THE LEXICAL NEEDS OF CHEMICAL ENGINEERING UNDERGRADUATE STUDENTS
AT SURANAREE UNIVERSITY OF TECHNOLOGY
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หัวหน้าโครงการ : Asst. Prof. Jeremy William Ward

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สาขาวิชาเทคโนโลยีสังคม
มหาวิทยาลัยเทคโนโลยีสุรนารี

ได้รับทุนดุลยพินิจในการวิจัยจากมหาวิทยาลัยเทคโนโลยีสุรนารี ปีงบประมาณ พ.ศ. 2540

ผลงานวิจัยเป็นความรับผิดชอบของหัวหน้าโครงการวิจัยแต่เพียงผู้เดียว

สิ้น暅คม 2541
ABSTRACT

This project first investigated SUT chemical engineering undergraduate behaviour in relation to their English language textbooks. It was found that although students do in fact use these textbooks, they tend to read the examples and problems much more than they read the text. A likely reason for this was the relative difficulty of the text, and it was hypothesized that this difficulty might in part be caused by the presence of many more “text-structuring” words (as in Winter 1978) in the text than in the examples. Using a 3-million word corpus of basic engineering and chemical engineering textbooks used by SUT undergraduates, it was established that there are lexical differences between text and applications, but these were not describable in terms of “text-structuring” words. Finally, a list was produced of the 5000 most common words in engineering/chemical engineering textbooks was produced, and it was discovered that large parts of the SUT lexical syllabus are irrelevant to the needs of chemical engineering undergraduates.
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Introduction

The three objectives of this project were:

1. To establish students reading behaviour; do they read the applications (i.e. the examples and problems) more than the text proper? Do they read the text proper at all?

2. To establish whether the presence of more “text-structuring” words in the text might be a factor in its greater relative difficulty

3. To establish what words students need to know to study chemical engineering textbooks in English, and whether the current lexical syllabus was likely to meet these needs.

1. Reading behaviour

A questionnaire was prepared, based on two student focus groups and interviews with faculty in the engineering and chemical engineering departments. The questionnaire was translated and back-translated and discussed with the School Research Chair. It was administered to three classes of chemical engineering students, totalling 106 students.

The questionnaire was partly based on a 5-point Likert scale (the “S” items below) and partly on direct closed-ended questions (“Q” items) (see appendix 1.)

Findings/discussion:

1.1 Students do use their English language textbooks (hereafter referred to as SSETEs)

Q1) How many hours a week do you study English SSETEs?
zero: 0
1-3 hrs: 26
4-6 hrs: 29
6-8 hrs: 24
9+ hrs: 21

S1) “I need to study English SSETEs to pass courses at SUT”
Mean response: 3.84 (sd 1.03)
S2) “Thai textbooks are adequate for study purposes”
Mean response: 2.06 (sd 1.02)
S3) “As I study at a higher level, I need SSETEs more than previously”
Mean response: 4.71 (sd .83)

Table 1: Correlations between items concerning need for SSETEs

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR</td>
<td>.0261 (+)</td>
<td>n/s</td>
<td>.0483 (+)</td>
</tr>
<tr>
<td>S1</td>
<td>********</td>
<td>.0171 (-)</td>
<td>.0000 (+)</td>
</tr>
<tr>
<td>S2</td>
<td>********</td>
<td>********</td>
<td>.0021 (-)</td>
</tr>
</tbody>
</table>

We conclude that students do actually spend some time studying their SSETEs; they perceive both a necessity to use SSETEs, and also an inadequacy in Thai textbooks; and this perception grows as they progress through the university.

1.2. Students study the examples and problems

Q2) What proportion of the examples do you read?
57% all: 43% some: 0% none

Q3) Mark the sections of the book that you found useful.
Examples: 100% yes
S4) “The examples in the SSETEs help me to understand the subject matter”
Mean response: 4.64 (sd .81)

Q4) “What proportion of the problems do you read?”
4% all: 3% none: 93% some
Q5) Mark the sections of the book that you found useful.
Problems: 70%: yes 30%: no
S5) “The problems in the SSETEs help me to understand the subject matter.”
Mean response: 3.94 (sd .105)

We conclude that students read most or all of the examples and find them very useful; and read some problems and find them useful.

1.3. Most students have difficulty in using the text to learn about the subject matter

S6) If I have a choice, I prefer to read new subject matter in Thai
Mean response: 3.68 (sd 1.19)
Q6) How do you read the textual material?
20% in detail : 76% superficially: 4% not at all
Q7) Mark the sections of the book that you found useful.
Text: 68% yes : 32% no
S7) “It is necessary to study the text in SSETEs to pass the courses at SUT”
Mean response: 3.63 (sd 1.03)
S8) The textual material in the SSETEs helps me to understand the subject matter
Mean response: 3.31 (sd .105)
There are correlations between nearly all these items, as shown in table 2 below.

Table 2: correlations concerned with attitudes to text

<table>
<thead>
<tr>
<th></th>
<th>Q6</th>
<th>Q7</th>
<th>S7</th>
<th>S8</th>
</tr>
</thead>
<tbody>
<tr>
<td>S6</td>
<td>n/s</td>
<td>n/s</td>
<td>n/s</td>
<td>.0093</td>
</tr>
<tr>
<td>Q6</td>
<td>*****</td>
<td>.0011</td>
<td>(+)</td>
<td>.0226</td>
</tr>
<tr>
<td>Q7</td>
<td>*****</td>
<td>.0098</td>
<td>(+)</td>
<td>.0045</td>
</tr>
<tr>
<td>S7</td>
<td>*****</td>
<td></td>
<td>.0000</td>
<td>(+)</td>
</tr>
</tbody>
</table>

S9) If I don’t understand new material, I read the textual material to help
Mean response: 3.59 (sd 1.1)
S10) I can pass by studying lecture notes in Thai and the examples and problems in English
Mean response: 3.73 (sd .103)
S11) It is very difficult to understand the textual material if I haven’t attended a lecture on the subject first
Mean response: 4.11 (sd .91)

These results indicate that students are not using the text to learn about new subject matter. Firstly, 76% say they read the text superficially. This is not an appropriate style of reading for studying new content, but more suitable for purposes like checking information, or locating specific formulations. Secondly there was only a 3.31 mean response to the statement about the text helping students to understand new material. This, in view of the “acquiescent response set” (de Vaus 1995:89), where “...some people agree with the statements regardless of their content.”, is not much of an agreement at all.
1.4. Students use examples and problems more than textual material

The mean responses about the usefulness of text, examples and problems show clear differences:

Examples help: 4.64  
Problems help: 3.94.  
Text helps: 3.31

S12) "In the SSETES, it is generally easier to study the problems than the text.”  
Mean response: 4.07 (sd 1.13)

We conclude that students have a strong preference for the examples and problems rather than the text.

1.5 Two other factors

1.5.1 GPAX:

Students with higher GPAXs spend more time with their SSETEs, but that is the only thing we can say about them. These “cleverer” students are not reading the text more, or finding it more useful, or preferring it to the other parts.

1.5.2 Year:

The only factors which seem to be related to the year of study are those described in section 1.1, concerning attitude to SSETEs. But there is no apparent corresponding change in behaviour. Seniors, it seems, behave like junior students. Their education doesn’t seem to change their behaviour.

1.6 Conclusions

Let us put the contents of SSETEs on a continuum. What’s necessary, what’s useful, what’s accessible, and what’s helpful to understanding are at the top; at the other end is what is difficult, unnecessary (avoidable!), and unhelpful. It seems fairly clear from this study that the examples in SSETEs are close to the top; that problems are somewhat lower down; and that text is much lower again. It is indeed questionable whether students are using the text to learn new subject matter.

2. Text-structuring words

2.1 Open/closed-system words

A distinction commonly made in linguistics is between open-system words and closed-system words. Closed-system words are relatively few in number and normally express relations between the much more numerous open-system words. The number of closed-system words does not increase except slowly and rarely; open-system words are added to all the time. Closed-system words are also commonly called grammatical words. They are of course much more complex to understand and learn than open-system words.

Winter (1978) proposed a class of words that although traditionally classified as open system, actually functioned much like closed system words in the way that they bound parts of the text together and depended for their interpretation on the context. These were later called “text-structuring” words (McCarthy 1987).

An example: Some people sympathised with him but I could not forgive his actions.

There is no way to understand what the word in italics actually means, or refers to, without having read the surrounding sentences. Thus “actions” might be said to be performing a “connecting” or “replicating” function.
This class does not mean the class of adverbials commonly referred to as “inter-sentence connectors” (although these are of course closed-system); it means vocabulary items which perform a comparable function. A list is appended below (see appendix 6).

### 2.2 Text-structuring words, text and applications

As text in textbooks is usually more general in nature, contains much less mathematics, and is physically “longer” than applications, it seemed reasonable to suppose that it takes more linguistic “organising”. The difficulties for the non-native reader in apprehending this organisation were presumed to be one factor in causing reading difficulty, and it was further presumed that text proper would contain more features showing this organisation - including “text-structuring” words - than applications. If this was the case, we might conclude that such text-structuring words would be a suitable teaching item when preparing our students to read academic textbooks, since reading text was shown in the first part of the study to present great difficulty to SUT students.

### 2.3 The scan

16 textbooks were scanned using OCR software. 5 of them were for engineering and 11 for chemical engineering (see appendix 3).

This gave us a corpus of 3 million words; 2 million in the chemical engineering corpus and 1 million in the basic engineering corpus. This corpus was divided first into engineering and chemical engineering and then into text, examples and problems (the latter two being the “applications”). The vocabulary in each of these sections was then compared to find out whether the text-structuring words were a feature of the text rather than the applications.

**Findings/discussion**

The “text” - the explanatory material - of the engineering corpus was compared with the examples and then with the problems; the text of the chemical engineering corpus was treated similarly. Using “Wordsmith” software, lists of “keywords” - i.e. words which are significantly (p<.01) more frequent in one section than in another - were drawn up. (From now, “more frequent” means significantly more frequent.) The keywords which were on Winter’s list of “text-structuring” words were singled out.

The table below shows, in the left hand column, the words from Winter’s list which are keywords, and, in the succeeding four columns, comparisons (by ratio) of each word’s frequency in 1. chemical engineering text vs. chemical engineering problems; 2. chemical engineering text vs. chemical engineering examples; 3. general engineering text vs. general engineering problems and 4. general engineering text vs. general engineering examples. If no ratio is shown (*), that indicates that there is no significant difference in frequency.

**Table 3: relative frequency of keywords in text, as against problems and examples**

<table>
<thead>
<tr>
<th>keyword</th>
<th>chem. eng. text/problem</th>
<th>chem. eng. text/example</th>
<th>gen. eng. text/problem</th>
<th>gen. eng. text/example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. different/cc</td>
<td>14.9</td>
<td>9.4</td>
<td>12.7</td>
<td>12.5</td>
</tr>
<tr>
<td>2. effect(s)</td>
<td>8.5</td>
<td>12.8</td>
<td>6.2</td>
<td>11.5</td>
</tr>
<tr>
<td>3. form(s)</td>
<td>12.5</td>
<td>10.6</td>
<td>12.3</td>
<td>9.6</td>
</tr>
<tr>
<td>4. means</td>
<td>4.2</td>
<td>4.2</td>
<td>4.1</td>
<td>4.2</td>
</tr>
<tr>
<td>5. method</td>
<td>12.7</td>
<td>7.4</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>6. particular</td>
<td>3.2</td>
<td>3.1</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td>7. case(s)</td>
<td>14.6</td>
<td>14.10</td>
<td>13.3</td>
<td>*</td>
</tr>
<tr>
<td>8. change(s)</td>
<td>5.3</td>
<td>11.8</td>
<td>11.6</td>
<td>*</td>
</tr>
<tr>
<td>9. similar</td>
<td>5.2</td>
<td>5.3</td>
<td>3.0</td>
<td>*</td>
</tr>
<tr>
<td>10. states</td>
<td>3.0</td>
<td>3.1</td>
<td>4.0</td>
<td>*</td>
</tr>
<tr>
<td>11. way</td>
<td>3.1</td>
<td>3.2</td>
<td>*</td>
<td>4.2</td>
</tr>
</tbody>
</table>
12. action * 2:1 3:1 *
13. common 4:0 4:0 * *
14. depend(s) * 3:2 * 3:1 *
15. like 2:0 * 4:1 *
16. parallel 2:0 * 3:2 *
17. situation 2:0 2:1 *

There are thus only 17 of Winter’s “text-structuring” words that appear significantly more in the text than in other parts of the books. Of these only 6 (items 1-6 above) appear more frequently in all types of text analysed (engineering and chemical engineering) than in applications. Items 7-12 occur more frequently in only three cases out of four; 13-17 in only two.

The other 80+ words on Winter’s list either
1) are not key at all in text compared with applications; or
2) behave inconsistently - i.e. are keywords in text in some cases, in applications in other cases, and perhaps not frequent at all in others. (e.g. the word “constant” is significantly more frequent in chem. eng. problems than in text; it is also significantly more frequent in chem. eng. examples than text; but it is significantly more frequent in general engineering text than in gen. eng. problems, and is not significant at all in comparing gen. eng. examples with text.)

The hypothesis that these “text-structuring” words, as listed by Winter (1978) will be a significant feature of academic text (engineering and chemical engineering) as opposed to applications, is thus not upheld.

This of course is not the same as saying there is no lexical difference between text and applications; But these facts are not accounted for by Winter’s list. The question of how to characterise text (vs. applications) will be the subject of further research.

3. A useful syllabus for SUT students

3.1 What words students need to know

Taking into account research described by Laufer (1997) I will be proceeding on the following assumptions;

- Mastery of lexis is an extremely important factor in reading ability.
- There is a “threshold” level of vocabulary knowledge. Below this level, learners cannot expect to be able to read L2 (the second language) in anything like the way they do the L1 (first language). Above this level, they are significantly more likely to be able to cope.
- A mastery of lexis is more likely to be a significant factor in improvement than a mastery of grammar. (see for example Ulijn & Strother 1990)

The chemical engineering corpus consists of just over 2 million running words (tokens), and something over 30000 different words (types). Of these 30+000, just over 5000 occur more than 20 times in the corpus. This is equivalent to appearing about once every 300 pages or more. The list appended here (appendix 2) consists of those 5000+ words, with the following adjustments.

1. Function words - closed-system words - have been omitted.
2. Many of the words here have been lemmatised. This means that the word “use” (the most common word on the list) has been merged with “used”, “using”, “useful”, and “user” etc. The number of entries has in this way been reduced to 2640. Lemmatisation is not an exact science. Usually, the first word (alphabetically) has been used as the headword below (thus “velocities” is an entry, although “velocity” is actually by far the more common form of the word in the corpus.)

In the light of the research it seems reasonable to say that a student with sight recognition of all the following words would be well equipped to read chemical engineering textbooks.

The list still needs refining to take account of polysemy, technical meaning etc.
3.2 The current lexical syllabus at SUT

In each of English 1, 2, 3 & 4 students are asked, as part of the CAI programme, to learn about 40 words per week. These words are taken from the texts that they read on the course. The total number of words they are asked to learn is 1620. (Appendix 4).

Note that these words, being from the texts used on the courses, and being content, open-system words; tell you a great deal about the subject matter of a text. One should thus be able to make some judgement about the relevance of the texts in use from the word list; these words tell you what the texts are about. It is not just a question of the relevance or otherwise of the lexical syllabus; it is a question of the relevance or otherwise of the texts themselves.

Of the 1620 words, 533 appear in the engineering corpus 10 times or more. Thus 1067 of these items occur less than (say) every 300 pages, i.e. 62% of the English vocabulary syllabus is extremely rare or non-existent in the engineering corpus.

The proportion in the chemical engineering corpus is not much different; 638 of the items occur 20 times or more (i.e. every 300 pages or so), while 982 do not; i.e. 66% of the English vocabulary syllabus is rare or non-existent in the chemical engineering corpus.

If the chemical engineering corpus as a whole (not just the words occurring 20 times or more) is taken, then 1241 items of the English 1/2/3/4 lexis is found. This means that 603 (about 36%) of the English 1/2/3/4 lexical items occur between 1 and 20 times in a 2 million word corpus. In the engineering corpus, if all the corpus (not just the 10+ words) is included, 960 of the English 1/2/3/4 words appear. This means that 427 (about 26%) of the English 1/2/3/4 words appear between 1 and 10 times in a 1 million word corpus. This information is summarised in Table 4 below.

### Table 4: Occurrence of English 1/2/3/4 vocabulary in engineering/chemical engineering corpora

<table>
<thead>
<tr>
<th></th>
<th>TOTAL NUMBER OF DIFFERENT WORDS IN ENGLISH 1/2/3/4 VOCABULARY SECTION:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1620</td>
</tr>
<tr>
<td></td>
<td>BE = BASIC ENGINEERING</td>
</tr>
<tr>
<td></td>
<td>CE = CHEMICAL ENGINEERING</td>
</tr>
<tr>
<td></td>
<td><em>5000 MOST COMMON (BE)</em></td>
</tr>
<tr>
<td></td>
<td><em>5000 MOST COMMON (CE)</em></td>
</tr>
<tr>
<td></td>
<td><em>FULL CORPUS (BE)</em></td>
</tr>
<tr>
<td></td>
<td><em>FULL CORPUS (CE)</em></td>
</tr>
<tr>
<td>WORDS FROM ENGLISH</td>
<td>533</td>
</tr>
<tr>
<td>1/2/3/4 (1620)</td>
<td>638</td>
</tr>
<tr>
<td>WORDS FROM ENGLISH</td>
<td>N/A</td>
</tr>
<tr>
<td>1/2/3/4 OCCURRING RARELY</td>
<td>N/A</td>
</tr>
<tr>
<td>WORDS FROM ENGLISH</td>
<td>1087</td>
</tr>
<tr>
<td>1/2/3/4 NOT OCCURRING</td>
<td>982</td>
</tr>
<tr>
<td></td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>379</td>
</tr>
</tbody>
</table>

**BIBLIOGRAPHY**


Winter, E.O.: *A look at the role of certain words in information structure* in Informatics 3:1, ASLIB 1978
APPENDIX 1: QUESTIONNAIRE

QUESTIONNAIRE
Analysis of the methods used by Suranaree University of Technology chemical engineering students to study their English language textbooks.

This questionnaire is in four parts, dealing with the following:
Part 1: respondent’s personal details
Part 2: approaches to studying English language textbooks
Part 3: methods and problems in studying English language textbooks
Part 4: opinions about studying English language textbooks.

Part 1: personal details

Instructions: tick ( ) in the appropriate box.

Sex: male female

Year of study: year 1 year 2 year 3 year 4

GPA (as of the 3rd term of academic year 2540)
Part 2: approaches to studying English language textbooks

Instructions: most English language textbooks consist of a number of different parts, as follows:

**explanatory material:** this part explains the new subject matter in a chapter (usually to be found at the beginning of the chapter)

**examples:** this part contains examples of the new subject matter being studied

**problems:** this part contains problems to test your understanding of the new subject matter (usually to be found at the end of a chapter)

**diagrams:** this part consists of pictures, diagrams and charts to help make the subject matter clearer.

This questionnaire aims to establish to what extent and how students make use of these different parts.

Put a tick (✓) in the appropriate box.

1. On average, how many hours per week do you spend studying English language textbooks?
   - I never study English language textbooks
   - 1-3 hours
   - 4-6 hours
   - 7-9 hours
   - more than 9 hours

2. When reading English language textbooks, how much do you study the explanatory material?
   - I read it in detail
   - I read some of it
   - I never read it

3. When reading English language textbooks, how much do you study the examples?
   - I study them in detail
   - I study some of the examples
   - I never study the examples

4. When reading English language textbooks, how much do you study the problems?
   - I do all the problems
   - I do some of the problems
   - I never do the problems

5. When reading English language textbooks, how much do you study the diagrams?
   - I study all of them
   - I study some of them
   - I never study them

6. Which part of the English language textbooks do you find useful when studying? (You may tick any number of boxes)
   - The explanatory material
   - The examples
   - The problems
   - The diagrams
<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  The meaning of technical words presents a big difficulty for me when studying English textbooks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2  The <strong>examples</strong> in English textbooks help me to understand the subject.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3  I would prefer to read the subject matter in Thai if I could.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4  If I don’t understand new subject matter, I read the <strong>explanatory material</strong> in the English textbooks to help my understanding.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5  I can pass the tests by studying only lecture notes in Thai and <strong>problems</strong> and <strong>examples</strong> from English textbooks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6  In the English textbooks, it is generally easier to study the <strong>problems</strong> than the <strong>explanatory material</strong>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7  The <strong>explanatory material</strong> in English textbooks helps me to understand the subject.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8  As I study at a higher level, I need to study English textbooks more than previously.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9  The English in the <strong>problems</strong> is easier than the English in the <strong>explanatory material</strong>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Word meaning presents a bigger difficulty than grammar for me when I am studying English textbooks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 I need to study English textbooks to pass courses at SUT.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 I have an good understanding of technical terms before I go to study the English textbooks.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 The <strong>problems</strong> in English textbooks help me to understand the subject.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 The Thai textbooks which are available are adequate for study purposes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>15 It is very difficult to understand the <strong>explanatory material</strong> in the English textbooks if I have not already attended a lecture on that subject.</td>
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<td>16 It is necessary to study the <strong>explanatory material</strong> in English in order to pass the courses.</td>
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neither undesirable ambient propylene refrigerant split white gel ignore monomer nor categories demonstrated lead strategies accompanied central cloth electricity instant klin money pole recirculated rectification coolant disadvantage event former mold passage pipeline supersaturato unstable detergent fabricated hypothesis injected moderator origin sole think allowable business counter electronic transition analog country diaphragm downcomer gauge manometer object package spread stagnant sudden article brief conservation generate matrix molten prove reflect serious unique welded circumstances create emphasis federal flares perpendicularly pulsar slot basket neutron flange human insurance isomer phenol subrogated wave hexane mounted recognize rigid styrene asset contaminant electrolyte handheld intangible intangible mineral polynuclear scurried thoroughly upstream superheated zinc competing cone exponent hydraulic neutral otherwise science wilson fashion fruit person regulate remark station tabulated triangle deep journal offset possess realizable slab software top arithmetic coils coupled earth ensure grain henry's stock voltage arrive currently disappearance effort ice spent sulfite technical bath dng filtrate paragraph remainder disposal earnings indeed periodic propeller subtract graph happen inorganic interpretation limit legalization minus pan silicon virtually adjacent annular ask description nach bucket caps regular you attraction core denominator dactyl hepatic nicotine octane attained ecologically impact page presents throat abscessa advanced arbitrarily chemistry ease electrode limestone notation salage seed stroke discovered ether flexibility freezing glycerin historical land pair permanent ronin's review esoteric theorem equanimos evolve extremely hundred machinery nominal pilot regard stand variance honor deposition failure magna multisite noncondensable owing pharmaceuticals tell reliable technology throttle week droppers grape milk namely trough wafer alkyl amplitude dollar eventually locus oven try cone hollow hydrogenation interpopulation mechanics scope themselves thereby uranium algebraic branch cotton empty ess they find heterogeneous indirect intense screw uncertain vector additive capable gear odor osmosis really tool alternate barometer care companion conditioning corrosive duct economy fluctuations lake oscillating picture radical rated soil stem unsaturated cyclone did ignition immersed interior likely lives metallic monoxide nussel photographic raschig reuse warm xylene convergence fourth isotubene joined knit bleached marquis omitted pairs prevailing prob soon thousand triple capitalized emissivity familiar frugal health industry pentane polar separate thermometer today tuning electron justified lithium lamp middle after bacteria enclosed extra fines instantaneous murphy protein trace cucumber customary disc exception flavor government ingredient interpret liquefaction minnow nothing saturation saddles steep bleaching cumene escape flowchart glycol lift wind minus nonthermal risk sort trap via appearance bernoulli der fabric feasible fluidization guess interfacial kerosea paste penetration preheated softened textile acetylene assembly collision dropped fouling hydrosulcy miscibility rankine skin tall vinyl age claimed hydrofloric marked month national prior sulfite with allowance compensate greenroom gasoline soot water seawater sump hemp lessening depicted imitative intermolecular logic member moreover naphthalene narrow public thieke unexpected whenever body butyol disruption drain occasionally rollstream linha subjective successful sure universal vases adheres bank chance coalesce concrete equipped feel gave graphic lap paraffin role beet downspout exponential formaldehyde fusion immiscible kwong microorganisms peripheral spring sucrose area vent vortex bromine chloroform closer delay differential ector endothemic fin platinum polynymo popular ready schmidt segment skill soft startup annulus anode apart century circuit damage everywhere identity nyquist patent performance policies regard regardless sensor solar tree unfortunately blue certainly contrast emitted intake seconds sink strictly winery beer casing chlorobenzene flammable inflow relation would seawater ammonia butadiene colloidal cores ever filament guide nutrient overcome play potash segregation sewage spinning ahead cathode dah discarded foam frictionless layout leg margin perry reserve sense termed wheel yellow capillary character chief clearance dancing decide domestic elaborate envelope explicit house meal payment exploit shiprippage equipment car confidence cumulative favorable lubricant management mostly ozone paid quiet trial suited adjustable inversion investigation letting much optimal roller shock thermocouple trade usage admitted aim date incoming mode reforming round tunnel ammonia antique atom car abide chips duty evident extruded fine graphite gun antiintentional inversion lack leather mph nonvolatile numerous shut strain summer supercritical ten accordance bone cars current contraction costly declining diagonal ethylenebenezene favor invariant leaf mining overdamped peak pick pool regression specialized superior tetrachloride tight undesirable aniline aspects automobile biological bit bound cavity conduit diesel fusion focus goal opposed population pyridine supersaturated wear abrasion are electrostatic europe fish front horsepower nth olefin reasoning scrap verify counterflow doing enormous exhausting fountain's inherent juice majority modulator pneumatic river seven syrup viewpoint wind cat cation deactivation elemental hardware home kevin kinematic porcelain printing purge search serebatch settler summation confined crossflow daily electromagnet fair fused graphs hammer helpful image inclined joiue maximize miscellaneous mist penicillin polyvinyl rayon realistic revolving ribbon stokes titanium bundle cancel charcoal constantly datum england ill infinity inspection interchange intimate job memory noise nylon scrape scorcher tear temray thrust transient tracks underplay unobtrusive acetyldehyde array bell borax curvature deprivation dehydration devoted firm halide helium mediaotation numerator parentheses psychrometric rigorous routine sedimentation sherwood simulation stuffing subcooled task unimportant virtue wool bypass chrome cylinder dumped electronic ester furnish mild oversized peclet people plain poseuse polyethylene presentation sea sip straightforward+ thumb torque turbinee withstand adds asks caught composite convention coverage departure examination fluorescence impulse incorrect induced ketone lanirn metalurgical mined maxnessd particularistic personed presently progressive quibble rayon set back second subsidiary use原则 ago arguments attachments believed belr chromium continually domain electrolysis devoted fnt integral inventory likewise nonporous opaque pertinent presumed randall shah sinusoidal sulfonation superscript things thrown trioxide vat vice wells angular art asymmetric bag broad bristle cane cents ci corporation cottoneed dehydroacidificdti dipole extrapolation falhentein flashes ge gelatin ill instrumentatian jaw legal moment organization percussion ports soybean stone trans underground university wheeupon accord argon backward besides chicken chest cited confusion contacts devised downstream else elsewhere en entry facilitate foreign gate gold incomplete institute international issues knife latex longitudinal ls mesylene microscopic municipal noncommutation payout portland rework sublayer supervision taste universal amongo authors bicanorative binding buffer concentrate concave constant cono crosson crossover danger depicted diverging dolomite eight evacuated evolution false seawater formal forth fructose hydronodynamic incident insufficient intended loose pseudo repairs revolution slice spectrum subsystems tall unmeasured accommodate antibiotics assist beans boltzon manipulation brown bubblepoint biotone ferrous fictitious gray hagen iodine kraft labeled loc makeup mucebe miscellaneous nonflow noninteracting orst physics professional progressively pulley roof shrinkage summing supersonic voneds variances version weather aliphatic attrition constrictions conjunction cyclizene deletion dirt everything exercise flick's faller froth gulls gi goods governed hydrodealkylar implicit inexpensive inward ligatin mina military naphtha oblonge pinch plunger polyester pulverized resin rotamer shallow spit sm systematic taps tedious transparent unwanted visible analytic analytic arms asphalt assigned background bounded breakdown celsius chiefly classical cocking combustible compensator curing dammed dimethyl thinned generalization glycerol imposed insects isopropyi iith land liberated modest multipass neutrons nichols no objectionable optical gaze pivot polished promising quantum quarter redundant reflex relevant shutdown sight style subsoic supersulfate temporary tire tit vitamins wine yellow accessible adhering anion artificial bauxite bin brass calcined california coffee coincide contrary cyanide dehydrogenato destroyed disulfide enamei ferris ferric fursral gasification hydrostatic infinimals insects intoxication intermission introporphyrin macrol as nitrosoclosose nonporal pet prime pmt south survey switch trunctated vital vol accordingly adopted airmest app attain basin bends brackets compact count enclosure extermination eye face formation frequently fossil grashof hardening household inequality necessity neighborhood office options organisms pisat posed priming resembles rocket sluggish stage wise sticky supplementary surfactants tough ultraivolt unaffected unbound asp vh wink window bare
APPENDIX 3: BOOK LIST

Engineering

Montgomery D. & Runger G. (199x): Applied statistics and probability for engineers (Wiley)

Chemical Engineering

Badger W. & Banchero J. (1955): Introduction to chemical engineering (McGraw-Hill)
Austin (1963): Shreve’s chemical process industries (5th ed.) (McGraw-Hill)
Winnick J. (1997): Chemical engineering thermodynamics (John Wiley)
Levenspiel Octave (1972): Chemical reaction engineering (John Wiley)
Fogler H.S. (1986): Elements of chemical reaction engineering (Prentice Hall)
Stephanopoulos G. (1984): Introduction to chemical process control (Prentice Hall)
Peters, Timmerhaus (1990): Plant design and economics for chemical engineers (McGraw-Hill)
APPENDIX 5: WINTER'S (1978) LIST OF "TEXT-STRUCTURING" WORDS
achieve, addition, action, affirm, alike, analogous, antithesis, attitude, attribute, basis, case, cause, characteristic, change, common, compare, compatible, concede, conclude, condition, confirm, connect, consequence, constant, contradict, contrast, converge, correct, correspond, deduction, deny, depend, differ, differentiate, distinction, distinguish, effect, equal, error, evaluation, event, exemplify, exception, explanation, fact, feature, follow, form, function, general, grounds, hypothetical, identify, instance, instrumental, justification, kind, lead to, like, manner, match, matter, mean., means (of), method, name, object, opposite, move, observation, parallel, particular, point, problem, real, reason, reciprocate, repeat, replace, reply, requirement, resemble, respect, result, reverse, same, similar, situation, sort, solution, specify, state, subsequent, synonymous, technique, thing, time, truth, unique, way