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ABSTRACT

Teaching and learning, especially in higher education, appear to consist of complex analytic and synthetic processes which create concepts and relate them to one another. Sixteen model courses from the natural sciences, social sciences, and the arts and humanities were examined to establish some general characteristics of university course material and to understand the perspective of the professor teaching course material. Data were gathered by research assistants attending classes and from professors themselves. The following kinds of data were collected: number of relevant concepts: hierarchy of key concepts: definitions and degree of common usage: mode of representation: abstraction/concreteness: inclusiveness: salience: word associations: tree structure: similarity grouping of all concepts: word associations, overlap, related coefficients: and relatedness of meaning. Three case studies of specific courses are presented to illustrate the data more effectively. A list of eight implications of the study are compiled for professors, curriculum developers, quality control experts, and university planners interested in improving student learning structures through improved teaching techniques. References are appended. (DC)

STRUCTURES OF KNOWLEDGE AND IMPLICATIONS FOR TEACHING

Janet G. Donald

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Report #6

March, 1980

ABSTRACT

Teaching and learning especially in higher education appear to consist of complex analytic and synthetic processes which create concepts and relate them to one another. An understanding of the nature of the concepts in a course and their relationships should, then, suggest ways to improve teaching and learning. The structures of knowledge of sixteen courses from different disciplines were analyzed to reveal similarities and differences among courses, and the most adequate and useful representation of these structures. The findings provoke hypotheses and implications about curriculum structure and student learning.

Preface

The Standing Committee on Teaching was pleased to sponsor (in cooperation with the Education Research and Services Centre) a visit to U.B.C. of Dr. Janet G. Donald on March 6 and 7, 1980. Dr. Donald, on leave from McGill University, consulted with staff, held a graduate seminar and a conversation hour with faculty and delivered a colloquium address which forms the body of this report.

Consistent with the purposes of the Standing Committee and the Centre for the Improvement of Teaching (CITE), Dr. Donald's paper is addressed to professors who are concerned with course improvement. In it she reports the results so far of an intensive study of conceptual knowledge as it is structured in sixteen university courses in the humanities, social sciences, and natural sciences. Distinct quantitative differences in terms of number of concepts, and qualitative variations in concept structure were observed between courses and course types. Implications for teaching improvement and for further study based upon these findings are drawn.

We are pleased to present Dr. Donald's paper, a progress report on a large and important research project, in this format as the sixth CITE report. Dr. Donald delivered the third annual colloquium in the series begun exactly two years ago by her McGill colleague Dr. Patricia A. Cranton, and continued in 1979 by Dr. Harry G. Murray of the University of Western Ontario. The previous two colloquia concerned teaching evaluation and are Reports #1 and 5 in this series respectively.

The author and sponsors of this report invite comments, questions or remarks from recipient readers. Address these to Dr. Donald at the Centre for Teaching and Learning Services at McGill University, Montreal, P.Q., or to CITE at the U.B.C. Faculty of Education, Vancouver, B.C. Additional copies of this or other reports in the series are available from CITE upon request (enclose $2.00 Canadian for each copy desired to defray production and postage expenses).

Stephen F. Foster
Vancouver, B.C.

March, 1980

STRUCTURES OF KNOWLEDGE AND IMPLICATIONS FOR TEACHING

Janet Gail Donald, Ph.D.

There are some things in higher education about which we more or less agree. One of these is that the good teacher is someone who knows a great deal about his or her subject. Another axiom is that the good teacher knows how to get the material across. But our approach to teaching improvement seems curiously one-sided. We are very concerned about process, but consider the substance of educational content sacred ground. This leads, in education faculties, to methods courses which dwell on instructional strategies and, in teaching improvement units in universities, to research and practice which concentrate on the presentation of material. Our students sometimes remind us that attention to subject matter is important when they rate as good teachers those who show organization and conceptual clarity in their courses (Hildebrand, Wilson, and Dienst, 1971). To a student, what makes a good teacher is the ability to deal clearly with content and to analyze and synthesize course material, the very attributes that professors ask of their students. What this requires on the part of the professor is an overview of the content structure of the subject matter. This should result in not only more satisfied students but greater success in getting students to integrate and apply what they learn in a course. Error rates and confusion decrease when content representations and relations are clear. Another return for the professor who invests time in an intensive study of course content is the set of resulting suggestions for better sequencing and instructional methods. For the professor who is teaching a course where the major objective is the comprehension of a wide body of abstract ideas, focussing on course concepts and their relationships can provide insight into how and in what order the content should be presented for optimum learning and retention. One more reason for looking at what we teach is in the interest of justice or fairness in the evaluation of student learning. We all know of incidents in which grades have been challenged or the entire educational institution has been attacked, and we continue to live with grade inflation. An understanding of what is to be learned in a course is the first step to validating course grades.

The purpose of my study was therefore to investigate the knowledge structure of courses in various disciplines in the university. The study was exploratory in nature and of a scope broad enough to uncover different structures and to make comparisons among them. My mission was to establish some general characteristics of university course material and to understand the perspective of the professor responsible for the course. This was done by electing model courses in different disciplines. Each model course could be expected to exhibit the general characteristics of its discipline, although it would not necessarily be the most typical course. Only an investigation of all the courses given in a particular discipline would reveal the most typical. Choosing a course from each discipline, however, provided the opportunity of discovering different epistemologies and trends across disciplines.

In planning the study, attention was also paid to the premise that each course and each discipline is not like any other. Professors consider the framework or organization of a course to be unique; it appears that each professor creates a particular paradigm within which the course material is assembled. Furthermore, the paradigm appears to be necessary for the professor to be able to teach, in the same way that scientists require a paradigm to guide their research (Kuhn, 1970). The premise of uniqueness acts both as a caution to the research, in that it limits its potential generalizability, and as an hypothesis to be tested or clarified. The major research question was, then, in what ways is the knowledge structure of different university courses alike, and in what ways is it different?

The history of research into the structure of knowledge has been one of many paths. From Plato's attempt to define knowledge in the Theaetetus (Edman, 1956), to the work of

Bloom (1956), Tulving (1972) and Rumelhart, Lindsay, and Norman (1972), knowledge and its organization have attracted the interest of researchers from many fields. I will only briefly mention the major trains of investigation. One of the best known to curriculum developers is Bruner's (1960) emphasis on the underlying principles that give structure to a subject and should therefore determine the curriculum. In the spiral curriculum, these principles are presented in ever increasing depth and richness so that comprehension develops fully. In a similar vein, Schwab (1962) has emphasized the intricate organization of knowledge which constitutes subject matter structure.

Also in the field of curriculum but approaching it as a philosopher, Phenix (1964) relates knowledge to meaning and man's search for meaning. For Phenix, different disciplines provide different kinds of meaning and different ways of testing its validity.

Among psychologists who have looked at knowledge, some have searched for a basic unit of learning while others have approached the question at a broader level. At the most molecular level are the associationists such as Aristotle (1975), who declared that knowledge was associated with the laws of contiguity, similarity, and contrast. From Aristotle and Mill (1829) to Skinner (1957) and Berlyne (1965), associationists have represented learning as a connection between a stimulus and a response. This paradigm explains simple or rote learning phenomena but it cannot explain higher mental processes, although Berlyne tried when he introduced mediating responses and transformations to describe symbolic processes in a neo-associationist framework.

A more dynamic approach to knowledge had been taken by Tolman (1932), who introduced the term "cognitive map" to describe the means-end relationships by which a goal could be obtained. Bruner's (1956) Study of Thinking was based on this idea but he developed it to encompass strategies for organizing experience by categorizing it into concepts. A concept is an identifying response to members of a set of not completely identical stimuli (Hunt, 1962). Concepts exist at various levels of generality and abstraction and may be simple or complex. A concept may be a class or a category, and it exists within a larger framework which may take the form of a structure, script, or larger category. A concept is not considered to occupy discrete space but rather has a center of density of meaning (Deese, 1965). Concepts can, however, be represented as discrete entities, as nodes or clusters of information (Rumelhart, Lindsay, and Norman, 1972).

Concepts enter into diverse relationships with other concepts. The most frequent kind of relationship is one of similarity or likeness, according to Kintsch (1972), but subset, or consequence are two other frequently found relationships. For the purposes of this study, a taxonomy of relationships was developed to cover two broad sets of relationships. Similarity relationships included simple, functional and class, while a second set of dependency or assymetric relationships covered procedures and logical and empirical causation. To represent relationships, lines or links were established between related concepts, so that cognitive structures could be built up of nodes and links in a network.

At the most molar level of representing knowledge, contributing researchers have included Guilford (1967) for his structure of intellect, Chomsky (1965), with his "deep structuring" process to account for meaning in linguistics, and Herbart (in Murphy, 1949), who introduced the term "apperceptive mass" to mean the organized totality of past experiences in the human mind. Today we call "apperceptive mass" cognitive structure, defined by Ausubel (1968) as the substantive content and major organizational properties of a structure of knowledge. Cognitive structure is the product of previous learning and the basis for new learning. To represent cognitive structures, schemata or frameworks such as tree structures or networks have been used. In this study, the approach was to discriminate the principal concepts in a course and their relationships and then to represent these relationships schematically, while attempting to find the most adequate and useful representation for the professor.

Method

Domain of investigation

Sixteen courses from different disciplinary areas were analyzed to determine the cognitive structure of the professors teaching them. The five courses from the natural sciences included models from physics, chemistry, biology, entomology, and geology (see Table 1). Seven courses from the social sciences and related disciplines were chosen. Three of these were courses in psychology, sociology, and political science, and the remaining four were applied or professional courses in educational psychology, social work, law, and educational evaluation. The four arts or humanities courses analyzed were in history, English, classics, and philosophy. A language course was investigated but the concepts taught in the course could not be determined from the course materials and so could not be included in this study. Of the 16 courses fully investigated, 9 were 200 level courses, that is, courses designed for the entering McGill student who has had two previous years of college. Four courses, two in science and two in social science, were 300 or junior level, the geology course was 400 or senior level, and two courses, those in law and educational evaluation, were graduate level courses.

The professors who agreed to have their courses analyzed and who contributed much time and effort to the

TABLE 1

COURSES ANALYZED

Discipline	Course Title	Course Number
Physics	The physics and psychophysics of music	224
Chemistry	Physical chemistry	213
Biology	Laboratory in cell and molecular biology	301
Entomology	General entomology	330
Geology	Sedimentary rock and stratigraphy	442
Psychology	Thinking	303
Sociology	Deviance and social control	227
Political science	The government of Canada	221
Education-al psychology	The development of personality and social behavior in the school-age child	208
Social work	The public social services in Canada	352
Law	Torts	179
Educational psychology	Education evaluation: theory and practice	617
History	The United States since 1865	221
English	Introduction to Shakespeare	215
Classics	Introduction to Greek mythology	203
Philosophy	Introduction to moral philosophy	230

study, were invited to participate primarily because of their interest and expertise in university teaching. They had received high student ratings, had previously participated in detailed course evaluation or course improvement projects, or had expressed interest in understanding more about cognitive structure. The courses had been taught for at least two years before they were analyzed, and in some cases had been taught for over ten years. Most of the courses had been developed by the professors teaching them. The number of students in each course ranged from forty to over two hundred, although in the upper level courses there tended to be fewer students. All of the courses analyzed were given during the academic year 1978-79 at McGill University.

Procedure

As this was an exploratory study, it was entered into with two guiding principles. First, as much as possible, we wanted to understand the perspective of the professor, and to truly represent the structure of the course as he or she saw it. This meant that the professor's comments and reactions to the data collection procedures were considered, and that the professor was accepted as expert in the subject matter area. Emphasis was put on accurately depicting the cognitive structure of the professor. Second, in attempting to depict the course as comprehensively and as accurately as possible, a series of methods of analyzing cognitive structure were employed. In a pilot study on courses from three different disciplines, a variety of measures were taken to determine which would provide the most accurate, comprehensive, and useful results to the professor and for the study for comparative purposes. All of the measures yielded a form of useful information and each measure taken added to the information about the course as well as confirming the structure or pointing out possible problem areas in the coherence or connectedness of the course. The series of measures taken provided a firmer basis for describing each course and for making hypotheses about the similarities and differences among courses.

The general method for analyzing each course was to have a series of interviews with the professor in which different measures were obtained. Work on each course extended over a period of from three months to an entire academic year. During the period, a research assistant worked with the professor, made a detailed examination of all course materials, and attended a class to gain understanding of the way in which the course was taught and the kinds of students enrolled in the course. When all of the data on the course was collected and analyzed, a report describing the findings was produced. The research team, consisting of the principal investigator, the research assistant, and the professor then reviewed the report to determine the most important or useful findings to the professor and the implications of the report.

The data collected on each course included information about concepts in the course and on the relationships among key concepts, as well as a course description and the professor's statements about the themes and goals of the course, how the course was organized, and what it was most essential for students to learn in the course. The following kinds of data were collected:

Data on key concepts

1. Number of relevant concepts, important concepts, and key concepts
2. Hierarchy of key concepts
3. Key concept definitions, degree of common usage, comparison with dictionary definition, frequency of occurrence
4. Mode of representation in the course
5. Abstraction/concreteness
6. Inclusiveness
7. Salience
8. Word associations, meaningfulness

Data on relationships among key concepts

1. Tree structure
2. Kinds of relationships between pairs of key concepts
3. Similarity grouping of all concepts and of key concepts
4. Word associations, overlap, relatedness coefficients
5. Relatedness of meaning, strength of relationship, visual representation of relationship structure

Results

To describe the results I will use three model courses, one from science, one from social science, and the third from humanities so that I can portray the intricacies of each course while relating it to the general findings about all sixteen courses. The three courses had all received high student ratings.

The physics and psychophysics of music

This introductory course was offered by the physics department and served the music program as a core course as well as physics majors and psychology and physiology students as an optional course. The course was taught by means of lectures, demonstrations, and practical exercises. Demonstrations were given before any abstract or symbolic presentation in order to develop a context for the explanations of the course. The professor considered that what it was most essential for students to learn in the course were perspectives on the whole field of the interrelationships of physics and psychophysics.

To obtain the potentially important or relevant concepts in the course, the professor's prepared lecture notes, which were available to the students, course references, and tests and examinations were scoured, and any headings, titles, and frequently mentioned terms were collected with all those appearing to serve a main or linking purpose in the course. From these terms the professor selected 123 concepts which he considered to be relevant to the course, and from these, he chose 59 which had a main or linking function in the course. Because we could only work with a maximum of from 15 to 20 concepts in the course representation, he was asked to choose the most important 15. He then arranged them hierarchically in order of importance in the course. This hierarchy of importance served as a standard of comparison for other measures of the key concepts such as degree of inclusiveness. The number of relevant concepts chosen in this course was substantially greater than the overall mean of 99 for all 16 courses analyzed, and the number of important concepts was twice the average number chosen (see Table 2). Just over half the terms were technical, that is, they had a particular meaning different from an everyday dictionary definition, although the percentage of technical terms was lower than that for all science courses (83%). In addition, their familiarity rating, that is, the number of times the key concepts could be expected to be found in one million words, according to the Kučera-Francis (1967) study of present day American English, was half that of the mean for all courses and on a par with other science courses. These findings suggest that students entering this course will have a substantial amount of new vocabulary to learn, more than

TABLE 2

CHARACTERISTICS OF KEY CONCEPTS IN MODEL COURSES

	Physics Course	Ed Psych Course	English Course	Overall Mean (16 Courses)
Number of Relevant Concepts	123	98	58	99
Number of Important Concepts	59	29	20	30
Percentage Technical Key Concepts	53	54	54	62
Percentage Technical Key Concepts for Subgroup	83	63	33	-
Mean Key Concept Familiarity (per million) (Kučera-Francis Rating)	22	10	79	44
Most Frequent Mode of Representation	Enactive	Symbolic	Enactive	Symbolic
Percentage Key Concepts Abstract	34	100	31	71
Percentage Key Concepts Abstract for Subgroup	44	90	70	-
Mean Inclusiveness of Key Concepts	3.4	3.8	4.0	3.8
Mean Salience of Key Concepts	2.1	3.1	2.9	2.8
Mean Number of Word Associations to Key Concepts	7.1	12.7	-	8.3
Number of Links in Tree Structure	20	15	13	16
Percentage Similarity Relationships Between Key Concepts	30	67	54	54
Percentage Similarity Relationships for Subgroup	50	54	77	-

in the average university course, but slightly less than in science courses as a group.

The way that concepts were presented in this course was unusual, both compared to other science courses and to courses in general. Almost half were presented enactively, that is, so that students could manipulate the actual objects or events involved. Over one-quarter were presented iconicly, that is, with some graphic or image-based representation. A very small percentage (7%) were presented symbolically, by means of language or some other symbol system. This is in marked contrast with the majority of courses studied which relied primarily upon symbolic representation. Science courses on the whole tended to use more enactive and iconic representation than social science and humanities courses. The percentage of concrete concepts, or those with concrete or perceptual referents, as compared with abstract concepts, those without objective referents, was also unusually high. Two-thirds of the physics key concepts were concrete, in contrast with the general finding of two-thirds abstract. The use of enactive and iconic representation in this course and the relatively high percentage of concrete concepts suggest that students would be employing different modes or styles of learning in this course and that comprehensibility and subsequent retention would be greater because of the concrete concepts (O'Neill and Paivio, 1978).

The next measures that were taken were professor ratings of the inclusiveness and salience of the key concepts. Inclusiveness is the degree to which a concept includes other concepts and is therefore a measure of the expected ability to link or organize other concepts. Courses were more alike in concept inclusiveness than for any other measure. Using a scale from 1 for "non-inclusion of other course concepts" to 7 for "inclusion of all other course concepts," the average inclusiveness across courses was 3.8, just under "inclusion of half the concepts." The physics course was slightly below the average with 3.4. It could be expected that more important course concepts would be more inclusive, and a Spearman rank order correlation of +.46 ($p < .05$) was found between concept importance and inclusiveness in this course.

The salience or vividness or conspicuousness of the key concepts was examined because recall of learning has been found to be greater when more vivid language is used (Montague and Carter, 1973). It appears that the intensity or conspicuousness of a word affects its ability to serve as a cuing or centering device. On a scale from 1 (not vivid) to 4 (extremely vivid), the physics key concepts received a relatively low mean rating of 2.1 compared to a 2.8 rating for courses overall. The most important concept in the course was also considered to be the most vivid, but salience and concept importance did not correlate.

One other measure of the potential linking ability of key concepts was taken: a word association test showed that the physics key concepts evoked on average a slightly lower number of words (7.1) compared with all courses (8.3). This would suggest that concepts in this course are either less evocative to the professor or perhaps more independent. In summary, the most striking characteristics of the physics course concepts were the large number of important concepts, the use of the enactive mode of representation, and the large percentage of concrete concepts in the course.

To study the relationships between course concepts five different methods were used. Each method provided a different perspective of the structure of the course concepts and allowed for confirmation of the conceptual structure. In the first method, the professor linked the two most closely related key concepts, then related the other key concepts in order of their closeness of relationship to other concepts already linked. This produced a tree structure which described the dominant relationships in the course (see Figure 1). The physics course showed a hierarchical form, with the most important concept at the upper center of the figure and the concepts ranging in four tiers below. This structure was highly consistent with the hierarchy of key concepts with certain key concepts and pairs of concepts dominant over others. The

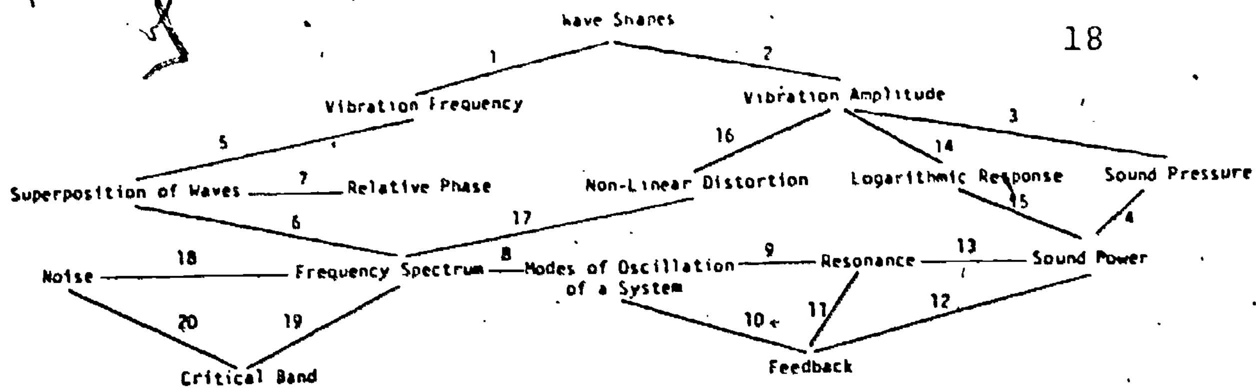

Figure 1. Tree structure of key concepts in a Physics course

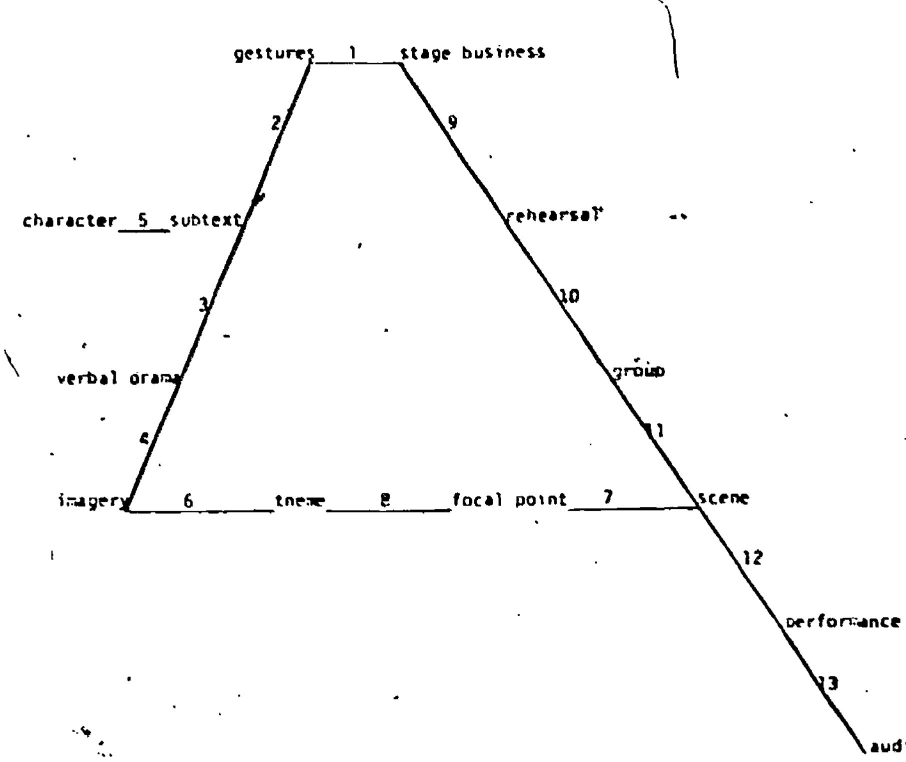

Figure 2. Tree structure of key concepts in an English course

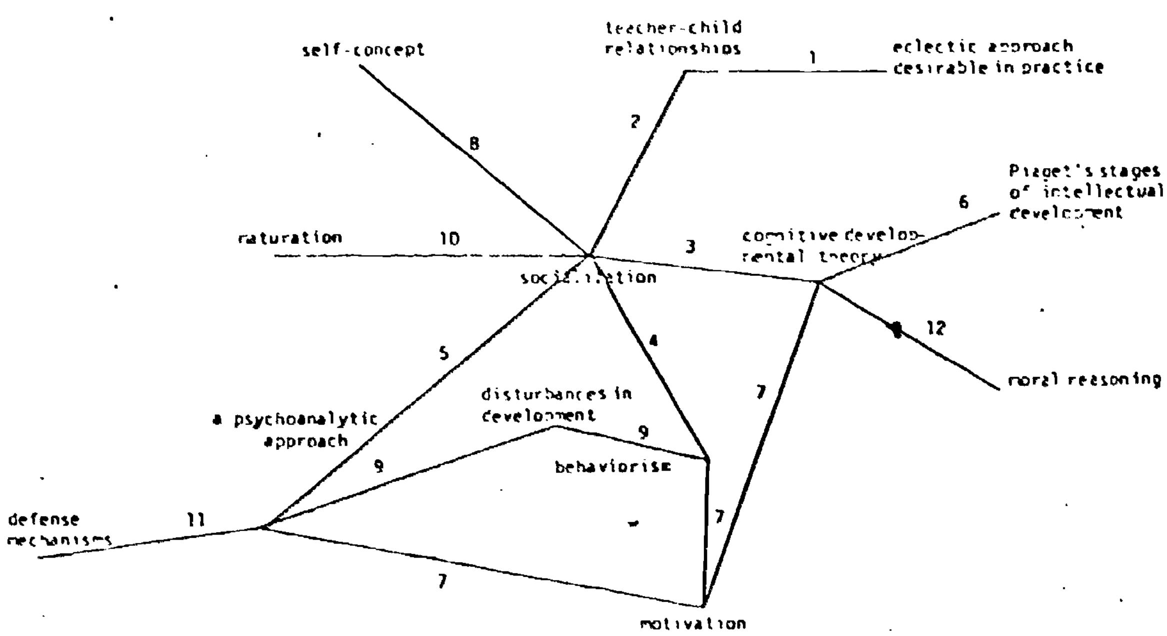

Figure 3. Tree structure of key concepts in a developmental Social Psychology course

figure also showed a tight content structure: several key concepts had multiple links.

This was a typical tree structure form for a science course to take. Over all the courses studied, three different forms could be distinguished: hierarchical; clustering or weblike, with pivot concepts surrounded by others; and linear, where a series of straight lines linked the concepts. All science courses showed hierarchies, while two had clusters in addition and two also showed some linear form. In comparison, social science courses showed clusters or networks, sometimes including sets of concepts together; and humanities courses tended to be linear in form, sometimes forming blocks and clusters as well. Overall, there were 7 hierarchies, 5 of them in the 5 science courses; there were 9 clusters or sets, 6 of them in the 7 social science courses; and 7 courses showed linearity, including the 4 humanities courses.

The professor next was asked to describe the relationship between each pair of key concepts linked in the tree structure. The relationships were classified according to the taxonomy of relationships. Similarity relationships could be one of three kinds: associative relationships were those in which concepts were contiguous or descriptive of each other; functional relationships were those where concepts had a similar outcome or purpose; and structural relationships showed a taxonomic or hierarchical relationship such as subset, inclusion, or kind or part. Dependency relationships were those in which a change in one concept implied a corresponding change in the other. Three kinds of dependency relationships were distinguished: procedural relationships described steps, order, or sequence; logical relationships were those where concepts had a logical or conditional order; causal relationships showed an explicit cause and effect linking. Across the 16 courses studied, just over half the relationships (54%) were similarity, and 41% were structural. The next most often found relationship was logical (18%) and 10% were procedural while 12% were causal. In the physics course, a far greater proportion of the relationships were causal (40%) or procedural (25%), and only 30% of the relationships were similarity based. This finding confirms the supposition that physics is highly causally based compared to other disciplines. It also suggests that the concepts are more tightly or necessarily linked in this course than in most others.

Another measure of the relationships among concepts is how they were grouped into categories on the basis of their similarity. This was done both for all the relevant course concepts and among the key concepts, and the groups were then listed hierarchically. The groupings suggested fundamental divisions among concepts which could serve as topic headings or a checklist for particular areas of student strength or weakness in the course. In the physics course 123 concepts were grouped into 7 categories, 5 of which contained 1 to 5 key concepts, so the key concepts were relatively broadly distributed among the course categories. There was relative consistency between the similarity group hierarchy and the key concept hierarchy: the most important 10 key concepts were found in the first three groups. The professor considered the key concepts to be too dissimilar to be grouped in similarity categories among themselves, but this was consistent with the finding that the relationships among the key concepts were not based on similarity but on causal or procedural relationships.

Word associations had been done for each key concept. Those concepts linked in the tree structure were then compared for overlap of meaning. In a method developed by Garskof and Houston (1963), a relatedness coefficient, which is the ratio of the overlap of associations between two key concepts to the maximum possible overlap, was produced for each tree structure link. The relatedness coefficients in the physics course were second highest of all the courses only to the chemistry course concepts, which suggests a high level of association of meaning in spite of their not being considered similar or alike. This finding also coincides with the dependent or causal nature of their interrelationships.

The last measure of relationship was a rating of relatedness of meaning between each pair of key concepts. A matrix of these relationships was created and used to produce first, a strength of relationship score for each key concept and second, a graphic representation of relatedness of meaning according to Waern's (1972) graphing procedure. This matrix will be used as a basis of comparison for student estimates in the planned second stage of this research.

The physics course thus showed most of the markings of science courses, with a greater number of concepts, more concrete concepts presented enactively and iconically, and relationships among them that were hierarchical but procedurally or causally based for the most part. This suggests a tight and necessarily related structure with a high degree of consistency.

The development of personality and social behavior in the school-age child

This applied social science course offered by the department of educational psychology was designed for students in the elementary education program including physical education majors. It included students from psychology, social work, management, and arts and science programs. Lectures, extensive use of readings and films, and an applied case study constituted the instructional format. Most essential for students to learn in this course were concepts and perspectives on children and procedures. Ninety-eight relevant course concepts were uncovered and 29 of these were considered particularly important, making this course the closest to the overall norm in the number of concepts. Just over half the key concepts were technical in nature and because the key concepts for the most part (62%) were noun phrases such as "cognitive developmental theory," they were the second least familiar according to the Kučera-Francis rating of present day English. All key concepts were abstract, compared to 90% abstract for the 7 social science courses and 71% for all 16 courses. A great variety of modes of representation, however, were used in the course, with one-quarter of the key concepts being presented in all three modes and an additional 39% being presented in both enactive and symbolic or iconic and symbolic modes. The use of films and case studies can be seen to have an effect here. Salience ratings and the number of word associations to each key concept were above the norm. Inclusiveness was average and the correlation between key concept importance and inclusiveness was positive but not significant ($p = .43$).

The tree structure showed a network or cluster of relationships located around the concept "socialization" (see Figure 2). This was a particularly clear network, taking into account three theoretical perspectives on the socialization of the child. The number of tree structure links exceeded the overall norm, suggesting that the course was relatively highly structured, and the second most structured of the social science courses. Two-thirds of the relationships between key concepts were structural-similarity relationships, which was a higher percentage than the norm for social science courses and all courses (54%). These relationships showed one key concept to be a part or subset of another: for example, "defense mechanisms" were part of "a psychoanalytic approach." The similarity grouping showed 11 categories, 10 of which were headed by a key concept. This suggests not only a clear course structure but also that the key concepts would serve as particularly good advance organizers for other course concepts. When the key concepts were grouped among themselves then ranked hierarchically, the resulting nine categories closely resembled the hierarchy of importance. The fact that so many categories were used for the 13 key concepts would suggest that the key concepts are not that closely related in meaning, and the word-association and relatedness of meaning ratings bore witness to that. The highest relatedness coefficient was only .397, compared to .911 in the physics course, and the mean strength of relationship was third lowest for social science courses.

This educational psychology course showed the major trends in social science courses, with an average number of abstract concepts, greater use of the symbolic mode of representation, although this particular course was noted for its use of a variety of modes, and the existence of clustering in the tree structure. The majority of relationships were not as close as in science courses. Students taking this course would have a different kind of learning task from those taking the physics course.

Introduction to Shakespeare

This introductory course was offered by the English department to students in any program and the majority of those enrolled were first year undergraduates, with a higher percentage not English majors. The main goals of the course were to make students approach dramatic text and the ways of dealing with such texts, as well as the use of performance as a learning technique. The course was taught by means of lectures, group work in the classroom, and practical skill development in theatre settings. Fifty-eight relevant course concepts were recorded and 20 of these were considered important, which was the norm for humanities courses. Just over half the concepts in this course had technical definitions, which made this course different from the norm for humanities courses of only one-third technical terms. The key concepts were much more familiar than the norm for all courses according to the Kučera-Francis rating. Humanities courses in general employed much more familiar key concepts than the other areas. This course differed in the mode of presentation from other humanities courses by having 77% enactive key concepts compared to 100% symbolic representation in the others. As might be expected in a course where the first concept was "performance," over two-thirds of the key concepts were concrete in contrast to the other humanities courses in which 70% were abstract. Inclusiveness and salience were normal for a humanities course and no word association test was done for this course. The number of word associations was, however, lower for humanities course concepts than for science or social science concepts. A contingency coefficient between key concept importance and inclusiveness was significant ($c = .64$, $p < .05$), showing hierarchical consistency.

The tree structure was a rhomboid with a tail, displaying a closed linear formation (see Figure 3). Each side represented either the language or the action of the course content, and the third side represented the form of the course. While the proportion of similarity relationships between key concepts matched the overall norm of 54%, this was much lower than for humanities courses in general which tended to have three-quarters similarity relationships. A far greater proportion of humanities courses displayed associative and functional similarity relationships than did other areas and the most closely related two concepts in the English course had a functional relationship. The similarity grouping resulted in five categories, one of which depicted the process and end-product of the course, while the remaining four groups were some aspect of theatre. The groups corresponded in order with that in the tree structure. The similarity grouping of key concepts was consistent with the larger similarity grouping, beginning with a breakdown into form and content as before.

This humanities course was representative in the number and familiarity of concepts and in its linear tree structure but a great amount of variation among humanities courses was found. The history course appeared more like a social science course in the number of concepts, their familiarity, and the clusters in its tree structure. The philosophy and classics courses were unusual in their low number of relevant key concepts, one-third the mean at 33 and 34 respectively, although an auxiliary 2300 concepts existed in the classics course. In the philosophy course, all key concepts were higher order abstract and were astoundingly familiar, occurring an average of 298 times per million compared to the overall average of 44 times per million. The philosophy and classics courses consisted of key concepts which related on the basis of similarity exclusively, as did only one other course of the 16, the psychology of thinking. Thus each course had its own pattern, although trends could be seen across courses and group similarities could be identified.

Similarities and differences in the knowledge structure of different courses

There were fewer similarities than differences among the courses studied but some of the most obvious regularities were, to me, the most profound. First, in all the courses studied but one, key concepts could be identified and considered for their relevance and importance in the course. In the one course studied where this was not possible, a French language course, the concepts, which were rules of grammar, were not presented in a formal manner and would only have revealed themselves to someone taking the course itself. Although some professors preferred to call the principle ideas in their courses "terms" or "principles," it was possible to work with the concept of "course concepts" with minimal discomfort. Further study of the course concepts will undoubtedly lead to refinements in thinking about them, but a working approach to studying a course by means of its concepts exists.

Second, it was possible to identify characteristics of the concepts and to rate them in terms of their technicality, familiarity, mode of representation, abstraction, inclusiveness, and salience. Some of these measurements are more precise than others: the measures of familiarity and abstraction are the most reliable.

Other measures, such as salience, would benefit from test standardization and analysis procedures, but the professors were able to work with these measures.

The third point of similarity that I would make about the knowledge structures of different courses is that they are not readily evident. Although the professors who took part in the project were experts and, indeed, initiators and developers of these courses, the methods used in this study required their intensive concentration: whether it was a matter of stating the relationships between pairs of key concepts or grouping course concepts into categories, considerable effort was involved. The most frequent response to the question of whether any particular method was more useful than another, it should be remarked, was that the process itself was enlightening. The project was seen as one of conceptual and structural clarification.

The differences among courses began with the selection of relevant course concepts and extended to the kinds of relationships found between key concepts and the manner in which these concepts could be graphically represented. The first difference was in the number of relevant concepts. The range went from 33 to 170 concepts for a one semester course. The average ranged from 134 in science courses through 98 for social science courses to 57 for humanities courses. The ranges of important or linking concepts in a course parelleled these figures with 37 in science courses, 31 in social science courses, and 21 in humanities courses. Approximately 30% of the relevant course concepts were considered important. The difference in the percentage of technical terms followed the same pattern showing that in science courses more terms specific to the discipline are used, with 83% technical, and with 63% technical in the social sciences compared with a 33% technical average among humanities courses. It is no wonder that science professors are accused of using jargon by humanities professors: the different groups of disciplines have very different perspectives on the use of terminology. The Kucera-Francis ratings of familiarity confirm this difference, particularly between humanities courses and those in science and social science: the average familiarity rating of a humanities course concept was an occurrence of 113 times in a million, while in science and social science courses, the typical key concept would occur only 21 or 22 times per million in present day language. The different groups of disciplines have, therefore, very different types of vocabularies to deal with.

The greatest difference in the quality of course concepts lay in the degree of abstraction of the concepts. The key concepts studied in the courses appeared to be very similar in terms of their inclusiveness, salience, and number of word associations, although there were exceptional courses with respect to each of these qualities. It was in concept abstractness that the greatest differences appeared. The science courses studied overall had a mean of 58% concrete concepts, that is, concepts with an objective or perceptual referent. Social science courses were almost exclusively abstract with a 90% average overall and any other concepts were concrete functional in nature, that is, a process or event rather than a concrete object. The humanities courses registered 70% abstract concepts with the philosophy course having only higher order abstract concepts. The different kinds of courses, therefore, require different kinds of thought processes, with social science and philosophy courses in particular requiring the ability to think abstractly. Reviewing these results, social scientists should be most alarmed by the results of scholastic aptitude tests which show that today's students have on average a substantially decreased ability to handle abstract concepts.

The mode of representation of key concepts, which brought an instructional element into this analysis, also confirmed the dependency upon symbolic representation and processing in the social sciences and humanities, with the exception of the English course which used much enactive representation. The law and educational psychology courses also used iconic and enactive representation to present the key concepts, but eight courses relied exclusively on the symbolic mode. In the science courses the distribution was quite different with a mixture of modes in every course. Students could be expected to require greater flexibility in their learning styles in science courses but would also have the support of multi-modal presentation.

The graphic representations turned up major differences in how concepts were related to each other in the courses. All of the science courses showed some hierarchical organization, which means that there is a necessary and dependent relationship among the key concepts. The highest relatedness coefficients were found in the science courses as well, confirming the tendency in science courses for clear and close relations among concepts. The social sciences in contrast showed lower relatedness coefficients and clusters or sets in the graphic representations. This suggests that a few key concepts are pivotal in the understanding of course material. Humanities courses showed a looser, more linear organization with even lower relatedness coefficients so that students would not have the opportunity to chunk or group information in the same way that could be expected in a social science course.

The kinds of relationships between key concepts revealed further major differences in disciplinary subgroups. The tight structure of science courses was reflected in the relatively high proportion of dependency relationships, whether procedural, logical, or causal.

The social science courses showed a greater reliance on structural relationships based on similarity, and in humanities courses, the dominant similarity relationships included a higher proportion of the looser associative and functional relationships. The relationships between key concepts must be important determinants of the learning and therefore the teaching processes involved with them. One could hypothesize, for example, that where concepts are closely linked in a structure, learning will more likely follow an "all-or-none" pattern, with students learning or not learning the subject matter. In a more loosely structured course, however, some parts may be learned well while others are not. This may explain different continuation patterns in the sciences and in humanities and social science programs. The findings of this study suggest that we are requiring very different abilities and strategies on the part of our students in different courses. Some of these abilities appear to be programmable, that is, students can be alerted to specific ways of approaching a course with a heavy technical vocabulary or one which uses familiar words in a novel and potentially confusing way. If certain key concepts serve central or pivotal functions in a concept heavy course, these can be introduced as advance organizers or themes in a course so that they can serve as the foundation for the student's conceptual structure in the course.

Where a course is known to be difficult because of the kinds of concepts and strategies employed in it, students can be made aware of the extra attention such a course will require. For example, we were asked to examine the physical chemistry course because it is the one chemistry students find most difficult. Our analysis revealed that not only did it contain an extra heavy load of concepts but that these were familiar concepts used in a new and different way, and that a high proportion (85%) were abstract. What was more startling about this course, however, was that almost three-quarters of the relationships between the course concepts were similarity rather than dependency based. To a chemistry student, whose expectations would include observable and manipulable concepts with procedural and causal relationships, this course would present a foreign experience. A course introduction which prepared students for the different kinds of relationships and learning strategies required in the course might alleviate learning difficulties in it.

Implications

The results of this study have implications at three different levels. There are immediate implications for the professor planning a course. There are particular implications for departments in their curriculum development and quality control, and there are findings more generally relevant to university planning.

To the professor, consideration of the key concepts and their relations in a course can provide information about how to structure a course, where to concentrate attention to alleviate learning difficulties, and how to fairly judge student achievement in the course. The suggestions made to professors in the reports on the content analysis of their course included the following:

1. The use of the list of key concepts to test for background knowledge of entering students. Students could be asked to define the key concepts and their replies could be analyzed to reveal areas of knowledge, confusion, and lack of knowledge. Class homogeneity in background could also be established by this method. Where the background knowledge is low and the course is relatively tightly structured and dependent upon knowledge of these terms, the definitions of the course concepts could be provided to students as a glossary for their early attention. In one course where the list of key concepts was used as a pretest, students were able to define the terms with every-day meanings, but were not able to define those with technical meanings. Testing and provision of a glossary would be of particular importance where a sizable proportion of key concepts are technical. Where students register a lack of knowledge of certain key concepts, particular attention could be paid during instruction to the presentation of positive and negative instances of the concepts and to the discrimination of instances and attributes or

characteristics of the concepts.

2. The use of image arousing materials or instructions to aid student learning and retention. In one-half the courses studied the key concepts were represented exclusively in the symbolic mode. But where students are instructed to generate visual images for words and then create an interactive scene with images, memory of the words is facilitated (Kerst, 1976). Concrete and imageable materials are easier to remember than abstract materials (Levin, 1976; Rohwer, 1970). The explanation for this phenomenon is that there appears to be a direct path for concrete words from verbal to imaginal representations, while the path is indirect for abstract nouns (Paivio, 1975). Paivio argues that perhaps abstract ideas can be concretized in specific images.

3. The use of highly inclusive key concepts, which could be expected to have the ability to link or organize other course concepts, as advance organizers in the course. Their purpose would be to establish in the learner's cognitive structure relevant anchoring ideas for learning material subsequently presented (Ausubel, 1968). A hierarchical series of advance organizers could be expected to provide an ideational scaffolding, to enhance the discriminability of new learning material from previously related ideas, and to effect incorporation into the students' cognitive structure at a higher level of abstraction

and generality (Ausubel and Robinson, 1969). Highly salient key concepts could be used in the same manner and their attention getting property could be applied to the instructional process. Introducing a particularly salient topic during a period of flagging student interest has been shown to increase instructional efficiency.

4. The use of the tree structure in planning course organization, sequencing, and the evaluation of learning. Some professors pointed out that the tree structure, although it represented their own cognitive structure, would be either too complex or instructionally unsuitable for use in their classes directly. The tree structure does, however, describe the closest links in the course and does show which concepts rely on or are most closely related to others. These links can then be used in the preparation and sequencing of topics and in establishing the important relationships in the course. This is most obvious in courses where one or two concepts are pivotal or focal in a cluster of other key concepts. Hierarchically organized tree structures give even stronger direction in the way key concepts are interrelated. It follows that the evaluation of student learning should include questions about the relationships of key concepts to each other.

5. The use of the kinds of relationships between key concepts to cue students as to the nature of the thought processes or strategies required to comprehend the course

material. Where the majority of relationships are structural in nature, students can be instructed to look for similarities or likenesses among the themes and subtopics in the course. Where the relationships are procedural or causal, the appropriate strategies or expectations can be pointed out. In the case of logical connections, brief introductory attention to logical processes would establish a conceptual strategy framework for students. Advance notice of the kind of thinking expected of students would prove most effective in courses in which the relationships follow a different pattern from that expected, as occurred in the physical chemistry course where the relationships were structural instead of the expected causal.

6. The use of the similarity groupings as a base for topic sequencing and for student conceptual learning errors. For example, if students midway through the course are asked to sort topics into categories, these can be compared with the professor's sort to determine where student thinking is fuzzy or where conceptual links require clarification. Although it is not suggested that the similarity groupings should necessarily determine the course format, the groupings can be used to check coverage of particular topics or to raise questions of relationship both for the professor and the student.

7. The use of the relatedness of meaning matrix to judge student conceptual coherence. In the same way that

the similarity groupings could be matched for consistency between the professor's cognitive structure and the students', the matrix of meaning would provide an estimate of student understanding. It is our intention to pursue this question and to use this method with multi-dimensional scaling to more closely examine the nature of course concepts. The multi-dimensional scaling procedure would portray the extent and nature of the key concept relationships according to the students.

8. The use of several measures to discriminate how students learn well in a course. Highly achieving students in a course may be those who most closely match the professor's cognitive structure at the end of the course. They may be those with greater initial familiarity with key concepts in the course or they may be those who understand the nature of the relationships among concepts, or some combination of these tendencies. What constitutes good learning in a course is perhaps the most important outcome that this kind of study could serve for the professor.

The implications for departments in their curriculum development and quality control require joint responsibility and cooperation from department members but could yield substantial gains in teaching and learning efficiency. If a department curriculum committee has an understanding of what concepts are being taught in different courses in its programs it can plan a better coordinated program for students. Particularly in programs in which certain courses are prerequisite to others or where students complain of heavy course loads, this kind of cooperation can lead to substantial improvement in the program. An attempt is at present being made to analyze the first year McGill medical curriculum to discover gaps and redundancies in the different courses offered. A team of curriculum coordinators will use the information being gathered over the course of this year to streamline and strengthen the program. The process of course analysis can also serve to provide standards in a department about what should be taught and in what sequence. With information about student learning in a course to compare with the professor's structure, adjustments can be made across the program curriculum to increase student learning efficiency. Professors teaching in such a cooperative format could then make reference to the themes or important or difficult concepts in one another's courses to prepare students or promote the integration of their learning.

Finally, course content analysis can assist in planning and academic programming across the university. The more substantive information that a course analysis provides is probably of greater use in assuring teaching competence than peer review has shown itself to be. Because the university in fact has the contract to provide an education to students it admits, it is in the university's best interest to provide for and support course analyses. A suggestion was made by a McGill professor that this kind of analysis might move the university from awarding credit on the basis of the credit-hour, a procedure which many deplore, to a basis of credit per concept. This would have the effect of awarding credit more for learning than for time put in. Would this approach threaten faculty? My findings were to the contrary. Professors are among the most competent of individuals and those with whom I worked saw the process of content analysis as a way of helping their students and as a resource to themselves. The University allows for diversity and applauds excellence: this is one small way to promote excellence.

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