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CONCEPT MAPS FOR TEACHING AND ASSESSMENT

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ABSTRACT

Concept maps, a specific kind of mental model, are one method of representing and measuring an individual's knowledge. They are an alternative tool for teaching through building relevant associations, and a method for measuring knowledge and recall over time. Concept maps provide a visual representation of conceptual and relationship knowledge within a particular domain. Concept maps look like a spider web, consisting of many nodes (i.e., key concepts) connected to one another by lines that indicate relationships. In the learning process, students can develop concept maps as an alternative to traditional note-taking by building associations of non-linear key concepts and organizing them to fit with their individual learning styles and frames of reference. The presence of concepts and relationships on a map can provide an instructor with a snapshot of student knowledge and understanding. The proximity and connection of key concepts provide insight for instructors attempting to evaluate how ideas from class were absorbed by students. Conversely, the absence of concepts or relationships, or inappropriate connections between unrelated concepts, provide clues about what information students failed to internalize or incorporate. Concept maps may aid the instructor in assessing what students understand and how they relate the material to the overall course goals. They are easily taught and can be incorporated in introductory units, mid-term reviews and assessments, or end-of-course reviews and assessments.

Keywords: mental models, concept mapping, teaching technique, assessment technique

I. INTRODUCTION

Concept mapping is not new to academia, but is most often used in Education- and Psychology-related courses where the technique originated and developed. While previous conference

presentations and papers [Fisher et al., 1990; Freeman and Urbaczewski, 1999, 2001, 2002, 2003; Gaines and Shaw, 1995; Hoover and Rabideau, 1995; Markham et al., 1994; Taber, 1994] focused primarily on the empirical results of using concept maps as teaching and assessment tools, this tutorial focuses primarily on their creation and application within the classroom. Instructors who can use concept maps understand better how students incorporate and organize knowledge and information. This shared understanding allows both instructors and students to understand and use new technologies more effectively with greater ease.

While part of this tutorial focuses on the technique itself, a significant part of the tutorial is devoted to how participants can create and assess their own concept maps. This hands-on approach further aids in creating a greater awareness of the potential benefits and applications of concept maps within the classroom.

The remainder of this paper focuses on the theoretical background of concept mapping, the actual creation of a concept map, and some of the applications of concept maps within the classroom, including assessment techniques and issues.

II. CONCEPT MAPPING THEORY

Concept mapping was originally developed as a research technique in 1974 to make sense of data gathered in clinical interviews [Novak and Musonda, 1991]. Since then, concept mapping has been used in numerous ways in education, psychology, and organizational settings [Fraser, 1993; Novak, 1995]. Concept mapping enables people to visualize both the specific relationships among concepts and the hierarchical structure and organization of these relationships.

Two cognitive theories of memory are used to support concept mapping –

- Ausubel's [1968] Assimilation Theory and
- Deese's [1965] Associationist Theory.

Assimilation theory states that memory is hierarchical, and new information is processed and stored as either a more general or more specific concept to other, related concepts, i.e., assimilated into the existing structure [Fraser, 1993]. For example, if someone already knows the concepts of dog, bird, cat, and human, when the concept of animal is learned, it is put into the hierarchy "above" these others already present. Also, if this same person were to learn the concepts of eagle and canary, they would both be placed "under" bird as new branches of the hierarchy.

Associationist theory states that memory consists of a network of concepts that is not hierarchical, though is supportive of hierarchies. Relationships between concepts are formed naturally when two concepts overlap on some dimension. This is akin to word association games, though in these games the relationships are not labeled. As learning occurs, this network of concepts and relationships becomes more and more elaborate and complex. In the end, the memory structure in Associationist Theory is quite similar to that of Assimilation Theory, except that hierarchies are not required.

Both theories "eventually arrived at the same place" – a concept map [Shavelson et al., 1994, p. 16]. The concept map is intended to externalize an individual's cognitive structure, regardless of the theory behind it. The method for developing concept maps depends on which of the two theories is being followed and will be presented in more detail below.

III. CONCEPT MAP CREATION

A concept map is a pictorial representation of a domain that consists of concepts represented as nodes that are connected to each other by arcs. The concepts are words or ideas that represent events, objects, or even emotions and feelings. The connecting arcs represent the conceptual links – showing that the concepts are conceptually and logically related in some manner – between two or more concepts within the concept map [Dorough and Rye, 1997]. Fraser [1993]

provides the following rules to govern the construction of concept maps, supported by Novak and Gowin [1984] and Shavelson et al. [1994], and based on Ausubel's [1968] Assimilation Theory:

1. Concepts are located in rectangles or other geometric forms. Concepts can be represented by single key words or phrases or simple drawings. Arcs are lines used to connect the concepts. Linking words are sometimes written on the arcs to describe the relationship between the two concepts.
2. The linking words should specifically explicate the relationship between the two concepts. Together with the two concepts, the linking words form a proposition – such as "the grass is green" from the concepts "grass," "green," and the linking word "is." It should be noted that the literature views these linking words as optional in terms of concept map construction.
3. No right map exists, as all maps are idiosyncratic to each individual. Different people may produce very different maps for the same conceptual domain. A concept map can be wrong, however, if propositions are incorrect, such as "the bear speaks English."
4. The interconnections between concepts give rise to the power of the concept map. More interconnections and cross-linkages are an indication of a greater complexity and sophistication of understanding.

Concepts and key words may vary in their relevance to a lecture topic. Map creators often have quite a bit of latitude in using the terms they see fit in developing their maps. However, some words may be more "creative" – words that are consistent with some personal perspective or predisposition. At a point in time, these creative keywords may be meaningful, but over time they tend to lose their relevance.

Pre-constructed expert maps can be provided to students as a teaching tool. The maps are used in the tradition of lecture outlines or electronic presentations. Providing pre-drawn maps can create biases in the number of key words on a map and in the way the associations are defined between nodes. However, when using concept maps for imparting knowledge, the structure provides consistency more aligned with teaching goals and pedagogy and the interconnectedness provides more information than the standard outline. This may be particularly important longitudinally when considering recall (vs. assessment). We have not examined differences in free-form creative maps vs. structured expert maps, but this is an area for future research.

SPECIFIC INSTRUCTIONS

Given the different methods used to create concept maps, the easiest and most straight-forward is to do the following: 1) determine the topic or domain of interest to be modeled, 2) write that term (concept) in the middle of a sheet of paper, 3) think of related concepts to that initial one and begin writing them down on the paper near the first term, 4) connect related concepts with lines, and 5) keep adding more concepts and relationship lines to the map as it grows. Keep in mind there is no minimum or maximum size to a concept map – the size will depend on the understanding of the topic and the concepts the subject relates to the initial term.

So, for example, to create a concept map of Information Systems, one would start by putting the phrase "Information Systems" in the center of a sheet or a screen. Then one would think of related concepts and begin writing them down. In this example, concepts such as "organizations," "people," "applications," "technology," and "education" are possible. Using these ideas, a concept map could look like Figure 1.

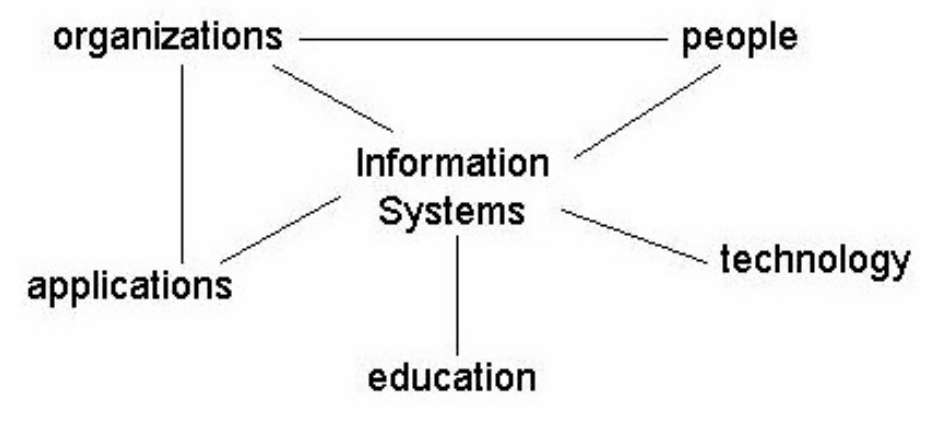

Figure 1. Initial Concept Map of Information Systems

The concept map would then be developed further by adding more terms and connecting them to each other and to the previous terms already on the map. No limit exists with regard to the number of relationships a single concept can have, though too many relationships create a very cluttered and noisy map that is hard to read and understand. It can be hard to find the right balance as many of the concepts could legitimately be related to many others. The concept map in Figure 1 can be expanded to the example shown in Figure 2 by adding more concepts.

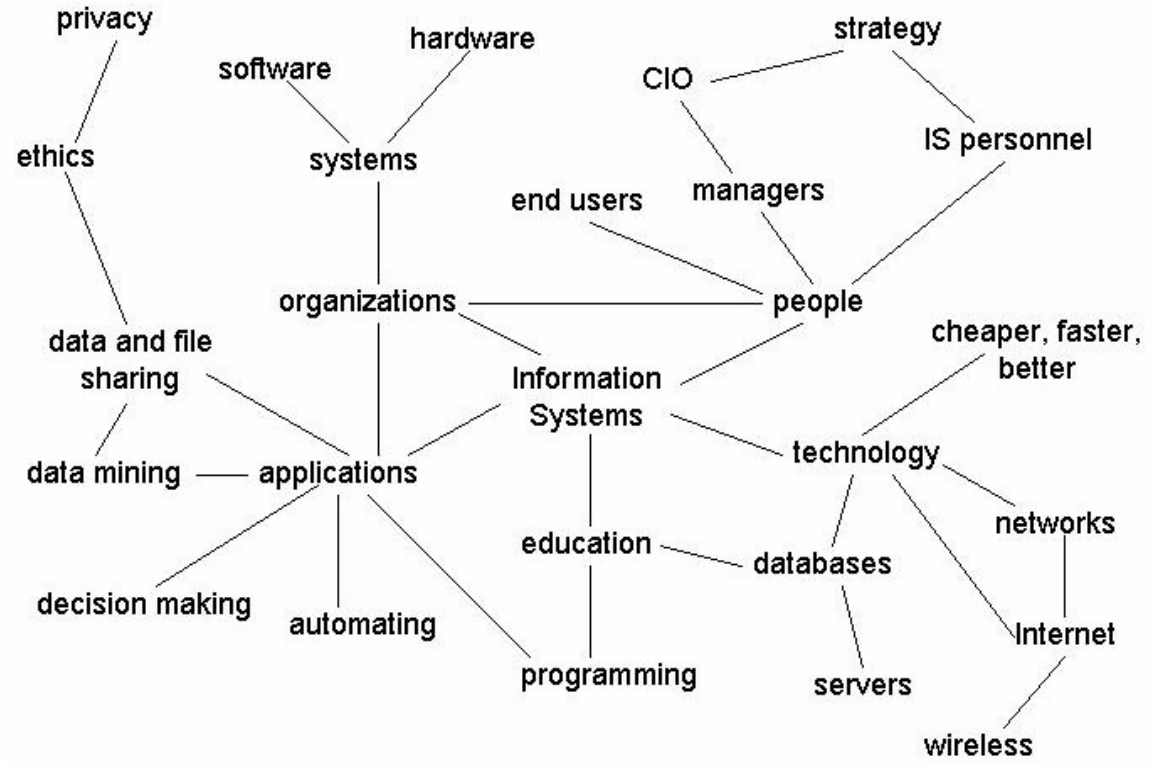

Figure 2. Final Concept Map of Information Systems

Assuming no more concepts were to be added, the concept map of Information Systems would be complete. The map provides insight into the understanding of Information Systems and the importance of key concepts and issues of the map's creator. This map could be compared to

other concept maps to understand the creator's point of view much better than if it were just explained in words.

IV. CONCEPT MAPS FOR TEACHING & ASSESSMENT

Concept maps are primarily used in a classroom as teaching aids and as alternate assessment techniques.

INTRODUCING A TOPIC DOMAIN OR COURSE

At the beginning of a course, or even at the beginning of a major unit or topic within a course, concept maps can be useful as a means of conveying to the students what will be studied and providing them with a big-picture overview of the topic. The instructor could create a concept map on the board (or computer), and the students could follow it and comment on it. The students could all create individual or small-group concept maps (following some explanation of what they are and how to create them) based on their understanding of the topic at that point in time. These student concept maps could then be collected and shown to the rest of the class as a way of informing everyone of the similarities and differences across the maps, and therefore also across students' own understanding of the topic. Such maps, whether student- or instructor-created, can then be used as a reference point for the course or unit.

USE AS A LEARNING TOOL

In the learning process, concept maps can be developed as an alternative to traditional note-taking by building associations of non-linear, key concepts and organizing them to fit with individual learning styles and frames of reference. Using traditional linear note-taking methods, key information is disguised, disconnected, and cluttered with irrelevant words [Buzan, 1974].

Concept maps help learners think holistically as they work to understand the interrelatedness of ideas. One outcome of these visual representations is a focus upon developing and recalling relevant associations rather than memorizing concepts recorded in a more linear fashion. Concept maps vastly improve the recall and application of important concepts [Buzan, 1974]. Some of the advantages concept maps offer over linear note taking are:

- Recall is easier using associated key concepts because less time is required and the recall itself is more complete.
- Main ideas are more clearly defined, and the relative importance of each idea is clearly indicated.
- Links between concepts are immediately recognizable because of their proximity and connection.
- Recall and review are more rapid and more effective.
- The structure allows for the easy addition of new information.
- The open-ended nature of concept map construction enables connections to be made more readily.

Wycoff [1991] suggests the use of color to group related concepts helps considerably in the recall of relevant associations. We observed anecdotal evidence in our work that suggests color-coding related concepts may help in recalling relevant associations and reinforcing associations. However, further investigation is necessary to establish empirically valid results.

Throughout the semester, students can use concepts maps to aid their learning within the classroom. As an alternative to note-taking, students can create on-the-fly concept maps during lectures and discussions. These maps can then be compared to maps (their own and others') created at different points within the semester and used for review and examination preparation. Expert maps can be provided to augment lectures in addition to or in lieu of more traditional classroom outlines. Providing maps in advance of a lecture may bias the number and types of associations generated by students in post hoc assessments.

MID-TERM ASSESSMENTS AND REVIEWS

As the semester progresses, it is important for instructors to know how students are assimilating the content of the course. Instructors may want to assess students' knowledge or review material already covered. In either case, a concept map can be quite beneficial.

The presence of concepts and relationships on a map can provide an instructor with a snapshot of student knowledge and understanding. The proximity and connection of key concepts provide insight for instructors attempting to evaluate how ideas from class are being incorporated. Conversely, the absence of concepts or relationships, or inappropriate connections, provides clues about what information students failed to internalize or incorporate. These inappropriate connections are often the most helpful to the instructor. For example, a relationship between the terms "operating system" and "10 Base T" would indicate that the student does not understand one or both of these terms, or possibly that the instructor mis-spoke in class, thereby confusing the student(s). When these inappropriate connections appear, the instructor can take the time to speak with the student or the class as necessary to clear up any misconceptions and misunderstandings. The earlier in the course these misunderstandings can be clarified, the better the student will perform on subsequent assignments and examinations.

Difficulties can arise in evaluating maps when students construct their maps using multiple terms to describe the same concept, one word that has multiple meanings, or keywords or phrases that are dissimilar from those used in lecture. In such cases, instructors and evaluators may need to translate maps using a thesaurus constructed from the body of concept maps created by the class.

END-OF-COURSE ASSESSMENTS AND REVIEWS

Just as with the mid-term assessments and reviews, concept maps are beneficial for end-of-course assessments and reviews. Many institutions, colleges, and programs now conduct not only end-of-course assessments, but also end-of-program assessments, or exit interviews, in an effort to see what students are learning over the course of their collegiate careers and how they can apply it. A concept map is a useful tool to assist in this process, complementing or even replacing the traditional multiple-choice exam. An earlier study [Freeman and Urbaczewski, 1999] did such an assessment with the MIS major at a large midwestern university. Students in their capstone course were required to create concept maps with "MIS" as the root term. Students generally used posterboard or other similar large sheets of paper to complete this task. In this case, students did not study for an exam. The results produced may be atypical representations of their knowledge of MIS due to recency effects. The concept map allowed for greater synthesis of seemingly disparate topics than the traditional examination would allow.

OVERVIEW OF ANALYSIS OPTIONS

Formal Analysis

Concept map analysis comes in many forms. For course assessments, the analysis may consist of

- counting the total number of concepts,
- counting the total number of relationships,
- measuring the map complexity (number of indicated relationships beyond the minimum needed to connect all concepts linearly – i.e., number of concepts minus one),
- comparing the maps to that of an expert or an instructor, or
- comparing the maps from the beginning or middle of the semester to the maps created at the end of the semester.

These highly quantitative analyses can be combined with more qualitative analyses that seek to understand how concepts are mapped and where they appear on the map.

To create such quantitative analyses, it is necessary that concept maps being compared with one another were created equally and analyzed fairly. For example, a concept map that contains several different terms meaning the same thing (e.g., "worker," "employee," and "end-user") biases the total count of concepts (and potentially relationships) on that particular map as well as the ability to compare it to other maps that use the term "user." The term "cable" on a particular concept map may be referring to the physical wire connecting computers and networks, or to the type of modem. Likewise, a concept map with the term "network" and another concept map with the term "LAN" may both be referring to the same thing, though it is just as likely that they are not.

As a result of the potential confusion and misinterpretation illustrated by the above examples, we suggest the following for analyzing and comparing concept maps to one another in a consistent and fair manner:[1]

1. Using electronic spreadsheets (for handling multiple rows and columns simultaneously), enter each term from each map into a column. As you progress through the maps, place synonyms – "worker" and "employee" – in the same row. If possible, multiple coders should be utilized to come to this agreement of synonyms.
2. After entering all terms from all maps, review each row and determine (if synonyms exist) which of the synonyms to use for comparison purposes. Place this term in the first column and all other terms within the same row.
3. Using the terms from the first column, re-create all of the concept maps on clean sheets of paper. Replace synonyms with the appropriate terms to allow for comparisons. Be sure that all relationships are re-created as well.
4. The re-created concept maps can then be analyzed for number of concepts, number of relationships, and any other variables in question. Using a grid design with the concepts along one axis and the individual concept maps along the other axis, a detailed accounting of which concepts appeared on which maps can be created (again, electronic spreadsheets are recommended).

Informal Analysis

From a teaching perspective, one might argue that the goal is to generate a reasonably accurate map. To facilitate this goal, the maps can be

1. provided,
2. generated during lecture, or
3. self-generated outside of class in concert with lecture notes or textbooks.

When the notes are provided or generated during lecture they contain more structure (however biased) that attempts to ensure that the proper nodes are identified while the necessary and appropriate associations are being made. This process can be augmented by small group study interactions that serve to review, compare, and modify maps based on the learning perspectives of the group, as suggested in the following steps:

1. Using the core concept as the center node, have each participant create a concept map to describe the concept. The amount of time necessary for this step may vary according to the needs and motivations of the facilitator/instructor.

2. Upon completion of the initial maps, instruct pairs of participants to compare their maps using the compare, contrast, and update method. Remind participants that

[1] For additional details, including a sample copy of the electronic spreadsheets used for the coding and analyses, please contact Lee Freeman at lefreema@umd.umich.edu.

there is no single correct map. Comparing maps helps students bring in concepts they had not previously incorporated and reinforces associations held in common.

3. Further comparison, contrast, and update can be completed in progressively larger groups to generate a consolidated large-group understanding and synthesis. From a teaching perspective, this approach allows the class to come to a common understanding. From an analysis approach, maps can be re-made to remove or reduce synonymous terms.

The goal here is to try and ensure that the maps are correct from a learning perspective and to insure accurate recall later on. No single map is correct. Students have latitude in how to construct the maps to ensure the best fit for them as individuals. This distinction may be subtle, but it is an important distinction between the analysis of maps used for assessment and those used for teaching and learning.

V. CONCLUSION

We introduce concept mapping to show one more technique by which students can be assessed, as well as a means by which instructors can convey information to their students. Just like the many methods for systems analysis and design, we do not claim that concept mapping is a silver bullet, appropriate to all situations at any given time. However, there are many occasions where the concept map is an appropriate tool for assessing learning and synthesis of major areas, either as an additional tool to use alongside more traditional assessment methods or as a replacement for them. Concept maps are also a helpful tool for the instructor to use in representing material to the class.

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