HOW STUDENTS PERCEIVE THE MANY ROLES THEY MUST PLAY IN AN ENGINEERING LABORATORY COURSE

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Abstract – This work focuses on the unit operations laboratory course given by the Chemical and Biotechnological Engineering Department at Université de Sherbrooke. In order to help students develop their organisation skills, our department developed a formula based on “directive teams” and “operative teams” in which each team is put in charge of one of 9 experimental setups for the duration of the semester.

A team is said to be “directive” when they are working on their assigned unit operation and “operative” when they are working on the other unit operations. As part of a directive team, the students must elaborate an experimental plan and protocol that they will ask the other teams to carry out. The success of this formula depends both on the ability of the teaching team as well as on the student-student work environment.

The present project seeks to better understand the work environment in which the students carry out this task by polling them about their experience in the unit operations laboratory course given by our department.

Keywords: Chemical Engineering: Unit Operations: Laboratory: Teamwork: Polling.

1. INTRODUCTION

An engineer’s role is to manipulate matter, energy and information for the benefit of society [1]. He/She must have an understanding of the nature of the phenomena taking place; thus incorporating practical aspects, techniques and technology. The engineer traditionally acquires these aspects in his/her industrial internships and laboratory courses.

Laboratory courses represent an integral part of any engineering degree and encourage students to play an active role in their education. According to McKeachie and Svinicki [2], this role enhances the integration of knowledge by allowing the student to distinguish between acquired notions from those requiring further study. In addition, cooperative learning, present in most laboratory courses, promotes teamwork, mutual support, motivation and appropriation of the discipline’s unique jargon [2].

Chemical and Biotechnological Engineering (CBE) education normally includes laboratory courses on fundamental physico-chemical processes (e.g. measuring gas diffusivity and fugacity) as well as unit operations commonly used in these fields (e.g. continuous distillation, liquid-liquid extraction).

This paper focuses on the unit operations laboratory courses given by the CBE department at Université de Sherbrooke. These courses are entirely given in the laboratory; the theoretical background is fully covered by previous and concurrent courses. Unit operation courses typically include notions relating to experimental design, applied statistics, instrumentation and experimental measurements [3, 4]. Thus, the objective of these courses is master the fundamentals of unit operations in CBE by carrying out hands-on experiments using pilot scale units.

The CBE department at Université de Sherbrooke offers two distinct undergraduate degrees: chemical engineering and biotechnological engineering. These cooperative programs include 8 study semesters interspersed with 5 semesters of remunerated industrial internships. Although these two degrees are distinct, there are many similarities between their respective academic plans. Two unit operations laboratory courses are taught at the CBE department: GBT-220 Unit Operations Laboratory in Biotechnological Engineering and GCH-220 Unit Operations Laboratory in Chemical Engineering. Given the many similarities between GBT-220 and GCH-220, a conjoint analysis for these two courses is undertaken in this paper.

2. METHODOLOGY

2.1. Course logistics

The concepts of “directive” and “operative” teams lay at the heart of the pedagogical formula adopted for the teaching of laboratory courses by our department. This document is based on the concepts and nomenclatures presented by Fauteux-Lefebvre et al. [5] developed for a physico-chemical laboratory course. Following this format, each team is responsible (i.e. coordinates) of one
experimental setups during the entire semester. At the very beginning of the semester, each directive team is asked to develop an experimental plan (including the choice of parameters and experimental conditions) to collect enough data to analyze the relevant phenomena with as much rigor as possible in the time allotted over the course of the semester.

During the remainder of the semester, each directive team is responsible to explain its unit operation to the other teams (i.e. the operative teams) and to ensure that the experiments are carried out according to their protocol. It is important to remember that a team is “directive” when working with its own unit operation and “operative” when working with the other unit operations. Table 1 lists the main functions of the students throughout the semester.

Table 1: Outline of the semester.

<table>
<thead>
<tr>
<th>Progression</th>
<th>Main tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Presentation of the course, recall notions of experimental planning and laboratory safety measures.</td>
</tr>
<tr>
<td>Week 2</td>
<td>First laboratory session acting as directive teams; determining experimental plan and experimental protocol.</td>
</tr>
<tr>
<td>Week 3</td>
<td>Second laboratory session acting as directive teams; validation of the experimental protocol.</td>
</tr>
<tr>
<td>Weeks 4 to 11</td>
<td>Eight laboratory sessions acting as operative teams.</td>
</tr>
<tr>
<td>Week 12</td>
<td>Compilation and analysis of data obtained by the operative teams.</td>
</tr>
<tr>
<td>Weeks 13 and 14</td>
<td>Final presentations by the directive teams.</td>
</tr>
<tr>
<td>Week 15</td>
<td>Final individual examination.</td>
</tr>
</tbody>
</table>

On a weekly basis, the operative teams must present a brief analysis of their experimental data and provide a copy of their results to the directive team responsible for the specific unit operation. Thus, as the semester progresses, each directive team collects the experimental data required by their experimental plan in order to carry out an in-depth study of their unit operation.

2.2. Laboratories

Nine unit operations are typically seen in this course:
1. **Continuous distillation.** Separating toluene and heptane in an industrial packed column.
2. **Pumps and fluid circuits.** Pumping incompressible fluids inside closed conduits.
3. **Stirring.** Studying flow patterns using standard turbines in closed vessels.
4. **Filtration.** Filtering a calcium carbonate suspension using a multi-plate filter press.
5. **Liquid-liquid extraction.** Extracting acetic acid from methyl-isobutyl-ketone (MIBK) into water using a pulsed column.
6. **Heat exchangers.** Heating intake water using co- and counter-current coaxial systems.
7. **Spouting bed dryer.** Drying several grains types in a spouting bed dryer.
8. **Evaporation.** Evaporating salt water solutions using a climbing film evaporator.
9. **Absorption.** Absorbing sulfur dioxide from an aqueous solution using a packed bed column.

3. POLLING

The unit operations laboratory course has been taught using the directive/operative team formula since 2006. It is in this context, and in order to better meet the needs of our students, that we conducted a survey of the 122 students who attended the unit operation courses (GCH-220 and GBT-220) between 2010 and 2012. This survey comprised 20 questions and was answered by 54 of the 122 eligible students. It was intended to gather the students’ experiences, preferences, comments and recommendations relevant to this teaching formula. In particular, we set out to answer the following questions:
- Is the directive/operative team formula well received by and beneficial to the students?
- The directive team’s experience depends, at least partially, on their allotted unit operation. Are certain unit operations appreciated to a greater, or lesser, extent?
- Does the formula cause conflicts among the students? If so, what are the reasons? Do certain students tend to face such situations more often than others?
- What is the perceived role of the teacher?

4. RESULTS AND DISCUSSION

In order to analyze the survey results, student subgroups, based on the following criteria, have been identified:
- **Degree.** 54% of respondents completed the course as part of their training in chemical engineering; 46% in biotechnological engineering.
- **Gender.** 37% of respondents are female; 63% are male.
- **Internships.** The number of internships carried prior to taking the course was used as a general indicator of their professional experience including teamwork. 46% of respondents had completed 1-3 internships.
before completing the course; 54% had completed 4 or 5.

4.1. Overall perception of the course

The first target set was to determine whether the students are in favor of the proposed teaching formula or not. The following points were addressed: 1) overall assessment of the course; 2) assessment of students’ experience as a directive team; 3) assessment of students’ experience as an operative team and 4) teaching formula contribution to students’ learning efficiency. Results are presented in Table 2.

### Table 2: Overall assessment of the teaching formula on a numeric scale ranging from 1 (poor) to 5 (high). The value shown represents the median response.

<table>
<thead>
<tr>
<th></th>
<th>Overall appreciation</th>
<th>Appreciation as a directive team</th>
<th>Appreciation as an operative team</th>
<th>Perception that the formula contributes to learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire population</td>
<td>4</td>
<td>3.5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Academic degree</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Biotech.</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>Male</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Number to internships carried out before the course</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>4 or 5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Results show a relatively high appreciation and uniform evaluation for each of these four aspects, as quantified by the median of answers. Although the results suggest that the appreciation of the experience as a directive teacher may be slightly lower than the others, the numerical results do make it possible to draw clear conclusions on the point. This point will be discussed again in Section 4.2.

Interestingly, these results show that students completing their undergraduate degree (who have carried out 4 or 5 internships) consider that this formula helped their learning as much as those who took the course earlier in their degree (1-3 internships). Recall here that students in the CBE program at Université de Sherbrooke is cooperative and the students perform their internships in industrial settings. This leads one to conclude that the course remains relevant despite the fact that many students have worked alongside many of these unit operations during their internships.

4.2. Experience as a member of a directive team

Each team was assigned the role of directive team for one of the unit operations. It is therefore possible that the experience of the teams depends on this initial assignment. To determine the relationship between the experience of the teams and experimental setup that had been assigned to them, the student responses were compiled by unit operation. Fig. 1 illustrates the answers of the students regarding the: 1) overall assessment of the course; 2) assessment of their experience as a directive team, 3) assessment of their experience as an operative team.

![Fig. 1. Overall assessment of the course, as a member of a team teacher, or as a team member operatively (median values): Numeric scale ranging from 1 (poor) to 5 (high).](image)

As discussed in Section 4.1, the majority of the responses are relatively high and uniform for each unit operation, but again, experience as a directive team seems slightly less popular than other aspects of the course. If this is the case, students may simply be reluctant to incorporating this new educational tool as stated by Nonesuch [6]. “Before I could successfully introduce such new activities, strategies, and techniques, I had to learn to honor and respect student resistance, to work with it, and to bring students on board with my reforms.” Finally, the results also suggest that two of the unit operations, filtration as well as the pumps and fluid circuits, may not be as appreciated by the students, regardless of their gender or degree of study.
4.3. Team interactions

In order to better understand team dynamics in this course, the students were asked whether they had experienced any conflicts: 1) with operative teams when acting as the directive team, or 2) with directive teams when acting as an operative team. In addition, they were asked to distinguish between conflicts occurring before and after the mid-term break. The results show a clear trend:

- For the period before the mid-term break, 31% (17/54) of the students said they had experienced conflicts with one or more of the directive teams while only 13% (7/54) of the students said they had conflicts with one or more of the operative teams.
- For the period after the mid-term break, these numbers fell to 11% (6/54) and 9% (5/54), respectively.

First, these results show a large reduction in the number of conflicts occurring over the 15-week semester, apparently indicating that students quickly adapt to a teaching formula to which they are not familiar. Moreover, the residual conflicts appear more often associated with an increased workload late in the semester that to interpersonal strife:

- Before the mid-term break, the quality of the other students’ work was involved in 78% of conflicts; delays / deadlines were cited in 28% of cases while communication problems did not seem to cause any problems (0%).
- After the mid-term break, the quality of the other students’ work remained stable at 70% whereas both delays / deadlines and communication problems both rose and were cited in 60% and 30% or conflicts, respectively.

The difference between directive and operative teams leads us to the conclusion that: 1) some directive teams were in conflict with several operative teams, or 2) some directive teams were not aware of the situation that had developed with one or more operative teams. The data do not make it possible to conclude either way with any certainty. However, early in the semester, 86% (6/7) of students who had conflicts as a directive teams also reported having conflicts as operative teams. This suggests that some teams often found themselves in conflicts regardless of their role in class.

In addition, their development as future engineers, represented here by the number of internships they had carried out before taking the course, seems correlated to their ability to avoid conflicts. At the beginning of the semester, 86% (6/7) of students who had experienced conflicts as a directive team and 71% (12/17) of students who had experienced conflicts as operative teams had only had 1-3 internships, a population which only accounted for 46% of respondents. Although this may be partly due to differences between cohorts, we believe it is rather a sign of their personal and professional development during their degree.

4.4. Perceived role of the teacher

When asked what they perceived the teacher’s main tasks to be, 65% of respondents answered “organizing the semester”, followed “assistance with data analysis” (37%) and “managing student interactions” (33 %). The other tasks, namely “teaching new subject matter” (26%), “assistance with the experiments” (26%) and “surveillance” (11%), were identified as representing a small portion of the teacher’s tasks. It is important to mention that the teacher is assisted both by teaching assistants, who contribute to the correction of the written reports, and by laboratory technicians, who ensure the proper running of the unit operations.

Managing student interactions was identified as being one of the main roles played by the teacher. According to Morris-Rothschild and Brassard [7], the personality of the teacher can have a greater impact on the resolution of student conflicts than may have the demographic composition of the school. In this regard, students were also asked to indicate if, following a conflict, they warned the teacher of the incident. A summary of results is presented in Table 3. About half the students warned the teacher about the situation, either before (56% - 10/18) or after (50% - 5/10) the mid-term break. Although there may have had a slight overall decrease in the number of reports of incidents in the current semester, an analysis of subgroups of students shows no clear trend.

Nevertheless, it is interesting to take a further look at students who experienced a conflict both before and after the mid-term break. First, we see that an equal proportion of students (67% - 4/6) saw fit to talk to the teacher before and after the mid-term break. It is important to note that it is in fact the same students who spoke with the teacher both before and after the break. We therefore conclude that these students consider it relevant to keep the teacher informed of the state of team interactions. This observation seems to support Morris-Rothschild and Brassard [7] in that the teacher can have a real impact on group interactions.
The authors would like to thank Serge Gagnon and Stéphane Guay, the course technicians, for their important contribution to the smooth running of the course. The contribution of numerous teaching assistants over the years has not only made the course possible, but truly pleasant; this contribution is greatly acknowledged.

References


