Using Real Industrial Projects to Teach Process Simulation

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McNeese State University offers a computer-aided process design course (CHEG 407) separate from the traditional design course. This is a required course and is in addition to two other design courses; therefore, its primary focus is not design, but preparing students to solve open-ended industrial problems using modern engineering tools. The professor of the course teaches simulation by having students work on real industrial projects. Since the projects are from industry and do not cover all unit operations, the students do not learn the entire simulator but learn what they need to know for their particular project. They learn to use the simulator more as a tool for developing and analyzing process models, rather than for designing purposes. However, some projects do involve design or redesign of equipment and could emphasize more design if desired.

This paper will discuss how projects are obtained, the types of projects obtained, how the course is conducted, and some of the key items students learn. It will also mention the course learning objectives developed for the ABET criteria and the assessment of these objectives. Finally, some benefits to the students, the professor, the university, and the industry will be provided.

How are the projects obtained?

Lake Charles, Louisiana, is surrounded by many chemical plants and refineries. Projects are obtained from these industries by talking to operation managers and process engineers, many of whom are McNeese alumni. These people are interested in working with McNeese and in developing simulation models for different units in their plants or units the company may be constructing in the near future. Sometimes they want to confirm the results they have received from a consultant or a previous simulation, while other times they do not have time for anyone to work on modeling the unit. In other cases, company engineers are working on the project at the same time as the students. (In areas without a concentration of process plants, projects could be obtained through alumni, co-op students, or recruiters from companies that hire the school’s graduates.)

For the fall semester, the plants are contacted by the professor in the middle of the summer to discuss possible projects with the engineers. If this is the first time the company is working with McNeese, the way McNeese handles the data and keeps it confidential is discussed. Sometimes the companies have McNeese sign a specific confidentiality agreement, but most of the time this is not required. McNeese provides the project data only to the students working on the project.
and then collects all the information back at the end of the semester. A reliable industrial contact is also determined for the project at this time. This person is responsible for supplying the necessary data for the project and being available for answering student and faculty questions throughout the semester.

When deciding upon projects, the scope of the projects and the ability to complete them in a semester are evaluated. In addition, it is important that the major chemical components in the process are available in the databank or reasonable properties for the components can be supplied by the company. A good project is a project that requires first a model of the process and then requires evaluating parameter changes for increasing capacity, improving the process through designing additional equipment, or investigating the effects of changing operational parameters. Some of the better projects have both design and operational data available to complement the model development.

Once a project has been discussed and decided upon with the company, the professor usually obtains initial data from the industrial contact a few days before class starts. This gives the professor a chance to review the project and data provided before giving it to the students. Since it is sometimes difficult to know what kind of problems may arise when simulating a unit, the project also evolves over the course of the semester. As in industry, additional goals may be added or goals may be revised based on the analyses during the semester.

**What types of projects are obtained? (including example)**

The projects vary widely: some projects may involve reactors or absorbers, but most of them involve distillation towers with auxiliary equipment due to the nature of the local companies providing the projects. Some projects involve a process unit consisting of many pieces of equipment while others only look at a small portion of the unit, containing only a few pieces of equipment. A process unit involves mostly modeling while a smaller unit requires more optimization. Usually the students need to model the process equipment and then look at varying different parameters to see their effects on the model. In some of the projects, they then need to do an economic analysis to evaluate these effects. It is not necessary for all students to be doing the same thing in each project, since the purpose of the class is to use simulation to solve open-ended problems and suggest the importance of life-long learning.

The projects usually involve more modeling than design and students, to their surprise, find that modeling is not as easy as they think. For most of the projects, the modeling is the most difficult part. It involves having confidence in the thermodynamic package being used in the analysis and having confidence in the industrial data being used for development of the model.

A generic project follows as an example to give an idea of what a typical project entails.

**Process unit** – The project simulates two distillation towers in series with the bottom stream of the first tower being fed to the second tower. The bottom stream of the second tower is used to heat the feed to the second tower. **Goals** - The goals of the project are to first model the process unit based on design data, and then use operational data to check the consistency of the model. Once a reasonable model has been developed for the process, the unit is to be optimized to achieve a specific purity of the distillate product in the second tower. **Limitations** - There are
impurity limitations on the distillate product stream from the first tower and bottoms stream from
the second tower. **Manipulative variables** - Examples of parameters that may be manipulated
are number of equilibrium stages, thermodynamic method, feed temperatures, reflux ratios, and
operating pressure and temperature of each tower. **Initial data** - The initial data provided by the
company are the three product stream compositions and flows with temperature and pressure, the
temperature and pressure of the feeds along with the feed design compositions and flows, the
design duties of the exchangers, the reflux ratios, and the number of actual trays and actual feed
tray of each tower.

The students then have to evaluate these data and determine how to use them for achieving the
goals of the project. They develop the tasks they need to accomplish and a timeline for
achieving these tasks. Some of the main tasks and decisions considered by the students for this
project are listed below.

1. Distinguish between the types of data provided (i.e. is it design data or actual process
data)
2. Fill in any gaps associated with the design and operational data, if necessary
3. Evaluate data for inconsistencies
4. Calculate the feed compositions and flows for the operating data using the product
   streams
5. Obtain the efficiency of each tower by determining the number of equilibrium trays
   needed to achieve the design separation
6. Determine the equilibrium feed tray for each tower to see if the efficiency is different for
different sections of the tower
7. Develop the simulation model and decide on the criteria for saying it is a good model
8. Decide whether to initially model the towers separately and then combine or begin by
   modeling the whole system
9. Decide whether they can use the equilibrium tray model for their optimization analysis
   or whether they need to use the actual trays with efficiency for their analysis
10. Establish variable limitations
11. Analyze the effect of the manipulative variables
12. Identify any equipment limitations
13. Develop recommendations for the company based on their analyses with respect to the
    manipulative variables and the results within the constraints provided by the companies
14. Determine the best way to present the results to the company

As the students progress through the project, they may want to obtain more data, such as tower
diameter and internals of the tower, areas of exchangers, or data to help them determine actual
duties of the exchangers. They have to decide if the data are necessary and ask the company
representative for the additional information. They may find out that some data they would like
to have are not available. Then they have to decide how to work on the project without the
missing data. One of the hardest things for the students to learn is that not all data are available
and data that are available are not always accurate. They are forced to make decisions based on
limited information.

**How is the course conducted?**
This is a 3 credit hour course with 1 hour of lecture and 6 hours of computer lab time each week that is generally taught once a year in the fall semester of the senior year. The course is usually limited to 10 students. If more than 10 students need to take the course, then the course is offered again in the spring semester. If the course has 10 students then 4 or 5 different projects are obtained from the industries for that semester. The limitations are imposed by a desire to ensure the professor has plenty of contact time with each student, simulation software availability, and scheduling three site visits for each project during the semester.

Students work on the projects in teams of two or three students, depending on the number of projects and the number of students in the class. From the author’s experience, teams of four students do not work well for this class as the fourth student tends to watch and lets the others do all of the work. Since students can discuss ideas about the project with the professor, the other students in the class, and the company mentor, teams of two students work as well as three students.

On the first day of class, the students are provided the projects and they either pick teams based on what project they want to work on or the professor picks the teams. Both methods have been used in this class. In the eight years the author has taught this class, student performance and ability to work together do not seem to depend on how the teams are chosen. The students have been used to working with each other during their academic careers because of the small class sizes in engineering at McNeese; therefore, the selection of team members does not seem to affect the performance of the team.

To help the students learn more about effective teamwork, advantages and disadvantages of teams are developed by the students. The students also develop what they feel are important qualities for teams to be successful. The students are required to buy The Team Memory Jogger™ A Pocket Guide to Team Members 1. Different aspects of the guide are discussed in class and each team develops specific goals for their team.

Before each team receives its project, the professor emphasizes that the information provided by the companies may be confidential and each student needs to treat all of it as confidential information. The students are not to talk about the project details to those outside of class. All project information is returned to the professor at the end of the semester; a final grade will not be given until all information is returned.

Once each team has its project, the team members review their project information and develop any questions they have for their industrial contact. Within the first couple of weeks, each team, along with the professor, visits the specific plant to tour the unit being modeled and to learn about the process. The students have a chance to ask questions and get a feel for why their project is important to the company. Once all of the teams have been on their plant visits and become familiar with their processes, they are required to describe the project and its goals in a preliminary presentation to the class and a preliminary report for the professor.

Since each of the projects is different and requires different aspects of the simulator, the students learn about the various aspects of the simulator as they need to apply it to their project. Many of
the students have had minimal experience with the simulator before this class. In addition, those that have no cooperative education experience are unfamiliar with some of the industrial terminology. As a result, some of the students are overwhelmed at first. To help them become more comfortable with the simulator before starting their project, they work on a small distillation problem to learn the basics of simulation. Also, as the students progress on their projects, the professor discusses ways they can analyze the data from their simulation models, develop more flexible models, and determine if their models are reasonable or not. The students work on their projects with the professor available to answer their simulation questions and basic industry questions. The students can also contact their industry mentors to obtain clarifications on the process, the data, and sometimes to see if more data are available.

The students submit progress reports about every two weeks as well as midterm and final reports and presentations. Midterm and final presentations are delivered in class and then each team goes out to its respective plant and gives the presentation for industry personnel. The industry personnel are also given a copy of the midterm and final reports. The midterm presentation is important because it helps the students make sure they are proceeding appropriately and they have a chance for feedback on their progress. The final presentation gives them a chance to show industry what they have accomplished for the semester.

Sometimes other faculty attend the presentations, but they have not evaluated the presentations as part of the students’ grades. Until last semester, informal feedback was obtained from the companies by the professor talking to the company representatives after the semester had been completed. Last semester, formal feedback from the industry mentors was obtained by having them fill out surveys. None of this feedback has been directly incorporated into the students’ grades; so far, it has been used only to improve students’ presentations, projects, and reports.

To ensure each team member is contributing to the project, midterm and final exams are given. These exams consist of 10 questions and are based on information in their reports and discussions they have had with the professor about their projects during the semester. If the students are working as a team on the project and each member understands the project, the exams are straightforward. If a student is not contributing, it usually shows up in the results of the exams.

Peer rating is also currently being incorporated into the class for individual accountability. Peer rating is conducted two ways. First, the students rate each team and its members on their presentations. The evaluation involves the students rating each others’ presentations on organization, readability of slides, eye contact, etc. Some of these questions relate to the entire team while others relate to individuals. An average rating is obtained for the team and for each individual team member. A ratio is then obtained for each student, which is used to adjust the team’s presentation grade to provide an individual grade for the presentation.

Each student also rates his team members including himself on how the team works together throughout the semester. This evaluation involves rating each member on several factors, such as providing input to team discussion, being prepared for team meetings, attending team meetings, etc. A ratio is determined based on the average student rating over the average team rating and this ratio is used as the adjustment factor to develop individual grades for the team reports.
The class also discusses each presentation after all of the presentations have been completed. This provides feedback to the students on their presentations so they can improve for the industry presentations; however, this feedback discussion does not get incorporated into the grades.

**What are some of the key items the students learn?**

Through using real projects students learn some key factors that they generally would not learn by using textbook type projects. Some of the skills that they may develop, depending on their specific project, are the ability to

- read flow diagrams,
- evaluate accuracy of data and to work with limited data,
- evaluate appropriate thermodynamic methods,
- develop criteria for model accuracy,
- develop flexible simulation models, and
- analyze results.

The companies may provide process flow sheets and design, actual process, or lab data. Students learn to read flow diagrams and learn that not all data are available or, if it is available, it is not always accurate. For example, students learn that it is important to do a material balance using the given data before using it in simulation. Sometimes the actual process data suggest that more products are leaving than came in. They also learn to judge which data are more likely to be accurate. For example, the product analysis is probably more accurate than the feed analysis because the product is being sold, and the feed may just be an intermediate stream from another process. Students working on refinery projects often learn about assay data, how to evaluate it, and how to use it in the simulator. They may learn that mass balances in refineries may not be as accurate as in chemical plants, because refineries aren’t making high purity products like many chemical plants. As a result, criteria for meeting mass balances in refineries may be set at higher percent differences than for chemical plants.

Students learn the importance of thermodynamics. They evaluate their process conditions and components and determine what thermodynamic methods may be appropriate. They usually try several methods, see how the results vary among them, and then compare the results to the actual data. They then discuss it with their industrial contact and decide upon the best thermodynamic method to use for further analysis.

The students have to develop criteria for determining when the simulation model is accurate enough with respect to the actual unit. If they have only one set of actual data, they realize they have limited information to compare to and must decide what they want to be the determining factors for comparison. The students begin to realize that their model may not be valid for other sets of data, an issue that may need to be addressed in their analyses. In addition, the students have to determine the critical components in their unit and how accurately they want to model these components. For example, do they want to be within 10% or 1% of the mole fraction for major components in a stream? Can minor components’ concentrations have a larger deviation from actual data? How accurate do the overall product stream flows need to be? These are
questions the students have to ask themselves and answer to set their model’s criteria and determine how close the results need to be.

They learn that just because their model is working and matching the real data reasonably well does not mean it will be their final model; they may need to adjust their model development to make it more flexible to look at various parameters. For example, in one project, a team had developed a very good model based on a mole fraction specification for one component in the distillate product. However, when they wanted to evaluate what happened when more of this component went out in the bottoms product, they found that reducing the mole fraction specification for this component in the distillate product did not force more of this component to leave in the bottoms stream. Instead more components from the bottoms stream began leaving in the distillate product stream. The students evaluated what was happening and realized that a percent recovery of this component in the overhead would work as a better specification for the model.

The students also learn more about overall and stage efficiencies. They learn when it is important to include efficiencies and real number of stages in the simulator and when it is okay to use equilibrium stages in the analysis. They also learn about analyzing distillation towers using a pseudo-binary McCabe-Thiele diagram to determine if there are pinch points or an improper feed location in their model.

Students also learn from the other teams and projects. Although this is not actually assessed or evaluated, students listen to the presentations and discussions of each project and observe what the other students are doing. During the presentations, many of the students ask questions about the information and projects being presented. Overall, most of them learn much more than if they were just taught how to use the simulator or if they just used the simulator for their design project class because they become intimately involved in their project and hear about other projects that are different than theirs.

**What are the learning objectives developed for ABET criteria?**

The following course learning objectives have been developed for the ABET criteria:

Student successfully completing the course will be able to do the following:

1. Identify what they know to successfully develop a solution to a real industrial project
2. Identify what they need to know to successfully develop a solution to a real industrial project
3. Identify what they need to do to successfully develop a solution to a real industrial project
4. Demonstrate independent analysis of a real engineering problem
5. Explain the problem to the rest of the class where everyone can understand it
6. Interpret and compare real data with simulated data
7. Prepare concise oral presentations and written reports
8. Demonstrate the use of process simulation in engineering design and optimization
9. Explain technical results to an engineering supervisory group
10. Describe effectiveness of teamwork

These objectives were assessed by several different methods (reports, presentations, exams, student feedback, and industry feedback) this past semester. This was the first time the objectives had been assessed. The reports and presentations demonstrated objectives 1 through 9. The midterm and final exams addressed objectives 1 through 6 and 10. Examples of exam questions used to address some of these objectives were:

1. Provide a brief description of the process being modeled.
2. What are the strengths and weaknesses of your simulation models?
3. Why is it important to develop team goals?
4. What problems have been observed in the given data and how have many of these problems been overcome?

In addition, feedback was obtained at midterm and at the end from all ten students on their own self assessment of these objectives. Table 1 shows the feedback results from the students on each objective based on a rating scale of 1 for strongly disagree and 5 for strongly agree. Overall the students felt that they had achieved the objectives of the course. Only one student (not necessarily the same student) stated a maybe on objectives 2, 4, 8, and 9. On all of the other objectives the students agreed or strongly agreed that they could do the objectives.

Table 1. Student Feedback for Course Learning Objectives

<table>
<thead>
<tr>
<th>Course Learning Objectives</th>
<th>Feedback Results</th>
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<tbody>
<tr>
<td>I can identify what I know to successfully develop a solution to a real industrial project.</td>
<td>4.5</td>
</tr>
<tr>
<td>I can identify what I need to know to successfully develop a solution to a real industrial project.</td>
<td>4.0</td>
</tr>
<tr>
<td>I can identify what I need to do to successfully develop a solution to a real industrial project.</td>
<td>4.5</td>
</tr>
<tr>
<td>I can do independent analysis of a real engineering problem.</td>
<td>4.0</td>
</tr>
<tr>
<td>I can explain my project and its objectives to the rest of the class where everyone can understand it.</td>
<td>4.6</td>
</tr>
<tr>
<td>I can interpret and compare real data with simulated data.</td>
<td>4.4</td>
</tr>
<tr>
<td>I can prepare concise oral presentations and written reports.</td>
<td>4.6</td>
</tr>
<tr>
<td>I can explain the use of process simulation in engineering design and optimization and apply it properly.</td>
<td>4.0</td>
</tr>
<tr>
<td>I can explain technical results to an engineering supervisory group.</td>
<td>4.0</td>
</tr>
<tr>
<td>I can describe how teams can work effectively.</td>
<td>4.4</td>
</tr>
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</table>
“Free-response” questions were also asked about how their teams worked together, the use of peer rating for adjusting grades, feedback by the professor on reports and presentations, what was the most important thing they learned in the class, and how they would change the class if they were conducting it. Some of the statements by the students on what the most important thing they have learned in the class show the diversity of the class and aid in the assessment of the objectives. A few of these statements are listed below.

I “learned about simulation, industrial terms, and a better understanding of ‘plant life’.”

I learned “ways to approach real problems and work towards a real solution.”

I learned to “find discrepancies on actual data, investigate reasons for inconsistencies between real and simulated data.”

I learned “real world problems do not have nice, neat solutions like the problems presented in class; teamwork is important; there are many different ways to approach a problem, not all necessarily wrong/right, and some might not be any better than the others, but one must choose one and run with it.”

The results from the midterm feedback were used to improve the class for the second half of the semester and all feedback will be used to improve the class next year. For example, students felt that the peer rating descriptions for excellent, good, satisfactory, etc. performance on presentations were not appropriate because the descriptions were geared toward team member participation rather than actual performance so the descriptions were revised for the second half of the semester. The students also suggested that next time maybe two weeks instead of one should be spent on the logistics of the simulator. This will be incorporated next year.

For feedback about teamwork, the students were asked how their team approached the tasks of the project, how their teams demonstrated effective teamwork, and how their team could have worked better together. Some of the responses on how the teams approached the tasks and demonstrated effective teamwork included identified problems and brainstormed for solutions, listened to each other, and divided up tasks and consulted each other. Most students said their teams worked well together.

Finally, company contacts were asked to provide feedback with respect to the teams on the above objectives. The company contacts were also asked additional questions:

1. What recommendations do you have on how this team could improve on future projects?
2. Do you think this team has provided useful information for you?
3. How do you think the class can be improved for future projects with your company?

Results were received from all four company mentors last semester. The mentors’ ratings show that they agreed to strongly agreed that the students met the above objectives with one exception. One mentor stated a maybe on effective team work. In addition, all industry mentors said the
results from the projects were useful to their company and would be incorporated in future analyses.

What are some of the benefits to the students, professor, university, and industry?

The benefits to the students are:

1. Exposure to the real world before entering it as an engineer
2. Learn to think independently
3. Learn to evaluate results and determine their implications in an actual process
4. Contact with industry who may be hiring them in the future
5. Can evaluate companies before interviewing with them

The benefits to faculty are:

1. Maintain relations with industry to learn what skills industry wants new engineers to have
2. Keep up-to-date on what industry is working on
3. Assist students in becoming independent thinkers

The benefits to the university are:

1. Maintain good relations with industry that may hire its graduates
2. Expose students to the real world
3. Industry personnel may recommend the program to prospective students
4. Industry personnel may recommend their employees take classes at the university to keep up-to-date

The benefits to the industry are:

1. Maintain contact with the university and the engineering program
2. Evaluate students before considering them for jobs
3. Have an independent analysis of a project with possibly new ways of looking at the project
4. May be able to provide recommendations for the university to include in the engineering program

With this class, it is a win-win situation for everyone involved.

Conclusion

This paper has described a computer-aided process design course being taught at McNeese State University. The course is different from a traditional computer-aided design class because the professor teaches simulation by having students work on real industrial projects. It is important for the professor to obtain projects that are pertinent to the companies and beneficial to student learning. By using industrial projects, the students are motivated and learn to be more critical of data and to think independently. Many of the ABET criteria, such as developing team,
communication, and problem solving skills, are integral parts of the class. Finally, the course is beneficial to all those involved.

Bibliographic Information


Biographical Information

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