CBE Undergraduate Capacity: Resources and Limitations

With the increase in interest in the Chemical Engineering major, undergraduate enrollment has increased to the limit set by the department. Enrollment in the program was at maximum capacity through much of the 1980’s, when graduating classes were 110-120 students. Undergraduate enrollment dropped in the late ‘90s following trends both at UW and nationwide. Student interest in chemical engineering as reflected in SOAR and pre-engineering statistics for intended majors is now well above the current official department capacity of 104 students/year, so it is useful to consider factors that determine the department’s undergraduate capacity:

1. Semester laboratory capacity
2. Summer Laboratory capacity
3. Classroom availability
4. TA staffing
5. Faculty size

Classrooms, TAs, and faculty are all related to course scheduling. The CBE degree has 12 required CBE courses and 2 CBE electives. Because of the large numbers of transfer students and co-op students in our program, each required course is taught in both semesters with typical enrollment of 35-50 students. When enrollment dropped, we considered conserving resources by shifting some courses to once/year, but could not schedule this and accommodate student needs. When enrollment was high in the ‘80s, some courses were taught in larger lectures while others were taught in 3 sections (2 in one semester, 1 in the other) to keep class sizes below 50. In most years class enrollments vary up and down by 5-8 students around the long-term trends. Some of this variation is deterministic propagation of the Fall/Spring high/low enrollment of students in CBE 250, while other variation from students taking semesters off for coop, or taking 16, 14, or 12 credits/semester can damp the large 250 oscillation. Since many of our courses have strict prerequisite CBE courses, we prefer to have our actual course capacity well above the average throughput number so we do not have to maintain waiting lists or defer students who are mid-program into another semester and delay their graduation date.

All factors are currently operating to make sustainable operation at recent levels of less than 90 students/year possible. Expansion to larger numbers will require debottlenecking of multiple components.

**Semester laboratory capacity:** CBE 324 – Transport Laboratory is the junior measurements laboratory, and has historically been the bottleneck in the curriculum. CBE 470 – Process Control also has a laboratory component that can be a limitation. CBE 324 is an afternoon laboratory course with 4 sections that meet Tuesday-Friday (Monday is typically used for equipment setup and maintenance). Each section has had 12 students working in 3 groups of 4 on parallel experimental apparatus. Historical capacity has been 4 x 12 students, or 48/semester and 96/year. By overloading and accepting 13 students/section, we’ve raised the course enrollment capacity to 104 students; this allows flexibility for accommodating students who drop, or have scheduling problems. Recent COE-funded projects (DIN, tuition differential, and 2010 programs) have allowed us to replace old apparatus and construct 4 multipurpose equipment kits so we now plan to handle 4 groups of 4 students per section. This will increase capacity to handle 64 students/semester (128/year if sustained!). It will also allow operation with 3 sections in semesters when 48 students request the course, saving on TA/instructor assignments.

CBE 470 is a lecture course that also operates an afternoon laboratory with 4 sections of 12 students. Students work in groups of 4 for each experiment; since this laboratory has only a single apparatus for each experiment, typical operation involves matching experiments in 3-week clusters and having student groups rotate through in the 3 weeks. This is more efficient in use of equipment, but requires additional preparation and training for the lab TA. To increase capacity to 16 students/session, the instructional staff has reorganized the lab schedule to identify 4-week rotations, while maintaining coordination between experiments and lectures.

Traditional capacity: 96-104 students/year

Upgraded capacity: up to 128 students/year

**Summer Laboratory capacity:** CBE 424 – Operations and Process Laboratory is the capstone laboratory course that students take in their final summer in the program. As a result, few CBE students graduate in May; large cohorts graduate in August and in December. It is an intense 5-week course that meets 40 hours/week. Students conduct 5 Formal experiments, 4 Informal experiments, and compose individual reports on each. With 9 written reports, 1 rewrite, and 1 oral report, this course also satisfies the Communication B component of the UW General Education requirement. Each summer, we offer this course in two 5-week sessions in Madison. We also have overseas sections as options for highly qualified students – Oviedo, Spain (14 students, along with Iowa State U), and Vienna, Austria (12 students, along with Clemson U). The overseas sections are staffed by local instructors in addition to one faculty member from each of the participating universities. The Madison course is staffed with a combination of UW faculty and experienced visiting instructors. For typical enrollment levels of 32-40 students the instructional staff is set at 5 faculty. When undergraduate enrollment was extremely high in the early 1980’s, sections of 48 were operated with 6 staff. One year 3 sections in Madison were operated (over a 13-week summer), but that experiment was not successful. As program enrollment rises again, we will need additional resources if Madison enrollment is to go above 40/session. We are also investigating possibilities to send more students overseas by either increasing our allotments in Oviedo and Vienna, and by starting to send a small group to Lyngby, Denmark (Danish Technical University) to try the international summer lab that they have begun offering to US universities there.

Current capacity: 2 x 40 Madison sessions, 14+12 overseas = 104/year

Extended capacity: 2 x 48 + (14+12+5) = 127/year

**Classroom availability:** Most CBE classes are taught in nearby classrooms of medium capacity. We use 3024 (54 seats), 3032 (63 seats), and 2239 (49 seats) for most core courses. Indeed, there are first-semester seniors who may have 3 consecutive classes in 3032 EH on MWF mornings and barely move out of their favorite seats. Larger service classes with enrollment beyond the department may meet in 1227 (103), and occasionally classes meet in other EH rooms. When classes get scheduled in other buildings (Russell Labs, Computer Science, etc.), this is rarely accepted by students or faculty. Engineering Hall has many classrooms in this mid-range size (47-63 seats) and also smaller rooms suitable for recitations (30-35 seats). If our average throughput goes above 50/semester (100/year), handling high enrollments of 60% of annual rate will require either splitting the class into two smaller groups fitting the available rooms, or scheduling many classes of ~70 students into the rare larger rooms. In Engineering Hall, 1800 is oversized and heavily used, 1610 is not available for routine instruction, and other large rooms (>60 seats) are few. Shifting classes to nearby Mechanical Engineering only give a similar room-size range and displace ME courses from those heavily-scheduled rooms. Any general increase in CBE enrollment will affect all 11 core courses, and result in individual instructors needing to decide between creating a 3rd section each year or finding new, larger rooms for the semesters with above-average enrollments. Thus, 5-6 courses each semester would need extra rooms or larger rooms. Such an increase could not be handled on a case-by-case basis, but would require a planned change in operating mode.

The current university General Assignment Classrooms listing from the web is appended.

Current capacity: 2 rooms of 55 students/section = 110/year

Expanded capacity: alternate 45/semester and 80/semester = 125/year

**TA staffing:** Most core courses use Teaching Assistants for recitations or lab sections. We plan for 1 TA/20-25 students; different courses or faculty have slight variations on when they recommend an additional TA or recitation section to support a large class. For a while now, we’ve required all PhD graduate students to serve as TA in their 2nd and 3rd-years. At typical, stable graduate class size of 23-28, this amounts to about 25 TAs/semester. We now have 4 TA/instructor positions in 324 and 470 labs, and 2 or 3 TAs in 250, 310, 311, 320, 326, 426, 430, and 450. We use 3 TAs in graduate courses in Fall, and 2 TAs in Spring. We use senior SAs in 255 and undergraduate paper graders in many of these courses to manage the homework evaluation component. This adds up to 29-30 TA/instructor spots to fill each semester, plus 10-15 paper graders and SAs. In recent years we have gained extra coverage by assigning academic staff like Rafael Chavez and Eric Codner to lead sections in the 324 lab related to course improvement activities; this is a temporary solution and is neither cost-effective nor sustainable. This semester we’re trying the experiment of hiring several additional TAs from outside the CBE graduate student pool. It has been difficult to identify qualified students from other departments and backgrounds, and to match them to courses suitable to their skills. At the semester end we’ll decide if this experiment can be expanded.

Other alternatives to staff additional sections as enrollments increase could include hiring more seniors to carry duties for lower-level classes, or increasing the PhD graduate student TA obligation. One possible option would be requiring a 3rd semester of TA from students beyond the 4th year who are not in their final semester. Increasing TA workload too much would hurt competitive recruiting in the graduate program, and increasing graduate student body size would be limited by research funding and lab/office space.

During peak enrollment in the ‘80s, we had more TA contributions from a similar sized graduate student body. There was no explicit TA requirement, but an expectation to TA twice during the PhD. A small cadre of students not on research support served as TA many semesters in a row, with the TA supplemented by a departmental RA while they were in good research standing.

These discussion-section TAs receive a 25% TA appointment, while lab TAs work at the 37.5% level. Our TA budget is funded at 5 FTE/semester; we are presently using TAs at 7.75 FTE augmented from other department resources. The paper graders are paid for 8-10 hours/week as LTE staff, at a $15.10/hour rate and a total semester cost comparable to a 25% TA. This appears to be from the ‘student hourly’ part of the budget. Providing an increase in either TA or grader staffing would also involve commensurate budgetary increases.

Current capacity: 90 students/year

Expanded capacity: ???

**Faculty size:** Larger enrollments require suitable faculty and academic staff to cover the core courses and the chemical engineering electives. If we only made all classes larger, we could increase capacity by any desired ratio. As described above, this is not realistic. As we add more sections of core courses, and more capacity for the CBE electives required (6 credits/student), we will need more instructors.

In recent years we have provided severely limited elective choices and strained to cover the required, core courses. Indeed, a common complaint in the EBI survey and from advising sessions is that students are disappointed to have so few electives of the many modern courses that could be taught by our active research faculty. In recent years we have put more staff into the core courses and graduate core courses, at the cost of offering few or no CBE elective courses. In the peak-enrollment era of the 1980’s, we had a larger faculty (20 professors, 2 teaching academic staff, and sabattical visitors teaching). Also, 5 of our senior faculty had little or no research activity and typically taught heavy undergraduate courseloads. We do not have these resources, and need more staff to return to that level of course coverage.

Current capacity: 90-100 students/year

Expanded capacity: 125+ students/year with 20% more teaching resources

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