

AC 2010-67: INDUSTRY INSTRUCTORS FOR A SPECIALIZED ELECTIVE COURSE

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Abstract

The University of Tulsa (TU) offered an elective course entitled “Combustion Engineering” for its chemical engineering students in the area of combustion technology taught by John Zink Co. LLC (JZ) which is a world-renowned supplier of industrial combustion equipment, such as burners and flares, to the process industries. This arrangement had many benefits for both organizations. TU could offer a course to their students in an area that was not a specific strength of its faculty. TU students had the benefit of learning professional practice from experienced industry engineers. JZ had close access to top senior and graduate chemical engineering students that were potential interns and permanent hires. JZ also benefitted from high quality student final project research reports and presentations in topic areas suggested by and of interest to the instructors. The main area for improvement for future classes is better coordination among the instructors for the quantity and difficulty of homework and exam problems, better consistency on grading projects, and eliminating unnecessary duplication. The main disadvantage of this instruction format is the difficulty establishing a relationship between students and multiple short-term instructors due to the short contact time. Student end-of-course assessments were very positive. This course will now be offered annually as a chemical engineering elective. This paper discusses the details of the course including the benefits, challenges, and lessons learned for this college-industry partnership.

Introduction

There are many ways that industry and academia can collaborate to educate engineering students. Industry can provide individual instructors to teach existing courses as adjuncts or visiting professors.¹ McMasters and Komerath (2005) describe a program developed by Boeing called “Boeing Fellow on Campus Program.”² In that program, Boeing employees acted as adjunct or visiting faculty at universities where Boeing recruited engineering graduates. For those universities located at a distance, the Fellow actually temporarily lived on or near the campus during the course. However, that arrangement proved to be unsatisfactory for the employees and the program was eventually discontinued.

Industry can help provide new course content, for example for emerging technologies, which can be taught by academia.³ Adjunct instructors from industry can temporarily replace faculty on sabbatical or on leave,⁴ help handle temporary increases in student course enrollments,⁵ relieve full-time faculty so they can do research,⁶ or co-teach with full-time faculty to help bring professional practice into the classroom.⁷ For example, Texas Instruments helped co-teach a heat transfer course with the University of North Texas and provided students with examples of electronic cooling problems and devices used to solve them.⁸ This was outside the scope of the typical heat transfer course and gave students a specific example of how the course materials were applied to actual industrial problems. Adjunct instructors can also teach specific topics in a course where

faculty are less knowledgeable,^{9,10} teach entire courses outside the specific area of expertise of the faculty,^{5,11} and teach courses at off-campus locations.¹² One example is using adjunct professors from industry to teach courses in a non-traditional professional engineering and technology graduate (Masters) program.¹³

Industry can partner with universities to provide guest speakers to tell students about various aspects of the “real world” of engineering.¹⁴ Many schools have a seminar series where different guest speakers from industry present each week to give students a broader view of various engineering disciplines. Companies can host field trips where universities visit local industrial facilities to see actual equipment in operation.¹⁵ Cooperative positions and internships allow students to work side-by-side with engineering professionals to see how what they have learned in class is applied in practice.^{16,17} Industry sponsors senior design projects to produce some type of product of interest to them while simultaneously educating students by allowing them to apply their knowledge and skills to an actual problem.¹⁶ Some universities have used industry to help teach senior design courses as part of capstone projects;¹⁸ Lehigh University refers to these adjuncts as “Professors of Practice.”¹⁹ Industry can sponsor research projects with faculty that also include student workers. Industry can also provide facilities for students to conduct research if these are not available at the university. Industry can provide formal mentors for university students and participate in supervisory thesis committees for graduate students,¹¹ including sponsoring industrial theses that are carried out in industry.¹⁴

This paper discusses a somewhat unique industry-university partnership that included industry designing and teaching an engineering course at a local university. In this case, industry developed and delivered an elective course of interest to the university which did not have the specific expertise in the subject area. The course combined previously learned theory by the students in other engineering courses with a large component of application.

The dean of engineering at TU was interested in offering an elective for engineering students in the area of combustion technology. TU is located in Tulsa, Oklahoma which has a long history of involvement in the combustion industry with many internationally recognized burner and heater manufacturers. JZ is a world-renowned supplier of industrial combustion equipment, such as burners and flares, to the process industries. JZ offers continuing professional development short courses related to its technologies to practicing engineers and plant operators through its John Zink Institute (JZI).²⁰ Because of the close proximity of JZ to TU (about a 15 minute car ride) and because of the many connections between the two organizations, JZ offered to teach a new course at TU entitled Combustion Engineering. JZ was given the flexibility to design the course content based on its extensive experience teaching these topics at its JZI. The ultimate success of the course would be judged by two factors: the student evaluations to determine if TU would offer the course again and feedback from the voluntary instructors to determine if the experience was satisfying enough that they would be willing to do it again.

Combustion is not a specific area of research at TU so there were no existing professors with particular expertise in this subject. Combustion courses are typically offered by either the mechanical or chemical engineering departments in universities, depending on the school. In this case, the chemical engineering department decided to offer this new course which would become an additional elective for seniors and graduate students. The course allowed students to apply theory learned in previous courses to solve actual problems encountered in the combustion industry. For example, the senior undergraduate and graduate students previously took courses in reaction chemistry, fluid flow, and heat transfer. These topics were briefly considered in the new course but from the specific perspective of industrial combustion. Many new topics were also included as well and will be discussed later.

Course Details

The course description read as follows:

Atmospheric pressure industrial combustion processes will be studied in this course. Approximately the first half of the course will focus on the fundamentals related to these processes including fuels, combustion chemistry, pollution emissions, fluid flow, and heat transfer. Some advanced topics including computational fluid dynamics, liquid fuel atomization, noise and combustion testing will then be presented. The last part of the course will focus on applications including boilers, process heaters, flares, and thermal oxidizers.

The course was initially offered in the spring 2009 semester as a three credit course open to senior and graduate chemical engineering students. It was offered twice a week for 75 minutes per class around lunch time which minimized the disruption to the work schedules of JZ engineers. Nine students completed the course: two graduate students (one male and one female), six undergraduate students (four male and two female), and one professor who audited the course to get Professional Development Hours required to maintain a professional engineering license in the state of Oklahoma. One female undergraduate student dropped approximately half way through the course due to overall work load.

The course schedule is shown in **Table 1**. The first half of the course focused on fundamentals, while the second half focused on applications. Twelve different instructors were used during the course where all taught for a single week (2 classes) except one (instructor #2) who taught for two weeks.

Table 1. Course schedule.

Week	Topic	Instructor #
1	Introduction	multiple
2	Fuels	1
3	Combustion Chemistry / Thermodynamics	2
4	Pollution Emissions	2
5	Fluid Flow	3
6	Heat Transfer	4
7	Computational Fluid Dynamics	5
8	Liquid Fuel Atomization	6
9	Midterm Noise	7
10	Combustion Testing	8
11	Boilers	9
12	Process Heaters	10
13	Flares	11
14	Thermal Oxidizers	12
15	Project presentations	multiple

The grading scheme was as follows: 25% quizzes and homework, 25% Exam 1, 25% Exam 2, and 25% project. Exam 2 was a non-cumulative final exam. Instructors were free to choose the content and format for quizzes, homework, and exams. Students were given a list of potential topics for the projects, but they could also suggest their own topic subject to approval by the instructors. The list of potential topics was generated by the instructors interested in finding out more about a particular subject. The eight topics selected by the students (the professor did not present a topic) were:

- burner circle / heater troubleshooting – effects on design in the field,
- carbon sequestration technologies,
- electrostatic precipitators,
- emissions from flares,
- global warming legislation effects on industrial combustion,
- NOx emissions for fuel gas mixtures,
- selective catalytic reduction systems, and
- selective non-catalytic reduction systems.

Undergraduate students were required to submit a 5-7 page single-spaced paper with at least five references from books and refereed journals and to deliver a 15 minute presentation. Graduate students were required to submit a 12-15 page paper with at least 15 references and to give a 30 minute presentation. The paper was worth 60% of the project grade and the presentation 40%.

The textbook for the course, *The John Zink Combustion Handbook*,²¹ was written by JZ. The students were given a free copy of the text, which lists for nearly \$200, by JZ. Many of the instructors were authors who wrote about the topic they taught in the course. Most instructors provided the students with physical or electronic copies of their materials which were usually PowerPoint slides. Many instructors made generous use of photographs and video clips of actual equipment in their presentations.

The format for the course was predominantly lecture although there were some in-class problems and discussions. The students also made a trip to JZ during the early part of the semester to see the facilities and get a personalized tour. This was done near the beginning of the class so the students would have the benefit of seeing some of the equipment they would be discussing in the course.

Student Performance and Feedback

A summary of the performance for the eight students taking the course for credit is shown in Table 2. The quizzes and homework component consisted of seven homework assignments, five quizzes, and one short paper, each with different weightings depending on the scope.

Table 2. Course grades.

Component	Minimum	Average	Maximum
Quizzes & homework	73.3%	85.5%	93.5%
Exam 1	60.0%	78.4%	96.0%
Exam 2	57.0%	78.9%	94.0%
Project	85.2%	93.5%	97.4%
Total	71.6%	84.1%	93.0%

Student end-of-course assessments were generally positive. The written comments were as follows:

- “I think the teachers worked very hard for this class. I think more TU instructor participation could have helped them be more cohesive. For example, grading was difficult for the students to get used to because a new person graded each assignment.”
- “I love having professionals from the Real World come in and talk about their field of expertise. While I know it takes a lot of effort and coordination, at least one class a semester should be offered in this fashion.”
- “The course was very informative and well organized. The only piece of the class that could possibly be improved on is reviewing the material each professor used to lecture. It seemed as if a lot of material was repeated. Overall, the class gave a good industrial perspective of the topic and was generally perceived as useful.”
- “This course was very interesting and will prove to be very useful in my internship this summer. I enjoyed learning directly from the industrial perspective.

The grading scheme was difficult, however, since there were so many professors. I would recommend something more standardized if the class was offered again.”

Benefits

This arrangement had many benefits for all three primary stakeholders: TU, JZ, and the students. TU could offer a course to their students in an area that was not a specific strength of its faculty. One of the graduating seniors taking the course went to work for a combustion company located in Tulsa and benefitted from the knowledge gained which should have been directly applicable at his new employer. The cost to the university to offer this new course was very minimal as there was no labor cost to TU because the instructors' time was donated by JZ. The relationship helped strengthen the ties between TU and JZ which employs many graduates from TU.

TU students had the benefit of learning from experienced industry engineers. All instructors had at least 10 years of industry experience and some had more than 20. A common complaint of university engineering students in general is that their education focuses heavily on theory with relatively little discussion of application. This course presented a fairly balanced mixture of theory and application. Students toured world class industrial combustion test and virtual reality modeling facilities. Each student received a free copy of the course textbook. Nearly all of the twelve JZ instructors (eight with Ph.D.s) were authors of the textbook.

JZ had close access to top senior and graduate chemical engineering students that were potential interns and permanent hires, which was an important motivation to deliver this course. The more intimate exposure to the students can add unique information useful in the hiring process. Instructors not only see students' grades in a course directly relevant to the company's business, but they also see work habits, enthusiasm, and participation. These characteristics are more difficult to determine from interviewing alone. Instructors can see which students come to class regularly and on time, which ones turn in complete and accurate assignments on time, which have read the materials in advance, and which actively participate in the class. All of the course instructors also teach as part of JZI and enjoyed teaching, so this was a more prestigious outlet for that passion. Teaching at TU was entirely voluntary and enthusiastically endorsed by the instructors. Feedback from the instructors after the course was very positive and all indicated their desire to teach their subjects again if the course would be offered again. The preparation time for the instructors was relatively minimal since all had taught their subjects before and had existing materials they could use with minor modifications. JZ also benefitted from the very high quality student final project research reports and presentations in topic areas suggested by and of interest to the instructors. In some cases, the instructors learned new information from these projects.

Challenges

As identified in some of the written end-of-course student comments, the variety of instructors was a major challenge for many reasons. It was nearly impossible for the students to develop any type of relationship with the instructors because they usually only

met for two class periods. This included simply learning the student's names – name tags were posted on each student's desk to aid the instructors. Some instructors handed out hard copies or emailed electronic copies of class notes, while others did not provide any notes. In the latter case, students noted the difficulty in taking notes on detailed PowerPoint slides while trying to keep up with the instructor. The teaching styles of any two instructors will normally vary so adapting to the styles of twelve different instructors proved to be somewhat challenging for the students. The grading standards varied by instructor so students were not always sure what was expected. This was particularly an issue with the final projects as each was graded by a different instructor with the appropriate expertise in the topic area. However, there was not as much variance as might have been expected because the quality of the projects was so high. The quantity and complexity of assignments varied considerably by instructor. Some instructors assigned homework and gave quizzes, while others did neither and one assigned a brief topical paper. As sometimes happens the first time a course is offered, the exams turned out to be more difficult than intended. While all instructors used in the course had previous teaching experience, some had no previous experience teaching college students. This may have explained some of the variance in the course content and difficulty.

One challenge of using multiple instructors was handling quizzes and homework given by one instructor and returned to the students by another instructor. Any questions about grading or solutions were generally directed to the instructor who gave the quiz or homework. Since that instructor was not in the classroom when these were returned to the student, the student normally had to call or email the instructor. None of the JZ instructors had an office at TU, nor did they have any set office hours which made it more difficult for students to discuss issues face-to-face after an instructor finished teaching their topic(s).

Another important challenge in the course was the broad scope of topics covered. For example, process burners are taught at the JZI over four full days but covered in only two and half hours total in the TU Combustion Engineering course. Due to time constraints, instructors had to greatly scale back the content. Therefore, students were only exposed to the key aspects of each topic. Instructors were given the freedom to include whatever they felt was most important concerning their topic, but this also led to some duplication of coverage for certain topics. For example, process burners were covered multiple times in a variety of topics such as pollution emissions, fluid flow, heat transfer, and process heaters.

The book used for the course does not have any problems at the back of each chapter like a typical text book. This meant that instructors had to develop their own problems which varied considerably in length and difficulty. Some instructors chose not to give any homework or quizzes so the workload varied considerably from week-to-week

Conclusions and Recommendations

This course will now be offered annually as a chemical engineering elective. JZ maintained close contact with the chemical engineering department head before, during, and after the course. This was very helpful to ensure JZ was following the proper TU

procedures. This type of partnership works best when industry and academia are in close proximity. Course scheduling and logistics are important to make it as convenient as possible for both the instructors and the students. Minimizing the number of classes taught by a single instructor reduces the amount of time needed to prepare for the course and makes it easier for instructors to schedule other work-related activities such as business trips around the class meetings.

Although there are some advantages to multiple instructors, such as minimal work disruption and using the specific expertise of the instructors, there are also some challenges. Close coordination between the instructors is recommended. While the instructors held several meetings before and during the course, not enough specifics were covered. For example, general guidelines should have been developed on assignments and grading so there was more consistency for the students. Better coordination is needed to eliminate unnecessary duplication of content. Warning students up front of the challenges of having multiple instructors would likely better prepare them for the unique course format and may reduce the possible resulting stress.

Based on student and instructor feedback, this was an example of a successful university-industry partnership that can enhance learning, increase options for electives, and provide students with exposure to industrial practice including state-of-the-art technologies and facilities. In the course discussed here for example, students were shown a new technology that was recently patented but had not yet been commercialized. Improvements are recommended for future editions of this class to address some of the challenges associated with having numerous instructors in a single course.

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