A Case Study in the Chemical Engineering Freshman Course Using Enhanced Excel with Visual Basic and Power Point

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Abstract: A multicomponent gas–liquid system was considered as a case study project for the course Elementary Principles of Chemical Engineering. In this case study, students were responsible for preparing and using the graphical representation of vapor–liquid equilibrium (T_{xy} diagrams) for a variety of systems and conditions. The solution to this problem is designed as an interactive program utilizing Enhanced Excel, Visual Basic, and PowerPoint. Using a combination of these three software components necessitated the submission of the solution on a computer disk. Submitting only a printout of the same solution may not capture all of the information that is displayed when using generated events from interacting with the various software modules. By using Excel, freshman students can perform a what-if-analysis for which the problem's solution is sought, with minimum efforts. Furthermore, students will have a decent exposure to the chemical engineering process considered for this case study. Moreover, Excel spreadsheets are useful and easier to modify for parametric studies on the overall process than any other computational tool or program.

Introduction

Gas-liquid processes that involve several components in each phase include many chemical reactions, distillation, and transfer of one or more species from a gas to a liquid (absorption or scrubbing) or vice versa (stripping). When multicomponent gas and liquid phases are in equilibrium, a limited number of intensive system variables may be specified arbitrarily, and the remaining variables must be determined using equilibrium relationships for the distribution of components between the two phases.

These types of problems are usually assigned to freshman students (in the Elementary Principles of Chemical Engineering course) in order to reinforce the material they have learned about multiphase systems. For freshman students, these problems require a considerable amount of time and effort. Previously, such problems were either not assigned at all or were assigned at the end of the term. The primary obstacle was the lack of programming skills among freshman students. To complete their homework assignments, students were expected to master the problem-solving skills of multiphase systems; yet, these students were challenged with learning a new programming language, such as FORTRAN.

The learning objectives of this project could be met by assigning the project at the beginning of the semester. Students, hence, worked on parts of case studies as the course progressed. Students were guided through the solution sequence assisted by a preformatted spreadsheet and presentation slides. The applications of spreadsheets by freshman students assisted in improving their computational skills, and in helping them gain a better mastery of the problem-solving process.

Case Problem Statement

The details of the multicomponent gas–liquid system, which was the subject of our case study, are given in [1]. In this case study, students were required to prepare and use the graphical representation of vapor–liquid equilibrium (T_{xy} diagrams) for a variety of systems and conditions. The work was intended to combine Excel, PowerPoint, and Visual Basic software components. The project was divided into three parts.

Part I. Students write a program in Visual Basic to generate a T_{xy} diagram for an ideal binary solution. The program will have the following inputs: (1) the Antoine equation constants A, B, and C for each substance that was included and (2) the pressure (atm) for which the diagram is to be generated. The program evaluates the bubble-point temperature (T) at the given pressure for different mole fractions (x) of the more volatile component in a binary liquid mixture (x = 0, 0.05, 0.10, 0.15, …, 0.95, 1.0). Each evaluation will yield one point (T, x) on the liquid equilibrium curve. At the same time, once the bubble-point temperature has been determined, the mole fraction (y) of the more volatile component in the equilibrium vapor can also be calculated, yielding a point (T, y) on the vapor equilibrium curve. The program uses the Regula–Falsi trial and error method [1] for the bubble-point calculation.

Part II. The students test their programs by generating and drawing the T_{xy} diagram for chloroform and benzene at P = 1.0 atm. The computer is used to produce the graph.

Part III. The vapor–liquid equilibrium data shown in Table 1 that is obtained for mixtures of chloroform and benzene at 1.0 atm are plotted on the graph generated in Part II. The error in Raoult's law values of the bubble point and y_c corresponding to x_c = 0.44 is evaluated.

Table 1. Vapor-liquid Equilibrium Data for Mixtures of Chloroform (C) and Benzene (B) at 1.0 atm

T °C	80.6	79.8	79.0	77.3	75.3	71.9	68.9	61.4
x_c	0.0	0.08	0.15	0.29	0.44	0.66	0.79	1.00
y_c	0.0	0.10	0.20	0.40	0.60	0.80	0.90	1.00

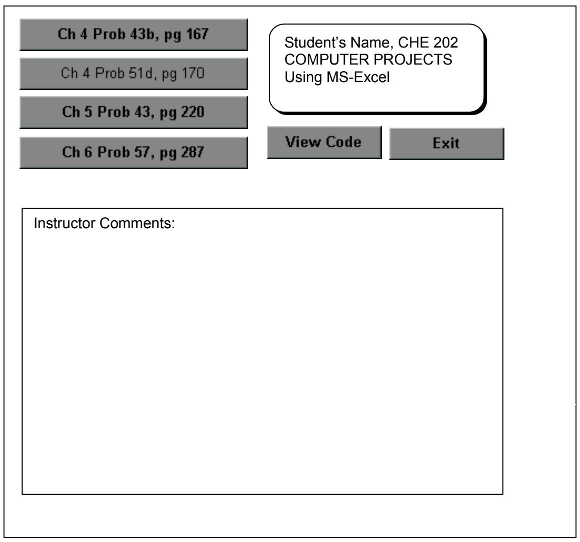

Figure 1. The Final Appearance of the Main Menu of the Project

Case Problem Procedures

In the beginning of the course, students were given the information to find the references that they needed to complete their work. These references included user manuals on Excel [2], Visual Basic [3, 4], and PowerPoint presentations [5]. Several sessions at the beginning of the course were dedicated to learning this software in order to address the problem at hand. In addition, students needed to learn the integration of the solution steps as supported by the various software components. The case study was then assigned as three separate parts to students. Freshmen were then expected to submit their project reports for each part separately. The reason for organizing the case problem in this manner is twofold. First, it is to encourage students to work on the project immediately and continuously throughout the semester, rather than postponing it to the end of the term. Second, it is to help students in preparing for course exams.

The classroom where the course takes place is equipped with desktop computers linked together as a local area network with a connection to the Internet. This setup enabled email communication between the instructor and the students inside and outside of the classroom. Moreover, the classroom was equipped with a software system to enable the instructor to gain control over any computer screen in the laboratory. The content of the controlled machine is then displayed through the projection system on a large screen.

Final Report

Students worked in groups of three. Each group was required to submit, on specified dates, three reports, one for each part of the problem. The reports included the completed spreadsheets, the Visual Basic source code and related files, and the engineering descriptions of the formulas. Using a combination of these three software components necessitated the submission of the solution on a computer disk. Figure 1 shows how the first page of the Excel project appears to the user or instructor. The interface, the way the program communicates to the user, needs to be selfexplanatory. It should not overwhelm the user with choices, but it should concisely display the available options. Figure 1 shows that the user can view the solution for any of the four problems displayed using different macros attached to different buttons, view the source code, or exit the program. By clicking on any of these buttons, the user will be linked to the worksheet where he or she can view the solution for that specific problem. The report was kept simple to encourage students to focus on the essential aspects to the problem and avoid all unnecessary explanations.

Student Performance

At the beginning, some students had difficulty understanding the details of the problem. This was clear based on the evaluation of their first report. After careful examination, it was determined that the poor quality of the students' work resulted for two key reasons: First, students did not spend enough time learning the software that they needed to complete their work. Second, students lacked the ability to define explicitly the assigned problem. The few students that completed the first part of the project correctly were asked to demonstrate their work in front of the class. Peer review encouraged discussion among students. To emphasize further the importance of understanding the details of the problem, the instructor made the students aware that the details of the project would be heavily weighted on the final examination. Peer review and the inclusion of the case study on the final examination not only stimulated better class discussion, but also improved the quality of individual participation in their respective group. These implications were evident as they resulted in an improvement in the quality of the students' second and third reports.

Conclusions

This work is intended to introduce students to complex chemical engineering problem-solving tasks to supplement course lectures and homework assignments. Usually, case-study-based assignments serve well to address these types of tasks. Performing a case study can be a difficult task for freshman students, who are not yet experienced in chemical engineering terminology, computer software products ,and engineering problem-solving skills.

This case study has contributed significantly to enhancing the repertoire of student skills in many areas. These include students' abilities to

- identify the desired objectives to be achieved from a particular case study,
- identify the needed data and details to address the problem at hand,
- enhance the problem-solving skills gained while trying to understand open-ended problems and use various

engineering, mathematics, and course-specific knowledge to conduct experiments and analyze and interpret data,

- develop essential computer software competencies needed in various parts of their coursework and apply these skills in acquiring case data and analyses,
- develop teamwork and group-dynamics skills, and orally communicate case-related issues to teachers and peers effectively,
- build confidence in tackling new tasks outside their field of study and to address problems with various levels of uncertainty (i.e., students had to learn how to use the three software components to solve the problem).

Supporting Material. The Excel Spreadsheet used in this exercise is available in a Zip file (http://dx.doi.org/10.1007/s00897020616b).

References and Notes

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