COMPUTER AIDED CURRICULUM ANALYSIS

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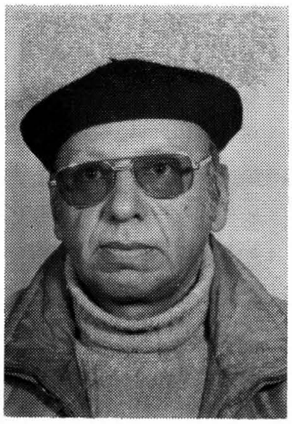
A CURRICULUM ANALYSIS must concern itself with both object matter and with the prerequisite knowledge a student needs to know in order to learn a subject. In general, the prerequisite analysis should

- **Identify a set of basic subjects needed to study a specific subject**
- **Identify all of the sequences of subjects to learn a specified subject**
- **Identify the optimal sequence to a specific subject where the optimality criterion might be: a) minimum time; b) minimum number of subjects; c) minimum effort.**

This type of analysis could be of help to administrators, teachers, and students in organizing and optimizing courses, evaluating examination results, student performance evaluations, etc.

In principle, it is possible to identify the prerequisite knowledge a student needs to learn a new subject. Then for a given number of subjects, each subject having a list of prerequisite subjects, it is possible to construct a figure such as Figure 1, which represents this prerequisite information. Figure 1 is a diagram for the subject matter of the Material and Energy Balance self-study modules being prepared for the CHEMI Project [1] by the CACHE Corporation under the sponsorship of the NSF Contract. Table 1 is a listing of the individual topics (modules) and the number associated with each topic in Figure 1. This listing was formulated by Professor Dave Himmelblau.



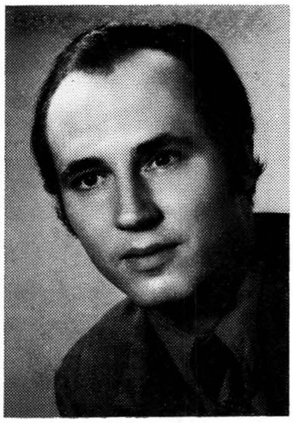


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TABLE 1
Material and Energy Balances

1. **Units and dimensions (including systems, conversion factors)**
2. **Methods of analysis and measurement (density, concentration, mole and weight fraction, specific gravity, etc.**
3. **General guidelines for solving problems (including selection of basis)**
4. **Temperature (measurement, scales, conversion)**
5. **Pressure (measurement, scales, conversion)**
6. **Sources of data for physical properties**
7. **Ideal gas laws for one component**
8. **Ideal gas mixtures (including partial pressure)**
9. **Real gas computations—equations of state**
10. **Real gas computations—compressibility charts**
11. **Real gas computations—mixtures**
12. **Vapor pressure**
13. **Saturation, humidity**
14. **Partial saturation, humidity**
15. **Phase phenomena (including phase rule)**
16. **Steady state material balances—algebra not required**
17. **Steady state material balances—algebraic solution required (includes the components)**

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18. Steady state material balances—recycle, bypass, purge
19. Steady state material balances—involving vaporization and condensation
20. Degrees of freedom in process specification
21. Steady state material balances—multiple process of equipment
22. Solution of steady state material balances via the computer, Part I
23. Solutions of steady state material balances via the computer—Part II—effective numerical techniques
24. Solution of steady state material balances via the computer—Part III
25. Concepts of energy and work (including heat, kinetic energy, potential energy, state, enthalpy, property)
26. Heat capacity (definition, measurement, computation, prediction)
27. Enthalpy (computation, application, tables, charts)
28. Enthalpy for phase change
29. Steady state energy balance—principle and formulation
30. Steady state energy balance—application
31. Mechanical energy balance
32. Heat of formation, reaction, and combustion
33. Change of heat of reaction with temperature and pressure
34. Incomplete reactions
35. Heats of solution and mixing
36. Steady state simultaneous material and energy balances—principles
37. Steady state simultaneous material and energy balances—applications to combustion
38. Steady state simultaneous material and energy balances—applications to enthalpy concentration charts
39. Steady state simultaneous material and energy balances—application to humidity charts and their use
40. Steady state simultaneous material and energy balances—application to . . .
41. Unsteady state balances—principles
42. Unsteady state balances—solution techniques for ordinary differential equations

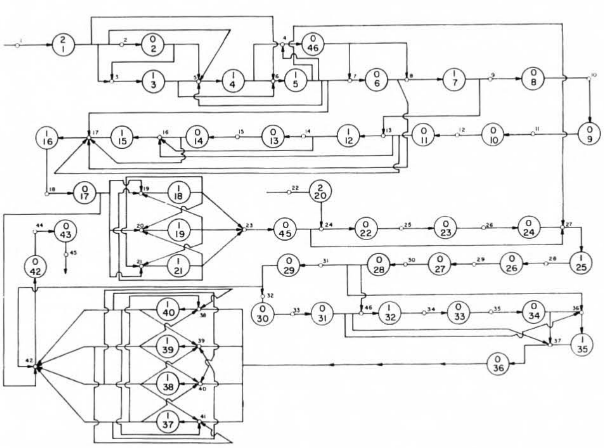

FIGURE 1. Material and energy balance modules.

43. Unsteady state balances—applications and examples
45. Module 45 is a dummy module since the algorithm can only handle "and" and "or" statements, and not combined and/or situations
46. Dummy module

Figure 1 is prepared by beginning with the most fundamental or basic modules having no prerequisites with respect to the other modules and then proceeding to the other modules asking the question whether the previous module is a direct pre-prerequisite (an "and" statement) or are there other direct prerequisite possibilities (an "or" statement). Note, only direct prerequisites need be considered for the construction of Figure 1. For this example, only module titles and the authors' teaching experiences were used. Once the modules are completed, it will be possible to use the prerequisite listing prepared by the module author to aid in the preparation of the diagram. While there will be variation in Figure 1, depending on who and how the diagram is

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constructed, the computer analysis discussed later provides a self-corrective method to help eliminate the variation.

The diagram shows only direct prerequisite relations of topics in a curriculum for a specified field, and consists of topics (modules), nodes, flag gates, and directed arrows. Nodes are used in the diagram as in block diagrams. They are of two types: input nodes and output nodes. They are represented by dots. The directed arrows are used to indicate the direction of flow in the diagram. The flag gates are located in the top half of the circle and topic number in the lower half. There are three types of gates:

2 Represents an originating topic (module)—no prerequisite needed
1 Represents an or gate
0 Represents an and gate

The diagram indicates, for example, that if one wants to study topic 2 one needs to study topic 1 first. On the other hand, if one wants to study topic 4 there are alternatives. One could study topic 1 and then go directly to 4, or one could study topics 1, 2, 3 and then 4, or one could study just topics 1, 3, and then 4, or 1, 2, and 4.

PATH MATRIX

PROCEEDING TO HIGHER numbered topics, we see that Figure 1 becomes somewhat difficult to follow and analyze. Henley and Caceres [2], and Henley and Longoria [3, 4] have developed an algorithm which aids in the analysis of this type of diagram. The algorithm, based on graph theory [5], develops a path matrix of all the possible paths to a given module or topic. This path matrix is then transformed into a form similar to a fault tree. Figure 2 is a typical output

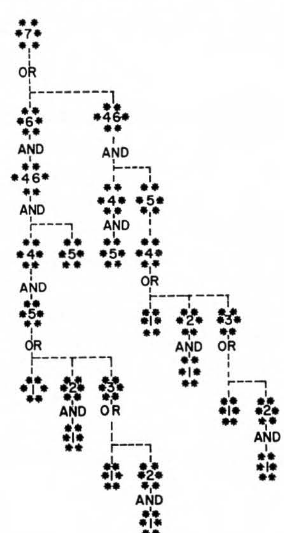

FIGURE 2. Prerequisite diagram.

where module 7 in Figure 1 was chosen as the 'Top Event.' Figure 2 enables one to clearly identify all of the sequences of subjects to learn topic 7, the ideal gas laws for one component. It enables one to quickly determine the number of different paths to the topic, the shortest path to the topic (time optimal path), and the most reoccurring prerequisite topics—those which appear in all the different paths to a topic. Also, from Figure 2, terminal topics and basic (beginning) topics are easily identified.

As an example, consider the computer printout for module 1—Ideal Gas Laws for One Component—shown in Figure 2. Examining Figure 2, we observe the following independent paths leading to module 7:

7-6-46-4-5-1
7-6-46-4-5-2-1
7-6-46-4-5-3-1
7-6-46-4-5-3-2-1
7-46-4-5-1
7-46-4-5-2-1
7-46-4-5-3-1
7-46-4-5-3-2-1

Since the sequence of modules 4 and 5 can be interchanged, there are 16 different ways of approaching module 7. We see that path 7-46-4-5-1 is the shortest path to module 7 if all modules involve the same time and effort. Ideally this is the case for the CHEMI modules, since each is designed to be equivalent to a one hour lecture. However, should the time and effort of the modules be different, the total time of each path could be determined simply by assigning the specific time to each module and then adding to arrive at the total time.

The most reoccurring prerequisite modules, that is—the modules which are near absolute prerequisites for a given topic are the same modules which comprise the shortest path. For module 7 we see from the sixteen possible paths, that modules 1-4 and 5 are required for each possible path.

Table 2 summarizes the analysis of all the modules in the subject heading of Material and Energy Balances with respect to two categories: possible paths to a given modules, and the time optimal path and/or the most reoccurring prerequisite modules.

The information in Table 2 can be used by both the student and the professor. The student desiring to learn given topics or modules can optimize his time by choosing the time optimal path. The professor, on the other hand, having a time constraint on his course, can structure his course based on the most reoccurring prerequisite modules, thereby giving the student the most general or fundamental background for future studies. For example, suppose only 16 hours of course time were available, then only 16 CHEMI modules could be studied. Which 16 should be taught? From Table 2 it seems clear from observing the most reoccurring module column, that we should start with module 1, then 4, 5, 7, etc. until we have 16 modules—skipping modules that are not as fundamental as others. This process should, however, not be followed blindly since higher numbered modules of importance can be neglected.

Continued on page 95.

TABLE 2
Material and Energy Balances

SUBJECT OF MODULE	POSSIBLE PATHS TO MODULE	TIME OPTIMAL PATH AND MOST REOCCURRING MODULES
1. Units and Dimensions	0	no prerequisite
2. Methods of analysis and measurement	1	1-2
3. General Guidelines for solving problems	2	no prerequisite
4. Temperature	8	1-4
5. Pressure	8	1-5
6. Sources of data for physical properties	8	1-4-5-6
7. Ideal Gas laws for one component	16	1-4-5-7
8. Ideal Gas mixtures	16	1-4-5-7-8
9. Real Gas Computations eqs. of state	16	1-4-5-7-8-9
10. Real Gas computations compressibility	16	1-4-5-7-8-9-10
11. Real Gas computations mixtures	16	1-4-5-7-8-9-10-11
12. Vapor Pressure	32	1-4-5-7-12
13. Saturation, humidity	22	1-4-5-7-12-13
14. Partial saturation	22	1-4-5-7-12-13-14
15. Phase phenomena	32	1-4-5-7-12-15
16. Steady state material balances—all, not req.	80	1-4-5-16
17. Steady state material balances—all req.	80	1-4-5-16-17
18. Steady state material balances, bypass, surge	400	1-4-5-16-17-18
19. Steady state material balances involving vap. and cond	400	1-4-5-16-17-19
20. Degrees of freedom	1	no prerequisites
21. Steady state material balances multiple process equipment	400	1-4-5-16-17-21
22. Solution of Steady state material balances—via computer—Part I	720	1-4-5-16-17-18-19-20-21
23. Solution of Steady state material balances—via computer—Part II	720	1-4-5-16-17-18-19-20-21-22-23
24. Solution of Steady state material balances—via computer—Part III	720	1-4-5-16-17-18-19-20-21-22-23-24
25. Concepts of energy and work	1448	1
26. Heat capacity	1448	1-4-5-25-26
27. Enthalpy	1448	1-4-5-25-26-27
28. Enthalpy for phase change	1448	1-4-5-25-26-27-28
29. Steady state energy balance	1448	1-4-5-25-26-27-28-29
30. Steady state energy balance application	1448	1-4-5-25-26-27-28-29-30
31. Mechanical energy balance	1448	1-4-5-25-26-27-28-29-30-31
32. Heat of formation, reaction and combustion	2896	1-4-5-25-26-27-28-32
33. Change of heat of reaction with temp. and pressure	2896	1-4-5-25-26-27-28-32-33
34. Incomplete reactions	2896	1-4-5-25-26-27-28-32-33-34
35. Heats of solution and mixing	5792	1-4-5-25-26-27-28-35
36. Steady state simultaneous material and energy balances—principles	10136	1-4-5-16-25-26-27-28-29-30-32-33-36
37. Steady state material and energy balances—combustion	10136	1-4-5-16-25-26-27-28-29-30-32-33-36-37
38. Steady state material and energy balances—enthalpy concentration charts	10136	1-4-5-16-25-26-27-28-29-30-32-33-36-38
39. Steady state material and energy balances — humidity charts	10136	1-4-5-16-25-26-27-28-29-30-32-33-36-39
40. Steady state material and energy balances—applications	10136	1-4-5-16-25-26-27-28-29-30-32-33-36-40
41. Unsteady state balances principles	52,208	1-4-5-16-17-41
42. Unsteady state balances solution techniques for ordinary differential eq.	50,208	1-4-5-16-17-41-42
43. Unsteady state balances applications and examples	50,208	1-4-5-16-17-41-42-43

CURRICULUM ANALYSIS: Heenan & Henley
Continued from page 67.

But certainly, with a course time constraint, the most reoccurring modules should make up the majority of the material covered if the professor desires to give his students the broadest possible background for future study.

One corrective feature of this computer-aided method of curriculum analysis is that while Figure 1 can be arbitrarily drawn, that is, the diagram could be different depending on who constructs it, it was found that errors, omissions, etc., in Figure 1 are easily found and correctable after examining the computer output. This results in a refinement of Figure 2 which removes most of the arbitrariness of the construction of Figure 1. This is similar to what often happens to a professor while teaching. Suddenly he realizes that he forgot to cover a needed subject in order to properly explain his topic. So he stops and goes back to cover the needed subject matter. The corrective sequence of events is as follows:

1. Construct Figure 1
2. Run program based on the information of Figure 1
3. Check all possibilities which are generated by the program, Figure 2
4. Eliminate impossible paths or add obvious missing paths
5. Modify Figure 1
6. Run program again
7. Repeat steps 3 to 6 until no further omissions or impossibilities occur

The use of the above procedure is believed to provide a satisfactory method of curriculum analysis which can be used by anyone knowledgeable of the subject area to be taught or studied. The method should also help both students and professors to optimize the learning process. □

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BOOK REVIEW
Continued from page 53.

numerous worthwhile conclusions concerning both the strategy and tactics of reactor simulation. However, it is very difficult to understand how many of the conclusions were obtained.

Unit Operation models are covered in Chapter 3. Distillation, Absorption, Compressors, Heat Exchange and Pumps are discussed. Although the author states that "The number of man-hours spent on costing a project can equal the number spent on its process design.", he devotes only 7 pages to the topic of costing.

Chapter 4 is entitled Specific Process Models. Simulation versus design models are discussed but without a strong conclusion for one or the other. The author implies successive substitution is an adequate recycle convergence method and that tearing to minimize the number of unknowns in a recycle system is the best approach; the reviewer's experience suggests otherwise. In discussing requisite output from a process model the author omits the need for any output showing the progress of the calculations; he does suggest output options are valuable, however. The author's discussion of the uses of process models for sensitivity analysis is good.

Chapter 5 covers generalized flowsheet programs. Since the vast bulk of model usage is generalize flowsheet programs, either publicly available or proprietary, or of other 'canned' programs, one should think this chapter would be quite long and comprehensive. Unfortunately it is not. The author spends only two pages on discussion of the data library and correlations and implies that the field is much further behind than it really is.

Chapter 6 is entitled The Use of Modelling at the Planning Stage. This is a survey on 'operations research' techniques such as LP, DCF and