Process Descriptions: An Introductory Library Research Assignment on Chemical Processes for First Year Students

S. Scott Moor
Lafayette College

Abstract

In our first year "Introduction to Engineering" class, each student passes through a three-week block on chemical engineering. In such a short period of time, it is always a challenge to give students a clear idea of the nature and diversity of chemical engineering. I have particularly wanted them to understand the process focus of chemical engineering and the wide range of products made with chemical processes. One tool I have used over the past two years is a assignment requiring students to research how some product is made, writing up a brief (two-page plus figures) summary of their research. Groups of three students work on a topic together and are given approximately one week to complete their research. They are required to look into the basic process for making their assigned product, the safety and environmental issues for that process, the uses of the product and some background on the economics of the product. In this paper, I present the details of the set-up of this assignment so it can be easily reproduced. Included are the over 50 topics currently used and references that cover these topics. I also present an assessment of our experience. Students seem to find this assignment interesting and enjoyable. The resulting summaries are generally well done. This assignment has the added benefit of getting the engineering students into the library early in their engineering studies.

Introduction

In our first year "Introduction to Engineering" class, I wanted students to gain insight into the nature of chemical engineering and the issues which chemical engineers face. I developed a simple library assignment in which students research how a product is made and review some of the issues important to chemical engineers.

This is the students' first assignment in a three-week section of the course devoted to chemical engineering. The goals of this assignment are to:

1. help students understand that chemical engineering is about processes for making a wide variety of products,
2. introduce students to some key concerns of the chemical engineer, particularly:
   a. process flow
   b. process environmental health and safety impacts
   c. product use
   d. product economics,
3. encourage engineering students to develop a habit of using the library.

In addition, it was necessary to design this assignment so that it: 1.) would be completed quickly, 2.) would be within a first year student's capabilities and 3.) would be enjoyable.

The Assignment

Groups of three students are asked to research how a product is made and to prepare a brief paper summarizing what they have learned. The paper is restricted to 500 words, and the use of diagrams is encouraged. Students form the groups themselves in class when the assignment is handed out. I give the students a limited list of references that provide the majority of the information that they need. Appendix B contains a copy of the assignment handout.

During the next class period, we meet in the library for a working session and that evening a bibliography is due. I require that the bibliography include specific page numbers and article titles. Groups are encouraged to start their search before the library session (most do not). This session is very productive with most groups nearly finishing their lists in this one session. For many students, this is their first actual use of the college library and a key introduction.

The paper is due one week after the assignment is made. They will often have another shorter assignment to work on during this week as well.

Students are asked to include several key areas in their report:

- an introduction to their topic including interesting facts or history,
- a summary of the basic process including key reaction and separation steps,
- a discussion of key environmental and safety concerns for the process,
- a review of the key uses of the product,
- a discussion of key economic issues including quantitative information such as current market price, total annual market, etc.

In addition students are encouraged to include a simple flow diagram usually copied from one of their sources.

I direct the students to eight basic references. Providing these references helps the project meet the constraint of this being a quick assignment that is within a first year students' capabilities. Three of the references provide simple introductions to the topics.[1,2,3] Three are standard chemical process engineering references which are still fairly accessible to students not yet trained in engineering.[4,5,6] A reference on toxic chemicals is provided to help with safety and environmental issues.[7] The *Chemical Marketing Report*[8] has product price information. Many of the references include economic information. An investors' guide obtained from the investment firm BT Alex, Brown is particularly helpful in this area.[3] I encourage students to seek additional references as needed and to use reference librarians, particularly for economics/commerce issues.

Appendix A includes a listing of the products that I have assigned and the references with material relating to each product. This list includes traditional petrochemicals, polymers, metals, industrial gasses, foods, beverages, pharmaceuticals and water treatment.

Assessment Results

Nearly 100 student groups have completed this assignment over the last two years. In the structure of Lafayette's "Introduction to Engineering" class, I teach one quarter of the class at a time, so this assignment was completed four times each year. There were no significant changes in the assignment between these two years. The handouts were essentially equivalent. Topics were not repeated during a single semester but essentially the same topics were used each year. I reexamined 85 reports to further assess this assignment.

The first goal was to build students' understanding of the process-oriented nature of chemical engineering. Three characteristics were examined. The results are shown in Figure 1.

First, I examined the process flow portion of each report to see if it covered the expected key information regarding the nature of the process. Each report was categorized based on whether it missed key process steps, whether it covered the key process steps or whether it significantly exceeded the expected coverage. In 85% of the cases, student reports included the key steps as expected or with more than expected results; the students captured the basic process ideas. There is little difference between Fall 2000 and Fall 2001. This analysis reviewed whether the technical information was present, not the quality of the writing.

Figure 1: Success in communicating a process orient

	Percent of reports		
Nature of Description of Process Flow	2000	2001	total
Key Information Missing	16	15	15
Expected Information Covered	71	77	74
Exceeds Expectation	13	9	11
Conceptual Errors found in Process Flow	34	26	29
Process Issues Addressed in EHS section	57	57	57

Second, I evaluated each process discussion for technical errors or misunderstandings. In some cases, the steps were there but some part was in error. For example, in one report on a polymer process, the reaction to create the monomer was mislabeled a polymerization - the step is there, but there is an error in the content. For a majority of the reports (61%), I found no such errors. One expects first year students to make some errors of this type.

Third, I reviewed the environmental and safety section to see if students looked at the process issues not just the product safety and environmental impact. This is the acid test: if they understand the issue is the process, they have begun to understand the process orient of chemical engineering. In 57% of the reports, students go beyond addressing the product safety and environmental impact to look at the entire process.

A majority of the reports show strong evidence of students understanding the process-oriented approach of chemical engineering and a vast majority included a complete set of process steps.

The second goal was to introduce students to some of the range of issues chemical engineers address. I evaluated this by looking at the other four subsections: Introduction, Environment and Safety, Product Use and Economics. As in the process section, the rating reflects whether students' reports include the key issues for their product or not. The results of this analysis are shown in Figure 2. One additional category has been added for when the section was missing or inadequate.

Figure 2: Quality of Coverage by Section (numbers indicate the percent of reports in each category)

	Quality of Coverage	**Intro.**	**EHS**	**Product Use**	**Econ.**
Total	Missing or Insignificant	2	4	0	4
	Key Information Missing	9	39	13	35
	Expected Information Covered	47	49	79	47
	Exceeds Expectations	41	8	8	14
2000	**Quality of Coverage**				
	Missing or Insignificant	3	5	0	5
	Key Information Missing	8	45	18	37
	Expected Information Covered	50	47	74	39
	Exceeds Expectations	39	3	8	18
2001	**Quality of Coverage**				
	Missing or Insignificant	2	2	0	2
	Key Information Missing	11	34	9	34
	Expected Information Covered	45	51	83	53
	Exceeds Expectations	43	13	9	11

A majority of the reports included the expected coverage of each section. The introductions exceeded expectations with many groups providing interesting facts about the product or the history of its production. The poorest showing was in the environment and safety area. Again, focusing on the product issues and not on the entire process was the source of most deficiencies. I plan to add the word "process" to the title of this section in next year's assignment to help point out this issue to students.

Over the two years, a slight improvement can be seen in all categories. This improvement is likely due to differences in the students between the two years.

The third goal of this project was to encourage students to use the library. Students show a great deal of energy during the library session. In addition, I examined the reference lists of each report to see if they included all of the relevant sections in the eight provided references and to see what additional references they used. Figure 3 shows the result of this evaluation.

Figure 3: Use of Library References

number	References Missed from Standard Sources	Additional Outside Library References	Additional Outside Web References
one	27	19	17
two or more	23	38	21
average 2000	1.1	1.0	1.3
average 2001	0.7	0.7	1.2
average (total)	0.9	0.8	1.3

figures properly referenced	2000	40%
	2001	38%
	total	39%

All of the expected references were included in 50 % of the reports and only one reference was missed in 27 % of the reports. However, nearly one quarter of the groups missed at least two key references.

Over 50% of the groups included additional library (print books or journals) references in their research. In addition, many groups used web resources. One occasional problem was when a group did not use the provided references and leaned almost completely on web resources. There is little difference between the two different years this assignment was used.

Most student reports included figures copied from one of the references (particularly flowsheets). Most groups seemed to miss that the source needs to be credited. Only 39% of the reports with literature figures gave proper credit.

However, another instructor observed that students who had this assignment in their first year do better at including proper citations in a paper required in our material and energy balance class during their second year. The instructor also observed that they seem more comfortable with a library research assignment in a technical class than students from earlier years before this first-year writing assignment was introduced. All indications are that this assignment is effective at encouraging students to use the library.

Students regularly complete this assignment within the week allotted and seem to enjoy it. This observation indicates that the assignment constraints (i.e., that the assignment be quick, be within the students capabilities and be enjoyable) were met.

Summary/Conclusions

A majority of student groups used an appropriate process perspective in their report. However, some groups do seem to have trouble recognizing this process perspective, particularly in assessing environmental and safety concerns.

Most groups covered the key issues in each of the report sections and gained experience working with the range of issues that chemical engineers encounter.

This assignment gave first-year students an introduction to using the library. A class library session proved productive and enjoyable for both students and the instructor. Most students successfully obtained the needed library information. Most groups found the key sections in the provided references and on average included two outside reference as well. One problem encountered was that over 60% of the groups failed to properly credit figures.

This simple research assignment, investigating how a chemical product is made, provides a good introduction to the nature of chemical engineering. The use of specific references allows it to be an introductory assignment that is completed in a short time.

Appendix A: Topics and References

Check marks indicate which of the standard references contains information on the given product. The reference numbers correspond to the numbers in the bibliography.

	Type of Reference	Introductory Materials			Chem. E References			E & S	Cost
	Reference number	1	2	3	4	5	6	7	8
	Product								
1	Acetone		✓	✓	✓	✓	✓	✓	✓
2	Acetylene	✓	✓		✓	✓	✓		
3	Acrylic Plastic (PMMA)	✓	✓				✓		
4	Activated Sludge WWT		✓		✓	✓	✓		
5	Aluminum	✓	✓			✓	✓	✓	✓
6	Ammonia		✓		✓	✓	✓	✓	✓
7	Ammonium Nitrate (Fertilizer)	✓			✓	✓	✓	✓	✓
8	Antibiotics	✓	✓		✓	✓	✓		
9	Aspartame (Nutrasweet)	✓	✓		✓		✓	✓	
10	Beer (Ale and Lager)	✓	✓			✓	✓		
11	Benzene		✓	✓	✓		✓	✓	✓
12	Carbon Dioxide Gas		✓		✓	✓	✓		
13	Cereal (Flaked and Puffed)	✓	✓				✓		
14	Cheese Curl	✓							
15	Chocolate	✓	✓				✓		
16	Coffee (beans or grounds)	✓	✓				✓		
17	Coffee instant	✓	✓				✓		
18	Concrete	✓	✓				✓		
19	Copper	✓	✓				✓		
20	Corn Syrup	✓	✓			✓	✓		
21	Ethylene Glycol		✓	✓	✓	✓	✓	✓	✓
22	Gelatin	✓	✓			✓	✓		
23	Glass (soda-lime)	✓	✓			✓	✓		
24	Glycerin		✓		✓	✓	✓		✓
25	Helium	✓	✓		✓	✓	✓		
26	Hydrochloric Acid					✓	✓	✓	✓
27	Lime (Calcium Hydroxide)		✓			✓	✓		✓

Appendix A: Topics and References (cont.)

	Type of Reference	Introductory Materials			Chem. E References			E & S	Cost
	Reference number	1	2	3	4	5	6	7	8
	Product								
27	Mercury	✓	✓		✓		✓	✓	✓
28	Nitrogen		✓		✓	✓	✓		
29	Nylon		✓				✓		
30	Oxygen	✓	✓			✓	✓		
31	Paper	✓	✓		✓	✓	✓		
32	Perfume (fragrances)	✓				✓	✓		
33	Phenol		✓	✓	✓		✓		
34	Phenyl ethyl alcohol (rose sent)					✓	✓		✓
35	Polyester	✓	✓	✓			✓		✓
36	Polyethylene, High Density		✓			✓	✓		✓
37	Polystyrene	✓	✓	✓	✓	✓	✓		✓
38	Polyvinyl Chloride (PVC)	✓	✓	✓	✓	✓	✓	✓	✓
39	Porcelain	✓	✓				✓		
40	Rayon	✓			✓	✓	✓		
41	Silicone		✓			✓	✓		
42	Soda Ash	✓	✓		✓		✓		✓
43	Sodium Fluoride		✓				✓	✓	
44	Sugar	✓	✓		✓	✓	✓		
45	Sulfuric Acid		✓		✓	✓	✓	✓	✓
46	Titanium Dioxide		✓	✓		✓	✓		✓
47	Vegetable Oil	✓	✓			✓	✓		
48	Vinegar, Cider		✓		✓	✓	✓		
49	Vodka	✓	✓		✓	✓			
50	Water softening		✓			✓	✓		
51	Whiskey	✓	✓			✓	✓		
52	Wine (Red and White)	✓	✓			✓	✓		
53	Zinc	✓	✓				✓	✓	

Appendix B: Assignment Handout

Chemical Engineering Block Assignment: Chemical Process Description

You will be assigned a product. You are to investigate the process used to manufacture that product. Please prepare a brief summary of how this process is carried out. This summary should be a **maximum** of 500 words (approximately 2 pages of text). You are encouraged to include graphs, figures and tables. Your summary should include the following sections.

- **Introduction:** Briefly introduce you process. Indicate key process issues and any interesting factoids you learned about your process or product. You may wish to include some history at this point.
- **Basic Process:** Describe the basic process reaction and separation steps. You should include a figure or outline of the process steps. You may reproduce a process diagram from a reference (with appropriate footnotes of course).
- **Environmental and/or Safety concerns:** Describe any environmental problems or safety issues that are important to this process. This description should include safety and environmental issues related to the raw materials, the intermediates and the actual process steps in addition to concerns with the product.
- **Product Use:** Explain the major uses of the product. Note if it is the raw material for any other product.
- **Economics:** Include any information you find on the value of this product – this might include answers to some of the following questions: How expensive is it per pound? How big is the total market? Is demand growing? How many companies produce this product? Are there factors crucial to its profitability? Please be quantitative
- **References:** All references used to develop your summary should be listed in a standard bibliographical format. Include specific pages where you found sections covering your process and the title of the sections you are sighting (see attached example process description references). You should check all of the key references below for information on your topic.

You may limit your summary to a specific method of producing the product, a specific variation of the product and/or to simply a portion of the process if that is more manageable. Please state any chosen limitations in your introduction section.

Key References:

The following are key references you **must** look at in preparation of your description.

1. Krapp, Kristine & Long, Jacqueline (eds.), **How Products Are Made: An illustrated Guide to Product Manufacturing**, Gale Research, 1998. Ref. TS146 .H67
2. **Encyclopedia of Science and Technology, 8th Ed.**, McGraw-Hill, 1997 Ref. Q121 M3 1997
3. James A. Kent (ed), Riegel's **Handbook of Industrial Chemistry, 9th Ed.,** Van Nostrand Reinhold, c1992 Ref TP145. R54 1992
4. R. N. Shreve, **Chemical Process Industries, 5th ed**., McGraw-Hill, On Reserve: 660.2 S561c
5. Sergey Vasnetsov and Milan R. Shah, **The Investors' Guide to Chemicals**, BT Alex, Brown Inc., 1998 On Reserve

6. **Chemical Market Reporter**, Schnell Publishing (NY, NY) Recent issues are in current periodicals.
   For chemicals, you can find the current market price by consulting the CMR.
7. Hart, John, et. al. , **Toxics A to Z : a Guide to Everyday Pollution Hazards** (UC press, 1991) Ref RA1213 .T76 1991
8. Wolfgang Gerhartz (executive ed.), **Ullmann's Encyclopedia of Industrial Chemistry**, **5th Ed**., Weinheim, c1985. Ref TP9 .U57 1985

As you read references you may find things you do not understand. Focus on what you do understand and contact me when you have questions. You may also want to try a search of the web. You are encouraged to consult with a reference librarian particularly when it comes to the economic impact. Feel free to use quotations. The use of more than six words from any source requires that you footnote that source.

Due dates:

Monday, November 12th, 5 p.m. emailed to me with "Process Description" in the subject line or drop off in my office	Reference list: This reference list, that will eventually be part of your full report, must include the page numbers where information on your process is found and the title of the sections. Include the title of your project on the top of the list.
Friday, November 16th at the beginning of class (may also be emailed)	Full report due.

Note:
Monday, November 12th, We will meet in the Library (in the bay just north of the reference stacks) during our normal class period so I can assist you with your research.

Your group is to investigate the manufacturing of the product circled below.

Aluminum from Alumina	Phenol
Cider Vinegar	Glycerin
Silicone	Aspartame (Nutrasweet)
Acetone	Acetylene
Activated Sludge WWT	Helium
Sulfuric Acid	Vodka
Acrylic Plastic	White Wine

[An example completed chemical process description is also included with this handout]

Bibliography

1. Krapp, Kristine & Long, Jacqueline (eds.), **How Products Are Made: An Illustrated Guide to Product Manufacturing**, Gale Research,
2. **Encyclopedia of Science and Technology, 8th Ed**., McGraw-Hill, 1997
3. Sergey Vasnetsov and Milan R. Shah, **The Investors' Guide to Chemicals**, BT Alex, Brown Inc., 1998
4. James A. Kent (ed), Riegel's **Handbook of Industrial Chemistry, 9th Ed.,** Van Nostrand Reinhold, c1992
5. R. N. Shreve, **Chemical Process Industries, 5th ed**., McGraw-Hill,
6. Wolfgang Gerhartz (executive ed.), **Ullmann's Encyclopedia of Industrial Chemistry**, **5th Ed**., Weinheim, c1985
7. Hart, John, et. al. , **Toxics A to Z : a Guide to Everyday Pollution Hazards** (UC press, 1991)
8. **Chemical Market Reporter,** Schnell Publishing (NY, NY)

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S. SCOTT MOOR

Scott Moor is an Assistant Professor of Chemical Engineering at Lafayette College. He received a B.S. and M.S. in Chemical Engineering from M.I.T. After over a decade in industry he returned to Academia at University of California at Berkeley where he received a Ph.D. in Chemical Engineering and an M.A. in Statistics. He is a registered Professional Chemical Engineer in the State of California.