MAPS FOR DEVELOPING MEDICAL PHYSICS CONCEPT NETWORKS IN THE MIND

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Abstract- Medical Physics Knowledge is generally a mental representation of the physical universe (instruments, equipment, interactions, procedures, etc.) in a combination of mathematical and verbal symbolic representations and sensory concepts. Both are required for the effective application of physics in clinical medicine. It is the sensory concepts that are the foundation of medical physics knowledge. Conceptual knowledge is most effectively developed through sensory interactions with the physical universe, especially visualization directly or with images. Conceptual knowledge can be developed from textbooks and in classrooms with appropriate presentations. However, this is often as a series of individual concepts or relatively small concept clusters. Concept maps can be used at the conclusion of a learning activity (class or textbook chapter) to unify the concepts into a comprehensive concept network that represents a higher level of learning and understanding. The creation and publication of high-quality concept naps provides an opportunity for medical physicists to gain recognition and contribute to the enhancement of medical physics education around the world.

Keywords— Concepts, Mind Maps, Concept Maps, Sequential Learning, Physics Knowledge.

I. INTRODUCTION

Our knowledge of medical physics and related topics is composed of a complex network of sensory concepts, especially visual, in the mind along with symbolic representations including verbal descriptions (words) and quantitative relationships with mathematical symbols and equations. Both types of knowledge, *conceptual* and *symbolic*, are required for the practice of medical physics, especially clinical applications. It is the network of concepts that is the critical knowledge for many medical physics activities. Sensory concepts are representations of the physical universe within the human mind and are generally developed by observing and interacting with the physical universe and can support many functions as illustrated in Figure 1.



Figure 1. The significant role of sensory concepts in medical physics knowledge.

Let's begin by considering our knowledge of the physics of water. When and how did we develop it? Not in a classroom but by many interactions and observations as illustrated in Figure 2.



Figure 2. Learning the physical characteristics of water.

Perhaps in a physics class we learned some of the quantitative relations, hydrostatics, and hydrodynamics, but our most valuable and useful knowledge of water is the network of concepts developed through observations and interactions as illustrated. This is the knowledge that can support many activities throughout our lives.

Now let's consider knowledge of medical physics. As with our knowledge of water, it is the network of sensory concepts that supports many medical physics activities and functions as illustrated in Figure 3.



Figure 3. Two types of medical physics knowledge structures; sensory concepts and symbolic representations.

All representations are significant to the practice and applications of medical physics but in different ways. Symbolic representations, especially mathematical as generally taught in the classroom are useful for understanding quantitative relationships and making calculations. It is the type of knowledge most often evaluated with tests and examinations which gives it special emphasis in classroom teaching.

However, it is conceptual knowledge that is the foundation and unification that supports continuing learning and effective application of physics knowledge (Ref. 1).

This knowledge exists as a complex network of many individual concepts. In addition to understanding the individual concepts, the relationship among concepts, the network of sensory concepts, is a critical part of our medical physics knowledge.

As we observed with the physics of water, the development of a network of sensory concepts is a natural learning process occurring as we observe and interact with segments of the physical universe.

Concepts are the mental representations of the physical universe developed as we observe and interact with our senses, vision, feeling, hearing, etc. A concept generally includes our understanding of an item or subject and its characteristics.

There are two major characteristics of conceptual knowledge that distinguishes it from symbolic knowledge (words and mathematical symbols). It is a form of natural learning as we interact with and observe the physical universe, sometimes in the classroom or laboratory but often in other experiences. The great value of conceptual knowledge is it supports many activities when interacting with the physical universe, ranging from everyday things we do to advanced medical physics functions. Evaluating image characteristics and quality, performing radiation safety procedures, and conducting laboratory experiments are examples.

Our minds are filled with perhaps thousands of concepts of objects, events, and conditions that we have encountered. While an individual concept, Water for example, can be very useful knowledge, it is the network of inter-related concepts that is knowledge required for many applications

Concept Maps (Ref. 2) as discussed here, are teaching and learning resources that when added to the more conventional teaching and learning methods can contribute to the formation of highly valuable concept networks in the learner's mind.

II. SEQUENTIAL TEACHING AND LEARNING

Teaching and learning are generally sequential activities in which a series of individual topics are presented and learned as illustrated in Figure This includes classroom presentations, textbooks, and modules.



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Figure 4. Sequential learning and teaching.

With sequential teaching and learning (Ref.3) and in textbooks, topics are often connected in a continuing series building on each other. As concepts are developed by the learners they are linked to other concepts. An example: to develop an appropriate concept of electrical resistance requires established concepts of voltage and current. This is to develop a useful concept of resistance, very different from memorizing Ohm's Law.

Most concepts developed in sequential learning activities are connected to other concepts; resistance is an example. These are generally small clusters of concepts as illustrated in Figure 5.

Concept Clusters as Developed in Sequential Teaching and Learning



Figure 5. The development of concept clusters in classroom activities.

As learners develop concepts of a specific topic, for example resistance, it is generally linked to other concepts, including voltage and current. This can be considered as a *cluster* of concepts. It is a small network but not yet included in the larger concept network of medical physics knowledge.

In typical sequential learning activities, classrooms and textbooks, concepts are developed in clusters because of the way the information is presented and the relatively short attention and memory span of the human mind. As a learning activity, class presentation or reading a textbook progress, attention is focused on additional topics in sequence. Concepts and concept clusters are formed but not integrated into the comprehensive concept network.

That is what can be achieved with *concept maps* to unify the many individual concepts and provide the "big picture" of medical physics.

III. CONCEPT NETWORKS AND MAPS

A comprehensive network of concepts is a significantly *higher level of medical physics knowledge* compared to many individual concepts and concept clusters. It supports many medical physics activities, especially relating to clinical procedures and teaching.

The development of an effective concept network is a specific activity summarizing and integrating concepts learned during a class presentation or textbook chapter. A concept map as illustrated in Figure 6 is an example.





Figure 6. Concept map related to MR image detail and noise.

A major medical physics activity is evaluating and optimizing image quality for the various imaging modalities and methods. MRI is an example. It is generally a complex process because of the many variable conditions and factors involved. The concept map in Figure 6 identifies the factors and relationships that affect the two image quality characteristics, detail and noise, in MRI. The reality is all of these must be considered to fully understand and optimize image quality.

Concept maps can be used at the end or conclusion of a class or textbook chapter to connect the concepts into a network to enhance learning and for future reference.

The concept map in Figure 6 is from the chapter on Image Detail and Noise in the Sprawls textbook provided in the Addendum.

Concept Maps are a category of Mind Maps that are used extensively in education and many other activities.

IV. MIND MAPS

Mind Maps (Ref.4) are diagrams used to show relationships among topics, objects, events, conditions, ideas, etc. They have many applications, education being one of them. Tony Buzan, a British innovator and author, is generally recognized as the creator of mind maps and the promotor over the years. Figure 7 is a mind map created to illustrate his many activities.



Figure 7. A mind map showing the activities and achievements of Tony Buzan.

This is used here to illustrate the features and characteristics of mind maps. They are usually hierarchical in nature, branching out from one specific item or topic. In this example it is Tony. A major value of mind maps is they present the "big picture" associated with a topic and its many relationships.

Mind maps, or more specifically concept maps, have been used over the years by the author as a concluding summary of textbook chapters, classroom discussions, etc. More on that later. For a general review of mind maps see:

https://en.wikipedia.org/wiki/Mind_map

V. DEVELOPING AND USING CONCEPT MAPS

A concept map is an illustration or diagram of a specific topic showing relationships to other topics represented by mental concepts. The assumption is that learners have developed concepts or concept clusters of the individual topics in a class, reading and studying, or direct interactions with equipment, instruments, and procedures. The concept map is then used to connect and understand the relationships of the concepts in the mind.

Concept maps can be developed with graphics software used for producing classroom or conference visuals (author's preference) or with software specific for concept maps available on the internet by searching for "concept maps templates".

For medical physics educators, developing concept naps is a creative (and perhaps learning) process requiring thought about the organization and relationships of the topics. Developing good concept maps and publishing them for others to use will give recognition to the creators and will enhance the teaching of those who use them.

An example of published concept/mind maps are those by the author in the Addendum.

VI. SUMMARY AND CONCLUSION

Figure 8, Provides an overview and summary to conclude our consideration of concept networks and concept maps.



Figure 8. A Concept Map relating concepts associated with Concept Maps.

A comprehensive network of connected sensory concepts provides the medical physics knowledge that supports many medical physics activities. This is especially significant for interacting directly with medical equipment and procedures. Individual concepts and concept clusters are developed in classrooms, laboratories, studying textbooks, and continuing experience. However, these activities do not effectively develop comprehensive concept metworks that are a higher level of learning. Including concept maps in educational presentations and discussions, modules, textbooks, etc. enhances the teaching and learning process to achieve this higher level of learning.

When used as a conclusion of a learning activity concept maps organize individual concepts and concept clusters into a comprehensive network with connections and relationships.

Using computer graphics to create and publish high-quality concept maps for others to use provides an opportunity for medical physics educators to use their knowledge and experience to enhance medical physics education around the world.

VII. REFERENCES TO EXPLORE CONCEPTS

- 1. Concepts: https://en.wikipedia.org/wiki/concept
- 2. Concept Maps: https://en.wikipedia.org/wiki/Concept_map
- 3. Sequence Learning: https://en.wikipedia.org/wiki/Sequence_learning
- 4. Mind Maps: https://en.wikipedia.org/wiki/Mind_map

BIBLIOGRAPHY

Sprawls P. Developing effective mental knowledge structures for medical physics applications. Medical physics international journal, vol.6, no.1, 2018

http://www.mpijournal.org/pdf/2018-01/mpi-2018-01-p128.pdf

Sprawls P. Effective physics knowledge for diagnostic radiologists. P. Sprawls. Medical physics international journal, vol.7, no.3, 2019 http://www.mpijournal.org/pdf/2019-03/mpi-2019-03-p257.pdf

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About the Author: Perry Sprawls is a clinical medical physicist specializing in diagnostic radiology and medical physics education. He is Distinguished Emeritus Professor at Emory University School of Medicine in Atlanta and now contributes to medical physics education around the



world through the Sprawls Educational Foundation, www.sprawls.org. It is the combination of his experience as a clinical physicist and educator that is the foundation for developing and sharing resources to support the teaching of medical physics. His continuing research and development activities are resulting in models for increasing the effectiveness of both the learning and teaching process, especially for clinically applied medical physics. Throughout his career he has used

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mind and concept maps, both in classes and textbooks. The current effort described in this article is to illustrate the value and encourage the creation and use of concept maps to enhance medical physics learning. Contact Information: sprawls@emory.edu.

ADDENDUM



Sprawls Magnetic Resonance Imaging P