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## Active Learning in an Undergraduate Management Science Course Through the Use of a Mobile Computer Lab

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# Active Learning in an Undergraduate Management Science Course Through the Use of a Mobile Computer Lab

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## Abstract

Our business school's undergraduate degree program includes a required spreadsheet management science course taught at the third-year level. Employers, faculty, and students consistently indicated that this course was not successful in teaching management science or even basic spreadsheet modeling skills. To improve students' understanding and retention of the course content, we purchased and implemented a "mobile computer lab" that could be set up in a regular classroom. We discuss how the lab supported a change to active learning, in which informal student groups would "discover" management science techniques, and we provide some examples of the exercises we have incorporated in the course. For instructors who are interested in implementing a mobile lab, we also provide details on the infrastructure of the lab, costs, software and hardware security, and classroom logistics.

**Keywords:** active learning; mobile lab; spreadsheet management science; undergraduate; business school; computers; laptops; management science; software; hardware; computer lab; mobile computer lab; informal student groups.

**Brief biographical notes:**

**Janice B. Eliasson** is an Instructor of Operations Management in the Haskayne School of Business at the University of Calgary, Canada. She teaches and co-ordinates the introductory undergraduate course in spreadsheet modeling for business decision making as well as the course in quality in products and services. She is also the co-ordinator of the Supply Chain Management Concentration. She obtained her MASc in Systems Design Engineering from the University of Waterloo and is a registered Professional Engineer. Ms Eliasson has published articles in the *Journal of Operations Management* and *Decision Sciences Journal of Innovative Education* and has developed case studies for classroom use. She was recently awarded the Haskayne School's Commerce Undergraduate Society Award for Teaching and Learning.

**Brent R. Snider** obtained his Honours Bachelor of Business Administration degree from Wilfrid Laurier University, a Certified Management Accountant designation from The Society of Management Accountants of Ontario, and an MBA Thesis degree from the University of Calgary. Brent teaches in the areas of Operations Management, Management Studies, and Management Information Systems primarily for the undergraduate program. His research interests focus on Enterprise Resource Planning (ERP) systems and innovative experiential classroom exercises. Brent's work has been published in the *International Journal of Operations and Production Management* and *Decision Sciences Journal of Innovative Education*. Brent has received both the Haskayne School's Dean's Award for Teaching Excellence and the University of Calgary's Students' Union Teaching Excellence Award.

**Diane P. Bischak** is an Associate Professor of Operations Management in the Haskayne School of Business at the University of Calgary, Canada. She obtained her Ph.D. in Industrial and Operations Engineering from the University of Michigan. She teaches undergraduate and MBA courses in spreadsheet modeling for managerial decision making and is a past recipient of the Haskayne School's Dean's Award for Teaching Excellence. Her research interests include statistical quality control and management science as applied to health services operations. Dr. Bischak's research has been published in such journals as *Management Science*, *IIE Transactions*, *Journal of Quality Technology*, *Health Care Management Science*, *International Journal of Production Research*, and the *Journal of the Operational Research Society*.

## **1. Background and Historical Challenges**

In the undergraduate program at our business school, one of the required core courses for the bachelor's degree is a spreadsheet management science course taught at the third-year (junior) level. Although a number of our senior electives deal with management science topics to some degree, this course is, for most of our undergraduate students, the first and only time that they will encounter management science techniques in their undergraduate education. Twelve sections of our management science course run during an academic year, with approximately 60 students enrolled per section. Each section meets for three classroom hours per week, with no regular weekly labs scheduled but with optional tutorials before assignment due dates with teaching assistants (TAs) scheduled in one of the computer labs in our building. A student's computer preparation for this course is typically limited to a non-business-school prerequisite course that introduces a number of popular software packages, including Excel.

Our course changed from a traditional, non-spreadsheet-based format in the mid-1990s to one which introduces management science topics using Excel spreadsheets and add-ins. Topics include optimization using the Solver add-in, Monte Carlo simulation using Crystal Ball (<http://www.crystalball.com>), and decision trees using TreePlan (<http://www.treeplan.com>). Historically, the course was taught in a lecture format, with overhead slides and demonstrations of the applications by the instructor on a projected laptop at the front of the classroom. More recently, PowerPoint slides replaced the overheads. These slides were posted for the students on the Blackboard (<http://www.blackboard.com>) course website before class and included screenshots of spreadsheets demonstrated during the lecture. The completed spreadsheets were posted to the course website for reference after class.

Assignments required the use of Excel or an add-in to complete a template to solve a particular problem.

Although we demonstrated the use of the software in class lectures, evidence of the lack of success of our approach emerged from four separate sources. First, students had much difficulty with the assignments, since it was essentially their first opportunity for a hands-on application of Excel and the relevant add-in software. In addition to crowding into the optional lab help sessions, many students would seek us out during office hours. The majority of their questions related to the use of the software, which created significant frustration and became an obstacle to understanding the concepts we were trying to illustrate. Second, faculty teaching follow-on elective courses indicated that students displayed limited retention and understanding of what was covered. Third, our school's Career Centre informed us of negative comments they had received from employers regarding our students' general Excel skills. Lastly, student course evaluations on the metric "I learned a lot in this course" were modest compared to the scores on other undergraduate courses and in need of improvement.

Our course was recognized (though not well understood) as the only course within the School of Business that was meant to improve the students' ability to use and apply Excel in a business context. We felt, however, that we were not meeting the expectations of our School's administration. Unhappy about our failure to provide our students with a substantial foundation in management science, as well as recognizing the possible long-term negative ramifications for the place of management science within the School, we were determined to make significant changes to the course delivery.

In the remainder of this paper, we describe the details of how we addressed these problems by making a change to active learning in our undergraduate course using a mobile computer

lab set up in a regular classroom. Considering that purchasing classroom laptops may present a significant cost to many schools, we first discuss the financial barriers to implementation and then detail the infrastructure of our mobile lab, including our actual costs, classroom logistics issues, and software/hardware security. Next, we provide three classroom exercises that we now use to engage the student and allow them to “discover” management science techniques. With two years of mobile lab use completed, we provide results-to-date of its effectiveness. Finally, we discuss some other implementation considerations prior to our conclusion.

## **2. Hands-On Learning**

After brainstorming a number of ideas that could potentially improve learning, we decided that a fundamental change needed in the course was to have the students themselves use computers, hands-on, during class. Experience had shown us that it was challenging for students to follow what was going on in an Excel spreadsheet from a PowerPoint slide or from the instructor’s computer. If students had a copy of the spreadsheet under their control, they could walk through the steps of setting up a problem, learning by doing—and from making mistakes—as they went along.

There is an extensive literature in education (e.g., Bonwell and Eison, 1991; Meyers and Jones, 1993) that promotes such “active learning” as a way to engage students beyond what can be achieved with the lecture format of course delivery. An active learning approach has been proposed by Gudigantala and Hoffman (2008) to teach systems analysis to undergraduate students. Their approach includes the use of case studies, collaborative teams, and in-class exercises. In operations research and management science education, Liebman (1994, 1998) was an early proponent of active learning. Seal and Przasnyski (2003) discussed their experimentation with a number of hands-on in-class learning technologies for

a core operations research/management science (OR/MS) MBA course. Rather than providing laptops for students, as we did, Seal and Przasnyski had Excel, Crystal Ball and TreePlan installed onto each student's personal laptop. Seal and Przasnyski suggest a strategy for integrating technology into MBA OR/MS courses, concentrating first on easily implementable, low cost/high benefit technologies. Extrapolating from their experience, we felt it would be ideal if we were able to provide a technological upgrade to the course that built on our students' increasing comfort with computers and the Internet but required minimal course content redesign and no additional learning of software on our part. Since we were already teaching our course by demonstrating various applications of course concepts in Excel and add-ins, shifting the course to such an environment might provide high student benefits but low costs from an instructional standpoint.

As noted by Wagner (2005), introducing technology does not guarantee that better learning will be the result. However, Kolar et al (2002) evaluated the impact of bringing laptop technology into the classroom by comparing the performance of civil engineering students in one course section that required hands-on use of (student-supplied) laptops to conduct spreadsheet-based experiments and those in another section in which the students merely watched as the instructor demonstrated the experiment. They found that students in the active learning section performed better on every one of seven evaluation metrics used. While their results were not statistically significant, they may well indicate a real difference in learning, as the grade point average of the students in the laptop-based section was lower upon entering the course.

### **3. Financial Barriers to Implementation**

Like most university units, our school operates in a limited funding environment. We recognized that our proposed solution must have a low cost or be funded external to the

business school. To reduce the associated costs, we first investigated changing the course sections' room assignment from lecture halls to one of the business school's computer labs. There are three computer labs in our school, but only the smaller, 30-computer lab is truly suitable for teaching: it is set up theatre-style, with computers on tiered tables and the instructor's computer and a projection screen at the front. However, the room is not large enough to hold 60 students, and reducing the class size was not an option. The other labs can seat 50 to 60 students each; however, since they have a rectangular flat layout their sightlines and acoustics are not ideal. In discussions with the school's Information Technology (IT) department, reconfiguring the setup of the labs was deemed infeasible due to space limitations and cost considerations. Of greater concern to us as advocates for management science education within the School was that, with six to seven sections meeting each semester for three hours per week, our course would monopolize the already-busy computer labs. This would cause frustration for students and instructors whose assignments require the use of various software packages available only in the labs. A final low-cost option was to require students to bring their own laptops to the classroom. This too was infeasible, as owning a laptop is not a requirement for our students. Furthermore, given the assortment of software we intended to use, we required a uniform and controllable hardware environment that conformed to the conditions required under our software licensing agreements. Essentially, we needed a new computer lab, but there was no money or space in our building to add one.

It was at this time that a funding opportunity presented itself in the form of a teaching and learning initiative at the university level that was aimed at improving undergraduate education. With the help of our IT department, we developed and submitted a proposal for a "mobile computer lab" that would allow a lab to be established temporarily in any classroom. As Alexander (2004) indicates, the flexibility of a "nomadic" mobile lab may often present

more benefits than raising funds for another fixed-in-place computer lab. Mobile labs have been implemented at the university level in education (Davies et al, 2003) and engineering (Markey et al, 2007). In particular, Markey et al (2007) present three case studies of courses taught using a mobile lab in chemical, electrical and computing, and biomedical engineering at the University of Texas at Austin. Referring to the concept of combining instructor-presented information with hands-on, technology-based exercises as an “integrated lecture-lab environment,” they found that students in these courses were able to spend more time in higher-level learning activities such as analysis, synthesis, and evaluation of concepts.

Approximately six weeks before the 2007 fall term commenced, we were informed that our proposal had been accepted and funded; however, the grant amount was exactly half of what we had requested. We immediately began to plan for and acquire a mobile lab, making do with 30 student laptops, where teams of two students would share a laptop during class.

#### **4. Mobile Lab Infrastructure**

To implement the mobile lab, we considered both physical classroom logistics and hardware/software security concerns while staying within our budget. Below (and further described in Appendix 1), we provide details of our actual costs and how we dealt with logistical and security issues.

##### ***a. Costs***

Although other instances of mobile labs (see Davies et al, 2003) have employed the Apple iBook Wireless Mobile Lab (<http://www.apple.com/education/k12/mobilelabs>), we wanted to ensure that our business students were familiar with the Windows-based software they were likely to face in the workplace. Dell was our source for 32 Latitude laptops, peripherals, resettable combination cable locks, and a rolling storage cart (see Figure 1). Table 1 provides

our actual cost details, including the hardware and software specifications and the suppliers used.

(Figure 1 and Table 1 about here)

Our one-time actual costs were approximately \$40,000 (all monetary values are in Canadian dollars). The mobile lab provided us with room flexibility (within the technical requirements) at a cost that was significantly less than the alternative of renovating an existing classroom into a computer lab. Other than annual software licenses, all costs are one-time purchases, allowing a single funding grant to provide a mobile lab for many years. Given our limited scope of use (Excel and add-ins, Internet for file downloading), we expect the hardware specifications will be sufficient for at least five years. Amortizing the \$40,000 capital cost over five years and assuming that 750 students take the course each year, the incremental cost is approximately \$10 per student.

***b. Classroom Logistics***

Although we initially assumed that our mobile lab could be wheeled in and set up in almost any classroom, we became aware of three key infrastructural requirements for the mobile lab to be successful. Sufficient electrical outlets (limited battery life) and ethernet connections (wireless system limitations) with continuous tables and movable chairs (to facilitate group work) created an ideal classroom environment. The setup/takedown process had to be completed within the fifteen-minute scheduled interval between classes (see Figure 2).

(Figure 2 about here)

*c. Hardware / Software Security*

A primary concern about the mobile lab was the risk of theft of the laptops. With the movement of 60 students in and out of the classroom and some students bringing their own computers, it was possible for someone to pick up a computer and walk out with it. This was addressed by using a cable combination lock to physically secure each laptop to the classroom desk. Other mobile lab implementations have required that a student swap his or her identification (ID) card for a laptop (Davies et al, 2003). However, we found that the cable locks allowed efficient setup (it was not necessary to wait for students to arrive) and all but eliminated any administration. We were able to simply employ this setup for consecutive course sections in the same room, as there was no need to have a departing student return the laptop for their ID card and then to re-distribute the laptop again to an arriving student.

On the software side, our IT department employed a few strategies to make things go smoothly in the classroom, including eliminating passwords, and tying a “reset” function to the shutdown and reboot process.

## **5. Management Science Active Learning Exercises - Examples**

Given the opportunity presented by having computers available during class, we included some hands-on exercises for students to “discover” management science concepts independently. Below are three simple exercises we found particularly effective.

*a. Linear Programming – Solver’s Sensitivity Report*

Solver’s sensitivity report was designed to provide management with insight into the sensitivity of the optimal solution to changes in parameter values. However, we had noticed that our students were often intimidated and confused by the report, as the terms “shadow price” and “reduced cost” are not intuitive for students. Therefore, we incorporated a class

exercise for student teams to iteratively conduct sensitivity analysis prior to introducing Solver's sensitivity report. The hands-on exercise required the student teams to change certain parameters and observe the corresponding changes that occurred (or did not occur) in the optimal solution. The following questions were used for a simple product mix linear programming problem:

- By how much would our profit increase if we could obtain one more labour hour?  
(*shadow price*)
- How much (increase / decrease) would the profit per unit of product *X* have to change before the product mix that is optimal changes? (*allowable increase / decrease for objective function coefficient*)
- By how much would the profit per unit of product *Y* have to increase before we would want to include some units of product *Y* in our product mix? (*reduced cost*)
- By how much would our profit increase if we could obtain  $n$  more labour hours?  $n+1$  more labour hours? (*allowable increase / decrease for shadow price*)
- Would our profit increase if we dropped our promise to make a customer some units of product *Z*? (*negative shadow price*)

Only after students completed the exercise and the results interpreted was Solver's sensitivity report introduced as a more convenient way to obtain the same information students "discovered" in the exercise. This approach resulted in improved understanding of, and respect for, the sensitivity report. We subsequently provided class examples that used sensitivity reports exclusively and asked students about the impact of proposed changes.

***b. Decision Trees - Sensitivity Analysis using Excel's Goal Seek and Data Table Functions***

Having introduced the concept of sensitivity analysis, we extended students' "what if" skills into decision trees. To teach decision trees, we use an oil drilling scenario in which management could choose to drill immediately or to conduct seismic testing to identify the underground formation, which would update the prior probability of finding oil. By setting up the decision tree in TreePlan and placing costs, probabilities, and payoffs into cells in a separate data area and using cell references, sensitivity analysis can be conducted by changing any of these values. For example, we first asked students to manually determine by how much the value of a "large oil find" would have to decline before we would decide not to conduct seismic testing. In addition, students could evaluate how changes to the drilling cost, seismic testing cost, and success probabilities would impact their decision.

We then introduced the Goal Seek function to find the exact value at which the optimal decision would change. The Goal Seek function, however, does not provide insight into how changing a particular parameter would affect other aspects of the decision tree. Excel's Data Table function, which iteratively places input values into an identified cell and records the result from an output cell, such as the optimal decision's expected monetary value, was ideal for this purpose. Furthermore, a two-way Data Table can also be used to discover the interaction effect of two changing parameters (such as price per barrel and recoverable barrels found) within the decision tree. Finally, the Data Table values can be quickly graphed for presentation and easier interpretation.

### ***c. Simulation Using Excel's Random Number Function***

To introduce simulation concepts prior to the use of Crystal Ball, we incorporated an exercise that uses Excel's RAND random number generator to simulate the classical newsvendor problem. Given that we had already introduced a few of the more advanced Excel features (e.g., the VLOOKUP and IF functions, absolute cell referencing, pivot tables), we challenged

students to identify a way that a random decimal value generated by Excel could be mapped to a value from a discrete demand distribution. Most students quickly determined that VLOOKUP would allow this. Next, the students used Excel's IF function to determine the storage and stockout costs for a given day. Once all the relevant formulas to simulate a single day were completed (with appropriate absolute cell references), students copied the formulas down to fill 1000 lines in Excel. By pressing the F9 key, students were able to instantly simulate 1000 replications for a given stocking level. To our surprise, we often heard students express their appreciation for the power of what they had just created in mere minutes.

Student teams were then asked to calculate and provide the average daily cost for one of their simulations, and their results are recorded by the instructor. Although the values were all relatively similar, students observed that a range of average values occurred, introducing the concept of variability within simulation. The students completed a similar analysis for various stocking levels and made a stocking level recommendation. In the following class, Crystal Ball was introduced as a tool that could make simulation more convenient (as 1000 lines of simulation are not needed) and provide extensive statistical analysis. Finally, the concept of automatically varying the decision variable (stocking level) was introduced by showing Crystal Ball's decision table functionality.

## **6. Mobile Lab Results To Date**

After two years of mobile lab use, we have evidence of positive impacts. The benefits that resulted from having two students share a laptop were a pleasant surprise, and significant improvement in course evaluations emerged.

### ***a. The Surprising Benefits of Students Sharing Laptops***

Given that only half of our funding request was granted, the only feasible solution was to halve the number of laptops purchased and to require two students to share one. To our surprise, this approach became critical to the success of the mobile lab and might actually be more effective than providing a laptop for each student. First, the setup and takedown of 60 laptops within fifteen minutes would have required twice the teaching assistants and more likely would have been physically impossible. Second, we were concerned about the possibility of inappropriate Internet use during class. Like many university instructors, we have had negative experiences in the classroom with students using their laptops or cell phones during lectures (see Markey et al, 2007 for a discussion). Such behavior can be annoying to the instructor and distracting to other students. We considered using SynchronEyes to monitor each laptop display and prevent the use of the Internet during class time. Unfortunately, using SynchronEyes would require each student to log on, adding setup time. We decided to use SynchronEyes only if inappropriate laptop use became an issue. We asked our TAs to informally monitor what students were doing while we were lecturing. The incidence of inappropriate activity on the shared mobile lab laptops was very low but was significantly higher for individual students who were using their own laptop (which we allowed them to do). We speculate that the difference was due to positive peer pressure: the person sharing a laptop with you may not appreciate it if you are sending e-mails when they want to use the laptop for class activity. Based on these positive results, we plan to continue to provide unfettered Internet access on our mobile lab laptops.

By providing only one laptop for every two students, we inadvertently forced students to form informal cooperative learning groups. Liebman (1994) used cooperative groups in teaching OR and reports excellent results. There has been no formal study of the efficacy of such groups in operations management or management science education. However, a study by Borreson (1990) in an introductory statistics course showed that students in course

sections where groups worked on in-class assignments obtained significantly higher final course grades than in course sections where students worked individually on the assignments. Informal groups provide the opportunity for students to clarify their thinking by discussing the concepts presented with their teammate, stimulating the student to take greater responsibility for his or her own learning (Meyers and Jones, 1993). In addition, having two students share a laptop helps to reduce the risk that students will fall behind during class, as their teammate has an incentive to help them immediately, resulting in very few “could you repeat...” questions for the instructor.

Many of our observations on the efficacy of sharing a laptop have also been made by computer science instructors who have introduced a similar practice known as “pair programming” into their courses. Nagappan et al. (2003) describe pair programming as a collaborative procedure in which two programmers share one computer, one “driving” the computer by typing in and documenting code and the other “navigating” by observing the driver’s work, watching for errors and brainstorming in partnership with the “driver.” Nagappan et al. report an experiment in which students in one section of an introductory programming course worked alone on assignments to complete a given computer program in a required lab session each week, while in another section students worked as collaborative pairs. Students who pair programmed did as well on the assignments as the students who worked alone, and the success rate (in terms of completing the course with a C or better) for non-majors, who might be more intimidated by the technology and concepts, was higher among pair programming students. Students also reported the advantages of having their partner available to answer questions immediately, and they pointed out that pair programming required them to work on communication skills that would be important in the real world, an important concern for business students as well.

***b. Evidence of Mobile Lab Effectiveness***

We have considerable evidence suggesting that the introduction of the mobile lab has addressed the four unsatisfactory course outcomes that we noted above. First, we noticed that assignments had become less onerous for the students. Our teaching assistants commented on “how much easier” it was for this year’s students compared to when they took the course without the mobile lab. Current students have even asked us how students in previous semesters could have learned the material if they did not have a chance for hands-on work in class. We observed better attendance during the class throughout the term compared to previous years, and significantly fewer questions were being asked during the optional tutorials and our office hours. Second, faculty members teaching the follow-on elective courses have described a marked improvement in their students’ retention of our course concepts and tools. Third, our Career Centre recently provided us with positive feedback from employers about the spreadsheet skills of our summer co-operative education students.

Lastly, since our lecture-based course had had a relatively low average score on student course evaluations, we were keen to see if there was an improvement in the results after the introduction of the lab. Only one of our instructors had taught a significant number of sections before and after the introduction of the lab. A Kruskal-Wallis test of the equality of the two populations (where the data are the average scores for each class section taught) indicates that the improvement in this metric from 5.48 to 6.14 on a scale of 1 (Unacceptable) through 7 (Excellent) was statistically significant ( $p=0.0043$ ).

## **7. Other Implementation Considerations**

One concern we had regarding implementing the mobile lab compared to the historical lecture format was how a slower pace of instruction would affect the amount of course content we could complete. However, we found no significant reduction in the content covered during the term. As discussed above, student teams that share a laptop inherently

help each other, reducing lecture interruptions. Additionally, we have incorporated five-second pauses between hands-on steps to enable students to watch and then repeat the step on their laptop, and this drastically reduced the amount of dedicated assistance required during class. Adherence to this measure was simplified by taking a step back from the instructor's computer after each click. The combination of these factors was so effective that our TAs often went an entire class session without requests from students for assistance.

If class ended in the middle of an example in Excel, we simply saved the file at that point and posted it to the course website for use in the following class. When the example was eventually completed, we removed the "in progress" file and posted the completed file. Also, various versions of an exercise template can be posted to the course website to provide schedule flexibility for the instructor. For example, if the class was running behind schedule, we can instruct the students to download a version that already has some of the required steps completed. This also allows for different teaching speeds in courses taught by multiple instructors.

We have had no significant in-class challenges on the technical side, as close coordination and proactive testing with our IT department allowed a few minor issues to be identified and addressed prior to the course commencing. Purchasing an additional laptop for our IT department also allowed testing and problem resolution to be conducted at any time, rather than having to wait for mobile lab downtime. Avoiding technical difficulties was important, as they can become distractions that reduce teaching effectiveness (Chompu-Inwai and Doolen, 2008; Markey et al, 2007). For example, Markey et al (2007) suggests that wireless infrastructure could become slow with many simultaneous file downloads, an important consideration if downloading during class time.

## **8. Conclusion**

We have described how a mobile lab can be successfully implemented for an undergraduate spreadsheet management science course in a business school. Specifically, we detailed how the mobile lab enabled us to overcome the course's historical challenges resulting in significantly fewer student questions, higher content retention for follow-on electives, much improved employer evaluations of our students' spreadsheet skills, and a statistically significant improvement in the "I learned a lot in this course" evaluation metric. The implementation of the lab has improved management science education for our undergraduates, and has become an integral part of our undergraduate core course. Students' understanding of both the software applications and the conceptual material increased, allowing us to shift the focus of our teaching to the power of spreadsheets for making business decisions. The lab has also strengthened management science's position within the business school. For example, faculty members from other areas have acknowledged students' improved modeling skills. We are continuing to improve our course to make the learning even more student-driven, incorporating more "discovery" exercises and planning a capstone exercise or case study to integrate the various management science concepts that we cover in the course.

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Table 1: Actual Costs of the Mobile Lab

Details	Source	Unit Cost	Total Cost
<i>Per Unit Costs:</i>			
32 Laptops <sup>a</sup> (students: 30, instructor:1, IT tester: 1)	Dell	\$ 1,110	\$ 35,520
AC adapter (power cords)	Dell	\$ 20	\$ 640
Ethernet cables <sup>b</sup> (3 feet)		\$ 5	\$ 160
Resettable combination cable locks (laptop to desk)	Dell	\$ 30	\$ 960
Software: Crystal Ball annual license	Oracle	\$ 15	\$ 480
Software: Microsoft Excel (university wide agreement)		\$ -	\$ -
Software: Solver (included in Microsoft Excel)		\$ -	\$ -
Software: TreePlan (free with textbook)		\$ -	\$ -
<i>Subtotal for per unit costs:</i>		\$ 1,180	\$ 37,760
<i>“Fleet” Expenses:</i>			
Mobile cart for storage / recharging of 32 laptops	Dell		\$ 2,100
Software: DeepFreeze "reset on reboot" - annual	Faronics		\$ 175
Software: SynchronEyes lab license (initial purchase)	Apex AV		\$ 935
<i>Subtotal for single expenses:</i>			\$ 3,210
<b>Total</b>		<b>\$ 1,180</b>	<b>\$ 40,970</b>
<sup>a</sup> Laptop specifications: Latitude 131L, 60GB hard drive, 2.0GB double data rate 2-533 SDRAM, 8X fixed DVD+/-RW, 15.4 inch wide screen WXGA. Cost includes 2 button USB mouse and 9-Cell 85W lithium ion primary battery. <sup>b</sup> Wireless internet connection can be substituted			

**Figure 1: The Mobile Lab Storage Cart and Peripheral Kits**



- **Figure 2: The Classroom Setup for the Mobile Lab**



## **Appendix 1: Mobile Lab Additional Details**

### *Costs:*

- Microsoft software (Windows XP, Office) was added at no additional cost due to our university's agreement with Microsoft regarding university-owned computer labs.
- Operating costs are exclusive to TA in-class labour, which varies with the number of class sections and the hourly compensation rate. To hold down labour costs, one could attempt to schedule university IT staff to assist with the setup and takedown or designate student volunteers.
- Although mobile printers are also available, one was not necessary for our course.

### *Hardware Security:*

- Outside of class time, the storage cart with laptops was placed in a locked service room, where the laptops can all be recharged by simply plugging in the cart.
- The cable locks are programmable, so the combination can be changed as frequently as desired. Our IT department changes the codes each term, and all the locks are set to the same combination.
- To date, no laptops have been stolen, although occasionally the odd peripheral (mouse, power adaptor) has gone missing. When this happened, we simply informed the students and reduced the number of laptops distributed accordingly. Within days, the peripheral would be returned.
- An additional theft deterrent is to select one of the less desirable colors or designs that are now available from laptop providers for the mobile lab laptop "fleet."

### *Software Security:*

- There is no password for the laptops, eliminating the potential hurdle of a sign-in.
- Considering that the students have access to the Internet for template file downloading and license verification, the laptops need to be protected from unauthorized system configuration changes, malware and viruses.
- Each laptop has DeepFreeze (<http://www.faronics.com/html/deepfreeze.asp>) software that allows the laptop to be reset upon shutdown and reboot. With this software, all student activity was placed in a quarantine area. Students can copy their file to a USB or e-mail it to themselves for later reference, however once the laptop was rebooted, this quarantine area was wiped clean. In addition to the security benefits, this process eliminates any completed class exercise files prior to the next class section.

- Each laptop has SynchronEyes (<http://www2.smarttech.com>) software that enables the instructor to monitor the activity on each laptop, take control of a laptop if necessary, display any laptop screen (via the projector), and send out and receive files.

#### *Classroom Logistics:*

- The laptops are wheeled in on the storage cart and kits of peripherals (mouse, power adaptor, Ethernet cable, and lock) in large plastic zipper bags are employed.
- Teaching assistants distribute a laptop and peripheral kit to every second seat (since the students work in pairs) and secure the laptop to the desk with the combination cable lock. The students then attach the remaining peripherals and turn on the laptop.
- The takedown process takes slightly longer than the setup. At the end of class, the instructor asks students to shut down the laptops and place the peripherals in the zipper bags. TAs then undo the combination locks and return the laptops and bags to the storage cart.
- Two TAs, or one TA and the instructor, can typically set up or take down the 30 laptops within fifteen minutes.
- To minimize setup and takedown time class sections should be batch-scheduled for a block of time in the same room. If this is not feasible, two alternatives are to lock the unused classroom between sections or, with faculty permission, to leave the laptops closed and locked down while another class uses the room.
- Our IT department recommended that our course be assigned to a classroom that had electrical outlets available due to the limited life of the laptop batteries and the reality of consecutively-scheduled course sections.
- IT also informed us that, at the time, our university-wide wireless system might not have the capacity to handle 30 simultaneous file downloads efficiently. Since the students would be downloading the template file from the course website each time a new class example was introduced, employing the wireless system would likely result in significant classroom delays. Ethernet connections were strongly recommended.
- The rooms had theatre seating and continuous tables with movable chairs to facilitate group work.