An Industrial Approach To The Unit Operations Laboratory Course

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Repackaging of the two unit-operations laboratory (UO) courses has resulted in a dual student learning experience. The hands-on experience of applying the knowledges acquired in the chemical engineering lecture-recitation courses has been retained, albeit in a slightly reduced form. The emphasis of the repackaging has been to enhance the student's communication skills.

The initial phase of the unit-operations laboratory deals with fluid mechanics and heat transfer. Here the communications effort is accomplished using four requirements for each experiment. Each student group must prepare and discuss a pre-laboratory memorandum before initiating data collection. Each student is required to submit two progress reports. Prior to submission of a final report, the group gives a briefing on their laboratory experience where difficulties encountered in the data analysis are recognized and constructively reconciled during the briefing. The final report is thus significantly improved.

The second phase of the unit operations laboratory deals with mass transfer and kinetics-reactor operation. Here the communications effort has a different approach. Four managerial positions are created using a four-student group module. With four experiments, each student can rotate through each of the following positions: Project Manager; Research and Development Manager; Operations Manager; and Health, Safety and Environmental Affairs Manager. Here the emphasis is on the development of individual written communication skills.

The Traditional Unit-Operations Laboratory Courses

The chemical engineering laboratory course sequence continues to be structured to interface with the curriculum and course scheduling. The laboratory course sequence has as its initial focus the concepts of fluid mechanics and heat transfer, then in a second course the knowledges associated with mass transfer, kinetics, and reactor operations are addressed. Normally five to six laboratory experiences would be provided each semester. With a total of ten to twelve experiments, the objective of giving students experience in the operation of industrial-scale equipment, and reinforcing the concepts of previous courses is achieved.

With this number of experiments, the focus is on the concepts associated with the experimental experience and the idiosyncrasies associated with the equipment. What is lacking within this structure is an emphasis on developing the ability of current students to communicate in written reports the concepts associated with the experimental experience, the results obtained by

performing the experiment, and finally a discussion of the analysis performed on the data. Because of the time spent acquiring the technical skills of equipment operation, data collection, and analysis, the ability to communicate effectively had been traditionally given lower priority, but not totally ignored.

Recognition of the Need for Inclusion of Technical Report Writing

The traditional laboratory schedule using five unit-operation experiments per semester, coupled with the combination of a single formal report and the balance as informal reports plus a single oral presentation, was found lacking in intensity for the enhancement of student communication skills. Feedback from the industrial sector indicated that the written communication skills of the graduating chemical engineer were lacking. Since the industrial sector is the "market place," the curriculum needs to address the communication-skill area. The obvious place to initiate this added emphasis is in the unit-operations laboratory course sequence. The second place is the process and plant design course.

Improvement in the student's written communicative skills is obtained through repetition. Thus the preparation of several written reports on each experimental experience is necessary. Incorporation of industrially relevant reports into the laboratory course requires **time** to prepare them, **time** to properly review them, and finally **time** to provide direct feedback to the students with the opportunity to revise the document. The result of this effort is that the experimental schedule is reduced by at least one experimental experience.

Repackaging of the UO-Laboratory Course to Enhance Communication Skills

The repackaging of the initial unit-operation laboratory course commenced in 1995 under the direction of David B. Van Dongen, and has been enhanced continually since then. The repackaging required that the number of experiments be adjusted to accommodate the increased emphasis in the development of communication skills. Thus the number of experiments was reduced to three, but we required all students to accomplish the essential fluid-flow and continuous-heat-transfer experiments. A third experiment selection was left as a student option.

The current format requires that each group accomplish the following for each experiment:

- Prepare and orally defend a pre-project memorandum before initiating data collection,
- Prepare two individual progress reports on the previous weeks data collected,
- Present an oral group report on the results, and
- Prepare and submit a written group report.

The key items in this sequence are the pre-project outline and the oral presentation.

The pre-project outline must present a thorough understanding of the technical concepts involved with the experiment. This is reflected in a knowledge of the physical limitations of the equipment, limitations of the relationships and correlations being used, what experimental data must be collected, what the predicted values of the measured data will be, and how the data will be analyzed to obtain the preset experimental objectives. Prior to the group commencing experimental-data collection, each student is involved in briefing the instructor on the pre-project outline's contents. The results are, needless to say, interesting. The primary benefit of calculating predicted experimental results is to assist the students in time-management skills.

That is, it avoids the common scramble before the deadline to submit the final report with possibly questionable data.

The group oral report is evaluated on how the presentation is packaged and not on the technical content and accuracy. Even aware of this, the student groups do expend considerable effort in processing and analyzing the experimental data, and in preparing the briefing materials. The groups are aware that their results will be constructively critiqued and respond positively to the experience. The message is clear: organization of the material is essential. The group preparation for the oral presentation necessitates the development of a draft version of the report. The briefing is thus the initial presentation of the report. It has been found by experience that it is best not to evaluate the technical content but rather to provide constructive assessment, with the areas of difficulty being reconciled at the end of the briefings. With the following week being the report suspense date, there is time for the group to revise and hence improve the report.

The overall assessment of this process is a significant improvement in the communicative skills of the students. The reduction in the number of experiments has not been detrimental since the inclusion of the "pre-project outline" has required the student group to become pre-focused on the experiment and thus better able to exhibit time-management skills. Feedback from student interviews has been positive with strong recommendations from the industrial sector to continue this effort. One underlying result is that the student begins to ask, "Why am I doing this?" The development of individual self-analysis is a definite sign of the maturing of the young engineer.

The Second Phase of the Repackaging Effort

The second phase of the unit-operations laboratory extends the repackaging but with a different focus. The emphasis in the second course is to shift from a group effort to an individual effort with the group serving as a resource. This is a marked change in philosophy but the results justify the approach.

The desired structure is to have four students per group with a total of sixteen to a class. With this group structure, four different job functions are created with the students rotating through a four-experiment sequence. The experiments used were selected from those available in the mass transfer and kinetics-reactor area. The four managerial positions are:

- Research and Development Manager,
- Operations Manager.
- Health, Safety, and Environmental Affairs Manager, and
- Project Manager.

The project manager is required to organize and continually assess the performance of the entire group on the experiment. If there are any problems with the group, the project manager has the overall responsibility for group performance.

The "Project Outline" memorandum is the initial report submitted by the Research and Development Manager. This memorandum contains the objectives, the predicted results with numeric values where appropriate, the experimental plan and references. This document is to be reviewed at the beginning of the first week of experimental data collection. The review is conducted by the instructor with the Project Manager and will address procedural matters, the

experimental plan, and the technical specifics of the correlations being utilized. Unsatisfactory performance results in the Project Manager being informed that this document needs to be revised and resubmitted for evaluation before experimental data collection can commence.

The Operations Manager is to prepare two documents. The first is an "Operating Manual" for the complete experiment. This document covers all aspects of the experimental procedure: start-up, normal operation, analytic procedures, emergency shut-down, and normal shut-down. The format must conform to industrial practice associated with such a document. The initial submission of this document is at the beginning of the second week of data collection, with the final version due at the beginning of the final week of data collection. The second document is a "Process-Data Audit" memorandum. This is an evaluation of the experimental data collected by the group (reliability, confirmation of steady state, anticipated trends, etc.). This memorandum is due at the beginning of the second week of data collection and reflects an assessment of the first week's work by the group. A second memorandum is due at the beginning of the third week.

The Health, Safety, and Environmental Affairs Manager is to submit at the beginning of the second week of data collection a "Process Safety Audit" memorandum. The function of this report is an assessment of the safety of the process equipment, chemicals involved (including analytical materials), and the procedures. The report should also cover a safety audit, hazard analysis, and definition of all chemical species with their associated health hazards. To be included in the report is a Material-Flow Diagram (cradle-to-grave track of the flow of all materials) and, if appropriate, the design of a safety valve. The authors are not aware of a suitable undergraduate-level textbook covering these materials, but there is a sufficient wealth of information in the open literature. The Operations Manager and the Health, Safety, and Environmental Affairs Manager are also to individually submit short memorandum reports on the results of the experiment.

The Project Manager is required to submit a formal report on the experiment the week after the final data-collection session. At the end of the semester, the project manager is also to give a short briefing of the results of the experiment. The schedule for the oral reports by the respective Project Managers is focused since the presentations are by specific experiment type.

Overall Assessment

The repackaging of the two laboratory courses results in a total of seven experiments, but with a greater emphasis on what the students are expected to know before they begin the assigned exercises. In addition, the increase in competence of the students in their communication and planning skills is definitely noted. Students returning from interviews with prospective employers have stated that discussion of their experiences have made a significant impression.

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