Laptop Computers and Curricula Integration

Jerry A. Caskey
Rose-Hulman Institute of Technology

Introduction

Four years ago, Rose-Hulman Institute of Technology required each entering freshman student to purchase a laptop computer. The class of 1999 was the first class to graduate under this requirement. Students now bring their laptops to class in much the same way as they brought slide rules in former years and calculators in recent years. Each department has made use of this new technology in different ways. The chemical engineering department has made use of laptops in class in several ways. Students in Material and Energy Balances use them to work group problems in class that were too unwieldy previously. Students in Process Control can call up software from the campus network (for example Tutsim™) for in-class demonstrations because each seat in most classrooms can be connected to the Institute network. Students in our Statistics elective course can also connect to software such as Minitab™ for in-class calculations. Student groups in Unit Operations Laboratory can perform data analysis and calculations while in the laboratory. During the 1998-99 academic year all chemical engineering students had ChemCad IV™ design simulation software available for loading onto their laptops. ChemCad has been used to demonstrate in-class the effect of thermodynamic assumptions on equilibria calculations.

This paper describes an expanded use of laptop computers in the chemical engineering curriculum at Rose-Hulman. The new use of laptops has been made possible by the development of a CD-ROM that has discussion/homework situations for most of the required chemical engineering courses taken from a refinery saturate gas plant. **This CD-ROM can be used as a resource to provide an integrating link between subjects regardless of the textbook or teaching method used in any particular course**. Marathon Oil Company has made available to Rose-Hulman the engineering record books for the final design of a saturate gas plant designed by Bechtel Engineering Co. and constructed at the Robinson, IL refinery by Bechtel Construction Co. Much of this design information has been taken from the Bechtel engineering record books and scanned as *.jpg files. Pictures of actual equipment--pumps, valves, flow meters, distillation columns, heat exchangers, etc. have been taken at the refinery using a digital camera. This information has been placed on a CD-ROM available to each student at a cost of $8. This Marathon case study CD-ROM provides instructors with ready made discussion/homework situations from a real plant complete with pictures of actual equipment, audio files describing the equipment, actual pump performance curves, heat exchanger duty specification sheets, etc. The ease of producing a CD-ROM with multimedia has made this possible. In-class discussion situations and homework problems for most required courses in the Chemical Engineering curriculum have been developed starting with Material and Energy Balances and continuing with Fluid Mechanics, Heat Transfer, Mass Transfer, Thermodynamics and Process Design and Economics. This CD-ROM is meant to serve as an **integrating supplement** to existing courses and not to replace material or methods currently being used. A student can perform a material balance on a multicomponent absorption column in Material and Energy Balances (sophomore year), complete a vapor/liquid calculation on the same column in

Thermodynamics (junior year), calculate heat losses from the same column in Heat Transfer (junior year) and calculate the number of stages required for this column in Design(senior year). Hopefully, students will sense how courses build and interconnect with each other. All calculations can also be compared to the Bechtel design and in some cases to actual plant performance data. The sections below describe typical problems and illustrate how these build from course to course.

Material Balances

The second chemical engineering (ChE) course at Rose-Hulman is a Material Balances course. The first ChE course is an Introduction to Design course in the freshman year designed to give students a perspective on the field of chemical engineering. The textbook in recent years for material balances has been <u>Elementary Principles of Chemical Processes</u> by *Felder and Rousseau*. The CD-ROM developed from the Marathon Sat Gas plant contains information for calculating material balances for the following situations:

1.	Distillation column
2.	Gas absorption column
3.	Three-phase water separator

The distillation column and the gas absorption column problem sets are reasonably straightforward; however, each operation contains 11 components including water and hydrogen sulfide. In addition to material balance calculations, each problem set includes information to initiate class discussion on corrosion, H_2S removal, H_2O removal, H_2O solubility, alternate processes, etc. The CD-ROM shows pictures of equipment in the plant so students get a feel for what process equipment looks like. The three-phase water separator mixes 3 streams and has three output streams: a vapor stream and a liquid stream (which contains aliphatic hydrocarbons plus some water) and a liquid water stream. Again digital pictures of the equipment are shown. The CD-ROM also provides hotlinks to an overall process flow diagram so students can not only do the material balance problems but the instructor can ask students to think of various alternate ways of removing water. These problems also provide an opportunity to talk about mass transfer, thermodynamics, process design, etc.

Energy Balances

In recent years our Energy Balances course has also used <u>Elementary Principles of Chemical Processes</u> by *Felder and Rousseau*. This is a sophomore level course. The CD-ROM contains the following energy balance situations:

1.	Energy balance around a distillation column
2.	Reboiler steam requirement calculations
3.	Energy balance around a gas-fired reboiler
4.	Energy balance around a distillation column product cooler.

The curricula integration of the software really begins with the Energy Balances course. Problem set 1 is a straightforward energy balance application. Problem set 2 makes use of the steam tables. Problem set 4 reinforces energy balances and makes use of estimating heat capacities of hydrocarbon mixtures. Pictures of the actual plant equipment can be viewed by clicking the appropriate text. Audio files are also available to further explain the equipment. Problem sets 1, 2 and 4 listed above are all developed around the depropanizer distillation column. Since students have previously completed a material balance around the depropanizer, these problems are hopefully more stimulating. Problem set 3 is similar to combustion problems in *Felder and Rousseau* except in this case the fuel contains 11 components. This type of problem is not conceptually more difficult than using a single component fuel, but the bookkeeping is significantly more involved. Students are given the design parameters specified by Bechtel and then asked to calculate the lower heating value, the stack temperature, and the heat give off by the reaction. A picture of the gas-fired reboiler is available for viewing.

All problem sets have a number of qualitative in-class discussion type questions. The following questions from problem set 3, illustrate the types of discussion questions included for all problem sets.

> The designers assumed 20% excess air. Why? Why not 15%? 25%? Do you think the combustion chamber currently operates with 20% excess air? How would you control the system to obtain 20% excess air? If the reactor operates with 15% excess air, what effect does this have on the rest of the process? The design calls for complete combustion of carbon to carbon dioxide; do you think this really happens? How could you determine if it does? Does it really matter? Why not use a steam heated reboiler?

Fluid Mechanics

Chemical Engineering students at Rose-Hulman take Fluid Mechanics in the sophomore year after completing the material and energy balance sequence. In recent years two textbooks have been used for this course: Unit Operations of Chemical Engineering by *McCabe, Smith and Harriott* and Fluid Mechanics by *deNevers*. The CD-ROM contains seven problem sets. Each problem set has numerous discussion questions and problems requiring calculations. The problem sets are listed below:

1.	Pipe diameter for vapor flow
2.	Pipe diameter for liquid flow
3.	Orifice meter for vapor flow
4.	Orifice meter for liquid flow
5.	Pump size/horsepower calculations
6.	Friction loss calculations for liquid flow
7.	Net positive suction head

None of the above problems on the CD-ROM are much different than problems found in standard Fluid Mechanics textbooks. What is unique is that students begin to feel the Marathon Sat Gas plant is becoming a real friend and hopefully students begin to see the importance and interrelationships between the required courses. In addition, problems 5, 6 and 7 were developed using the depropanizer column and material and energy balances have been completed on this column is previous courses. Pictures of actual pumps are included for student benefit. For problem set 5, the pump specified was an Ingersoll-Rand vertical in-line centrifugal pump. The CD-ROM contains numerous discussion questions not included in most Fluid Mechanics texts. Examples are listed below for the depropanizer reflux pump (from problem set 5).

Why did the design engineers specify a centrifugal pump as opposed to a positive displacement pump? Why did the design engineers specify a vertical in-line pump? What is a vertical in-line pump? Who cares? Why does the plant photo show 2 pumps? The suction line specified was a 6 inch line and the discharge line specified was a 4 inch line. Why? Why not make both 6 inch? 4 inch?

These types of questions keep students alert and interested in class. The CD-ROM also has the Bechtel design specification sheets for the orifice meters and pumps available for student viewing. These were scanned and imported as .jpg files. The Ingersoll-Rand pump specification sheets and the pump performance curves for some of the pumps were also scanned and imported for student viewing. Having actual pump performance curves available brings an additional level of realism to standard problems.

Thermodynamics

Chemical engineering students at Rose-Hulman take 2 quarters of thermodynamics in the junior year. Several textbooks have been used in recent years for the thermodynamics courses. <u>Introduction to Chemical Engineering Thermodynamics</u> by *Smith and VanNess* has been used most often. The CD-ROM has 4 types of problems taken from the Marathon Sat Gas plant as shown below.

1.	Bubble point calculations
2.	Flash drum calculations
3.	Ideal versus real gas calculations
4.	Three phase equilibria
5.	Reboiler vapor/liquid equilibria

Probably no course in chemical engineering seems more fuzzy and sometimes irrelevant than thermodynamics (at least this has been my experience). The above problem sets give the instructor ample opportunity to show to students that thermodynamics is very important in the "real" world. Problem set 2 illustrates a material balance that can't be made without vapor/liquid calculations. Problem set 3 requires calculations of the density of the overhead vapor from the depropanizer column. This shows the student that these material balances need density which in turn require an equation of state. The density is also needed to calculate the vapor velocity, which is needed for estimating pressure drop. These calculations integrate material balances, fluid mechanics and thermodynamics.

The three phase equilibria problem was developed from the following part of the Sat Gas plant. Three hydrocarbon streams (one liquid stream and two vapor streams) all containing some water are mixed. The resulting mixture is cooled producing a liquid hydrocarbon stream, a vapor hydrocarbon stream and a liquid water stream. Unfortunately the two hydrocarbon streams still contain a small amount of water. It is important for downstream calculations to know the amount of water still contained in the two hydrocarbon streams. The water distribution is a 3-phase equilibria problem. It is hard for students to avoid seeing the importance of thermodynamics when considering this part of the overall process.

Heat Transfer

Heat Transfer is taken by our junior students. Heat Transfer by *Incoperra and deWitt* is the textbook currently used. The CD-ROM developed from the Marathon Sat Gas plant contains the following 5 problem sets.

1.	Heat losses from distillation columns
2.	Reboiler(boiling) heat transfer coefficients
3.	Liquid/liquid heat transfer coefficients
4.	Condensing heat transfer coefficients
5.	Overall heat transfer coefficients

The types of assignments contained in the 5 problem sets above are similar to those normally assigned in a heat transfer class. The calculations involve conduction and convection along with energy balances over heat transfer equipment. However, all the calculations and in-class discussion questions involve the Sat Gas process that the students have seen before. Problem set 2 involves the reboiler on the depropanizer column. By this time students have done a material balance over this column, calculated the size of the reflux pump, completed calculations on an orifice meter and performed vapor/liquid equilibria calculations on this same column. So the relevance of the equations studied in class is obvious when applied to this plant that by now is a friend (hopefully not an enemy). Pictures of the condensers, reboilers, coolers and heaters studied are available for student viewing.

Supplemental material has been included on the CD-ROM that is not normally a part of a heat transfer class. One such supplement is the duty specification sheet for each of the heat exchangers studied. These heat exchanger sheets provide ample information for in-class discussion on why designers chose a 2-4 exchanger as opposed to a 1-1 exchanger, why mild steel (or whatever) was used as the material of construction, why the outlet water temperature was chosen as 110 F and not 115 F, is the cooling water inlet temperature really 85 F in January, how did the designers obtain physical property information for mixtures containing 11 components, etc.

Problem set 5 contains a particularly interesting problem involving an overhead condenser on a distillation column. Part of the overhead vapor for this column is condensed using a finned tube condenser with air as the cooling medium; the partially condensed overhead product is then fully condensed to a saturated liquid in a shell and tube exchanger with cooling water as the cooling medium. The actual heat transfer calculations are routine, but an in-class discussion on why the designers used two types of condensers for this one operation and why the heat loads were split as they are provides an interesting design discussion. This provides an opportunity to show students that there is not a single solution to designing an overhead condenser but that many designs will work. This also hopefully whets the student's appetite for senior design when this type of economic optimization is covered more thoroughly.

Mass Transfer

Rose-Hulman chemical engineering students take two courses in mass transfer: one in the junior year and one in the senior year. Unit Operations of Chemical Engineers by *McCabe, Smith and Harriott* is currently used for these courses. The Marathon Sat Gas CD-ROM contains 5 problem sets as supplemental material for the mass transfer courses as shown below:

1.	Calculation of minimum reflux ratio
2.	Minimum trays at total reflux
3.	Number of ideal trays: binary distillation
4.	Number of ideal trays: multicomponent distillation
5.	Flooding velocity and column diameter

As with previous courses, the types of questions and homework assignments on the CD-ROM are not greatly different than normally assigned in class. However, all five problem sets shown above have been developed using columns students have seen before in material and energy balances, fluid mechanics, heat transfer and thermodynamics so that by now the students have developed a sense of "ownership" with this process. As with the previous topics, photographs of the columns at the refinery are included for student viewing. Also, the Bechtel design specification sheets have been scanned and are available on the CD-ROM for students to compare their results with. In some cases current (1998) plant operating data have been included. All this provides a sense of realism, continuity and integration throughout the curriculum.

Other Courses

At this point the only other Chemical engineering course having problem sets developed using the Sat Gas Plant is senior design. Future developments will include problem sets for our required Process Control course and problem sets for two electives: Health and Safety and Petroleum Refinery Engineering.

Summary

Several years ago Marathon Oil Company made available to Rose-Hulman the engineering record books as developed by Bechtel Corporation during the design and construction of a Sat Gas Plant at their Robinson, IL refinery. Marathon also gave to Rose-Hulman the iconic model used during construction and start-up of the process. The Chemical Engineering department has used this information during recent years and students have appreciated "real world" discussion questions and problems used in various classes. A barrier has existed in using this information systematically, because only a single copy of these engineering record books was given to us.

This created an energy barrier for sharing these books, copying information for students, etc. By scanning required information, developing audio files for detailed explanation of this scanned information, taking digital pictures of actual plant equipment, making problem sets for most required chemical engineering courses and placing this all on a CD-ROM, the resource given to us by Marathon can be used more effectively. This CD-ROM has been completed and is ready for distribution at the beginning of the 1999-2000 academic year to all chemical engineering students. Even though the actual problem sets developed for each of the courses are not greatly different from textbook problems, the Marathon Sat Gas CD-ROM has provided a type of curricula integration not available previously. The benefits of the CD-ROM can be appreciated more fully by personally using it as opposed to reading the textual description above. To this end a CD-ROM will be sent to those interested by e-mailing the author at *jerry.caskey@rose-hulman.edu.* The CD-ROM is copyrighted and can be used like any copyrighted material, but cannot be reproduced without permission.

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JERRY A. CASKEY
Jerry Caskey is Professor of Chemical Engineering at Rose-Hulman Institute of Technology. Dr. Caskey received a B.S. degree in Chemical Engineering from Ohio University in 1961 and a Ph.D. from Clemson University in 1965. He is a registered Professional Engineer in Indiana. Dr. Caskey previously taught at Virginia Polytechnic Institute and State University (1967-72) and was a Research Professor at the Israel Institute of Technology (1972).