ENHANCING MEDICAL PHYSICS TEACHING WITH IMAGE REPOSITORIES AND SHARED RESOURCES

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Abstract— **The effective and safe clinical application of modern diagnostic imaging and therapeutic procedures requires a comprehensive conceptual knowledge and understanding of the physics principles and relationships. It requires learning activities (classes and conferences) with extensive visual representations of the physical interactions and relationships of the procedures with a strong focus on clinical images. A continuing limitation to effective classroom teaching by medical physicists is the availability of adequate visuals and images that can be presented and discussed. This limitation can be overcome and the teaching of medical physics around the world can become much more effective with experienced medical physicists creating and sharing high-quality visuals that can be used by classroom teachers. This is the process of *collaborative teaching* in which both are contributing to the learning process, one as a resource creator and the other as a classroom learning guide…both are teachers. It follows the model of clinical image "Teaching Files" that are the foundation of radiology education.**

The connection between the collaborating teachers can be through teaching image "Repositories" provided by medical physics organizations or institutions. These dedicated Repositories provide opportunities both to the resource creators and the classroom learning guides. Of special significance is that a medical physicist anywhere in the world can use their experience and creativity to contribute to international medical physics education--one visual and image at a time. Guidance is provided for the resource creators, classroom learning guides, and organizations on the development of teaching image Repositories as a major contribution to international medical physics education.

Keywords— **Teaching, Creativity, Collaboration, Visuals, Learning.**

I. Introduction and Overview

Teaching is one of the most valuable and rewarding activities performed by medical physicists around the world. It is the process of helping someone learn or build knowledge structures within the brain. Teaching occurs in many form-- traditional classroom lectures and discussions, mentoring individuals, and providing guidance for laboratory and practical activities. These are direct interactions between the teacher and specific students, or better described as learners. In this role a significant function of the teacher is to guide the learning process which is happening within the brain of the learner. Another highly valuable form of teaching is the process of creating and developing items that can be used to help someone learn, including textbooks and a variety of educational materials. In this context we will identify these two types of teachers as *classroom learning guides* and *resource creators.* There is the opportunity for medical physicists to use their knowledge, experience, vision, and creativity to teach through both of these functions. The contribution of the resource creator/teacher is by creating resources, especially visuals and images that will help learners develop knowledge structures that support the effective application of physics to clinical procedures, both diagnostic and therapeutic.

Images are visuals and we will be using both terms somewhat interchangeably. However, "image" will be used specifically in reference to clinical images (CT, MRI, mammograms, etc.) which are the major physical objects being studied in many medical physics classes. While visuals are also images it will generally be used for composite illustrations developed to show physical functions and relationships, often containing clinical images. The objective of the initiative described here is to develop visuals (images) that will often contain clinical images illustrating various image characteristics and related factors. Fig. 1 is an example.

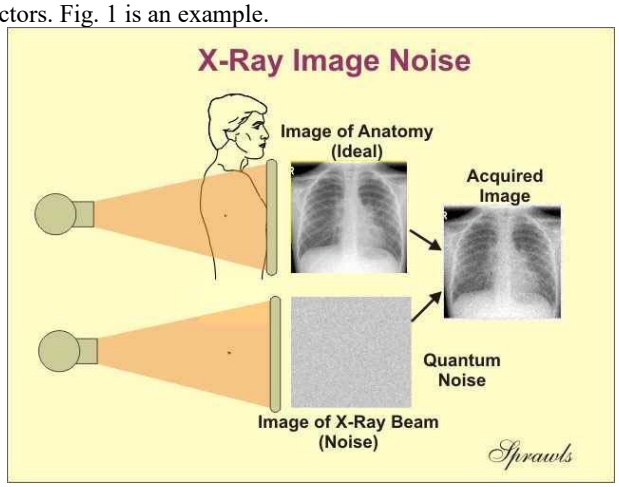

Fig.1. A visual with an imbedded clinical image illustrating the effect of quantum noise.

This is a highly effective visual introducing the concept of x-ray quantum noise that is easy to understand by radiologists and radiology residents. For medical physics students it provides a conceptual understanding to go along with their mathematical knowledge.

When these visuals are made available and shared with classroom learning guides there is the highly valuable process of *collaborative teaching.* Teachers, the resource creators and the classroom learning guides, are applying their knowledge and experience to produce highly effective learning experiences. For this to enhance medical physics education, especially on an international scale, there must be an effective process for connecting the teachers. This can be achieved through the creation of medical physics teaching image Repositories as illustrated in Fig. 2.

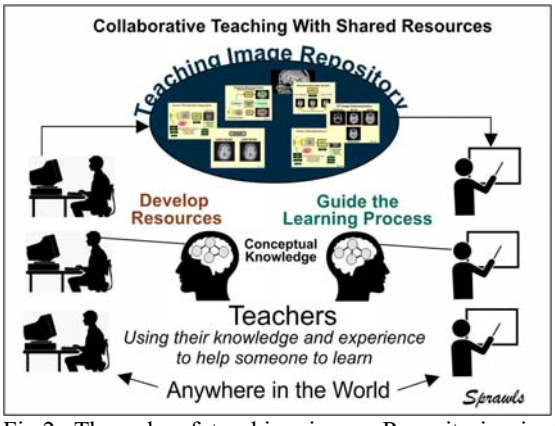

Fig.2. The role of teaching image Repositories in the process of collaborative teaching.

The World Wide Web provides the connection or link between the resource creators and the classroom learning guides. It provides a place where the resource creators can place or post their creations and where the classroom guides can find them. At this time there are many useful visuals and images on the web that can be used for teaching coming from many sources and somewhat randomly posted on a variety of websites. Here we describe a systematic process leading to a much more extensive activity for sharing resources and enhancing medical physics teaching around the world.

The foundation for this is the establishment of teaching image Repositories by medical physics organizations or institutions around the world. The Repositories provide web space for all resource creators to post their visuals in a form that is optimized for finding by classroom learning guides.

After reviewing the concepts of the learning and teaching process, especially for clinical medical physics, and the significant role of images and visuals, the process of developing effective teaching image Repositories will be described.

II. RADIOLOGY CLINICAL IMAGE TEACHING FILES

A major resource for radiology education, especially for residents, are the "teaching files" developed by organizations, institutions, and individual faculty containing clinical images showing various pathologies and normal variants. These are often contributed by individual radiologists as they encounter "interesting cases" during clinical activities. They can be used for self-study by residents and presentations in classroom and conference discussions. A great value is it gives those conducting classes and conferences access to a much greater range of clinical images and cases than they can develop from their own activities. It is an example of *shared resources.*

Clinical radiology teaching files can be considered as a model for the medical physics image teaching Repositories discussed here. There shared characteristics are the use of images to enhance learning, providing access to an extensive range of images and visuals for teaching, an opportunities for individuals to use their experience and contribute to the educational process for many.

III. EFFECTIVE TEACHING

Effective teaching of medical physics, especially clinically applied physics for both physics students and radiology residents, requires images that enable the learners to visualize the physical elements and interactions of the imaging process including the characteristics of images and their relationship to visibility of anatomical structures and pathological conditions as illustrated in Fig. 3.

Fig.3. Using visual resources in the classroom to enhance effective learning and teaching.

Both learning and teaching are human mental activities. The effectiveness of each activity, both learning and teaching, can be enhanced or enriched with an appropriate learning and teaching environment, typically the classroom, physically together or online. A continuing challenge is the availability of appropriate visual resources for classroom and conference learning activities. The development of effective visuals requires medical physics experience, capabilities, resources, and efforts beyond what each

individual classroom leader can provide. A solution is the availability of shared resources prepared by many resource creators from around the world.

IV. BUILDING EFFECTIVE KNOWLEDGE STRUCTURES

Teaching should be the processes of helping learners build effective knowledge structures that can be used to perform specific medical physics activities. Effective knowledge structures and their significance in the learning and teaching process have been described in previous publications contained in the Bibliography at the end of this article. A brief review is provided here. The relationship of mental knowledge structures to the physical environment is illustrated in Fig. 4.

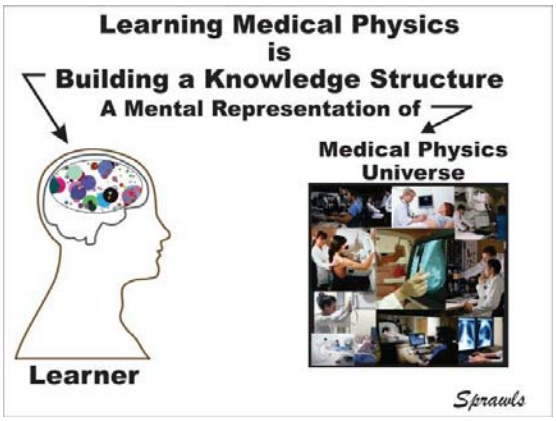

Fig.4. A knowledge structure is a mental representation of segments of the physical universe like medical procedures.

Here we are considering the characteristics of medical physics knowledge structures that determine the types of resources that can be used to enhance the teaching process of *helping the learner develop appropriate knowledge structures.*
Let's "look" into our own minds at our knowledge structures of medical physics and also how we developed them. Typically we can visualize many mathematical equations, memorized verbal descriptions, definitions, and facts. That is good and necessary but is not the knowledge that enables us to perform many medical physics functions, especially in clinical applications.

Sensory Concepts

Learning is an ongoing natural human process throughout life and does not always require classrooms and teachers! The natural learning process, both outside and within formal education school classrooms occurs as we interact with the environment around us with our senses, especially vision, hearing, and touch. These interactions produce knowledge structures consisting of *sensory concepts*. These are generally complex networks of experiences that are mental representations of specific areas of the physical universe. For example, all of us medical physicists have mental concepts of x-ray tubes that perhaps began when we were students and have been expanded and enhanced by our continuing experience and interactions with x-ray tubes.

It is our sensory, especially visual, conceptual knowledge structures, which are required for many applications of physics in clinical medicine. This is especially significant in relation to the physics of images.

V. TEACHING

One method of teaching is just the transfer of information from the mind of the teacher to the mind of the learner. This can be very appropriate and adequate for many situations, but not for many medical physics activities. The application of medical physics in clinical procedures both therapeutic and diagnostic imaging requires a comprehensive conceptual knowledge structure that cannot be developed with verbal lectures and conversations. It requires an intellectual interaction between the learner and the physical reality or sensory representations, especially visual, of the physics within the clinical procedures. That is what can be provided by *resources.*
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Effective Teaching

Effective teaching is the process of helping someone develop knowledge structures that enable them to perform specific functions, often referred to as tasks. These can be very different ranging from making high scores on a written examination to optimizing an imaging procedure with respect to image quality and radiation exposure. Both are important but require different approaches to teaching.

VI. VISUALS FOR EFFECTIVE LEARNING AND TEACHING

The desired characteristic of visuals for teaching is to enable the learner to form sensory concepts of the physical process being studied. Especially for radiologists and radiology residents *images* are the *physical objects* that are the focus of their required physics knowledge for clinical application. The several functions that require knowledge of the physical characteristics of images and the imaging process are illustrated in Fig.5.

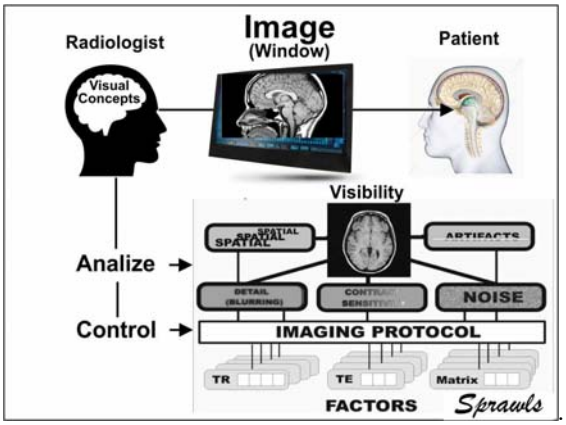

Fig.5. Functions performed by radiologists that require a conceptual knowledge of image characteristics and the formation process.

An effective knowledge of the physics of medical imaging can only be developed by viewing images and visual illustrations of image characteristics and related factors. The following are two illustrations.

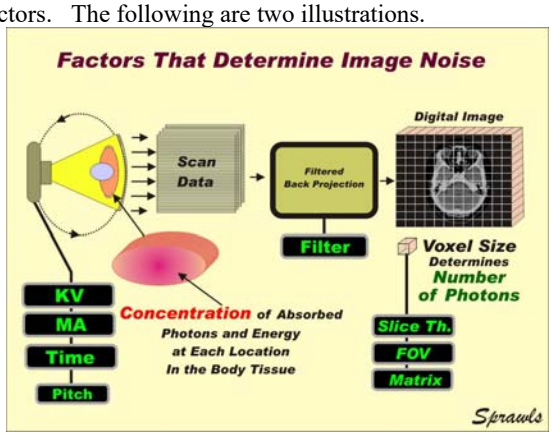

Fig.6. The combination of factors that have an effect on CT image noise.

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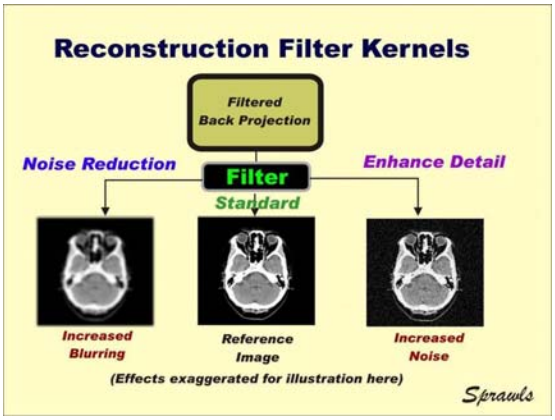

Fig.7. Illustration of the general effect of CT reconstruction filters selections on image quality.

One of the more complex factors in CT imaging is the function of the reconstruction filters as applied in clinical imaging. This visual provides an introduction and illustrates the conflicting effect on image quality that must be considered in clinical imaging.

VII. PRODUCING IMAGES FOR TEACHING

Computer graphics software for producing visuals and images for teaching, like those shown in Figs.6 and 7, use two different mathematical methods, generally referred to as *draw* and *paint*. Each has functions that are needed to produce visuals that illustrate the characteristics of medical images and related factors. The display for the software used by the author that provides both methods is shown in Fig. 8.

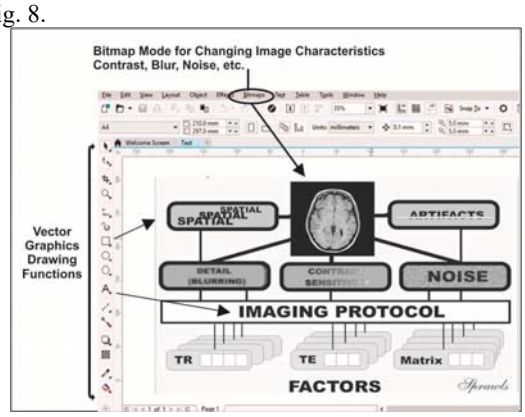

Fig.8. Computer graphics software used to produce visuals for teaching medical physics.

The combination of the two functions, draw and paint, enables the development of comprehensive visuals with embedded images with a range of characteristics.

Programs for Vector Based Images (Draw)

Each object in an image is represented by a series of numerical values (a vector) representing each characteristic, size, shape, position, color, location, etc. The advantage is these are adjustable through the various drawing functions shown on the left side of Fig. 8. This is used to develop illustrations composed of various objects and text. Images of objects from other sources can be imported. An example would be anatomical drawings.

When a visual is completed in vector format it can then be exported into a bitmap for posting on the web or other applications.

Programs for Processing Bitmap Images (Paint)

Virtually all medical images, digital photographs, and images on the web are bitmaps consisting of a matrix of pixels each having a numerical value. Unlike a vector based image the objects in a bitmap cannot be changed with

respect to size, shape, location, etc. Those characteristics are fixed. However, the numerical values within each pixel can be changed. These are the factors that represent the image characteristics including contrast, blurring, and noise. The significance is that the bitmap based paint software has many functions for changing these image characteristics, One application is to use the noise function to modify a clinical image with different levels of noise to produce images for teaching.

The Human Factor, Visualization, and Creativity

A computer with the graphics software described here is a tool that can be used by medical physicists to create images that illustrate and convey to learners much of our conceptual knowledge and understanding of applied medical physics. It provides an opportunity for us medical physicists to transfer knowledge from our brains to the brains of others in a visual form that can be applied especially in clinical applications.

Producing visuals like Figs. 6 and 7 requires extensive effort, time, and experience. It is neither possible nor practical for each classroom teacher to produce the visuals they need. The initiative described here is a solution and contribution to more effective medical physics teaching on a global scale.. It is for many medical physicists to produce some visuals and share them with all other teachers anywhere else in the world. It is an opportunity for individual medical physicists to use their unique knowledge and experience to "teach" others…one image at a time. The value of the creations of individuals is magnified many times when they are shared with others to use in classrooms and conferences around the world.

Before discussing the development of image Repositories for teaching it is helpful to confirm the several values of collaborative teaching and its contribution to more effective and efficient medical physics education. There are four major parties that can benefit from the development and sharing of visual resources as described.

Learners: Radiologists and Medical Physics Students

It is the learners who benefit from the greater availability of visual image- based teaching resources that enhance their conceptual knowledge of physics especially applied to medical procedures.

Classroom and Conference Learning Guides

The increased availability of visuals for classroom and conference presentations and discussions can contribute to a higher level of professional performance by medical physics teachers, both in terms of *efficiency* and *effectiveness*.

Their *efficiency* in terms of time and effort is increased by not having to develop all of the visuals for their classes and thus devote more effort in interactions with the learners and guiding the learning process.

Their *effectiveness* as teachers is greatly enhanced by the availability of classroom visuals that can be used to connect learners to the physical objects, systems, interactions, and functions they are studying. The teachers can then contribute their knowledge and experience to the learning process.

Medical Physics Organizations and Institutions

The specific opportunity to medical physics organizations and institutions around the world is to host Teaching Image Repositories on their websites. The details of creating and hosting Repositories are described below. The value to an organization is through the opportunities it provides to members by providing a Repository and encouraging members to use it both as classroom teachers and resource creators. Organizations can promote this through presentations at conferences, periodic publications, and on websites.

Medical Physics Visual Resource Creators

There are generally two categories of medical physicists who are potential contributors to medical physics teaching image Repositories.

Current Classroom Teachers

Many classroom teachers conducting courses for both medical physics students and radiology residents have developed for their use high-quality visuals that would be of value to teachers in other institutions and programs. These teachers can contribute to the global educational process by creating open source teaching image Repositories on their institutional websites and posting selected visuals that they would like to share.

Practicing Clinical Physicists

There is the opportunity for medical physicists with experience in clinical applications to become teachers "to the world". This is done without writing textbooks or providing complete courses and classes--just by creating individual visuals for teaching. The values to the individual physicist are many. It provides an opportunity to use their experience, especially clinically applied medical physics, to create visual "windows" into the physics of medical procedures. For all of us medical physicists this can be an interesting learning experience—first by giving thought to how to best visualize the physics so others can learn from it and then by the process of producing the visuals using computer graphics software.

Of special significance is the fact that medical physicists can acquire international visibility and recognition for their creative work, especially with high-quality visuals that contribute to the learning and teaching process.

When there is an opportunity it is helpful to collaborate with radiologists and residents on developing visuals they see as helpful for learning applied physics.

VIII. REPOSITORY DEVELOPMENT

A Repository provides the connection between two collaborating teachers, the *resource creator* and the *classroom learning guide*. It provides specific opportunities for each. The first is the ability to develop and post images in the Repository with information or "labels" that identify and describe the image subject in sufficient detail. The second is the ability to search a Repository from anywhere in the world to find images illustrating specific concepts and topics. This requires an understanding of the process and how it can be used effectively.

Images on the Web

There are many medical physics related images on the web. These are from many sources including various publications, institutions, organizations, equipment manufacturers, commercial enterprises that sell images, and many more. Even when images are within the context of documents, publications, and various websites they often appear as individual image files with some distinguishing identification characteristics such as file name, content within a specific website, and associated personal names.

There are several web-based programs that can be used to search for specific images, Google Images (https://images.google.com/) is the example used here. These programs, often called "search engines" organize the images on the web into *categories* identified by a combination of words that teachers can use to guide a search.

Here we illustrate by entering " CT Image Artifacts" into Google Images. The result is an extensive collection of images-- many of which can be used for teaching.

Web Crawlers/Spiders

A first function performed by search engines like Google is to detect the images that have been posted on the web and assign them to various categories where they can be found when someone searches like we just did for the category "CT Image Artifacts". The individual images in that category had many different identifying factors or labels that were considered for assigning to categories.

That function is performed by automated computer ro**bots** or bots that are generally known as web crawlers or spiders. This is somewhat descriptive of how they function. They move around the web going into the various web sites analyzing the content, both text and images. Our interest here is the images which can be more difficult to analyze that written text. As described later there are actions we can take when posting images for teaching that will help to get them into appropriate categories.

Many of the images on the web from the many sources are valuable for teaching medical physics and can be found by searching various categories as we just did for "CT Image Artifacts" even though they were not developed for teaching purposes.

The purpose described here with the creation of medical physics teaching image Repositories is to encourage and provide an opportunity for individual medical physicists to create and share images specific for teaching that will enhance international medical physics education.

Search Engine Optimization (SEO)

The ability of web crawlers to find and place images into appropriate categories depends on the information associated with each image that is posted along with the image. Preparing items to maximize their being placed into appropriate categories by web crawlers is the process of search engine optimization (SEO). This is a somewhat complex process when applied to all aspects of a website and tutorials can be found on the web at sites including Search Engine Optimization (SEO) Starter Guide provided by Google.

Our interest here is specifically on optimizing images to enhance the search process. This is by "labels" added to images by the resource creator and repository website manager. The two significant labels are *file names* and *alternate text*.

The file name assigned by the resource creator should be as descriptive and specific to the image as possible using a combination of several words. An example could be CT image noise 01.jpg. There should to be a balance between names that are broad and specific. Generally somewhat broad names, like three words, will enable web crawlers to list the images into categories where they can be found by teachers. When there are several images in the same category, numbers included in the file name (01, 02, 03, etc.), provide specific identity for an image and maintain a category description.

Image *alternate text* is the description of image content added to images when they are posted on the web. This is the text that will be displayed if the actual image cannot be viewed for some technical reasons. Also the alternate text is used by web crawlers to determine the content of images and place them into appropriate categories. Effective alternate text is a series of words describing image content with specific terms (MRI, noise, voxel, etc.) and limited use of general terms (illustration, image, relationship, etc.).

IX. HOSTING A REPOSITORY

A medical physics teaching image Repository is designated space, generally on an organizational or institutional website with an URL of the form www.sprawls.org/repository. This is a model repository provided by the author to illustrate some of the characteristics and functions of Repositories. Organizations and institutions might use variations of this design to best serve their members. A suggestion is a folder or directory with the name "repository" on the website and the index or

default webpage within with the name "medical physics teaching images".

Some Repository hosts might include a Table of Contents or Directory on the website so searchers can go directly to the Repository and see what visuals are available. However, the greatest visibility from around the world will come from searches on specific categories like our example "CT image artifacts".

Hosting Organization

A hosting organization, or institution, can establish the Repository project within the appropriate committee or administrative unit. Those would provide the specific design, organization, and operation of the Repository that provides support and teaching opportunities for the members. This will include creating a Repository manager or designated individual to manage the content.

Repository Manager

The Repository manager performs several functions as image files are received from the resource creators. First is to check submitted images for both content and format to determine if they are appropriate for the Repository. Then as images are posted on the website providing *file names* and *alternate text* to enhance the function of the web crawlers and search engines.

X. INTERLECTUAL PROPERTY AND PERMISSIONS

One of the purposed of having designated teaching image Repositories on organization or institutional websites is to provide content with specific conditions for us in educational activities including classroom teaching.

Intellectual Property Recognition

The visuals contributed to a Repository are generally the intellectual property of the resource creator that are being providing as an open and free resource to be used for educational purposes. The visuals should not contain any copyrighted material, by the creator or others, that would limit the ethical or legal use in educational activities. The established procedure is for each visual to have an identification of the creator, typically at the bottom.

This identification should not be removed or altered by classroom teachers.

Copyrighting

Unlike much material posted on websites the content of the teaching image Repositories should not be copyrighted that would limit its use or require permission for educational purposes. Copyright protection against unauthorized commercial use is appropriate.

XI. THE SPRAWLS RESOURCES

The concepts of collaborative teaching and shared resources described here are based on the extensive work of the author and provided on the website: www.sprawls.org/resources.

That site is actually a "Repository" of many images and visuals that are used in classrooms around the world to support classroom teachers/learning guides in helping learners develop highly effective and useful conceptual knowledge of medical physics.

XII. THE ENCYLOPAEDIA OF MEDICAL PHYSICS

The Encyclopedia online at: http://www.emitel2.eu/emitwwwsql/project.aspx is a major resource of visuals that can be used for teaching along with discussions and references for virtually every topic in medical physics. It can be searched for specific topics and is a valuable aide in preparing teaching materials, especially on recent developments in medical physics and clinical applications. The content is developed and contributed by many medical physicists from around the world who have knowledge and experience with the various topics. It is an example of the value of shared resources in medical physics education.

XIII. CONCLUSIONS

Physics is the fundamental science of many highly valuable diagnostic and therapeutic methods and procedures. With the increased capabilities and complexities of these procedures a more comprehensive conceptual knowledge of physics is required for the effective and optimized clinical applications. Teaching to help learners develop this knowledge requires extensive visual representations and images that can be used in classroom and conference discussions and learning activities. The creation of teaching image Repositories by medical physics organizations or institutions provides an opportunity for medical physicists from around the world to create and share educational resources in the form of visuals and images that can make a significant contribution to medical physics education.

The teaching of medical physics with visuals and images, especially for radiology residents and other clinical professionals provides several values. The physics class or conference is similar to and connects to those for clinical radiology with a visual focus on images. Most significantly it provides a highly effect conceptual knowledge that is required to apply physics in the practice of clinical radiology.

BIBLOGRAPHY

The publications provided here are devoted to two specific but related issues in medical physics education. One is the factors that determine the effectiveness of educational activities to support clinical applications. The other is the application of specific learning and teaching principles in the optimization of medical imaging procedures.

Effective Learning and Teaching

- Sprawls P. Duong P-A T. Effective Physics Education For Optimizing Ct Image Quality And Dose Management With Open Access Resources. . Medical Physics International Journal, vol.1, No.1, 2013 http://www.mpijournal.org/pdf/2013-01/MPI-2013-01-p046.pdf
- Sprawls P. Education Models for The Expanding Role Of Clinical Medical Physics**.** Medical Physics International Journal, vol.5, No.2, 2017 http://www.mpijournal.org/pdf/2017-02/MPI-2017-02-p167.pdf
- 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

Optimizing Medical Imaging Procedures

- Sprawls P. Physics Education For The Optimization Of MRI Clinical Procedures: Visualizing The Invisible And Collaborative Teaching. Medical Physics International Journal, Vol.1, No.2, 2013 http://www.mpijournal.org/pdf/2013-02/MPI-2013-02-p134.pdf
- Sprawls P. Optimizing Medical Image Contrast, Detail And Noise In The Digital Era. Medical Physics International Journal, vol.2, No.1, 2014 http://www.mpijournal.org/pdf/2014-01/MPI-2014-01-p041.pdf
- Sprawls P. Digital Elements, Image Quality, Radiation Exposure, and Procedure Optimization. Medical Physics International Journal, vol.6, No.2, 2018 http://www.mpijournal.org/pdf/2018-02/MPI-2018-02-p255.pdf

About the Author:

Perry Sprawls is a clinical medical physicist specializing in diagnostic radiology and an 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. This can be reviewed in the Bibliography.

The current effort described in this article is to encourage the collaboration of medical physicists in the creation, sharing, and use of visuals and images to enhance medical physics teaching and learning.

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