Engineering Design: the Information Component

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Abstract

The curriculum of the Bucknell University Chemical Engineering Department includes a required senior year capstone course titled Process Engineering, with an emphasis on process design. For the past ten years library research has been a significant component of the coursework, and students working in teams meet with the librarian throughout the semester to explore a wide variety of information resources required for their project.

The assignment has been the same from 1989 to 1999. Teams of students are responsible for designing a safe, efficient, and profitable process for the dehydrogenation of ethylbenzene to styrene monomer. A series of written reports on their chosen process design is a significant course outcome.

While the assignment and the specific chemical technology have not changed radically in the past decade, the process of research and discovery has evolved considerably. This paper describes the solutions offered in 1989 to meet the information needs of the chemical engineering students at Bucknell University, and the evolution in research brought about by online databases, electronic journals, and the Internet, making the process of discovery a completely different experience in 1999.

Introduction

In the fall of 1989, in my first year as a librarian at Bucknell University, I was faced with a challenge in what we then called “bibliographic instruction.” Dr. Michael Hanyak wanted me to meet with his chemical engineering senior design course not once, but three times. His suggestion was to begin with a general introductory session on library research and online databases. A second session would cover patents, patent searching and acquisition. In a third meeting we would examine a wide range of technical literature sources including handbooks, laws and regulations.

The course assignment is challenging. The students in CHEG 400, Process Engineering, are divided into three-member teams, each working on the same problem. As senior chemical engineers in the Process Engineering Department of the fictional consultant company “Bison Engineering and Evaluation Firm or BEEF, Inc.”, their goal is to design an efficient, cost-effective process for the dehydrogenation of ethylbenzene to styrene monomer for the client "Hawbawg Chemical Company". Design teams consider technical, economic, and environmental aspects of their process design: feed stocks, flowsheets, material and energy balances, equipment design and plant siting, profitability analysis, and compliance with environmental regulations.

The design teams must write three reports during the fall semester: process scope, process requirements, and process profitability. The quality of the last two reports is strongly dependent on the quality of the scope report. In the first report, a team begins with a primitive problem statement like “make styrene monomer from ethylbenzene” and must select a chemical process flowsheet to manufacture styrene monomer. Basically, they must define the scope of the assigned primitive problem by answering the following specific technical questions:

1. What is the market picture for styrene monomer?
2. What are the most competitive process technologies?
3. Which process is the “best” to select and why?
4. What is the description of the selected chemical process?
5. What are the constraints for the selected chemical process?

The market picture addresses such things as product use, supply and demand outlook, price profiles, existing plant capacities, and product target market. Under competing processes, a student design team needs to identify an overall block flowsheet, the feedstock, chemical reactions, catalysts, and pros/cons for each process. Selection of the "best" process involves defining the evaluation criteria, creating a decision table, and justifying the team's selection of a process flowsheet. The process description is a written statement of how the raw materials are converted to the desired product and byproducts using basic unit operations such as pumps, reactors, heat exchangers, and distillation columns. The process constraints are not only the operating conditions for the process but also the health and safety factors, the environment impact (on the air, water, land, and people), and legal issues (on patents, plant location, and transportation liability).

Obtaining information on the scope of the design problem is critical to the quality of the three reports that a design team must write. The amount of information and the time required to gather it play an important role in how well a team will do on the design assignment in the fall semester. In 1989, design teams were assigned in May of their junior year, and students were asked to solicit information from chemical companies over the summer. This source was sporadic and not uniform for all of the design teams. The available library resources particularly in the areas of patent acquisition, health and safety, environmental impact, and legal issues were not robust for doing extensive literature searches in a timely fashion in the fall semester. As an example, students did not have access to material safety data sheets and had to rely on what limited data chemical companies might send.

Methodology, 1989

My first meeting with the senior chemical engineers took place in the first week of the fall semester, in a darkened room, lit by the glare of an overhead projector. The students faced me in rows of chairs as I described our new online public access catalog, and showed them, via transparency, the results of a typical search such as “subject = styrene”. The results were zero! The Bertrand Library collection of over 500,000 books, although it supported undergraduate and masters level programs in chemistry and chemical engineering, had not one title on styrene, ethylbenzene, or the dehydrogenation of same.

In 1989, my library instruction always included an extensive printed pathfinder or bibliography of sources. My handout for the course included a list of chemical dictionaries and encyclopedias, directories of chemical prices and suppliers, handbooks on chemical hazards, and a selection of print periodical indexes. The most creative student use of this handout included the construction of a tubular paper airplane. While I assumed they needed a general review of research tools and techniques and literature searching, the students were in a hurry to find the practical tools they would need to answer their very specific questions. The most important monographic resources covered in this first meeting were some key reference books. The Kirk-Othmer Encyclopedia of Chemical Technology (3rd Edition) was to prove a fundamental source, including a sample flowsheet of the dehydrogenation process. McKetta's Encyclopedia of Chemical Processing Design was also useful, although in 1989 it had not yet published volumes up to the letter "s"!

The design teams needed answers for at least the first two questions that had been put to them, and I hoped that the journal literature would provide both the market picture and information on competitive process technologies. Transparencies made from photocopied pages of the Wilson Applied Science and Technology Index showed how a search would yield current articles in trade journals such as Chemical Marketing Reporter and Oil and Gas Journal. Students also found useful articles in the more technical AICHE Journal, or Industrial and Engineering Chemistry Fundamentals. A tour of the periodicals department of the library showed students where to find current issues of these publications.

I encouraged the student design teams to make an appointment with the librarian to conduct an online database search using DIALOG, to find more comprehensive results in the Chemical Abstracts and Engineering Index. Bucknell students and faculty are not charged online searching fees, and all of the engineering teams took me up on the offer. At this stage of their research, each team wanted the same basic information, so it proved easier to create one comprehensive bibliography based on these online searches and put the results on Reserve for that semester.

Our second meeting focused on patents. The patent literature had great potential for answering the team's questions concerning the "best" process, and for detailed descriptions of selected chemical processes. In 1989 our government documents collection included a short run of the print Index to Patents and the Manual of Classification. Again, my handout focused on these print sources, and our classroom time was taken up with an explanation of patent classification, such as the intricacies of Class 440 subclass 165. When it came to actually identifying patents, students had to rely on citations in Kirk-Othmer and in the journal articles they had researched. Fortunately, DIALOG provided access to the Claims patent database, and again each student team was encouraged to make an appointment for a database search.

Having found references to specific patents assigned to Mobil or Badger or Fina, the next challenge was acquiring these documents. The Pattee Library at Penn State University is a patent depository library and students could drive an hour to use their patents on microfilm. Interlibrary loan was a less demanding option, but much too slow. We realized that a better system was required to support this information need in 1989 and in the future. It was decided that all patent requests filled through ILL for the chemical engineering seniors would be purchased through Rapid Patents Service in Arlington, VA. Photocopies were usually delivered within 72 hours. Since we were dealing with non-copyrighted materials, we also decided to keep a copy of each patent requested. These were put on Reserve for the course, and by the end of the semester, we had the beginnings of a library of patent literature on the dehydrogenation of ethylbenzene to styrene.

The third course meeting served as an introduction to technical literature. Lacking material safety data sheets, students were directed to review sources such as Sax's Dangerous Properties of Industrial Materials. The CRC Handbook of Chemistry and Physics was our best source for physical properties. The paucity of technical information, specifically on the dehydrogenation of ethylbenzene to styrene, was a factor in the quality of the student reports, especially in their attempts to answer Question 5, concerning "constraints" on their chosen process design. Given the small size of the library's legal collection, guiding students through the laws and regulations of hazardous waste was also a challenge. Concerning the environmental impact of their process, searches in Title 40 of the Code of Federal Regulations were tedious. We strayed further from the student's comfort levels when we looked into the economics of siting and building a process plant; tax laws in Texas, feedstock transportation regulations and costs, and health and safety issues were quite vexing questions given our information resources in 1989.

By the end of that third library presentation, I was determined to discover or develop better information resources for our senior students. In ten years we have diligently built a collection of library materials on the chemical engineering design process, and on dehydrogenation specifically. My own thinking on the extent and usefulness of classroom bibliographies has changed considerably. Most importantly, the Internet has done much of the development work for me, and I can report on a completely transformed research process.

Methodology, 1999

The assignment and the schedule of library lab sessions for CHEG 400, Process Engineering, have not changed much in ten years. The change in research methods and tools is dramatic. My first meeting with the chemical engineering seniors now takes place in the library's electronic classroom, where I can project images from the instructor's workstation and students can follow along on their own PC's. I demonstrate the library web page and the online catalog, showing how a keyword search for "(styrene or ethylbenzene) and dehydrogenat?" will retrieve several books, a doctoral dissertation (Kim, Jae Jo, 1991), and even a Bucknell honor's thesis (McClaine, Brian, 1997) on the topic. Search results may include government documents in both print and electronic formats, providing information such as water quality criteria for ethylbenzene, or occupational exposure standards for styrene. Discussion of the reference books available for their research includes the 4th edition of Kirk-Othmer, and the now completed McKetta's encyclopedia.

A button labeled "ArticleFinder" on the library web page takes students to the IAC Expanded Academic ASAP Index, where articles from Oil and Gas Journal or Hydrocarbon Processing can be read full-text online. The list of databases available to students in the fall of 1999, via the web from anywhere on the Bucknell campus, included Applied Science and Technology Abstracts (OCLC First Search) and COMPENDEX (Engineering Information). As the design teams attempt to answer Question 1 concerning the market picture for styrene, they can consult the Chemical Market Reporter full-text online. I point out that the business periodicals database ABI Inform Global, also a full-text resource, will actually give them a better picture of competitive process technologies than the engineering literature. I still make the offer of a free DIALOG database search for the student design teams, but the students prefer to work on their own with these new electronic resources.

Over the course of ten years, my classroom handouts had become shorter and shorter, as I tried to focus on one or two absolutely essential print information sources to serve as examples for each of our course meetings. As more and more resources became electronic, the course handout faded from importance. Ironically, now all of these new information resources can be highlighted, with appropriate web links, on a “handout” or bibliography, which is made available as a web site for the senior design course. It can be accessed from the library’s E-Reserves page, referred to during course meetings, and modified during each semester as new information comes to light. The process of research has actually become interactive, and reciprocal, as students from the design teams will inform the librarian if they discover a particularly good online resource.

Our second library lab still focuses on patents, but again the web has transformed the research process and the quality of the results. The IBM patent server Intellectual Property Network, and the U.S. Patent Office database provide many patents online, including patent drawings, from 1976 to the most current. The library still maintains a growing file of patents on Reserve. The librarian keeps a list of known patents on the dehydrogenation of ethylbenzene to styrene, including related patents on catalysts, arranged by patent assignee. This list is kept up-to-date through both online database and web searching, and our collection of print patent documents has grown to incorporate all the appropriate patents issued prior to 1976, providing seamless coverage with the web resources. Students typically use the Reserves list to identify appropriate patents, then access the text and graphics on the web. The number of requests for patents via ILL has slowed to a trickle.

Finally, the senior engineers meet to consider more technical aspects of their research, including legal and environmental questions. The Bertrand Library had attempted to provide electronic access to some of the answers by subscribing to the Law of Hazardous Waste (Matthew Bender), a print and CD-ROM textbook including the full text of the Code of Federal Regulations Title 40: Protection of the Environment. The CD searching software is difficult to use, and now the CFR is available on the web directly from the federal government and from several online database vendors. The engineering students can also search the web for Material Safety Data Sheets, current chemical market prices and suppliers, and physical and chemical data. Even the vexing question of tax laws in Texas has been solved online with access to the Lexis-Nexis Universe of legal databases.

Conclusions

Students in 1989 were reliant on the librarian to point them to appropriate printed information resources that they may have never used before. The process of discovery was time consuming and labor intensive, as well as being repetitive for each team of engineering students. The library collection and resources were barely adequate to the task.

In 1999, engineering students are intimately familiar with the World Wide Web, and introducing them to electronic resources seems effortless. Web surfing is far less time consuming and laborious, and often provides better results in a more usable format. The challenge of library support and instruction is to make available the most useful and appropriate tools, and to point students to the right resources. Building an electronic collection of information resources, and guiding students to them seems a world removed from our efforts of only a decade ago.

Over the past ten years, the quality of the written design reports has been significantly enhanced with the introduction of online databases, electronic journals, and the Internet. With the advances in information technology, we no longer require student design teams to begin their search for information in May with chemical companies. They begin with library resources in the fall semester and are successful in finding rich sources of information in a timely manner. Furthermore, all design teams have an equal opportunity to acquire the needed information to define the scope of the problem. The scope reports in 1999 are richer in information and have better arguments for a chemical process selection. We now get process selections that are hybrids, where the student teams pick subparts of competing technologies to design a new process for study. Furthermore, design teams are better prepared to complete the tasks associated with the second and third reports of process requirements and process profitability. Overall, the advancements in information technology have allowed the chemical engineering instructors to focus more on coaching students to critically process the literature information and thus develop a better design solution.

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