Handbook of Research on Collaborative Learning Using Concept Mapping

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Chapter 9
Teaching Critical Thinking and Team Based Concept Mapping

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ABSTRACT

Critical thinking cannot be fully developed without involvement in collaborative learning activities that elicit problem solving dialogue. Concept maps are effective tools for dialogue because they require decisions about the organization of and the relationships between facts and concepts. This active decision making process develops both long term memory and the ability to apply that knowledge. The authors describe a new method for incorporating scored concept maps into an established collaborative learning method, Team-Based Learning, as a way to improve the effectiveness of individual preparation and for enhancing the problem solving dialogue during group activities. Their new method, Team-Based Concept Mapping, has advantages for students with different personality types and with different backgrounds because it provides greater clarity and precision in the group dialogue. The effect of concept mapping on the interaction between different personality types is discussed and suggestions for future studies to develop this method are offered.

INTRODUCTION

Collaborative learning is necessary to help students move beyond assimilative learning to become, as described by Mezirow (1991, p. 167), "…critically aware of how and why our assumptions have come to constrain the way we perceive, understand, and feel about our world…" This "critical awareness" by students is revealed to us when we observe the dialogue that occurs during team problem solving. Dialogue allows team members to hear alternative ways of perceiving a situation and to reflect on their own approach to solving a problem. During the collaborative learning process, the individual team members use the critical thinking skills of analysis, interpretation, inference, evaluation, and

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explanation (Facione & Facione, 1997) to reach decisions that produce a new understanding for all members. New understanding by the students, in turn, converts their "working memory" into long-term memory. Thus, students participating in the process of team problem solving avoid the pitfalls of assimilative learning which simply layers new information onto old understanding. The process of using current knowledge to create new knowledge has been termed transformative learning (Boyd & Myers, 1988), and this functional transformation is accompanied by a parallel anatomical transformation occurring in the brain itself (Zull, 2002). Collaborative learning physically transforms the brain by establishing a greater number of long lasting synaptic connections through the growth of nerve cell dendrites. This physical transformation occurs in two interactive areas of the brain: 1) the temporal area and 2) the prefrontal area. The temporal area accesses existing memory and adds to that memory when new learning takes place. The prefrontal area uses knowledge from the temporal area to establish new possibilities and to make logical decisions about them. The active use of both of these areas of the brain is necessary to develop critical thinking skills thus indicating that the growth of dendrites occurs both in the area of the brain that stores memory and in the area of the brain that uses that memory for decision making (Zull, 2002; Bransford, Brown, & Cocking, 2000).

Prior to our research on team problem solving, we discovered that individual preparation for participation in team problem solving exercises is enhanced by concept mapping. This is because the construction of a concept map requires analytic reading through the constant formulation of focused questions (Cañas & Novak, 2006). The back-and-forth process of asking a question ("Where does this go in my map?") and then answering it ("It is connected here…and here…") helps the student discover how new knowledge can be organized. This facilitates, in turn, the retrieval of this knowledge during the team dialog when each student must defend their decisions to the rest of the team members. The formulation of a rationale for suggesting new possibilities, or for choosing among optional solutions, requires more than recall knowledge of factual content. Such a rationale also requires an understanding of the meaning of factual content and the construction of a concept map reveals that meaning through patterns and organization.

Concept maps are effective tools for helping students understand their individual learning style and how their preference for processing information affects their individual learning strategy, both for remembering information and for using it in problem solving. Students who are either Sensing or Intuitive personality types, as determined by the Myers-Briggs Type Indicator (MBTI), process information very differently with dramatically different outcomes in learning and test achievement (Pelley & Dalley, 1997). If the Sensing type students follow their preferences, their learning is focused on facts and details that are committed to recall memory (a temporal area brain function). They learn in linear order and consequently do not spontaneously look for patterns and relationships. This is in contrast to their opposite, the Intuitive type student, that spontaneously seeks out new patterns and relationships (a prefrontal area brain function). Because they tend to emphasize the use of one area of the brain over others, both types can have learning "blind spots" that are corrected by the use of concept maps. The concept mapping process motivates the Sensing type to seek out relationships in order to construct a concept map complete with cross-links and it motivates the Intuitive type to seek out details that are overlooked when they focus on the "big picture." The use of concept maps has led to improvement in learning skills by both types of students in health care professional education (Pelley & Steele, 2002)

We have found an exciting new way to extend the use of concept maps in individual learning to group learning by incorporating them in a highly effective collaborative learning method, Team-

Based Learning (Michaelsen, Knight, & Fink, 2004). This learning system was developed to permit small group learning in large classrooms and utilizes multiple choice questions to not only score learning achievement, but to serve as the vehicle for dialogue in team problem solving. Although the process is highly engaging and students are able to debate and decide on their choice of answers, the discussions frequently suffer from difficulties in communication of knowledge. It occurred to us that the substitution of scored concept maps would provide a method for assessing learning while communicating knowledge more accurately and reliably. As a result, we describe here a modification of Team-Based Learning (TBL) that incorporates concept maps. We have given our method a similar name, Team-Based Concept Mapping (TBCM).

Upon completion of this chapter you will be able to:

1. Describe the different ways that students prefer to process information and how collaborative learning makes the most efficient use of those differences in the development of critical thinking skills.
2. Implement Team-Based Concept Mapping in your learning environment.
3. Develop improved methods for teaching the process of concept mapping and for evaluation of critical thinking using concept maps produced by groups.

BACKGROUND: PERSONALITY TYPE, CONCEPT MAPPING, AND TEAM-BASED LEARNING

Personality Type Influences on Teaching Critical Thinking Skills

It is logical that a learning tool such as concept mapping, designed to develop critical thinking skills (Novak and Gowin, 1984), is used differently by students who process information differently. These differences can be identified with the Myers-Briggs Type Indicator (MBTI), a personality instrument developed to sort preferences within several dimensions of thinking (Myers, McCaulley, Quenk, & Hammer, 1998). The Myers-Briggs personality types represent different mental habits used for information processing and, as such, they represent predictable aptitudes and attitudes with respect to the construction of concept maps. Additionally, they represent predictable aptitudes and attitudes with respect to the critical thinking process. Since the Myers-Briggs preferences do not represent limitations in thinking, they become opportunities for using concept maps in the development of critical thinking skills.

The Myers-Briggs Type Indicator is a psychological instrument that was developed to reliably determine the personality preferences first described by Jung (Myers, McCaulley, Quenk, & Hammer, 1998). When taken together, the mental functions observed by Jung describe mental habits that lead to a consistent thinking style in information processing. These mental functions involve: 1) information input, 2) generation of alternative possibilities, 3) deduction of the most logical alternative, and 4) assessment of human outcomes/values. Although all types use all of the functions in their learning, they are differentiated from each other by the emphasis of one of these functions over the others. If left unbalanced, the student's critical thinking skills will have strengths in the most used functions, but weaknesses in the less frequently used functions. Identification of the emphasized function allows the adoption of strategies to develop the lesser used functions.

The MBTI only measures normal differences in behavior that are established as mental habits, and thus does not measure abnormal behavior. Since all of the preferences that are measured are found in normal thinking, personality type is nothing more than a comfort zone where thinking occurs with less effort and with the greatest amount of trust. When a student of a given personality type uses a non-preferred mental function, for example at work, they use more mental energy and tire more easily. But, like any motor skill, use of the non-preferred side can be developed and mastered. Thus, no one is limited, or compartmented, by their type; the limitation is usually a lack of awareness of type preferences and, therefore, a lack of awareness of why some aspects of thinking are more difficult than others. The available data do not support a relationship between personality type and intelligence nor a connection with any psychopathology. Each dimension of type, as described below, is exercised to different degrees by individuals of the same type preference due to the influence of other personality traits and life circumstances (Myers, McCaulley, Quenk, & Hammer, 1998).

Extraversion and Introversion Preferences

Students differ in their preference for whether their best thinking is achieved through "talking it out" or through "thinking it through." Those students who have extraversion preferences will have an easier and more effective learning experience if they can verbalize their learning as it is happening. Although verbalizing learning is impractical in some learning settings, such as lecture presentations or seminar settings where verbalization would be disruptive, it has an energizing effect on study groups where verbalization is expected.

The opposite preference for introversion is seen in students who have a more effective learning experience when they are able to process new information quietly before it is discussed. While this type of learning can lead to isolation from others, if used regularly in a study group it will bring depth of thinking to the group process. Thus, extraverts talk-to-think while introverts think-to-talk.

Sensing and Intuitive Preferences

Students differ in their preference for the way they give their attention to new information. Those students who have sensing preferences tend to trust information that is perceived directly by the senses, i.e. vision, hearing, touch (manipulation), taste, and smell. This information exists in the present as facts and details and carries a high degree of certainty. If a pattern or relationship exists, it is also perceived as a fact…but is only "discovered" as a relationship with great effort. When studying in a group, the sensing student is always alert to completeness of the facts.

The opposite preference for intuition leads students to trust their ability to find patterns and relationships. This information exists in the future as a possibility and several ways of organizing these relationships might be perceived. While a minimal set of facts is needed to form a pattern, once the pattern is decided the remaining facts are ignored by the intuitive type student. When studying in a group, the intuitive students help with the discovery of patterns and bring the alternative points of view that are essential to critical thinking. Thus, sensing types think about "what is" while intuitive types think about "what if."

Thinking and Feeling Preferences

Students differ in their preference for the way they react to or make a decision with new information. Those students who have thinking preferences tend to trust their logic to evaluate the facts and possibilities. They are impersonal and objective in their analysis since they seek to obey the laws of deductive and inductive reasoning. While they have feelings, they do not trust their feelings in reaching a decision or making a judgment. When studying in a group, the thinking types draw attention to the "correctness" of relationships and the clarity of thinking.

The opposite preference for feeling judgment leads students to trust learning decisions based on personal and subjective analysis. This analysis is still a rational process, but it references against human outcomes rather than laws of logical reasoning. When confronted with a conflict between a logical alternative or a personally valued alternative, the feeling type will choose the latter, even while realizing the former is also valid. When studying in a group, the feeling type students bring harmony and enhance communications. Thus, thinking types need to include feelings and values as facts in their thinking while feeling types need to realize that thinking types have difficulty trusting feelings and values.

Judging and Perceiving Preferences

Students differ in their preference for the way they conduct their learning activities. Those students who have judging preferences tend to organize their time around a plan. They are motivated to obtain closure by completing their plan or checking off items on their task list. They will tend to sacrifice learning additional information if that learning prevents them from completing their schedule. When studying in a group, they keep the group on task and help it to be more efficient.

The opposite preference for perception leads students to conduct their learning in a flexible and adaptable manner. They are motivated to discover new information that makes a more complete set of facts or a more complete pattern. They may attempt to follow a schedule, but they will value the acquisition of additional information over meeting a deadline. When studying in a group, they keep the group open to new information in resolving learning issues. Thus, judging types seek "the joy of closure" while perceiving types seek "the joy of discovery."

Concept Mapping as a Tool for Dialogue

Individually constructed concept maps have been used to understand the development of team cognition (O'Connor, Johnson, & Khalil, 2004). Aggregate team concept maps were synthesized from separate individual maps that were constructed by team members at predetermined stages of a team task. The aggregate maps were considered to represent a shared mental model that represented team understanding. While this study showed that aggregate concept maps are one way to visualize group knowledge and understanding, it was not designed to assess the effect of the process of constructing a concept map on the group dialogue. We have studied concept mapping during the team task as a method to help focus dialogue while producing a shared mental model.

Our earlier work involved group study sessions where individually constructed concept maps were discussed. We found that the visual construct provided an effective vehicle for students to explain their own thinking and to share it with others. However, it was noted that the dialogue rarely ended with the maps in their original condition. Instead, the groups questioned existing structure and proposed alternative structures without prompting from faculty mentors (Pelley, 2006). The repeated spontaneity of this process caused us to organize a more structured process to facilitate the dialogue between team members by assigning construction of group maps from previously constructed individual maps as a team task (Scott, Taylor, & Pelley, 2006). The dialogue during construction of the group map involved discussion not only of the informational content to be learned but the rationale for the organization of this content, i.e. branching and cross-linking. We found that the contribution from Sensing type students in the group, at first, centers on the content of facts with less attention given to cross-link relationships between branches. In contrast, the contribution from Intuitive type students, at first, centers on the relationships and novel approaches to organization of facts and concepts. If the same group meets for several sessions, both the Sensing type students and the Intuitive type students display more balance in their thinking and demonstrate the skills of their opposite type. The reason for this is that, while personality type preferences are relatively constant, the development of thinking skills in the non-preferred mental functions is not restricted (Pelley & Dalley, 1997). Sensing types gain a "big picture" perspective by discovering and constructing organizational and conceptual relationships and Intuitive types gain a greater grasp of the facts by attaching them to their "big picture" concept map. This helps to avoid the problem of construction of primarily descriptive maps in place of the desired explanatory maps as cited by Cañas and Novak (2006). They point out that the choice of focus questions can prevent a map from serving as a classification of facts but, rather, can influence the student to construct a dynamic map that shows explanations of cause and effect.

Concept maps can be effective in facilitating the maturation of a team from a collection to a community. While a collection of students can be directed to work together, they do not achieve synergy until they trust each other as do members of a community. Team maturation has been reported to progress through four stages before students develop the trust needed for effective critical thinking skills (Tuckman, 1965). During the first two stages of team maturation, "forming" and "storming," the dialogue that is critical to effective team learning is less efficient and thus more difficult to bring to a focus. These early stages are characterized by the uncertainty of the students about their role and concern for their compatibility with other team members, thus diverting attention away from the team task. Even the more productive latter stages, "norming" and "performing," are vulnerable to inefficiency if team members are unclear in explaining their rationale for a particular decision. Our research has been aimed at addressing these issues with team dialogue by using concept mapping not only as a team task but as a vehicle for clarity in communication. We want to facilitate the maturation of teams as healthy, trusting communities that can quickly develop a focus and effectively reach a decision. We have found that team concept mapping indeed helps teams develop a more immediate focus for discussion and produces a more effective and efficient learning process.

Team-Based Learning as a Collaborative Learning Process

Team-Based Learning (TBL) is a unique collaborative learning approach that has been adopted around the world in business and science courses (Michaelsen, Knight, & Fink, 2004) and recently in health care education (Michaelsen, Parmelee, McMahon, & Levine, 2007). TBL brings together theoretically-based and empirically-grounded strategies for ensuring the effectiveness of small-groups working independently in classes with high student-faculty ratios (e.g., up to 200:1) without losing the benefits of faculty-led small groups with lower ratios (e.g., 7:1). The opportunity for whole-class inter-group dialogue confers a distinct learning advantage over methods where the groups work in isolation from each other. TBL can be used in conjunction with other teaching modalities to provide an efficient system for developing critical thinking skills in a team problem solving setting.

One of the primary characteristics of TBL (Michaelsen, Knight, & Fink, 2004) is that all of the activities involve teacher constructed multiple choice tests. In the TBL method, all teams work on the same multiple choice problems at the same time. This maximizes the opportunity for two valuable comparisons: 1) team members can compare the knowledge that each has brought to the session and 2) each team can compare their own performance with how other teams used their knowledge to develop a rationale for solving the problems. Thus, the teacher-directed whole group discussion establishes a common understanding of the basic concepts and facts and how they are applied in more challenging case-based multiple-choice questions.

This collaborative learning method balances individual and group accountability by including both individual test performance and group test performance in the final score. The requirement for individual test performance prior to the beginning of group activities maintains the learning responsibilities that are expected of each student. This assures that group morale and team motivation don't suffer from one or more students arriving for the group activities without making an effort to prepare. However, it is not a safe assumption that students who responsibly attempt to prepare for a team exercise have done so competently. Many students study in vain, unable to comprehend critical facts or organization. Thus, this otherwise highly effective collaborative learning process is vulnerable to the effectiveness of the individual learning skills of each student. We addressed this vulnerability by merging an effective method for individual preparation, concept mapping, with a proven method for collaborative learning. Because the student uses concept maps for both individual preparation and for participation in group dialogue, we have named this method "Team-Based Concept Mapping." Since the assigned material has already been organized into a concept map, the degree of mastery of the material can be assessed by deriving a score using a grading system weighted so that links representing higher order thinking, e.g. cross-links, receive a greater number of points. The substitution of scored concept maps for the multiple choice test assessment maintains the individual accountability for each student and provides a motivation for the deep analytical reading needed to find the more complex links to include in their maps. Thus, by substituting scored concept maps for multiple choice tests, we assure that individual preparation will be maximized while maintaining all of the important collaborative learning features of Team-Based Learning.

MAIN FOCUS OF CHAPTER: TEAM-BASED CONCEPT MAPPING

In order to describe the process of Team-Based Concept Mapping (TBCM) we will compare it to the established process of Team-Based Learning. This will further detail the advantages of TBL as a unique method of collaborative learning and will permit us to emphasize the advantages of incorporating concept mapping as part of the process. A section on Fundamentals will be followed by:

1. Teaching the process of concept mapping
2. Scoring concept maps
3. Composing teams
4. Conducting a TBCM session

Fundamentals

The format of Team-Based Learning as originally developed by Michaelsen, Knight, & Fink, (2004) is a structured sequence consisting of 3 phases. In Phase 1, students study independently outside of class to master learning objectives designed for the session. Phase 2 begins the classroom activities as individual learners complete a multiple-choice test to assess their readiness to apply knowledge from Phase 1. This "readiness assurance test" contributes points toward their final score. Then, groups of 5-7 students re-take the same test and turn in their group consensus answers for immediate scoring and posting toward their final score. As with typical examinations, outside reference materials are not used during the readiness assurance exams. At this point, the teacher leads a whole class discussion that enables clarification of concepts where needed. Phase 2 takes approximately one hour. In Phase 3, groups complete in-class case oriented assignments that require collaboration to answer multiple choice questions concerning the case. Answer choices for these questions are constructed with some ambiguity so that groups must select the most correct choice, thereby stimulating vigorous discussion and debate. At designated times, all groups are led by the teacher to simultaneously share their groups' answers with the entire class for easy comparison and immediate feedback. This stimulates an energetic total-class discussion with groups defending their answers and the teacher helping to consolidate learning as needed. Phase 3 takes from 1 – 2 hours. A complete TBL session addresses all three of the recommendations of the National Research Council that produce effective learning: 1) addressing pre-existing understandings, 2) teaching some subject matter in depth, and 3) teaching metacognitive skills that aid reflection on learning (Bransford, Brown, & Cocking, 2000). For a more thorough description of the TBL process, the reader should consult either Michaelsen, Knight, & Fink (2004) or Michaelsen, Parmelee, McMahon, & Levine (2007).

Our adaptation of TBL substitutes scored concept maps for the multiple-choice readiness assurance tests. This has shown promise for facilitating group maturation and more effective use of higher order thinking skills by all students. The student first develops concept maps from the individual preparation in Phase 1 (see Figure 1). The content of the maps is guided by the learning objectives which serve in the role of focus questions. As mentioned previously, effective focus questions are one of the essentials in effective map construction as discussed by Cañas & Novak (2006). Phase 2 of TBCM begins with the exchange of maps between classmates for scoring. This step has some advantages over a multiple choice test. First, each student has a motivation during Phase 1 to construct a map that is readable and readily interpreted by a randomly assigned classmate. This can encourage students to study together ahead of time to refine their maps for scoring during Phase 2. When more thought goes into the concept map, reading is deeper and more analytical. A second advantage of this scoring method is that each student is using the first part of the session to compare another student's thinking, as represented by their concept maps, with their own. This helps to mentally prepare them to enter the discussion during the group activities. Students have the opportunity to appeal the scoring of their maps with review by the teacher at a later date. This process takes longer to complete than scoring a multiple choice test and we have found that, rather than extend the time of the session, it is more effective to simplify the concept maps by narrowing the focus and reducing the cognitive load for the session. For example, instead of using an entire chapter from a text as the source material for the TBCM session, limit the exercise to a section within the chapter. It is important to emphasize that the goal of both TBL and TBCM is analytical problem solving, not comprehensive review.

Phase 2 continues after the score for the individual maps has been recorded with each team collaborating to complete a group concept map (See Figure 2). Just as in the original TBL method, the groups receive a score on their "team map." The maps are turned in for scoring at a later date by the teacher, but are posted in the classroom for reference and discussion of any concepts that remain unclear. The teacher has a similar opportunity in this step for review and clarification of the topic by referring to each of the group maps to point out strengths and opportunities for improvement. This is comparable to the systematic whole-class review in TBL by the teacher of each question on the "readiness assurance" multiple choice test at the end of Phase 2.

Phase 3 involves team analysis of one or two cases by the teams. The team score for each case is based on two factors: 1) answering one or more multiple choice questions concerning the case and 2) concept maps that illustrate analysis of the case. Teams should be encouraged to construct two separate maps, one that shows the relevance of each important element in the case and one that shows the relationship for each answer choice with the elements of the case. The first map directs discussion of the group to the material they have just reviewed in class and begins the process of

Figure 1. Reproduction of an original individual concept map of a reading assignment in "ethics." The student was only able to identify three cross-links with the remaining elements of the map in a branched hierarchy. This student has sensing preferences in her learning and thus does not seek out these relationships. The scoring is discussed later in the chapter below

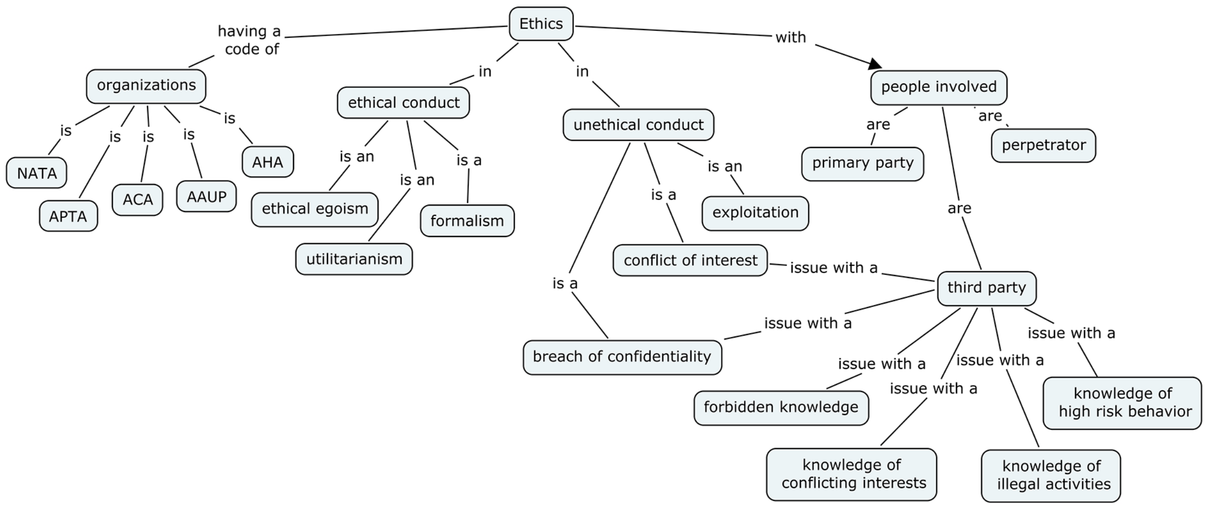
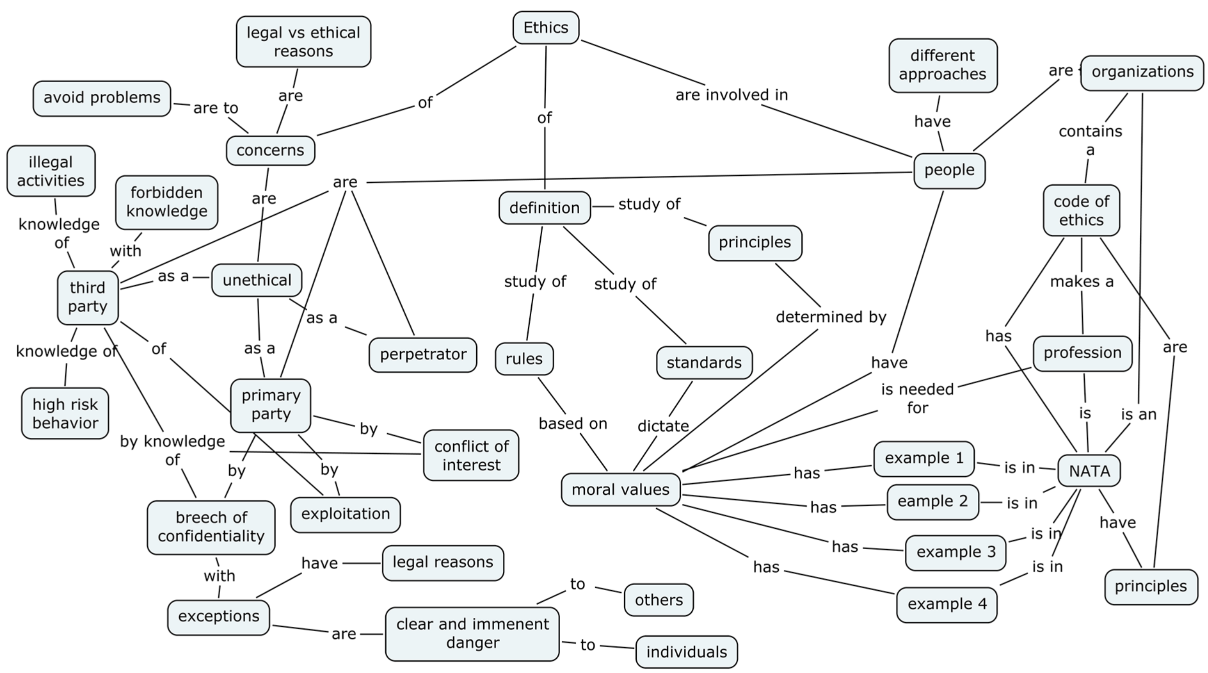


Figure 2. Reproduction of an original group concept map of a reading assignment in "ethics." Many more cross-links are present indicating a stronger input by intuitive type members of the team who tend to see relationships more readily. The scoring is discussed later in the chapter



prioritizing importance and relevance. The second map uses deductive reasoning to associate the relevant elements of the case to each answer choice. This second step is the most powerful in eliciting higher order thinking because it is a visual demonstration that, while the greatest number of links will be associated with the correct answer, other incorrect answers also have some links associated. This is of great importance to the Sensing type student that expects all answers to be either totally correct or totally incorrect.

By the end of the TBCM session, all students have had an opportunity to discuss facts and concepts with a common visual focus and to develop the greatest number of relationships within the topic area. The discovery of relationships is a thinking skill that will carry over into all future learning for each of the team members. The analysis of the relevance of different elements of a case is aided by a common visual focus to illustrate that most real world problems are not "black-or-white."

Teaching the Process of Concept Mapping

Because Intuitive types and Sensing types react differently to the process of concept mapping, it is important to include training sessions prior to conducting TBCM. This is accomplished effectively with a mock TBCM session so that the training occurs in a setting that begins training in team problem solving skills.

We teach concept mapping as a communication tool. When the student is studying alone, concept maps help authors or teachers to communicate with them through the written word. Similarly, when the student is learning in a group, concept maps help them communicate with team members through the spoken word. Communication can become very frustrating when Intuitive type students are talking about patterns and relationships that the Sensing type students missed and when Sensing type students talk about details and facts that the Intuitive type students missed. The following approach will help in training all students to become proficient with concept mapping so that each type can see what the other type is trying to say.

"List-Group-Compare" – Students can commit this simple phrase to memory for use during individual study. It reminds them to follow a sequence that guides reading in a way that facilitates construction of a concept map. The first step in the sequence is a reminder to survey the material and pull out terms that are more general and inclusive. Even though this appears to be a simple and obvious step, the Sensing type student will in many cases overlook that there are more general terms that are different in nature than other more specific terms. This type of student can be so focused on details and facts that all are given equal importance. This serves as an initial frustration in construction of a proper concept map. It serves as an equally powerful motivation when this type of student "sees" the reading in a new light through concept mapping.

The grouping step involves extracting the first terms to be included in the map and beginning the organization of the map itself. This should be illustrated first by the teacher with constant reference to the list. Reassurance is important at this stage for the students to understand that the initial list will become more accurate and useful over time. Additionally, it is important for Sensing type students that the map is constructed from the top-down and not center-out. It is of no consequence to Intuitive type students where the map begins, so it gives a common ground for ease of understanding and dialogue if the top-down model is used. If necessary, a left-to-right map will also be easier for Sensing type students to construct and interpret.

Sensing type students have a need for certainty that affects their acceptance of and proficiency with concept mapping. This need can be satisfied readily if the teacher reviews their maps with them to help support the overall process. It is always important that the teacher does not show the student how to map the material, but instead asks the student about their thinking. Students can converse with each other about their maps and acquire this sense of certainty through the dialogue. Whenever a teacher shows all or part of a map, they are showing their thinking and missing what the student is thinking.

The comparing step overlaps with the grouping step as the map is completed in greater detail. At this stage students are asked to complete the map by including all subtopics within their main topic branches and to seek out comparisons, i.e. relationships, between major branches that are represented as cross-links. This is a natural step for the Intuitive type student and an extra step for the Sensing type student. Many Sensing type students never seek out relationships and rely on the teacher to point them out as additional facts to memorize. The process of seeking out relationships is taken for granted by Intuitive types, but it is a skill that can be learned by Sensing types.

Scoring Concept Maps

A simple scoring system will drive the desired behavior of seeking out integrative relationships in the learning assignment. We have used a modification of the scoring system reported by West, Pomeroy, Park, Gerstenberger, & Sandoval (2000).

1. Links (1 point). Any two concepts or facts, enclosed to form nodes of a variety of shapes, correctly connected receive one point to reward the acquisition of factual knowledge. It has a special value for the Intuitive type students who tend to overlook facts that do not contribute a "big picture."
2. Branch points, excluding convergences (5 points). Nodes that branch into two or more links receive 5 points to recognize the discovery and documentation of an indexing hierarchy. This is a higher order thinking skill that is needed during problem solving and this score emphasizes the importance of organization of knowledge over simple memorization.
3. Cross-links, including convergences (10 points). Links between branches, including links that converge on a common node receive 10 points, instead of 1 point, to recognize the discovery of valid comparisons between branches. This develops the ability to identify cause-and-effect relationships, similarities, and differences. This is most valuable to the Sensing type students who tend to overlook patterns and relationships.

The scoring for the map in Figure 1, above, produced: 22 links, 5 branches, and 3 cross-links yielding a final score of 77. The scoring for the map in Figure 2, above, produced: 42 links, 9 branches, and 9 cross-links yielding a final score of 177. The additional 100 points represents the additional learning produced when students of different learning styles discuss the same reading assignment.

We have noticed from subjective feedback by our students that the identification of cross-links to achieve a higher score is a function of the number of branch points. Likewise, the establishment of valid branch points which are more valuable than simple facts are a function of the number of facts identified. Thus, the higher scoring components of the maps drive the learning of the lower scoring components.

Composing Teams

It is very important to the development of team maturation, that care be given to the composition of teams. It has been shown by Michaelsen, Knight, & Fink (2004) that when students self select into teams, maturation is delayed. The reason for this is that self selection tends to compose teams of students who think alike. This deprives a team of the varied intellectual resources needed to solve problems. Instead, the recommendation is that teachers direct the composition of teams so that resources are distributed as evenly as possible. For example, a science course would want to distribute students who are science majors evenly among the groups followed by students with some science background and finally with those remaining students with minimal science background. This type of heterogeneity has been shown to produce the fastest and strongest team maturation.

One caveat regarding insights gained from the Myers-Briggs research is that type only indicates a preference for a mental function and does not measure the degree to which the preference is developed as a thinking skill. Just as students of the same intelligence use their intelligence differently and students with the same life or work experience have used that experience differently, so do students of the same type use their type skills differently. Thus, it is better not to use personality type to compose teams but rather, after the teams are composed, to discuss how each member can use their type best. Placing the focus on best use of type encourages personal (and thus professional) development instead of creating a stereotypical expectation.

Research shows that group size for this type of collaborative learning has a range of 5-7 students (Michaelsen, Knight, & Fink, 2004). This is smaller than the generally accepted size of 8-10 members for small group work. Groups that are too small generally don't have enough different contributions to effectively apply their knowledge in solving problems and groups that are too large break down into subgroups so that collaboration is reduced.

Conducting a TBCM Session

After the students have received training in the fundamentals of preparing concept maps, they can start their individual preparation for the first TBCM session. Since the construction of concept maps is a learned skill, students will demonstrate increased proficiency and higher scores after several TBCM sessions are conducted. Much of their skill development will occur during the TBCM session itself as the students compare and defend their maps.

The TBCM session starts with each member handing copies of their concept maps to another teacher-assigned student in the group. This allows rotation among different members of the group from session to session. After the maps are scored, the maps are then scored by one more member of the group to check for discrepancies. If a student wishes to appeal a score, time does not have to be taken from the session. Copies of the scored maps can be retained by the student who can then prepare a written appeal to be turned in for a decision by the teacher at a later date. The appeals process is an important part of the development of mapping skills and should be encouraged.

After the individual maps have been scored and turned in, each team starts the construction of their group map. In our limited experience with this step, we have found that the usual strategy is for team members to agree on one map as a "core" to which other elements from the remaining maps are added. Subjective data indicate that students derive a great deal of satisfaction from their learning at this stage since they can see the thinking of others who studied the same material. When the teacher has determined that the group maps have been completed, they are turned in for scoring by the teacher or an assistant at a later date. The teacher uses the group maps to diagnose any concepts that may need further clarification.

Groups are now permitted to use any resources they wish in analyzing a case. The teams are given a case and one or two multiple choice questions concerning the case to answer. The answer choices are chosen by the teacher to correlate with the case information to different degrees, thus requiring teams to discriminate the "best-fit" answer choice. The teams first create a new map of the case information to establish what is known about the problem and to evaluate its relevance. These maps will be used by the teacher for a subjective assessment of the team rationale in evaluating the information in the case. The teams then create a second map that links the greatest amount of case information to each answer choice. The goal is to determine the answer choice with the greatest number of links with the case information, thus forming the strongest rationale. When all maps are completed and turned in, the teacher conducts a discussion session where groups compare and defend their answers. This process is very comparable to that of TBL with the exception that the team problem solving dialogue has been facilitated by the use of concept maps. The teacher led discussion brings out the rationales used by each team so that inter-group dialogue can occur, further enhancing the development of higher order thinking skills.

FUTURE TRENDS: TEACHING SKILLS AND EVALUATING RESULTS

Both the economy of faculty resources and the orientation toward collaborative problem solving provide a large return on investment in the college classroom. This will drive a greater adoption of this teaching method in a greater variety of educational settings. In our experience, there will be several factors that may serve as barriers and, therefore, need to be better understood.

1. Personality Type Influences on Concept Mapping Behavior

The motivation to learn and use concept mapping skills is dramatically different for sensing and intuitive type students. Our experience has shown that sensing type students resist concept mapping because the construction of a map requires them to abandon their usual linear reading style. This resistance is overcome by metacognitive training that teaches them not only about their own learning but about how their learning compares with other learning styles. When coupled with step-by-step training in map construction, these students become devoted converts. Their personalities do not change, but instead they become more balanced in their learning skills.

The research challenge suggested by these observations is to understand more completely the most efficient approach in teaching both intuitive and sensing types the necessary metacognitive insights into concept mapping as a learning tool.

2. Mapping as a Dialogue Facilitator

Collaborative learning requires more than simple dialogue. It requires clear and unambiguous dialogue. Our experience has shown that students acquire both an increased clarity in their dialogue and an increased enthusiasm for the collaborative process (Pelley, 2005). When the collaborative effort involves students with both sensing and intuitive type preferences, it helps both preferences understand the thinking of their opposite. It is important to take research design into account regarding the impact of personality type on learning as evidenced by the study reported by Laight (2004). This study showed no significant influence of learning style as self-reported by pharmacy students on the utility of concept maps, but the study supplied the students with maps prepared in advance. This study also showed the student's reaction when the faculty revealed their own thinking to the students, but it did not reveal how receptive the students were to constructing their own maps or whether maps helped them discuss their learning.

The research challenge is to document more objectively the effects of concept mapping as a tool for organizing group dialogue and to avoid the use of maps as an additional representation of the instructors' knowledge. Our data are only from subjective evaluations and direct observation at this point. The development of instruments that document time on task for each team member as well as other behaviors related to collaborative problem solving are needed.

3. Scoring and Evaluation of Maps

The method for scoring the content of a map appears to be simple and straightforward when provided to the students. The reality, however, is that scoring requires judgment and thus improves with experience. Students are at different stages of understanding when they construct maps and their maps reflect that thinking. The inspection of one student's map by another student is a moment of truth where learning and knowledge are exposed. In the end, scoring drives analytic reading.

The scoring process as we have implemented it in Team-Based Concept Mapping needs further study to improve accuracy and objectivity. We have found that members of the same team are naturally supportive and this eases the tensions. It would be important to know what steps can be taken to hasten the scoring skills and maintain accuracy. We want to compare the scoring of individual maps when conducted by members of other teams to determine if there is a scoring bias due to team loyalty or to peer pressure from members of the same team. We also see a need to assess the effect of awarding points for finding mistakes. While this sets up a competitive attitude, it could be a stronger incentive for analytic reading since all students will use the same learning objectives to prepare for the session where they will be scoring concept maps.

4. Peer Evaluation Within Teams

Peer evaluation is an integral part of the original derivation of Team-Based Learning. It is intended to provide an additional control on individual preparation so that no single team member can rely on others to make up for their lack of preparation. If this is detected by team members, peer evaluation provides a mechanism for removing some credit toward their final score. We think that training in peer evaluation can be incorporated into the early stages of team training.

We have not yet employed peer evaluation in our TBCM sessions. Future studies will help to show the most effective format for training and implementation of peer evaluation in this setting.

CONCLUSION

Concept maps are a tool for enhancing communication. When used during individual preparation for collaborative problem solving, they facilitate communication between the author of the text or the teacher of a lecture and the student. When used during the group process in collaborative problem solving, they facilitate communication between the team members. Our system of Team-Based Concept Mapping uses scored individual and group concept maps to achieve a more complete, accurate and analytical dialogue. The construction of concept maps during individual preparation will help students regardless of different learning styles acquire a better grasp of the information and thus it will help them participate more effectively in the team dialogue. The consolidation of individual maps during the early steps in group tasks will allow team members to synthesize and strengthen their grasp of the material before applying it to the case-based problems. Concept maps further enhance the problem solving dialogue by providing a tool for collaborative discussion of the relative importance of information given in the case and for prioritizing the answer choices for questions concerning the cases. Since case problems contain real-world ambiguity that can suggest more than one possible solution, each team is forced to prioritize their choice. Collaborative agreement on cross-links between answer choices and information mapped from the case will elicit and develop the ability of students to prioritize the importance of information to support their conclusions. It is this prioritization process that develops higher order thinking skills and communication skills.

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KEY TERMS AND DEFINITIONS

Concept Map: A visual construct composed of encircled concepts (nodes) that are meaningfully inter-connected by descriptive concept links either directly, by branch-points (hierarchies), or indirectly by cross-links (comparisons). The construction of a concept map can serve as a tool for enhancing communication, either between an author and a student for a reading task, or between two or more students engaged in problem solving.

Critical Thinking Skills: The ability to solve problems by generating alternatives from existing facts and to prioritize these alternatives with respect to their logical justification and/or human outcomes. Both recall skills and higher order thinking skills are utilized in this process.

Group Concept Maps: Concept maps constructed through active collaboration among group members. More content and cross-links result due to contribution by different learning styles that bring different knowledge to the task.

Intuitive Type: A preference for perceiving new information by discovering patterns and relationships in an integrative sense. This type tends to construct and interpret concept maps easily and to include more cross-links in their maps.

Myers-Briggs Type Indicator: A psychological instrument that determines preferences in normal thinking processes. Provides a self-assessment that indicate constructive strategies for personal development.

Sensing Type: A preference for perceiving new information by observing details and facts in a literal sense. This type tends to be uncomfortable when either constructing or interpreting concept maps.

Team-Based Concept Mapping (TBCM): Team-Based Learning with scored concept maps substituted for multiple choice exams. Concept maps become a tool for more effective dialogue.

Team-Based Learning (TBL): A three step process that progresses from individual learning to collaborative learning by teams in large classroom settings. Requires specific decisions on the same problem by all teams in order to share rationales.

Team Maturation: A change in the nature of the interactions and dialogue between members of a team over time. Dialogue is more meaningful and effective as members develop trust in each other.

Transformative Learning: The process of using information received from a teacher and creating new knowledge by using higher order thinking skills.

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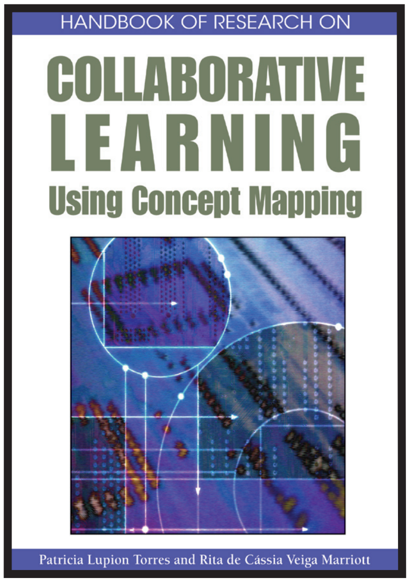

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