KNOWLEDGE vs. KNOWLEDGE STRUCTURES

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The Problem

How do instructors determine what their students know? Some information is potentially available in the classroom setting, such as the questions students ask or their expressions of apparent comprehension or confusion. The traditional way to determine what students know is to test them. But different types of exams reveal different aspects of knowledge. Some simply demonstrate what students can remember from readings and/or class presentations. Performance on such exams could reflect either short-lived memorization of individual facts or long-term comprehension – or most any state between these two extremes. Furthermore, many exams assess quantitative aspects of learning (how much students have learned) rather than qualitative aspects (how they understand what they have learned). In short, exams usually reveal more about what knowledge has been acquired than the structure of that knowledge.

Amount of knowledge

Certain exam formats are typically used to evaluate the amount of knowledge acquired (such as definition, matching, and multiple choice questions), while others are used to evaluate synthesis, problem solving, and application (such as short-answer and essay questions). In any case there can still be a discrepancy between what students know and what they can report. All exams inquire about a subset of the available pool of information. Although students with 70% correct on an exam appear to “know” 70% of the course materials, they could know much more or less, given the correspondence between what happens to be on the exam and what they actually know.

They type of question asked, even on so-called “objective” exams, can also make students appear to know more or less than they actually do. For example, people typically score lower on recall tests than on recognition tests (Klatzky, 1975, -0.214, provides a useful overview of these findings). For example, history students may know quite a bit about the Norman Invasion, yet not be able to remember when it occurred unless given a list of possible dates (e.g., 1966, 1492, 1268, 1066). Any type of question can also be made more or less difficult, for example, but asking for recall of minor points or by providing difficult distractors in a multiple choice question. In sum, percent correct on any exam is only an approximation of the amount of knowledge students have acquired. Furthermore exam formats affect not only what students can show they know but eventually alter how they study and how much they actually learn, remember, and think (if at all) about the course material.
Structure of Knowledge

Many instructors do a reasonable job of assessing how much their students know, despite problems such as those described above. However, qualitative aspects of this knowledge are more elusive – and potentially more important – than such quantitative aspects. Consider a definitions test such as that shown schematically at the top of Figure 1. It shows an exam paper with short wavy lines representing definitions provided by the student. If students get a perfect score on this test, we know that they were able to remember a set of definitions – but do not know whether they understand the concepts or any relationships among them. Thus the definitions test assesses sheer knowledge but not the structure of that knowledge.

The bottom part of Figure 1 shows possible knowledge structures a student might possess, even when he/she does well on a definitions test. In these displays, the concepts from the test are shown closer or farther apart to indicate that the student understands them to be more or less related. In Knowledge Structure #1, there is no apparent structure, with terms scattered in a haphazard way, suggesting that the student sees no systematic relationships among them, and may well have simply memorized the definitions. In Knowledge Structure #2, there is some clustering of concepts plus a connection between two clusters. In Knowledge Structure #3, all the terms fit together in a systematic way; although this particular example is hierarchical in form, systematic representations can take a variety of forms. Clearly Knowledge Structure #3 has more overall structure than #1 or #2; it may also come closer to the way experts in the discipline understand the concepts.

Focus of This Paper

A perfect score on a definition test tells little about knowledge structures such as those in Figure 1. This fact raises two important questions: 1) How can we determine the amount and type of structure students possess? 2) What can we do to facilitate the development of appropriate knowledge structures? This paper focuses on concrete ways to assess knowledge structures; to do so, it uses two tasks, the Core Concept Task and the Sorting Task. Although it also suggests some ways to facilitate the development of appropriate knowledge structures, that problem is discussed more fully elsewhere (Day, in preparation).

Most of this paper deals with student knowledge structures. However it is very useful to assess the knowledge structures of instructors as well. Instructors are “experts,” in that they teach the course material and may also specialize and do research/scholarship in the given field of inquiry, while students are “novice,” in that they know something about the course material but are relatively inexperienced in dealing with it. Students may possess less structure or a different type of structure from that of the instructor, which in turn may cause difficulties in both teaching and learning. Therefore research on the knowledge structures of professors is presented first, followed by that of
Figure 1 – Possible knowledge structures (bottom) that may underlie performance on a definitions test (top). Short wavy lines = course concepts, long ones = student definitions.
Knowledge Structures in Professors

Core Concepts

A useful concept for exploring knowledge structures is the core concept. A core concept in a given academic discipline is one that is central to the field. All scholars may not agree that it is “correct,” yet it heavily influences their thinking (through acceptance, modification, or rejection), and is likely to stand the test of time. It is useful to know what types of concepts are at the core of a given discipline, then use them to study knowledge structures.

In a series of studies, college professors attending a short course on “Cognition and Teaching” offered by the author were asked to generate 15-20 core concepts from a course they teach. They were encouraged to select a course they have taught at least several times, especially at the introductory or intermediate level. They had about ten minutes to generate these core concepts and wrote them down in any order that they came to mind. Wide latitude was given for what constitutes a “concept,” including theory, specific principle, finding, event, example, or technique.

Since the professors were from a wide variety of disciplines (as well as a variety of institutions), they generated core concepts for courses across the traditional divisions of academic inquiry (natural and quantitative science, social science, and humanities). Concepts for sample courses are shown below:

Organic Chemistry

- REACTIVE INTERMEDIATE
- KINETICS
- TRANSITION STATE
- REARRANGEMENT
- RATE-CONTROLLING STEP
- CARBOCATIONS
- MOLECULARITY
- FUNCTIONAL GROUPS
- NEIGHBORING GROUP
- PARTICIPATION
- FREE RADICALS
- NUCLEOPHITES
- HYBRIDIATION
- SUBSTITUTION REACTIONS
- ELIMINATION REACTIONS

Macroeconomics

- FISCAL POLICY
- BUDGET DEFICIT
- UNEMPLOYMENT
- KEYNESIANS
- MONETARY POLICY
- INFLATION
- KEYNES DIAGRAM
- INTERNATIONAL DEBT CRISIS
- SUPPLY SIDER
- EXCHANGE RATE DETERMINATION
- BUSINESS CYCLES
- AD/AS
- GROWTH THEORY
- CLASICALS
- UNEMPLOYMENT

Modern Novel

- NARRATIVE
- DICTION
- CHARACTERIZATION
- DESCRIPTION
- TIME
- SYTLE
- THEME
- ANALOGY
- CAUSALITY
- FLASHBACK
- IMAGERY
- SETTING
- POINT OF VIEW
- PLOT
- STORY
Various measures are of interest in these lists of core concepts, such as the types of concepts selected (e.g., theory vs. observation) and the order in which they were generated. The concepts generated are, in some sense, at the top of the “cognitive deck” of these professors – the ones that come to mind most readily when they think about their subject matter.

**Sorting Task**

**Method.** After generating a list of core concepts, the professors were asked to sort the terms into piles (clusters) based on the “general similarity” of the concepts, defining similarity in any way they wished. They could put any number of terms into a given pile and use any number of piles, with two exceptions – they could not put all terms into the same pile or every term into a separate pile. It was all right to change assignments of terms to piles as they worked in order to achieve the best overall sorting. If they thought a given item should go in two or more piles, they had to make a decision and put it in only one pile. After sorting their own terms, professors recorded their responses on an answer sheet by writing the terms for each cluster in a list and enclosing each cluster with a circle. Further information about this general approach is provided by Miller (1967).

**Results.** Various simple measures of sorting provide information about the professors’ knowledge structures. For example, the number of clusters generated can suggest whether they view their field in a broad, fairly unified way (few clusters) or as various subareas or issues (many clusters). Since the focus of this paper is on assessing student knowledge structures, details of professors’ sortings are provided elsewhere (Day, in preparation). However discussions with the professors after the Sorting Task were very useful and are easy to describe here.

The professors were asked about how they performed the sorting task, problems they encountered in doing so, and what (if anything) they had learned in the process. Most found the task revealing; they said it enabled them to think about the core concepts in new ways, see new relationships among them, make explicit their existing knowledge structure, and in some cases forced them to revise their knowledge structure. Furthermore, lively interchange ensued when professors who chose the same course content discussed the concepts they selected and how they sorted them.

**Discussion.** Assessing professors’ knowledge structures provides additional and potentially important benefits to the overall teaching/learning process. For example, some instructors (especially when they first offer a course) teach a collection of informational chunks but do not organize them sufficiently for students to understand and remember the material well. Performing the sorting task enables instructors to discover possible organizing schemes. Also, many professors teach the same course semester after semester, year after year. Despite attempts to stay fresh by adding new examples, many become “stale,” just saying more or less the same old things without thinking about them anew. A main teaching goal becomes “getting through the material,” without necessarily engaging the students along the way. The sorting task is a simple and quick way to get
the professors re-engaged with their material; this in tern helps them engage students in
thinking, rather than just copying down notes about what the instructor said.

**Predicting Student Knowledge Structures**

Prior to discussing their own sortings and knowledge structures, professors were
asked to predict how their students would sort the same terms. They gave their
predictions in the same form that they recorded their own sortings, as lists of terms
enclosed in circles. Many professors left their answer sheets blank and were stunned to
report that they absolutely no idea how their students would cluster the terms nor think in
general about course concepts. Others predicted that students would make more piles
than they themselves had, arguing that students know something about concepts but do
not see many relationships among them nor integrate them into an overall framework.
Most responses fell into these two categories. During the discussion period, some
professors reported that they had thought about the structure of knowledge, but only in
terms of the knowledge itself; they had not considered the representations held by their
students or themselves, nor that alternative structures might be valid and provide different
insights about the material.

In can be argued that what is transmitted in the classroom and through textbooks is
not knowledge _per se_, but a representation of that knowledge. Therefore it is important
to consider these representations and the sort task provides some (though incomplete)
information about them. For professors, it can not only enable them to examine their
own knowledge structures, but also help them to consider student knowledge structures –
to select better ways to assess these knowledge structures, identify mismatches between
instructor-student knowledge structures (and decide which need correction and which do
not), and seek ways to get students to develop more useful knowledge structures.

**Knowledge Structures in Students**

**Core Concepts**

Asking students to generate a list of core concepts for a course is an unusual but
rewarding thing to do. In an en-class situation, students may fail to generate the
requested number of concepts, overlook some of the most important ones, pick
unimportant ones, and/or produce a complete jumble of unrelated concepts. In a take-
home situation, they will do a better job on the task since they can review the available
pool of concepts, check their definitions, and generate the requested number of concepts;
nevertheless they may still have difficulty making judicious selections.

Instructors interested in having students generate core concepts\(^1\) for a course or
portion of a course (e.g., textbook chapter, specific topic, lectures prior to the mid-term)
might consider using it as an ungraded exercise, at least the first time. It is also important

\(^1\) Procedures and materials for the core concept and sorting tasks are available from the author, along with
suggestions for guiding subsequent class discussion.
to stress that there is no one “correct” list of core concepts, even though some concepts are more central than others. The obtained lists can be used to improve the teaching-learning process in various ways. Instructors can provide feedback on an individual basis by agreeing with certain concept selections and inquiring about others. They may also modify their teaching to address whatever common problems may emerge. It is useful to maintain a fairly accepting posture in such individual feedback. Class discussion can be used to share selected student lists (all of which are good but differ in interesting ways), ask about problems encountered in the task, and discuss reasons for selecting some concepts and rejecting others. In general, discussion of core concepts stimulates more (and often better) class discussion.

**Sorting Task: One Domain**

Although it is useful to have students generate core concepts, it is better for the instructor to supply the concepts to be used in the sorting task; otherwise some students may have too haphazard a set of terms to learn much from the sorting, and it will be impossible to make generalizations across students using different sets of terms. In order to illustrate what can be learned from student sortings, a detailed example is described here for one academic domain, cognitive psychology. Several levels of observation are provided for the same results – simple inspection of clusters to get an overview of each student’s choices, inspection of results from all students pooled in matrix form to observe within-cluster agreements, and complex analyses to determine whether general dimensions underlie the dimensions. Most instructors do not have the time and/or resources to go beyond simple inspection (and discussion) of clusters from individual students; such inspection is nevertheless very useful and should meet the needs of most instructors. The more complex analyses are also provided below to show that clustering results may well be based on a few very general and intriguing principles.

**Method.** Sixty-four students in a basic cognitive psychology course at Duke University were introduced to the sorting task in the middle of the semester. They were given a week to practice the task at home, using instructions provided on a hand-out. They did so with whatever 20 concepts they thought were most important in the first half of the course. Then, during a class session, they were given 20 concepts selected by the instructor, defined each, and sorted them into clusters. When finished, they wrote down the terms in each cluster, drew a circle around each cluster, and wrote a brief essay describing the nature of each cluster and what they learned from performing the task.

**Alternative Solutions.** The selected concepts can be sorted in a variety of different ways. Figure 2 shows two alternative ways to do so. The top part of the display shows four clusters based on the major topics in the first half of the course, beginning with the first in-class topic (pattern recognition) through the most recent one (memory). The last cluster containing the terms STRUCTURE and PROCESS is very general and cuts across
Figure 2 – Alternative ways to sort the same terms into clusters. Cluster names and dashed lines (indicating further conceptual distinctions) are provided here for clarification but were not part of the sorting task.
all topics; these terms are shown in brackets because they were the only ones not discussed in class and were mentioned only briefly in the readings. Dividing lines within clusters show further conceptual distinctions; for example, FILTER and ATTENUATION are similar types of attention models, while ERASURE and SENSORY STORE involve sensory memory. Although some terms could go in more than one cluster, they are shown in only one location, as required by the sorting task. Cluster titles and dividing lines are shown here to reflect how the terms were discussed in the course and provide more information about their meaning; students wrote down only the clusters, without these additional markings. The bottom part of the Figure 2 shows the same terms sorted into two general clusters, distinguishing mental structures from mental processes.

Many variations of the alternative clusterings in Figure 2 are possible, as well as other alternatives based on quite different principles. The two shown represent different types of thinking about the course material. Clustering by course topics may reflect considerable understanding of the concepts and/or simple memory for the order in which they were presented. Clustering by structure vs. process requires original thinking; the distinction had not been discussed in class, yet the terms are general enough to provide a new way to think about the other concepts.

Cluster Inspection. Figure 3 shows the clusters produced by sample students; for ease of reference the clusters are numbered here. Student #15 made heavy use of the course topics approach, with cluster #4 containing all the pattern recognition terms, #2 all the attention terms, and #1 all but one of the memory terms. Cluster #3 contains STRUCTURE and PROCESS which could go together as “opposites,” but it also contains PROTOTYPE and SCHEMA which are both structural; however all these terms are quite “general,” and the written description provided by this student indicates that this area was indeed the theme he intended. Thus Student #15 shows good course learning plus a modest amount of new thinking.

Student #6 produced three times as many clusters as Student #15. Nevertheless, there are close conceptual connections within all her multiple-item clusters (as determined by instructor inspection and/or student essay). The student essay revealed more organization than is apparent from the many one-term clusters; for example, beginning with Cluster #4, she wrote this account: “By the process of REHEARSAL you can reach MAINTENANCE. Taken further, you can achieve AUTOMATICITY. These are shallow LEVELS OF PROCESSING ….”

Student #60 had problems. She describe Cluster #1 as “sensory stimulation,” #2 as “Filtering,” #3 as “a priori knowledge,” #4 as “output responses,” and #5 as “terms of which I don’t know the definition.” Although these are a reasonable set of distinctions, her assignments of terms to the clusters are often wrong (especially in cluster #3 and #4), suggesting that she really did not understand the concepts very well.

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2 For further information concerning the meaning of the 20 terms, consult any basic cognitive psychology textbook, such as Solso (1988).
Figure 3 – Clusters produced by three students for the same terms.
Matrix Analysis. Inspecting the clusters produced by the individual students can be quite instructive, as illustrated above. However, the viewer may not understand the theme of specific clusters, so student descriptions are also useful. Even so, this simple approach is limited. For example, students may actually have good reasons for their clusters but be unable to articulate them, or the viewer may read more into the clusters than the students intended. Also, it is difficult to track agreements across students with results in cluster form. For example, two out three students in Figure 2 clustered STRUCTURE and PROCESS together, but it would take considerable effort to note how many times this happened across all 64 students and for each of the 190 possible pairs of 20 terms.

In order to study how pairs of terms were clustered across students, a data matrix was prepared, listing the 20 terms along the side and top (in the same order); an excerpt from this matrix is shown in Figure 4. Entries in each cell indicate the number of students who put pairs of terms in the same pile, independent of whatever else they put in the pile. Thus one student might put ATTENUATION and AUTOMATICITY in a pile along with ten other terms, while another might put them together with only one other term, yet both students would contribute one entry to the ATTENUATION-AUTOMATICITY cell. If students knew absolutely nothing about the 20 concepts, there would be no discernable pattern in the matrix entries. Fortunately this was not the case, as described below.

Two types of cells in the matrix are especially interesting, those with many entries and those with few. For example, 56 out of 64 students put ATTENUATION and FILTER in the same cluster. This is an encouraging result, since both terms deal with how humans cope with information overload – by filtering out some parts of the information and attenuating (reducing in strength or clarity) other parts. In fact, two important models of attention are called the filter and attenuation models. ATTENUATION is also heavily clustered with AUTOMATICITY (36 students), which is another important ingredient in many attention models. DISPLACEMENT and ERASURE (43 students) are ways that items can be lost during information processing, while DIMENSION and FEATURE (954 students) are structural aspects of items. The nature of the relationship between any two terms can take many forms; both may be examples of the same thing, one may be a subset of the other, they may be opposites, and so forth.

The cells with no entries are quite encouraging, for it is difficult to specify a close and meaningful relationship between their respective terms. For example, DISPLACEMENT involves bumping old information out of short-term memory as new information arrives, while FEATURE is a specific aspect of information. Of course we could conjure up a scenario in which DISPLACEMENT is more likely if items have a certain FEATURE, but this is not consonant with other aspects of short-term memory models. Potentially disturbing cells are those which contain a small number of entries. For example, it is hard to understand why one person put ATTENUATION and

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3 Note that the diagonal cells are crossed out since an item could not be clustered with itself. Also, the bottom half of the matrix is left empty because it would contain the same information provided in the top half.
Figure 4 – Matrix analysis (excerpt) of clustering results, pooled across students. Entries show how many students placed a given pair of terms in the same pile (irrespective of other terms in the pile).

DIMENSION together. That does not necessarily mean that this student has a misunderstanding, but it is cause for concern, and he/she needs to provide a very convincing reason for this pairing.

**Multi-Dimensional Analysis of Concepts.** The matrix analysis provides information not readily available from inspection of the original clusters. However, it, too, has limitations. For example, it does not provide information concerning general principles that might guide the sorting of terms into clusters. Although it is beyond the means of most instructors to perform such analyses, the results of multi-dimensional scaling analyses are provided here to demonstrate that simple and meaningful dimensions can indeed underlie the apparent heterogeneity in the original clusters.
The clusters were analyzed using a standard multi-dimensional scaling program (INDSCAL model), with data entered according to the approach of Friendly and Collis (in preparation). The analysis revealed some general dimensions underlying students' clusters, as shown in Figure 5. Inspection of the two dimensions and the location of the items within their space suggest the following interpretations – Dimension #1 (D-1) provides a Memory/NonMemory distinction, while Dimension #2 (D-2) provides a Perceptual/Conceptual distinction. Although not every item fits this description, most of them do.

The relationships among items in this two-dimensional space are also revealing. For example, the identical location of FEATURE and DIMENSION is encouraging, for they are in fact highly similar; however they were discussed together both in class and in the textbook, so their proximity here could be based in part on these somewhat uninteresting circumstances. In contrast, the close proximity of TEMPLATE and PROTOTYPE in the display is quite exciting, since they were discussed within different topics; nevertheless they are similar since both presumably help people identify objects (TEMPATE) or concepts (PROTOTYPE). The close proximity of these two terms in the figure reveals an insight that goes beyond the information explicitly provided in the course.

Multi-Dimensional Analysis of Students. In Figure 5, the concepts are sorted the two-dimensional space defined by the Memory/NonMemory and Perceptual/Conceptual distinctions. In Figure 6, the axes have been altered to show the strength of each dimension, no matter which aspect of it was important. This change enables us to observe how important each dimension was for each student. Points within the space represent individual students (since several fell in identical locations, the number of observable points in the figure is somewhat reduced). The specific location of points shows how heavily each student relied on each dimension; this students in the lower right corner relied heavily on the Memory/NonMemory dimension, those at the top left relied heavily on the Perceptual/Conceptual dimension, and those lying along the diagonal relied more or less equally on both dimensions. In addition, those close to the origin (lower left corner) relied less on either dimension than those farther out into the display space.

The ellipse in Figure 6 identifies students who used both dimensions in a fairly equal and substantial way. The remaining students, termed “outliers,” emphasized one dimension more that the other, or failed to used either dimension to any great extent. Results of the definition task help explain the location of outliers. The class as a while did an excellent job in defining the terms (mean = 17.8 items, or 90% correct), although scores ranged from 12-20 correct. The class was divided in half, with students scoring 18 or above classified as high scorers and the rest as low scorers. All outliers except one above the ellipse were high scorers; these students relied more heavily on the Perceptual/Conceptual distinction. All remaining outliers except one were low scorers;

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4 The analyses were conducted by Ronald Collis.
5 Two-dimensional and three-dimensional solutions accounted for essentially the same amount of variance; since the two-dimensional solution is more interpretable, it is reported here.
Figure 5 – Location of concepts in the space defined by dimensions underlying the obtained clusters.

Figure 6 – Location of students in the space defined by the dimensions underlying the obtained clusters. Axes measure the extent to which students relied on the dimensions, no matter which aspect of the dimension they emphasized.
they relied more heavily on the Memory/NonMemory distinction or used neither distinction. Thus students with different amounts of knowledge about the concepts relied on different principles in the sorting task. This results is consonant with that of Friendly and Collis (in preparation) who not only discovered the same two dimension using a different set of cognitive psychology terms, but also found that undergraduates relied more heavily on the Memory/NonMemory distinction while cognitive graduate students and professors relied more on the Perceptual/Conceptual distinction. Thus the undergraduates above the ellipse in Figure 6 have knowledge structures more like those of experts.

Overview. The sorting task provides information that goes beyond sheer knowledge acquisition. In the example describe above, it demonstrates that students vary in the specific knowledge structures they possess, yet still rely on a small number of common principles in understanding course concepts. Even the simplest level of observation (inspection of individual student clusters) provides useful insights that are virtually unavailable from traditional approaches to teaching and learning. Other work in this project (Day, in preparation), demonstrates that this approach is useful across a wider variety of academic disciplines.

Practical Applications

Classroom Usage

The core concept and sorting tasks are a significant departure from activities normally performed in the classroom. Therefore instructors interesting in using these techniques are urged to begin in an informal way, following the general principles suggested here. Specific instructions, materials, and discussion questions for both tasks are available from the author.

It is important to introduce students to these tasks in an open and fairly accepting way; therefore no grades should be assigned, at least the first time. If they think the goal is to generate the same concepts and/or clusters as the instructor, then the purpose of these exercises will be defeated; students will try to out-guess the instructor rather than think about the concepts themselves. Class discussion should focus on the fact that alternative solutions are not only possible but useful in understanding the information more deeply.

Classroom Engagement and Interaction

Many discussions of the teaching-learning process in higher education focus on student learning and memory. The present research goes beyond memory to explore the nature of knowledge structures and does so for both instructors and students. A major practical goal of this work is to increase instructor-student engagement and interaction.
Very often there is a one-way flow of information in the classroom, as illustrated by the top part of Figure 7. Information flows from the subject matter (often taken from another textbook or scholarly work) to the instructor (link #1 in the figure), who then passes it on to the students (link #2), who in turn “receive” all the information they can and try to learn and remember it. Using the core concept and/or sorting tasks easily creates additional links, as shown at the bottom of Figure 7. Instructors may interact anew with the subject matter (link #3), even though they may have assumed they know all there is to know about it. Furthermore they can reconsider the same material in many new ways, simply by repeating the sorting task using the same or somewhat different terms (link #4). Students can also increase their engagement with the subject matter (link #5) and rethink about the concepts in various different ways (link #6). Thus participation in the tasks increases the engagement of both instructors and students with the subject matter.

Discussion of the sorting task also facilitates interaction between the instructor and students (link #7). Ordinary classroom interactions typically involve students asking specific questions and instructors providing specific answers. When discussed in an open way, the sorting task diverts attention away from getting the “correct” answer at all costs to examining alternative ways to think about the subject matter. It also gives both sides an opportunity to learn about and appreciate the knowledge each possesses.

Faculty Development

New faculty typically arrive at their first academic job filled with sophisticated knowledge about their field and a desire to be at least an adequate teacher. Too often they teach “the material” but not the students – that is, they tell (or read off from their notes) a vast array of information without considering the amount or structure of their students’ knowledge (Day, 1980). Over time they may (or may not) find a more appropriate level of discourse. Even so, with many repetitions of the same material and increased demands of research and/or administrative responsibilities, it is easy to become stale – to reel off information in the classroom without thinking much about it or engaging students in a meaningful way.

As the proportion of tenured faculty at colleges and universities increases, administrators seek ways to facilitate continued faculty development, especially in terms of intellectual engagement. Various types of programs are used, including sabbatical eaves, funding for new course development, newsletters about national research funding, establishment of interdisciplinary and team-taught courses, and various faculty development conferences. The work presented in this paper provides an easy and inexpensive way to re-engage faculty in thinking about their subject matter. It can enable them to stay fresh with old material, encourage them to learn about new advances, and perhaps even stimulate their research ideas and activities.

Faculty spend a considerable amount of time learning about their discipline in graduate school but little or no time learning about mental processes concerned with
acquiring, storing, comprehending, and using such information. As a general principle, if they learn more about the nature of cognitive processes – in general, in themselves, in their students – it should facilitate their intellectual engagement, classroom interaction, and research pursuits. Information about cognition relevant to the teaching-learning process is provided in Day (1980; in preparation).
References


