Concept mapping: a strategy for promoting meaningful learning in medical education

ANGELO J. PINTO1[1] & HOWARD J. ZEITZ[2]
[1]Allegheny University of the Health Sciences, MCP◆Hahnemann School of Medicine, Philadelphia, PA, USA, [2]Rush Medical College, Chicago, IL, USA

SUMMARY *Concept mapping is an educational tool that encourages meaningful learning. Fostering meaningful and self-directed learning among medical students is now recognized as a major goal of medical educators (ACME-TRI Report, 1992).* Meaningful learning *(learning with understanding) is much stronger and longer-lasting than* rote learning *(learning by memorization) because students address the conceptual meaning of the knowledge being learned, and link this new information with previous knowledge.*

Concept mapping is an active, creative, visual and spatial learning activity in which concepts are organized according to their hierarchical relationships. Linking words are used to describe the relationships among the concepts. To create a concept map, students must understand the information that will appear in the map. Students must also relate and integrate the concepts that will be recorded in the map. As a result students replace unidirectional linear organization with thinking which proceeds in multiple directions. This improves long-term information retention, reduces verbatim retention of non-meaningful information, and improves transfer of knowledge in future problem solving activities.

Interested students and faculty can acquire concept mapping skill through a 2–3 hour workshop. Participants are given a brief overview of meaningful learning and concept mapping. Then, with guidance from workshop facilitators, they create their own concept maps. Next, a debriefing session is held for participants to discuss their experience with concept mapping. Finally, to consolidate and enhance newly developed concept mapping skills, follow-up mapping activities are assigned.

Once students acquire concept mapping skill, they can use it to: (1) organize and integrate information; (2) assess existing knowledge; (3) gain insights into new and existing knowledge; and (4) relate basic science concepts to clinical presentation of the patient. Students can continue to use concept mapping as they go through clinical clerkships and residency programs. As practicing physicians they can use the method to gain a meaningful understanding of new concepts and to integrate these new concepts with prior concepts retained in long-term memory.

Introduction

Concept mapping was developed at Cornell University over two decades ago. This important strategy for meaningful learning came to the attention of medical educators shortly after the publication of a book by Joseph Novak and D. Bob Gowin (1984) *Learning How to Learn.* In the years that followed, education specialists and faculty members at several medical schools became interested in the possible role of concept mapping as a learning strategy for medical students.

In 1991, we began collaborative educational research and development efforts concerning the use of concept mapping by medical students. Initially we focused our efforts on the techniques needed by students to develop concept mapping skill. After identifying the techniques, we began offering faculty development workshops in which we have tried to share our insights and enthusiasm with faculty from many medical schools. The development of this guide is an effort both to make concept mapping even better known and to introduce faculty and students to this extremely valuable and highly successful technique for meaningful learning.

Learning

Rote learning vs. meaningful learning

Learning is a complex cognitive process that occurs in individuals of all ages. The learner may have a variable degree of understanding of the new information. At one end of the spectrum, the learner may have virtually no understanding of the new information. This condition is called *rote learning.* In such circumstances, the learner acquires new information primarily through verbatim memorization. Because the conceptual meaning of the knowledge being memorized is not addressed, the new information cannot be linked to relevant concepts that the learner already knows. The outcome of rote learning, therefore, is that little if any of the new information is transferred into long-term memory. It also may lead to interference with future learning and fails to aid students in

Correspondence: Dr. Angelo J. Pinto, Allegheny University of the Health Sciences, MCP◆Hahnemann School of Medicine, 2900 Queen Lane, Philadelphia, PA 19129, USA. Tel: (215) 991-8378. Fax: (215) 848-2271. Email: Pinto@AUHS.edu

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overcoming misconceptions (Ausubel, 1968; Novak, 1991b).

At the other end of the spectrum, the information may be understood very well by the learner. This approach to the acquisition of new knowledge has been defined as *meaningful learning* (Ausubel, 1968). Because the conceptual meaning of the new information is clear, the new knowledge can be linked to related concepts already familiar to the learner. When this is accomplished by the action of the student, self-directed learning occurs. Studies have clearly shown that meaningful learning is more efficient and lasting (Novak & Gowin, 1984; Novak, 1991b) because of the integration and linkages made. In contrast to rote learning, the outcome of meaningful learning is that the new information is transferred into long-term memory in a relevant linkage with prior knowledge.

Learning by medical students

How do medical students learn? According to a recent study by Regan-Smith *et al.* (1994), the answer appears to depend on the type of curriculum in which the student is enrolled. Data collected from students at several different medical schools in North America showed most students enrolled in a traditional basic science curriculum (i.e., lecture-based) use rote learning as the most common strategy for dealing with basic science information. This is true not only for students enrolled at schools which offer only a traditional curriculum but also at schools that also offer a parallel problem-based learning (PBL) curriculum.

In contrast, only a very small fraction of students enrolled in a PBL basic science curriculum use rote learning to any significant extent (Regan-Smith *et al.*, 1994). This is equally true for students enrolled in the PBL basic science curriculum at schools that also offer a parallel traditional curriculum and for students enrolled in schools that offer only a PBL basic science curriculum. Similarly, students use meaningful learning to an overwhelming degree when they are enrolled in the clinical curriculum at their school, regardless of their original approach (traditional, rote; PBL, meaningful) when enrolled in the basic science curriculum.

Due to the rapid changes in science, meaningful learning skills are becoming more important for students who, as physicians, will need to keep abreast of these changes as they relate to the practice of medicine. Thus, to remain professionally competent, today's medical students must be encouraged to become life-long meaningful learners.

How can basic science faculty help medical students to learn meaningfully? Clearly, students enrolled in a PBL program need less assistance than do students enrolled in a traditional curriculum, but all students can benefit from acquiring skills that enable them to reduce their use of rote learning.

Concept mapping as a tool for meaningful learning

One strategy that can lead to meaningful learning is concept mapping (Novak & Gowin, 1984; Novak, 1991a; Novak, 1991b; Okebukola, 1992; Watson, 1989). Novak (1991b) has provided a primer for educators seeking to carry out this strategy. The process involves: (1) identifying important concepts, and (2) interconnecting concepts by using linking verbs that describe the hierarchical relationship among the concepts. A working definition for a concept word or phrase is that it 'forms a picture'. The process of identifying the *important* concepts, and of forming the *important* links between these concepts, is the essence of concept mapping. Using this definition, the most simple concept map has just two concepts connected by a linking word, for example, **grass** *is* **green**. This small concept map forms a valid relationship between **grass** and **green**. As more linking words and concepts are added (for instance, **grass** *is a* **plant**, **grass** *has* **narrow leaves**) the meanings of the concepts grow. The resulting map illustrates the student's thinking about the multidirectional relationships that exist among the concepts. Examples of the types of relationships that can be described in concept maps are shown in Figure 1.

According to Novak (1991a), once students learn to concept map, they seek out patterns and apply their thinking to problem solving (Okebukola, 1992) and more successfully integrate basic and clinical sciences (Small, 1988). The tool has been used successfully to develop courses, curricula and cases for problem-based learning (Edmonson, 1994; Moriera, 1979; Starr & Krajcik, 1990; Willerman & Mac Harg, 1991). In general, concept mapping has been shown to improve long-term information retention, reduce verbatim retention of non-meaningful information, and improve transfer of knowledge in future problem solving activities (Mayer, 1989; Small, 1988). This approach is an active, creative, visual and spatial learning activity in which the student organizes concepts according to their hierarchical relationship. To accomplish this, the student must be able to relate and integrate the concepts used in the map. The act of organizing concepts in spatial relationship to each other leads by itself to meaningful learning; this learning is enhanced by the visual processing of the concepts in the map and the interaction between the visual and spatial systems (Dansereau, 1989; Novak & Gowin, 1984).

One outcome of concept mapping is that the student replaces unidirectional linear thinking with thinking that proceeds in multiple directions. Because the student must understand the new information (meaningful learning), another outcome is that the new information will be trans-

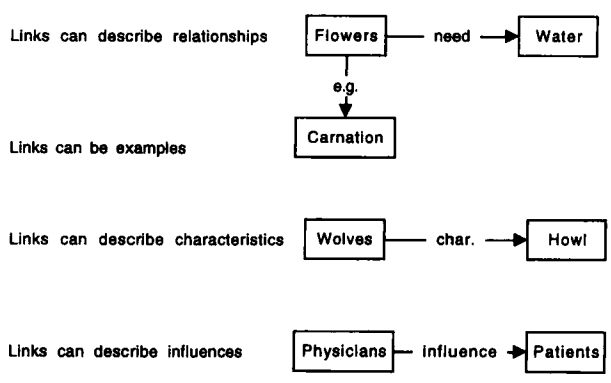

Figure 1. Examples of some of the relationships and associations that can be described in a concept map.

ferred to long-term memory for storage via connections with related concepts.

Concept mapping helps meaningful learning in several other ways. For example, concept mapping is an activity that provides the student with an opportunity to organize, summarize, analyze and evaluate many different ideas. Thus, concept mapping promotes the development of critical thinking skills, which can then be used for other meaningful learning activities. Furthermore, because the concept mapping process externalizes the concepts in the student's existing knowledge structure, it is possible to identity misconceptions, incongruities and weaknesses in that structure. Correction of these errors leads to greater understanding (i.e., learning which is more meaningful). Finally, during concept mapping, a student may recognize a new component of a concept and/or a new relationship between concepts, which can lead to deeper understanding of the material under study.

In summary, concept mapping is an important strategy for meaningful learning. Concept mapping helps students to organize new knowledge, to review and if necessary to adjust existing knowledge, and to relate new information to what they already know, thereby promoting long-term retention of the information in a usable, integrated network.

Concept mapping skill

Final product: concept map

The final product of the activity called concept mapping is a concept map. A completed concept map is a fully developed collection of concepts organized spatially and hierarchically. Figure 2 is a concept map that summarizes important information on concept mapping presented in this paper. Figure 3 is an example of a basic science concept map on inflammation. The ability to create concept maps is an acquired skill. To develop usable skill, interested medical students need to complete some introductory exercises. Then the students need to complete four to seven follow-up activities with feedback in order to sharpen their newly developed skill. Once students can create concept maps, they can apply this skill in many ways, both in a traditional curriculum and in a PBL curriculum. Students can continue to use this skill while they are in residency training and beyond. Finally, faculty themselves can use the technique to improve the organization and presentation of lectures or to develop integrated curricula or PBL cases.

Acquisition of skill: introductory workshop

It has been our experience that a hands on workshop is the best way to introduce interested medical students to concept mapping. A 2–3 hour workshop is sufficient to introduce students to concept mapping. The workshop should include:

(1) An introductory section that defines meaningful learning and describes concept mapping; examples of a completed concept map are displayed, and a guide for constructing a concept map is distributed (Table 1).
(2) Separating students into breakout groups (two to six students per group); each group should concept map an identical page containing three extremely well written paragraphs on a science topic. Generally it will take the groups 20–25 minutes to complete this first concept map.
(3) Posting the resulting concept maps and allowing a 15 minute time for participants to view the concept maps of others. This activity illustrates the idiosyncratic nature of concept mapping. Each concept map is different because it reflects the thinking and experiences of the author(s).
(4) A faculty facilitated debriefing session in which the students can comment on their active learning experience and their observations concerning similarities and differences between the multiple maps.
(5) After a short break, each student should individually construct a second concept map. The topics can be either student selected (e.g., a science or non-science subject well known to the student) or faculty assigned (e.g., the attributes of an outstanding resident). Again, all maps are viewed by workshop participants, and another debriefing session is conducted.

Acquisition of skill: follow-up activities

To consolidate and enhance their newly developed concept mapping skills, the vast majority of interested medical students should participate in four to seven follow-up activities. Students in a traditional basic science curriculum can create concept maps from the notes they take at four to seven designated lectures. Students in a PBL curriculum can select four to seven mutually agreeable topics that emerge during the weekly case study. Students should meet in small groups to review all the maps and to discuss them with the guidance of faculty with skill in concept mapping and, if possible, with knowledge and experience in the topics mapped by the students.

Applications of skill

Traditional curriculum

Within a particular lecture-based course, concept maps can be a valuable learning tool and used as an adjunct to other study methods. Students can use concept mapping to help organize and integrate multiple concepts and as a guide for deciding what is important to understand. They can assess their existing knowledge, gain new insights, relate new information to what they already know and detect areas where there are misunderstandings.

PBL curriculum

Students in a PBL program can use their concept mapping skill in two major ways. First, they can use their skill to create classical concept maps related to any or all of the student generated learning issues that emerge during the weekly case study. Second, each small PBL group of five to seven students can build a model specific to the case under study that week. During model building (also referred to as 'creating spaghetti and meatballs' by some PBL students),

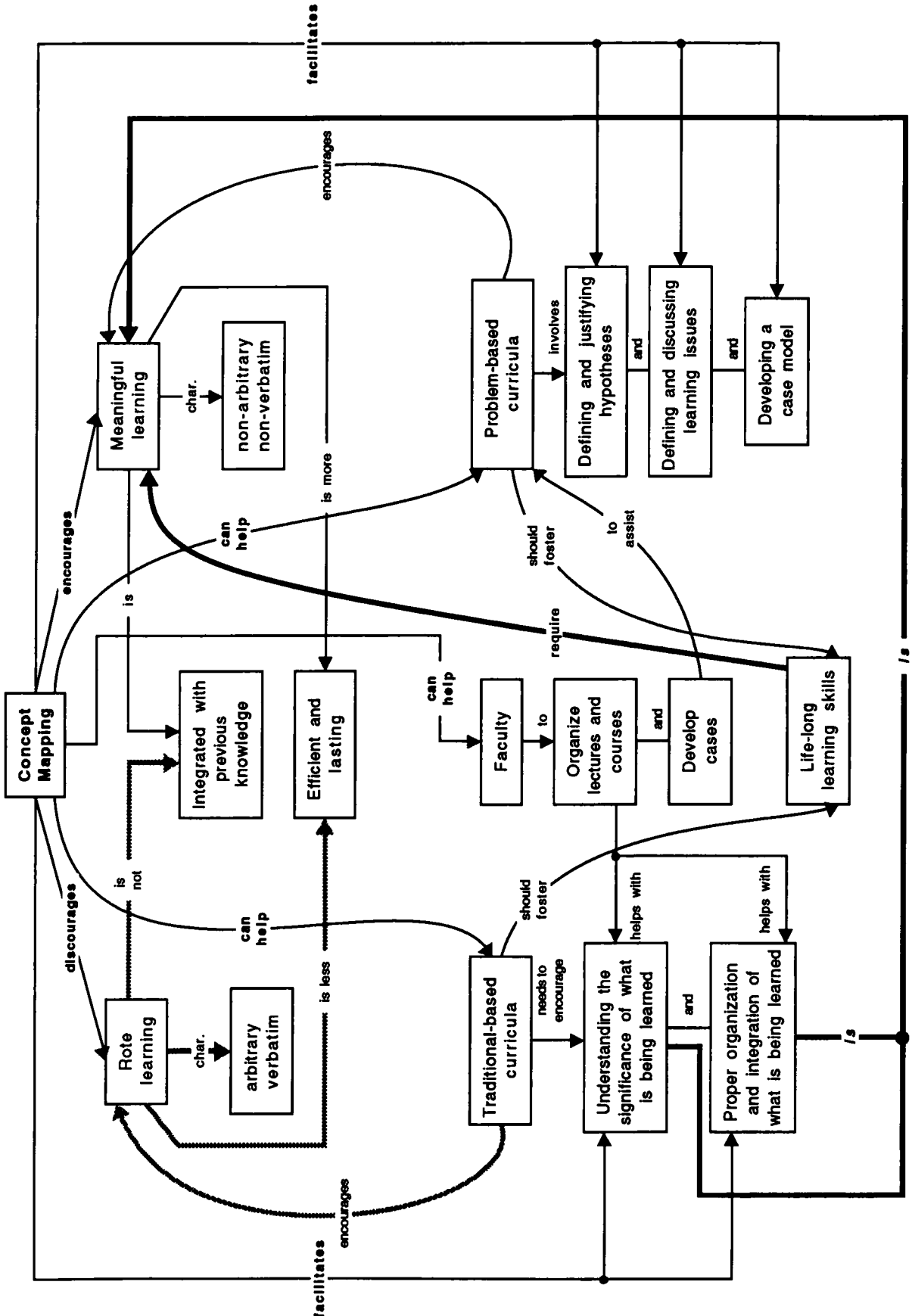

Figure 2. A concept map on the various uses of concept mapping in medical education.

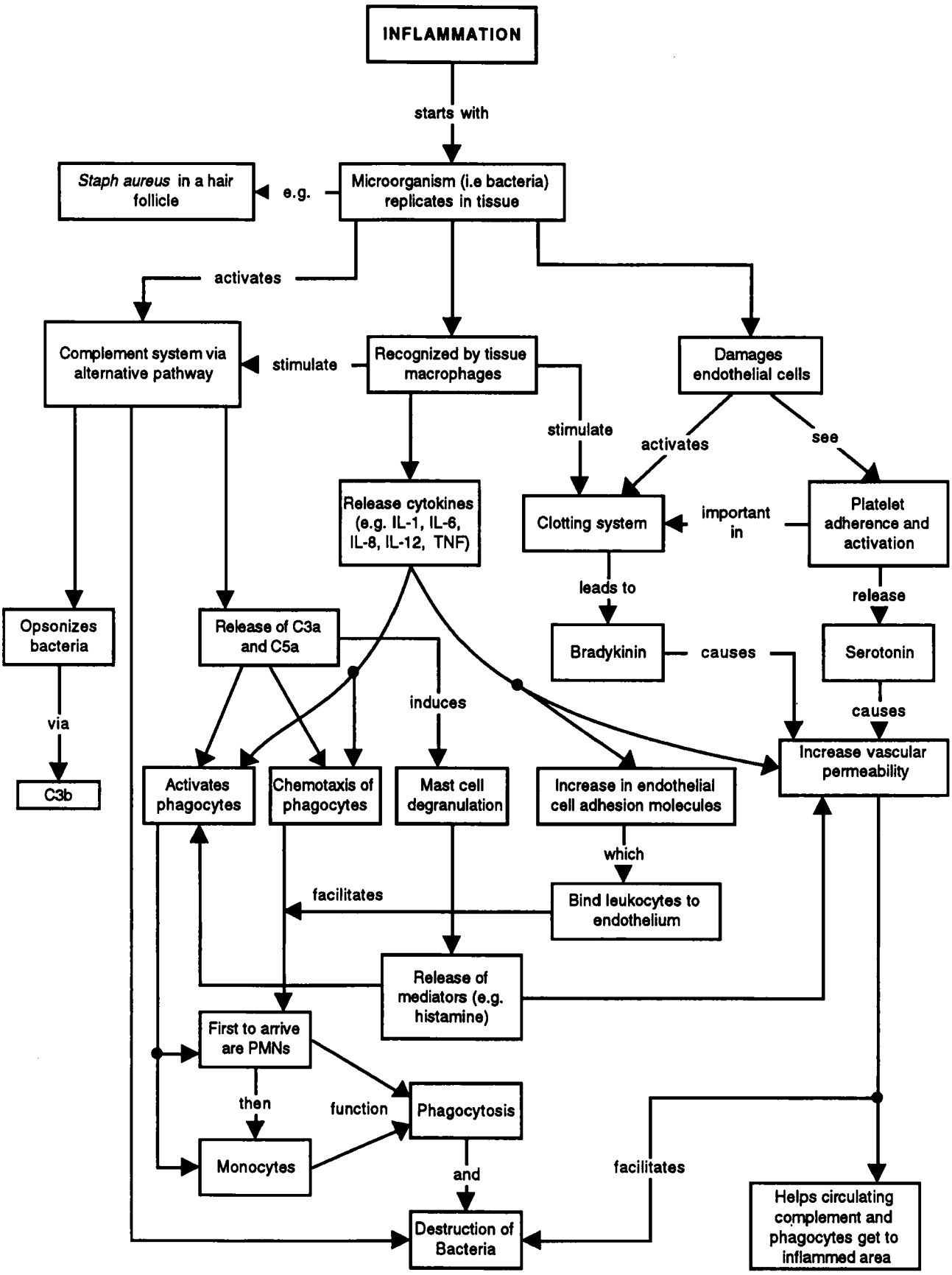

Figure 3. A basic science concept map on stimuli that initiate inflammation.

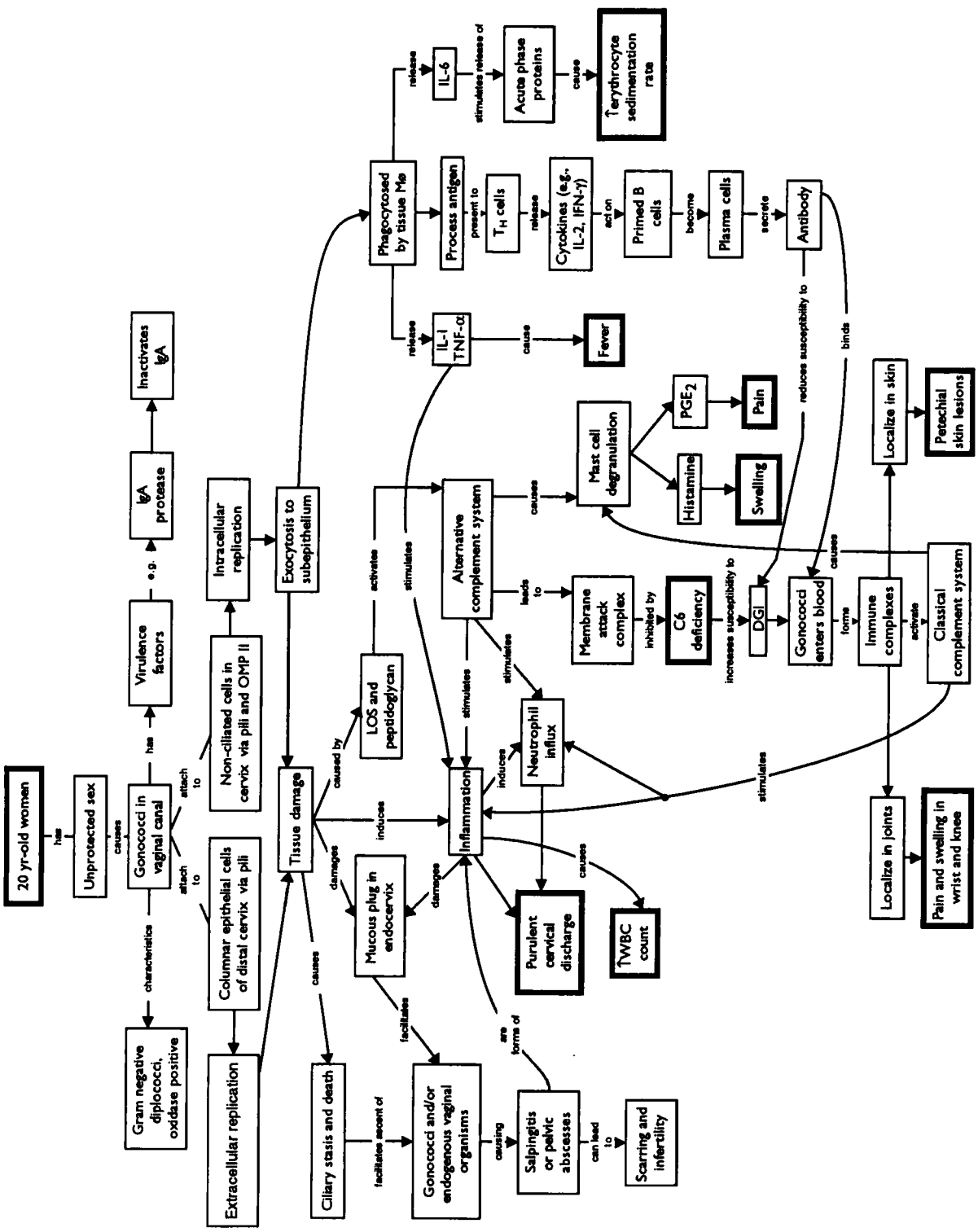

Figure 4. A case-based concept map (case model) of a gonococcal infection in a young woman developed by a group of first-year medical students in a problem-based curriculum. The map includes the case data (bold blocks) built around a primary hypothesis (disseminated gonococcal infection, DGI) and the major basic science learning issues addressed in the case (e.g., the inflammatory response, pathogenesis of gonorrhea, the complement system … etc.).

Table 1. Instructional guide given to workshop participants on constructing a concept map

1. *Identify the concepts*

What is a concept? A simple definition is that a concept is a word that forms some picture or event in your mind. A more formal definition is *a perceived regularity in objects or events, designated by a label, such as a word or symbol.* For our purposes we will choose the major concepts we need to think about in order to understand the material.

2. *Establish an order for the concepts*

After you identify the concepts, rank them in order from the general to the specific. Then build a hierarchical framework of your concepts.

3. *Determine the relationships between individual concepts*

Specify the relationships between the concepts. This is done by drawing a line between any two concepts and labelling the line with a *linking word* that describes the relationship between the two concepts.

4. *Look for cross links between concepts*

This is the same as in step 3 except that you make the links horizontally.

5. *Examine the arrangement or structure of your map*

Make sure your map shows the proper hierarchy and relationships.

the students incorporate basic science concepts, clinical science concepts, and when necessary student generated hypotheses into a final product, the case-specific model, which is similar to but not identical with a basic science concept map (Figure 4).

Clinical curriculum

Once students have concept mapping skill, they can apply this skill to mastering important concepts that emerge during the classical clinical clerkships. The same skill that was initially used for meaningful learning of basic science can also be used for meaningful learning of clinical science. In addition, concept mapping is a useful strategy for understanding topics in ethics, community medicine, preventive medicine and health care delivery.

Residency training

Medical education is a continuum in which the medical school program is followed by a lengthy period of residency training. Residents with concept mapping skill can reshape, sharpen and enhance the maps they made during their clerkship experiences. In addition, concept mapping can be used for meaningful learning of new concepts not recognized during the initial clerkships. The maps can serve as a means for integrating the new knowledge acquired during residency training with the knowledge achieved and retained during medical school.

Life-long self-directed meaningful learning

Of course learning does not stop upon completion of residency training. As new knowledge emerges, physicians are obligated to gain a meaningful understanding of the new concepts and to integrate these new concepts with prior concepts retained in long-term memory. Again, concept mapping skill can and should be used as a strategy for life-long, self-directed meaningful learning.

Concept maps as a teaching aid

Teaching faculty also can benefit from concept mapping. As an example, a teacher can organize a lecture by making a concept map to use as a teaching guide. This will give a conceptual flow to the lecture and help the teacher pinpoint what he/she feels is important for students to understand. Such maps may be shared with students but this needs to be done cautiously; the tendency is for students to memorize the map, which does little in helping them to understand or integrate the material. The map may be given as a guide to help students see the organization and integration of the important concepts. Some students may want to build or expand on these maps. Secondly, maps can be used to obtain feedback; having students concept map a lecture you give can be an eye opening experience about what students think the important concepts in a lecture are and how they are related.

Conclusion

Learning is a complex cognitive process that occurs in individuals of all ages. Meaningful learning requires understanding of the concepts that are important components of the topic under study. Learning with understanding allows integration of new concepts with previously learned concepts and leads to retention of information in long-term memory in a usable manner. Concept mapping is a strategy that can help medical students, residents and experienced physicians with their efforts towards meaningful learning.

Notes on contributors

ANGELO J. PINTO, PhD is Assistant Professor of Microbiology and Immunology and Assistant Director for the Program for Integrated Learning at MCP◆Hahnemann School of Medicine.

HOWARD J. ZEITZ, MD is Director of the Alternative Curriculum at Rush Medical College.

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