Remote vs. Hands-on Laboratory Experiences: What Works and What Doesn't

David DiBiasio[1], Jim Henry[2], Marina Miletic[3], and William M. Clark[1]. [1]Chemical Engineering Department, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609, [2]Chemical Engineering, University of Tennessee at Chattanooga, 615 McCallie Avenue, Chattanooga, TN 37403, [3]Department of Chemical and Biomolecular Engineering, University of Illinois Urbana-Champaign, 206 Roger Adams Lab, Urbana, IL 61801

Background

Increasing enrollments, reduced access to laboratory equipment, and limited resources place new pressures on departments wishing to maintain a significant undergraduate lab experience. One possible solution to the problem involves incorporating remotely-operated lab experiences.

Ideally, remote experiments can be conducted at any time from any place. They are particularly useful for students at universities where resources are severely limited and there is no access to any significant experimental equipment. Knowing how to optimize learning in a remote lab experiment is critical, as is knowing the limitations compared to hands-on. The literature indicates mixed results about student learning using remote experiments. And, there are only a few studies of chemical engineering systems. Our goal was to understand student learning and attitudes in one remotely-operated lab experience compared to hands-on.

At WPI distillation is taught in the sophomore year throughout a project-based spiral curriculum. All projects are team-based. We introduce basic concepts early in the sophomore year then revisit distillation throughout the year with successively more complex assignments and projects. This includes at least two lab experiences. The first experiment uses a batch column operated at total reflux to introduce students to multistage distillation including efficiency and energy balances at total reflux. A follow-on course explores pressure swing distillation without a lab component. Near the end of the year, the batch column operated at a constant external reflux ratio is used again in a lab project. This project engages students in process dynamics and challenges them to compare differences between theory and reality using the Rayleigh analysis.

Large enrollments forced us to teams of 8-10 people (not optimal) or to run experiments during times when safety and lab monitoring because serious issues. Simultaneously with struggling to deal with this problem, we discovered the work at UTC involving remotely accessible experiments. In fact, the UTC distillation column is physically nearly identical to the WPI column but much more flexible in its' operation. A partnership was quickly formed with the idea of probing learning differences between identical remote and hands-on experiments.

Methodology

We conducted a preliminary, pilot study that would inform a subsequent larger, more rigorous investigation. This spring we recruited 7 volunteer WPI teams from the cohort enrolled in the final sophomore year course to do the remote-only experiment using the UTC column. We also had 7 different WPI teams run the identical experiment locally using the WPI system.

Remote-only and hands-on-only teams conducted identical experiments with identical assignments and project reporting requirements. Evaluation had three components with direct

and indirect assessments, giving us some degree of triangulation. Both cohorts completed surveys managed by a third partner: UIUC. Course instructors compared final reports from remote and hands-on teams. An in-class quiz compared individual learning for students in the remote cohort compared to hands-on cohort in a quantitative manner. Qualitative measures include evaluating student attitudes about the experience and assessing students' improvement in ABET outcomes such as: (b) – design, analysis and interpretation of data; (d) – functioning on multidisciplinary teams; (g) – effective remote communication; (h) - have broad education necessary to understand the impact of engineering solutions in a global, economic, and environmental societal context; and (k) - using techniques, skills, and modern engineering tools (such as computers and web interfaces) necessary for engineering practice.

Results

Logistics

From the instructors' standpoint the logistics associated with running 7 teams in less than two weeks through either the local lab or the remote were roughly identical. The support team at UTC had to be ready to prepare the column for new runs on a daily basis, yet remote teams still had 24/7 access. Likewise, at WPI the support team had to cool down, recharge and restart the column on a daily basis (a 3-4 hour operation) to prepare for the following day's team. At least one hands-on team had to run during a weekend to complete their work. It would have essentially impossible to run 14 teams through the local WPI lab during the time allotted for the course. Hence, accessibility to the remote column literally kept us from dropping the experiment completely and going to something like a simulation instead.

Student Attitudes

Surveys from both cohorts were distributed to understand student perceptions about their hands-on and local experiences. Response rates were 52% for the local cohort and 75% for the remote cohort. There appeared to be little or no differences overall between the cohorts. In fact, for one item (improving your ability regarding ABET outcome b) 29% of the remote cohort selected "substantially new" compared to 18% for the local group. On the negative side, local students complained about a minor malfunction with an analytical instrument while remote students complained about minor server problems. In summary, we were pleased with these results. Remote students in general liked the 24/7 aspect and did not feel as if they had lost out on a valuable hands-on opportunity.

Student Learning

All reports were graded by the WPI instructor using the same rubrics. We evaluated presentation quality, analysis of results, and demonstration of appropriate concepts. Out of a possible 100 points, the average remote cohort score was 79.9 and the average local cohort score was 84.9. We gave an individual, in-class quiz about basic batch distillation concepts. Results showed an average score of 4.6 for the remote students and 4.9 for the local students, out of a possible 8 points. These results indicate that students who did the hands-on experiment, on the average, performed slightly better than students who did the remote experiment. However, as a class each cohort's performance was acceptable. These results are promising because they indicate that appropriately designed and implemented remote experiences can provide student learning at levels near hands-on experiences.

We completed a content analysis of the reports and quiz results to probe differences between cohorts regarding specific learning topics. Despite the differences in quiz scores there were no systematic differences between cohorts. For one item that asked about typical column transients, both cohorts scored similarly, indicating approximately equal knowledge regarding dynamic column behavior.

There were common deficiencies that were independent of remote or hands-on cohorts. These included a perplexing confusion of thermodynamic efficiency with stage efficiency; the typical mistakes with energy balance calculations; and another typical confusion over quantitative comparison of experiment to Rayleigh analysis. Students expect exact comparisons yet reality is never that predictable. In too many cases, the report presentation quality was barely acceptable. This result is not unusual given the end-of-semester time demands. However, remote students had access to archived data that could be easily and effectively displayed yet they persisted in printing pages of Excel files instead. In summary, it was difficult to extract any patterns or systematic learning differences between the cohorts. Most of the lab report scoring difference can be attributed to one particularly poor remote team, that most likely would have done equally poorly had they been in the hands-on cohort.

Our lessons learned in this first study included: running 7 teams through the WPI lab is difficult and requires 2-4 support staff to handle properly, while running 7 teams through the UTC remote lab is less difficult and requires one support staff with oversight by a faculty member. Student teams got unnecessarily frustrated with normal kind of issues. For hands-on teams it was use of simple specific gravity measurement while for remote teams it was server issues and software downloads. In conclusion the remote lab experience has great promise and can provide an acceptable learning experience compared to hands-on. WPI may introduce a simplified remote experience earlier in the year to better prepare students for this project, and future students will use Aspen BatchSep® simulations together with the lab experience to potentially enhance the learning experience.