joutsenvirta, Taina and Myyrypage, Liisa, Editors 2010. *Blended Learning in Finland (2010),* Faculty of Social Sciences at the University of Helsinki; Helsinki.

[11] Stenberg, L., Varua, M. E., & Yong, J. 2010. Multiple methods: How to help students succeed in quantitative methods for business unit. *Paper presented at the ALTC Leadership Symposium*, University of Wollongong, NSW, 15-17 February.

[12] Arum, Richard. 2011. *a-lack-of-rigor-leaves-students-adrift-in-college*. Available: http://ontheuniversity.com/2011/08/30/a-lack-of-rigor-leaves-students-adrift-in-college/. Last accessed 5 May 2012.

[13] Taylor, 2006 *Introduction to Management Science*, Bernard W. Taylor III, Prentice Hall, Ninth Edition, 2006.

[14] Anderson, et al. 2008. *An introduction to Management Science*, Anderson, Sweeney, et al., Cengage Learning, EMEA, 2009

[15] Rhode, Jason F. 2009. *Interaction Equivalency in Self-Paced Online Learning Environments: An Exploration of Learner Preferences*, Northern Illinois University, USA

[16] Noeth, Richard J. and Volkov, Boris B. 2004. Evaluating the effectiveness of technology in our schools. *ACT Policy Report.*

[17] Basturk, R. 2005. The Effectiveness of Computer-Assisted Instruction in Teaching Introductory Statistics, *Educational Technology & Society*, 8 (2), 170-178.

[18] Spradlin, K. 2009. Kathy Spradlin. The effectiveness of computer assisted instruction in developmental mathematics (*doctoral dissertation under the direction of Dr. Beth Ackerman*). School of Education, Liberty University, July, 2009.

[19] Kinney, D. P, & Robertson, D. E. 2003. Technology makes possible new models for delivering developmental mathematics instruction. *Mathematics and Computer Education,* 37(3), 315-328.

[20] Christine T. Kydd. 2012. The Effectiveness of Using a Web-Based Applet to Teach Concepts of Linear Programming: An Experiment in Active Learning. *Informs Transaction on Education*, Vol. 12, No. 2, January 2012, 78–88