ENHANCING MEDICAL IMAGING PHYSICS LEARNING AND TEACHING AROUND THE WORLD WITH SHARED VISUALS

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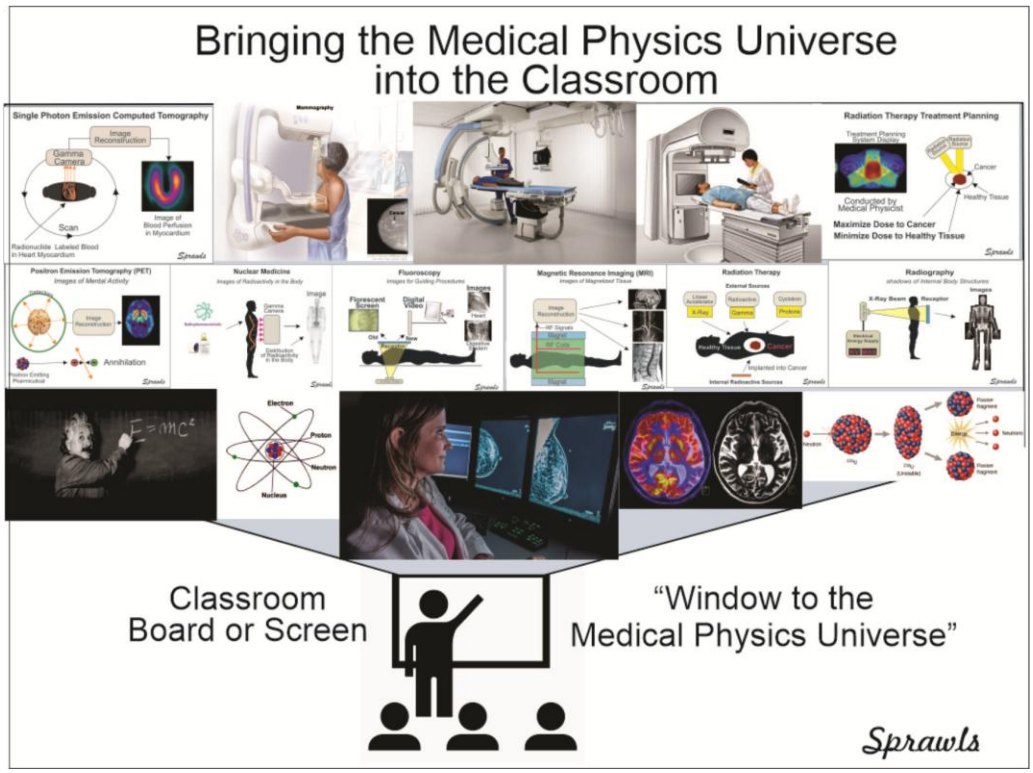


Abstract—**Teaching, a major professional activity of medical physicists, has two, often conflicting characteristics, effectiveness and efficiency. The effectiveness of a classroom presentation determines the value of the learner's acquired knowledge for performing future professional activities. The efficiency is determined by the time, effort, and resources required to provide the learning opportunity, typically a classroom presentation. Conceptual knowledge, rather than symbolic knowledge (text and mathematical quantities and relationships is generally more valuable preparation for professional activities, especially for radiologists and for medial physics educators teaching radiologists and residents. Visual representations of the often-invisible physics phenomena of medical imaging procedures are useful for connecting classrooms to the clinical environment for effective learning. Collaboration between visual creators and classroom teachers (collaborative teaching), contributes to increased effectiveness and efficiency both for the teachers and the learners/students.**

Keywords— **Effectiveness, Efficiency, Concepts, Visuals, Collaboration.**

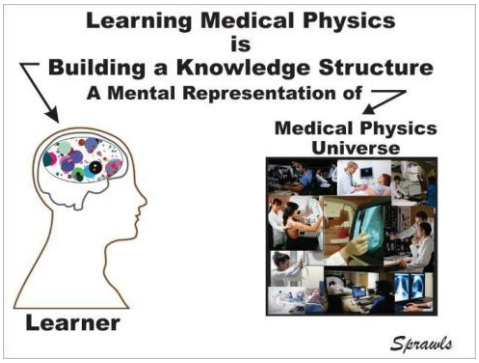
I. INTRODUCTION

Physics is the foundation science of medical imaging modalities and methods, requiring a comprehensive knowledge of the related physics topics for radiologists who use it for clinical detection and diagnosis of pathological conditions and medical physicists who have responsibilities for the effective and safe operation of the equipment. Physicists are also the educators (teachers) who provide learning opportunities (classes, conferences, etc.) for both medical physics students, radiologists, and radiology residents.

Learning physics is the process of building a mental representation in the mind of specific segments (like medical physics) of the actual physical universe. Each teaching and learning activity, especially classroom presentations, is affected by two, often conflicting characteristics, *effectiveness* and *efficiency*. These need to be considered when developing classes and other types of learning activities.

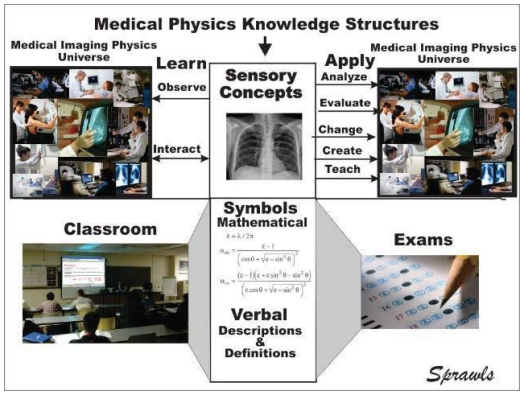
II. PHYSICS KNOWLEDGE

As described previously [1,2] physics knowledge is a mental representation of some segment, such as medical physics, of the physical universe. Learning is the process of building knowledge structures, and teaching is the process of *helping someone build* knowledge structures.



Knowledge structures are complex networks, for the most part, beyond what we need to know, except for specific characteristics that apply to the physics of medical imaging.

The two major elements of knowledge that are significant to us currently are *sensory concepts* and *symbolic representations.*



Sensory Concepts:

Sensory concepts are the natural form of knowledge we develop throughout life as we encounter and experience the world around us with our senses (sight, sound, touch, etc.)

It is the type of knowledge that is needed to perform many personal and professional activities. As illustrated above, valuable physics concepts are formed by interacting and observing in the actual physical environment, for us, the imaging clinic, and with the guidance of an experienced professional, the teacher.

Symbolic Representations:

Segments of the physical universe can be represented in the mind by symbols. Letters of the alphabet and words providing definitions, descriptions, etc. Mathematical symbols are used to represent quantities and quantitative relationships with equations and graphs.

Developing and Using Knowledge:

Both types of knowledge (concepts and symbolic) have value and are useful for specific, but often different, applications as illustrated. They are developed, or learned, in very different ways, a major factor that must be considered in creating and conducting learning activities, including classroom sessions.

Traditional physics, including medical physics, education has generally emphasized symbolic knowledge for two reasons. It is relatively easy to teach with lectures in a classroom and the objective of many courses and classes is to prepare for tests and examinations, both in college or university and professional board certifications. Examinations are easier to prepare and grade when they are based on symbolic knowledge (definitions, solving equations, etc.).

Laboratory sessions, often associated with classroom activities, provide direct interaction with physical objects and instruments that help develop conceptual knowledge. Using phantoms or test objects to evaluate image characteristics for radiography is an example.

This would be the most *effective* type of learning experience for physics of medical imaging using the actual imaging equipment for all modalities (CT, MRI, etc.). This is generally not practical, with the equipment being available only when not used for clinical procedures, limited to just a few students at a time, and requiring additional staff for equipment operation. Very much less *efficient* than having larger groups of students in a classroom, or laboratory session with one teacher.

In general, classrooms are highly *efficient* for teachers giving lectures to large groups of students at the same time. However, they are NOT *effective* learning environments for developing conceptual knowledge by observing and interacting with the physical universe, specifically the medical imaging methods and procedures.

III. WINDOWS FOR THE CLASSROOM

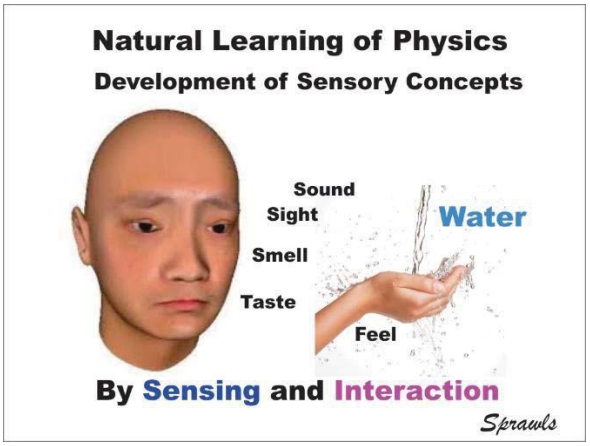
When the author (PS) first began teaching physics it was in a large classroom equipped with a writing board at the front and a few pieces of chalk. With this he could make a few sketches, solve mathematical problems, write a few words, and not much more.

Perhaps out of frustration, he developed the idea that a classroom was ‘just a box’ in which we enclosed our

students hiding them from the physical universe that they were to be learning about.

Classrooms needed "windows" through which segments of the physical universe could be viewed and learned about with a teacher guiding the process.

As an educator and his reading, research, and personal experience on the process of leaning, he developed an understanding and appreciation of *concepts* as valuable components of physics knowledge. He uses our knowledge of the physical principles (physics) of water to illustrate this.



Our knowledge of water is conceptual until we add the symbolic (words and mathematical) representations in physics courses later.

The challenge was bringing the physical universe into the classroom so it could be experienced and contribute to the formation of conceptual knowledge. This was possible with classroom demonstrations using small items…but not a CT machine!

Of the different senses, especially for medical imaging physics, sight or vision is the most significant.

Visual Representations for the Classroom:

This began a career-long activity of developing "classroom windows" in the form of visuals and images that could be projected in front of the class to provide a connection to the physical universe.

An early activity as a young teacher was to add" windows" to the classroom in the form of screens and two projectors, an overhead projector for diagrams and illustrations drawn or copied onto transparencies and a 35 mm slide projector for photographs of instruments, equipment, procedures, and illustrations copied from textbooks and other publications.

This was before computer graphics were generally available and illustrations were drawn by hand, a slow process. It was not practical or efficient for individual teachers to draw all the illustrations they needed, and it required some artistic talent to produce visually appealing illustrations.

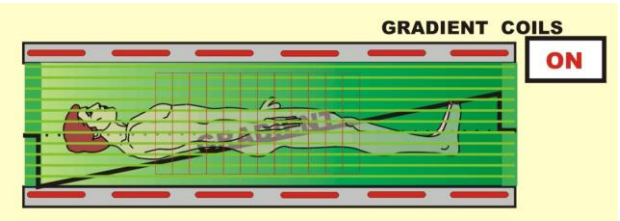
The author (PS) was also producing illustrations for a textbook and used a professional illustrator to draw the illustrations. Medical physics educators who used, or had access to the book, could copy the figures and use them in classroom presentations.

As computer graphics continued to develop with the capability to produce high quality images in color using vector-based DRAW and bit-map PAINT programs, it became more practical for teachers to produce visuals to use in their classroom activities.

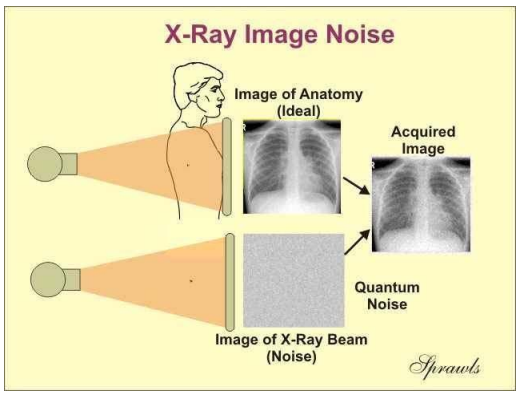
IV. VISUALIZING THE INVISIBLE

Unlike other fields of physics, such as mechanics, optics, and sound that can be touched, seen, or heard, much of the physics of medical imaging, including the magnetic fields and tissue magnetization, radiation and radiation interactions, are invisible to humans. This makes it difficult, or perhaps impossible, to form useful sensory (visual) concepts.

Visuals in which the *invisible* is made *visible* by the visual creator enhance the formation of concepts. The example shown here is using shades of green to represent the intensity of a magnetic field to illustrate the concept of gradients.



Another example is showing an image of the X-ray beam as the source of image noise in radiography.



V. EFFECTIVE AND EFFICIENT TEACHING.

Teaching is a complex activity with varying definitions, forms, and examples. It is a profession practiced by many at all academic levels, K-12 and College and University. Throughout much of our lives, we have been "taught" in many classes and have our view of what teaching is.

As medical physics educators/teachers we want to be both effective and efficient. Effective in helping our students develop the knowledge that will be useful in their professional activities and efficient with respect to the time and effort we must devote to preparing and providing a class activity, lecture or discussion.

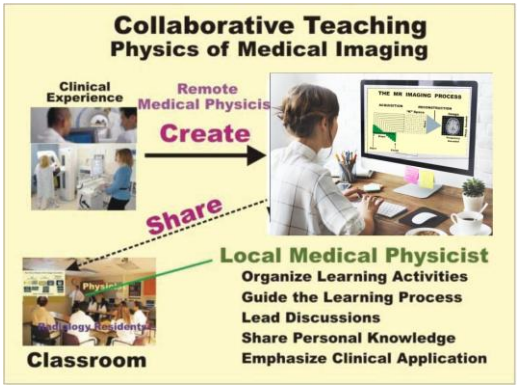
The almost universal model of teaching is a teacher in front of a class lecturing on a specific topic and attempting to convey some of their knowledge to the learners/students. This is very *efficient* because one teacher can "teach" a large group of students in a relatively short period of time. However, it is *not very effective* in helping learners/students develop knowledge, especially conceptual knowledge, that will be useful later in their professional activities.

. Recognizing that visuals (diagrams, illustrations, images, etc.) are required for providing effective learning experiences the challenge is producing or obtaining the many visuals that are needed. Sketching on the board at the front of the classroom during a lecture is traditional but not very effective with respect to quality and not efficient because of the time required and they are used one time and then erased.

VI. COLLABARATIVE TEACHING

Collaborative teaching is the comprehensive process of *helping someone learn* and includes several activities, not just standing in front of a class giving a lecture. Authoring textbooks are examples. Textbooks are not only studied by students they contribute to the effectiveness of teachers by providing material for lectures and figures or illustrations (visuals) that can be used in classroom presentations.

A significant and developing form of collaborative teaching is the creation and sharing of visuals with other medical physics educators/teachers.



As considered here, *collaborative teaching* is the collaboration between a *visual creator* and a *classroom teacher* to provide an effective and efficient learning experience for both the teacher and the students. Each one provides valuable contributions to the process.

Visual Creation:

The visual creator is generally an experienced clinical physicist who understands the imaging procedures and who can *imagine,* in their mind, the invisible elements of the imaging process, and express the concepts as visible illustrations.

Visual Sharing:

The value comes when visuals are *shared* with other educators, and the internet is the most effective method for this [3] A continuing issue that is being considered by some medical physics organizations, the AAPM is one, is the development of repositories where creators can post or publish their visuals in an organized format that will be available to all medical physics teachers.

The e-Encyclopaedia of Medical Physics on the web at: https://www.emitel2.eu/emitwwwsql/encyclopedia.aspx. is a source of visuals along with text and references.

Local Classroom Teachers:

With the availability of appropriate visuals, the classroom teacher can be both more *efficient* and *effective*. More *efficient* by not having to devote time and effort to preparing visuals. More *effective* by using their knowledge and experience, along with the visuals, to provide effective learning opportunities for students.

VII. THE SPRAWLS VISUALS SHARED FOR COLLABORATIVE TEACHING

The Sprawls Visuals described here is an example of what can be achieved with shared visuals.

Perry Sprawls (author of this article) is a clinical medical physicist in the field of medical imaging with a long career as an educator/teacher for both radiologists continuing education, radiology residents in training, and medical physicists, both graduate students and continuing education courses for medical physicists in over 30 countries of the world.

His work as a clinical physicist, usually in collaboration with radiologists, provided an understanding of the physics knowledge they needed in their professional practice. This included understanding image characteristics that affect clinical visibility and the related protocol factors for imaging procedures. This experience has been used to develop courses and visuals that contribute to effective

learning experiences and enhancements to class presentations and discussions.

These are available as an open and free resource on the web at: http://www.sprawls.org/SprawlsVisuals/

VIII. SUMMARY AND CONCLUSIONS

A major professional activity of many medical physicists is that of educators or teachers. This is a highly significant role because it prepares future professionals, medical physicists and radiologists for their careers. A continuing challenge is providing learning opportunities (classes, conferences, consultations) that are effective in contributing to the knowledge required for professional activities, from optimizing imaging procedures to understanding and adjusting image quality characteristics that affect clinical visibility. This generally requires conceptual knowledge to go along with symbolic knowledge (text and mathematical quantities and relationships). Concepts are a natural form of learning as experience the physical universe around us through our senses, especially sight, sound, and touch.

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