

# **Creativity, Community Awareness, and Engineering Design**

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## **Abstract**

Engineering undergraduates approach the senior design course with trepidation, for here is a course challenging them to make sound decisions based on knowledge studied and understood in the previous three years. The challenge to the professor is to put before the class a worthy problem that commands absorbing and semester-enduring interest. The professor has other constraints: the problem solution should be unpublished; the problem must be meaningful; the problem should assist students to achieve career goals and become responsible professionals in society. Ideally, the project would offer students the potential of presenting the results outside the university. What better way to encompass these demanding criteria than assign problems whose solutions are of direct benefit to the community? Our results from such an approach have generally fulfilled the stated criteria. The design projects have led to student presentations before technical societies and have benefitted student-employment interviews. More importantly, the approach has made the student more aware of his higher responsibilities as an engineer.

## **Introduction**

Would not any professor revel in the sight of his students engrossed in their studies, even excited about the outcome, working together toward a common goal? The involvement occurs spontaneously when the students are creative not only for a grade but for a higher purpose.

To motivate students in creative, meaningful endeavors, we have assigned projects in their terminal design course useful to the community--contributing to economic development, improving environmental quality, or otherwise benefitting society--yet requiring the traditional concepts studied in engineering for solutions.

As a culmination of the course, the students are encouraged to present the work to audiences outside-the-classroom. Creative solutions of technical problems impacting society afford opportunities for outside presentations by the students and afford recognition by the engineering as well as nontechnical community. Presentations and publications are heady occurrences at

the beginning of undergraduate students' careers. Furthermore, the approach is a needed influence on the student's view of engineering as well as the public's view of engineering. Foremost of the course's secondary benefits in the student's mind, however, is the attractive addition to the resume. For several reasons, the project may be of interest to a company in a job interview.

## **Procedure**

The organization of the course is outlined in the following discussion.

### **1. Topic Selection**

Obviously, selecting an appropriate topic is critical. Here, in order to select suitable projects, the professor should be aware of state and local community needs; he should be aware of technology developments from R&D publications; he must judiciously mesh the information into an assignment. Projects dealing with undeveloped natural resources, industrial contamination, recycling from waste disposal, and promoting economic development of the state have proven to be worthy.

For example, four projects assigned to senior design students in chemical engineering were the following.

- (a) Design a process to utilize major, untouched lignite reserves in the state.
- (b) Design a process to clean a major industrial contamination site in the state.
- (c) Design a process to utilize natural CO<sub>2</sub> reserves for economic development in the state.
- (d) Design a plant to recover platinum group metals from catalytic converters of abandoned cars.

After being presented the problem, students in teams of four outlined their concept and received

feedback from the professor before proceeding with their preliminary design.

Access to data for creative design projects can be a limiting factor. Consequently, the World Wide Web appearance has made more creative undergraduate assignments feasible. With judicious selection, the Web provided information, especially on equipment, otherwise difficult for students to find. On some topics recent nationwide research could be reviewed on the Web.

A concerted effort to obtain information from a wide range of conventional sources was necessary. Students ordered critical articles not available in the library. They surveyed library databases to locate current information in engineering periodicals, patents, chemical abstracts, and government documents. In limited cases, students consulted with other faculty or industry personnel on specific questions. When possible a guest speaker came to the classroom.

## 2. Project Development

While lectures on equipment sizing and selection, process calculations, economics and report assimilation continued, the groups developed their preliminary design and obtained background information. The professor periodically scheduled mandatory group conferences to discuss their work.

The students were required to develop a comprehensive economic model on spreadsheet to evaluate the profitability of their designed plant. The model included equipment costs, total capital investment, raw material costs, operating costs, total product costs, estimated cash flows for the years of operation, federal and state taxes, a discounted cash flow rate of return after taxes, payout, and net present value profit. With the model, detailed profitability analysis could be made with a minimum of inputs. More importantly, effect of alternative decisions on profitability could be viewed at will. With the model they could readily make sensitivity analyses on economic effects of certain aspects of their final design, for example, the effect on profitability of a raw material cost. The sensitivity analysis as an integral part of the final report was especially informative.

## 3. Presentation of Results

A final written report of prescribed format was submitted on the last day of class. During the prior week, each group made a formal oral report using presentations software and computer projection. Questions from the audience were fielded by each team in a manner expected in industry at the conclusion of a project.

# Projects

## 1. Lignite Project

Mississippi has the second largest lignite deposit in the country--some nine billion tons of the low-rank coal near ground surface. The Mississippi lignite has about one-half of the heating value of bituminous coal but a low 0.65% sulfur content. Found in the Wilcox formation, running as a crescent shape from the north boundary of the state to the central-eastern boundary, the lignite is a potential energy source, equivalent to 9.5 billion barrels of oil, that could supply the electrical needs of the state for the next 100 years.<sup>1</sup> The natural resource has never been used in the state.

The challenge of the students was to make a preliminary design of a power plant to utilize the lignite, estimating costs and profitability, determining the best location, and designing it environmentally benign. Properties of the lignite and geologic maps were obtained from the Bureau of Geology.

By happenstance, a month after the semester's end and the student design project completed, an announcement was made in the Wall St. Journal<sup>2</sup> of the intent of Phillips Coal Co. and CRSS Inc. to build a \$500 million power plant using 3 million tons per year of Mississippi lignite. (Although the student group's work played no part in the deliberations, the parallel corporate activity indicated the project assignment was on target as to state and community needs.) The announced project intentions of the two companies<sup>3</sup> provided an interesting check for the students of their assumptions and calculations as well as creating intense interest in the community.

The preliminary design of the students was fairly close to the eventual process announced by the companies.<sup>4</sup> For example, the location of the plant would be within 20 miles of the student-selected site; both selected a "mine-mouth location". Instead of a 400-MW facility, the students designed a 600-MW facility. Estimated lignite requirements were similar. Calcined limestone, limestone being another abundant local resource, was specified to remove sulfur from the burned fuel. Solid waste products and their means of disposal were identified. Excavated soil would be returned to an initial state. The plant was estimated to operate profitably by the students for 20 years; the companies estimated a 30-year life based on their lignite reserves.

It was interesting to the students that the companies proposed a plant exemplary in pollution control. A circulated fluidized bed, the cleanest commercial process for burning lignite, was chosen by the companies. The fluidized bed includes crushed limestone

which gives dual environmental benefits of removing sulfur and of lowering combustion temperatures to minimize nitrogen oxides.

The timing of the announcement was propitious, for it verified the quality of work of the students. Moreover, it gave a unique gratification at the conclusion of the course.

The team presented the results of their project at the Mississippi Academy of Sciences' annual meeting while interest of Mississippians was running high from publicized development of the plant.

## 2. Remediation Project

Another project assigned to the students was the design of a process to clean a site near Wesson, Mississippi, contaminated with trichloroethylene (TCE), associated chlorinated compounds, and PCBS. Data from about 20 wells drilled for sampling by the state's Department of Environmental Quality (DEQ) gave areal extent of the plume of TCE contaminants in the soil and in the water as well as a geological survey of the site. The reports obtained from DEQ gave basic information needed by the students to start their design.<sup>5</sup>

The TCEs had been partially leached from the soil to contaminate the ground water, including the city's water supply. The contamination accumulated after a small firm's formation in Wesson in the 1950s. The firm at the site had used TCE as a degreasing agent for metal parts, as was customary in that era. Waste solvent had contaminated the back of the property for 20+ years. Abandoned transformers in the back scrapyard had leaked PCBs. The PCBs were confined to three areas without serious migration, but the TCE and related compounds had spread to the water level at 50-150 feet below the surface.

Students worked in groups of four to design processes to remediate water and soil. They were encouraged to design the most practical, economical process. But they also had the option to incorporate into their design innovative techniques that might be in the research and development stage with an accompanying economic analysis that reflected on the potential of the process.

Thorough literature surveys were made. An engineer with the state DEQ familiar with the contaminated site made a presentation to the class and fielded questions. The students developed and discussed concepts with the professor. Flow sheets, equipment selection, sizing, and costing continued to the final design with comprehensive oral and written reports at the end of the semester.

A news item about this particular site appeared during the semester in Jackson's *Clarion Ledger*, the state's premier newspaper, which heightened interest in the project: A seemingly high incidence of cancer among youth near the Wesson site reportedly implicated the contaminated water.<sup>6</sup> Again, the class found themselves working to help solve a problem of heightened community interest.

One team presented their report as an entry in a regional university design contest and placed first in the competition. Prompted by a stimulated public interest, a paper was presented by the students at the 1997 annual meeting of the Mississippi Academy of Sciences.<sup>7</sup>

## 3. CO<sub>2</sub> Utilization Project

Near the center of the state, Mississippi has a unique natural resource of carbon dioxide in the Norphlet and Smackover formations at a depth of 15,000 - 20,000 ft; the resource has barely been tapped for any use. The quantity of gas in-place is estimated to be about seven trillion cubic feet at standard conditions with purity of the carbon dioxide reaching 99.6%; bottom-hole pressures in the deep reservoirs go as high as 11,500 psi. Industry has made only minor uses of this unique CO<sub>2</sub> resource in Mississippi, notably one 40-mile pipeline constructed northeast to the Tinsley oilfield and a second 200-mile (trunkline) pipeline constructed south to the Gulf Coast vicinity for enhanced oil recovery projects; both pipelines are now inactive because of the marginal economics of enhanced oil recovery.

The students were to evaluate the feasibility and design a process utilizing supercritical carbon dioxide for the decaffeination of coffee. Although no such process has ever been suggested for the state, such a process might contribute to the economic development of the state by introducing a new industry. The project was selected for study for six reasons:

- (a) Supercritical carbon dioxide has solubility for caffeine but not other ingredients of the coffee bean.
- (b) The CO<sub>2</sub> reserves of Mississippi are cheaper and of higher purity than other sources.
- (c) If situated on the Mississippi Gulf Coast, such a plant would have direct access to coffee beans shipped from South America.
- (d) The existing CO<sub>2</sub> pipeline to the Mississippi Gulf Coast might be utilized.

- (e) High pressure of the fluid reserves would reduce costs of transportation and process injection.
- (f) No toxic residue or waste byproduct results from using supercritical CO<sub>2</sub>.

Consequently, the students designed a 1.4 ton/day facility with an estimate of costs. The resulting design predicted an economical operation with a payout of 3.3 years. Their process would extract 97% of the caffeine.<sup>8</sup>

#### 4. PGM Recovery from Catalytic Converters

Platinum group metals (PGM) of platinum, palladium, and rhodium comprise an essential part of the U.S. economy as catalysts in the process industries and as catalytic converters in automobiles. About 80-90% of the PGMs come from South Africa and Russia, sources politically unstable. Most of the PGM catalysts in abandoned vehicles in America are not recovered; most of those recovered are shipped to Japan or Europe for processing.<sup>9</sup>

In the early 1990s the U.S. Bureau of Mines (USBM) patented a process to recover PGMs that overcomes the excessive energy of a thermal process and the excessive corrosion of an acidic process. The USBM process also has no hazardous chemical byproducts to be disposed.<sup>10</sup> Based on the published laboratory data of USBM and the patent details, students were asked to design a processing plant to recover PGMs from automobile catalytic converters.<sup>11,12</sup>

The USBM process involves sodium cyanide for the PGM recovery. (The chemical is degraded to nontoxic components at the end of the process.) One new challenge to the students was to design for the safe use of this toxic chemical.

With Mississippi's strategic waterways, the student's selection of sites reflected relative transportation costs of shipping their raw materials from population-dense centers of eastern United States. Supplementary information on catalytic converters and processing chemicals were obtained from the World Wide Web. A dearth of information at the beginning of the project became a wealth of data as the work progressed.

The students estimated a high discounted cash flow rate of return for such a plant.<sup>13</sup>

After completion of the project, recognition was given to the students for the project and details of the process published in the *MISSTAP Newsletter*, a regional newsletter of a technical assistance program for southern

states to disseminate current information on pollution prevention and waste disposal.<sup>14</sup>

## Summary

The goal of the course was to convey the conventional process design experience while stressing innovation and creativity to projects for community and state benefit.

Besides conventional data sources, the WWW helps make such innovative projects practical classroom exercises. (The Web helps bridge the data gap of design projects. In some instances it allows the student to "walk into research laboratories" to review the latest work on a subject.)

The awareness that their design dealt with a project that could impact the state and community provided incentive to the students throughout the semester. The best groups have presented papers to the scientific community, entered collegiate paper contests, and received public recognition through news reports. These recognitions provided incentives. The students have found an interested audience in employment recruiters--the design project has occasionally become a focal point of the interview. Since undergraduates mention their projects on their resumes, the hard work is evidently justified

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