ENHANCING THE VALUE OF DIGITAL VISUALS FOR TEACHING MEDICAL PHYSICS

P. Sprawls

Emory University, Department of Radiology and Imaging Sciences, Atlanta, USA
Sprawls Educational Foundation, www.sprawls.org

Abstract— **The development and availability of digital image technology and methods, including the internet, adds several significant values for the teaching and learning of medical physics. It addresses and provides solutions to several long-standing challenges relating to both the *effectiveness* and *efficiency* of classroom teaching. Medical physics educators, teachers, can provide *effective* classroom and conference learning experiences by using their knowledge and experience along with visuals (images, diagrams, illustrations, etc.) to enhance the formation of useful knowledge structures within the student's minds. The values provided by using visuals in the classroom include multimodality (audio and visual) teaching, enhanced comprehension and understanding of complex concepts, ability to physically engage (with sight) with the physical universe, memory enhancement, (we remember what we see better than what we are told), encourages critical thinking, and visuals are a universal language especially valuable for international medical physics education. The specific value of digital image technology is providing all medical physics classrooms and teachers, in every country of the world, with access to highly effective visuals contributing to the formation (learning) of conceptual knowledge that is required for many medical physics activities. This is through the process of Collaborative Teaching between *visual creators* and *classroom presenters*, each "teaching" and helping students learn. Digital image *repositories* provide the link and availability of visuals for all to use.**

Keywords— **concepts, digital, effective, efficient, teaching.**

I. Introduction

Learning physics is the process of developing knowledge structures or mental representations of segments of the physical universe. It is a natural human function and process that begins at a very early age as we interact with the objects and conditions around us through sensory interactions, especially sight, sound, and touch. The development of our physics knowledge of water is an example illustrated here.

This knowledge is a complex network of sensory concepts developed through interactions with physical water. It is the type of knowledge that is especially valuable for guiding future interactions with and applications of water.

Formal learning of physics comes later in academic courses and classrooms where the learning process is organized, directed, and provided by teachers. Traditional classroom teaching generally provides abstract representations of the physical universe in the form of verbal (word) and mathematical symbol representations.

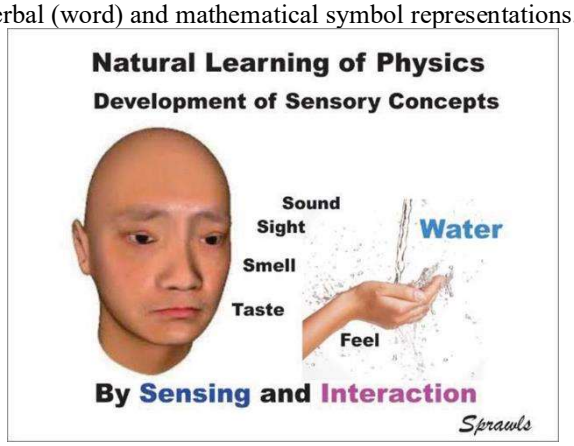


Figure 1. Learning the physics of water through sensory interactions.

While this type of knowledge is important, especially preparing learners for tests and examinations, it does not provide the type of knowledge that will be most useful for many future applications, especially applications that involve direct interactions with components and systems of the physical universe, ranging from preparing a cup of hot tea to optimizing a computed tomography imaging procedure. Both require conceptual knowledge, and not symbolic knowledge of words and mathematical symbols. This is especially true for both medical physicists and physicians practicing diagnostic and therapeutic radiology procedures [1. 2. 3.].

The physics classroom, including the medical physics classroom, has evolved over the years driven by the development and availability of technology [4.].

Teaching medical physics in the class or conference room has several significant challenges. First, the medical physics universe is outside of the classroom located in the hospital and clinics, and not always accessible for teaching. Student laboratory sessions and practical exercises in clinics do contribute to the development of conceptual knowledge but is often limited to the physical equipment and not the invisible radiations, interactions, etc. that is the major component of medical physics.

This significant limitation of the traditional class and conference room can be overcome with visuals that provide for a sensory (visual) interaction with the medical physics universe, both visible and invisible.

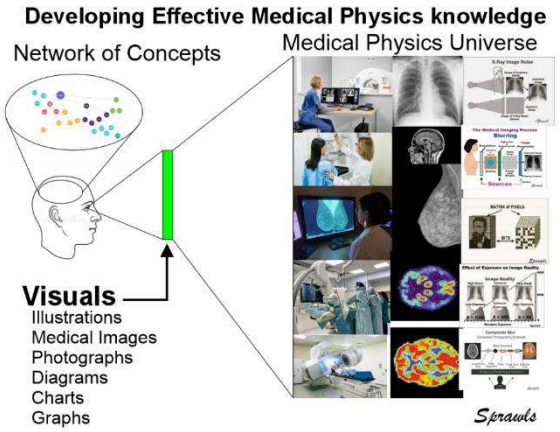


Figure 2. Visuals enable students to develop useful knowledge, or mental representations of the physical universe with a network of sensory concepts.

II. Effective teaching

Teaching is the process of helping someone learn and can occur in many forms. Lecturing and telling others what we know, for example, "Roentgen discovered X-radiation" conveys facts that can be memorized and is good to know. The ability to make calculations and solve mathematical problems is a critical requirement for the practice of medical physics, a quantitative science. These symbolic (words and mathematical symbols) do not contribute to the formation of significant conceptual knowledge that is necessary for applied physics applications, especially relating to clinical procedures. Teachers can provide highly effective learning opportunities, that is *effective teaching*, by combining their knowledge and experience with visuals that provide visual connections with the clinical procedures or other real-world applications.

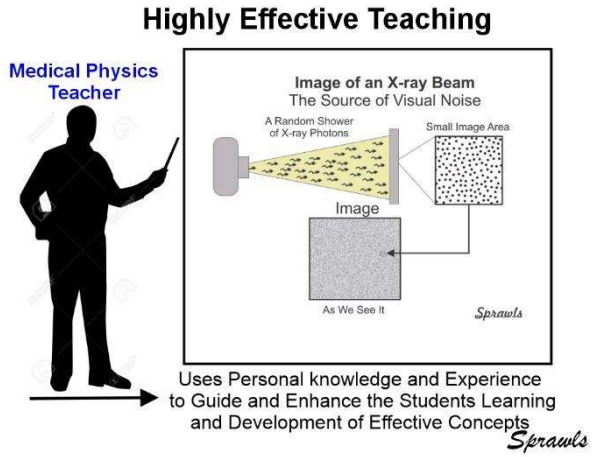


Figure 3. Effective teaching resulting from the combination of visuals in the classroom and discussions by an experienced medical physicist.

III. Enhanced comprehension

A major value of visuals used in teaching is that of enhancing the understanding and comprehension of complex ideas, for example "image quality", systems, procedures, interactions, etc. Recalling the old phrase, "a picture is worth a thousand words". A visual can create immediate interest and interaction with the subject that leads to a more comprehensive understanding. The visual shown here contributes to the understanding of the very complex issue of blurring in medical imaging, including its effects, sources, and control.

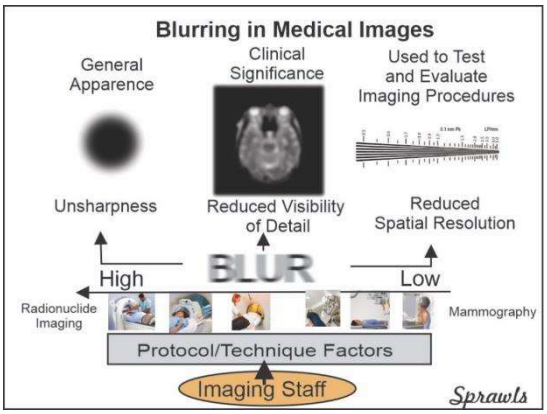


Figure 4. A visual to help students understand and develop conceptual knowledge of the many aspects of image blurring.

IV. Memory enhancement

We remember what we have seen much better than words we have heard or were told. Visual memory is a significant function of our mental process and scientists have classified it into three distinct categories: iconic memory, visual short-term memory, and visual long-term memory. For medical physics education long-term visual memory contributes to the formation of "visible" mental representations of items and conditions in the physical universe, for example what an image with specific artifacts looks like. This is the type of knowledge needed to evaluate images. Teaching with visuals provides students with knowledge that will be remembered and useful in future work. An example is shown here.

With this visual representation of the Inverse Square Relationship, often referred to as a "Law", students develop a concept, or understanding that is useful knowledge for the future. It will be remembered much longer than verbal definitions and equations. With this conceptual knowledge and understanding the quantitative relations, equations can be added for making calculations of actual values if needed

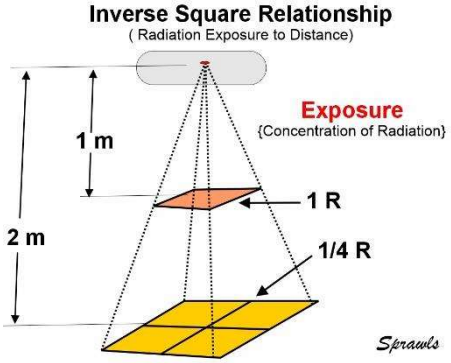


Figure 5. A visual representation of the inverse-square relation that is easier to remember and understand than definitions and equations.

V. MULTI-MODALITY TEACHING AND LEARNING

Using visuals along with a vocal lecture presentation or discussion combines two sensory "channels" of information (vision and sound) that can enhance each other. Each has specific characteristics. Visuals provide access to information in the form of objects with characteristics and relationships distributed in space throughout the area of the visual. This is especially significant when it is a representation of actual physical objects, relationships, events, and activities. The viewer, typically the student, can get the "big picture" and explore, concentrate on, and study details throughout the image. Vocal lectures are in the form of a continuing series of words, usually organized in sentences that often express facts. Especially in teaching physics, facts are presented as true and verified descriptions of some physical phenomena, observable condition, or event. An example of a vocally expressed fact is, "aluminum filters are used to modify the spectrum of an X-ray beam". Students can memorize this and correctly answer examination questions but can have no understanding or concept of what it means in relationship to an x-ray system. The vocal process is very different from the information provided with visuals. It has its value when used together with visuals as illustrated here.

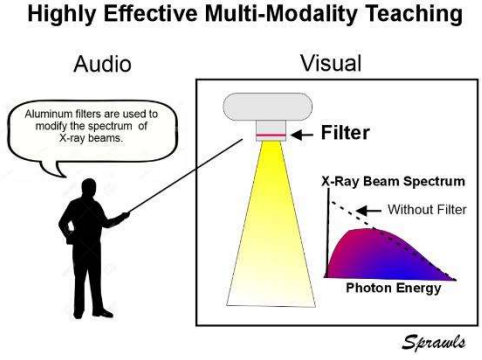


Figure 6. The value of a visual along with a spoken description in developing useful knowledge about the use of filters.

VI. VISUALS FOR TEACHING PHYSICS THROUGHOUT HISTORY

Throughout the history of teaching physics, one of the major challenges has been the availability of visuals to use in classes, usually limited to sketches on a blackboard during each class, erasing, and doing it again for the next illustration. This resulted in low quality illustrations requiring time to produce, and not permanent for use in other classes. This was a major factor that limited the use of visuals in physics classes and encouraged the use of symbolic representation, words, and mathematical equations, which were much easier to do.

Fortunately, textbooks often provided high-quality visuals along with discussion for "multi-modality" teaching. The early physics textbooks often contained high quality and detailed illustrations produced by skilled illustrators or "artists", as shown here.

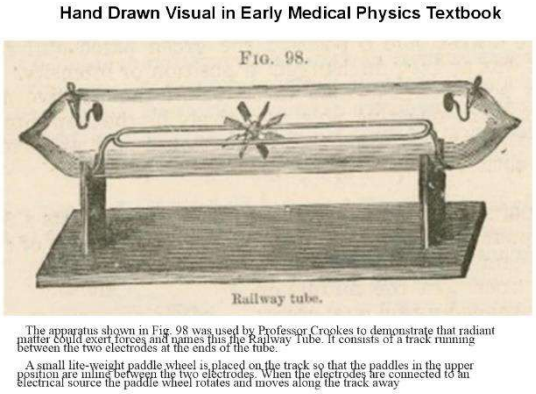


Figure 7. An example of high-quality visuals, produced by skilled artists and illustrators, used in some medical physics textbooks in the past.

Textbooks continue to be a major source of visuals for physics education but have transitioned from hand-drawn to computer-graphics creations.

With the development of copy machines that produce images on transparent sheets, "transparencies", and overhead projectors, illustrations copied from textbooks and other sources, provided classrooms and conferences with high quality visuals that were permanent and could be used many times.

The next major step was the development of 35mm photography and projectors, especially the Carousel projector. It became the practical method for copying and projecting clinical images, photographs of equipment and procedures, and copied from textbooks, and other printed sources…and in color. Most radiology and medical physics programs had cameras mounted on copy stands to photograph and produce slides that could be projected.

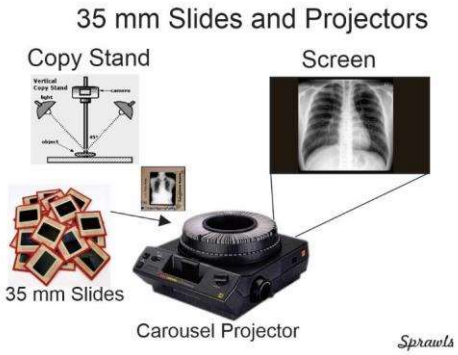


Figure 8. The photographic 35mm slides and projectors were a major advancement in providing high-quality visuals for both classrooms and conferences.

Along with the many values this provided, especially the ability to display high-quality images on large screens from permanent records, the slides, remained one limitation. The slides were physical objects that had to be organized and stored for potential future use, often occupying valuable office space. Even though slides could be duplicated for others to use, this was a limited activity.

VII. Digital Imaging

A revolutionary and continuing advancement in teaching medical physics is the development of digital imaging methods and techniques with technology for both the creation and sharing of high-quality visuals.

Digital photography, that everyone now has on their phones, can be used to produce high-quality images of clinical images, equipment, procedures, and anything else that is physically visible.

A variety of computer graphics programs are used to create visual representations of much of the invisible world of medical physics, including radiation, interactions, relationships, systems, and much more.

Both methods are valuable, especially when used together, to create visuals for teaching as illustrated here.

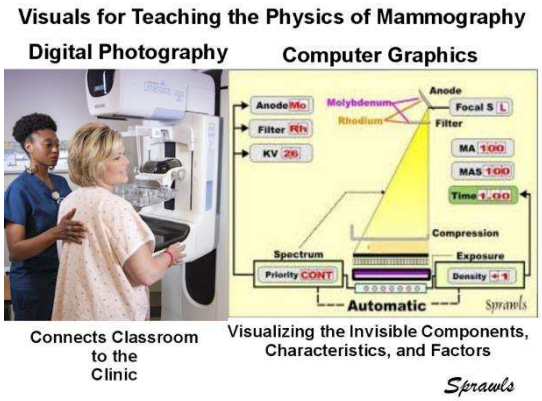


Figure 9. The combined value in using digital photography and computer-generated graphics for teaching medical physics.

The medical physicist who creates and shares visuals is a teacher with the potential of "teaching" many students in classrooms all over the world. A visual creator is like a textbook author with contributions to medical physics education, doing it with individual visuals.

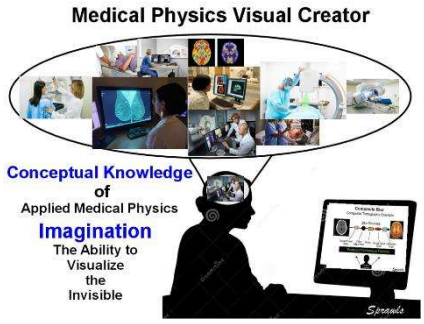


Figure 10. The requirements to be a successful visual creator.

The two requirements to be a successful visual creator is to have a comprehensive understanding and conceptual knowledge of applied medical physics and clinical procedures and a good imagination…the ability to visualize the invisible. While visuals, including diagrams of physical systems and circuits along with charts and graphs are useful in the classroom, that is for teaching the quantitative and mathematics of medical physics, it is the visuals of the invisible that contribute to effective learning and the development of conceptual knowledge networks in the mind.

VIII. Collaborative Teaching and Shared Visuals

There are two factors contributing to the ultimate value of visuals for teaching. One is the quality of the content that helps students learn and build appropriate and useful knowledge structures and the other is the number of students that have access to the visual. The value of visuals in textbooks is that they are viewed and studied by many students. The value of digital images is that they can be shared and used in classrooms around the world.

Collaborative Teaching is an established educational process that exists in several different forms or models. The common characteristic is that several individuals are involved together in providing a good learning experience for students. Generally, everyone brings specific knowledge, experiences, or resources to enhance the learning process. sometimes known as team teaching.

The interest here is in a specific model of Collaborative Teaching in which visuals are shared to enhance medical physics classroom and conference presentations and

discussions and the collaborators are the classroom teacher and the visual creator.

The general process for sharing visuals over the internet is illustrated here.

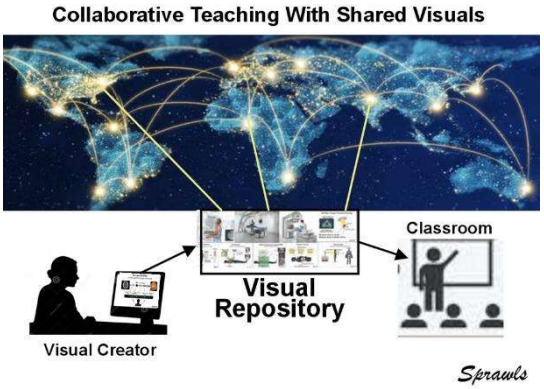


Figure 11. The purpose of a visual repository for collaborative teaching and enhancing medical physics education around the world.

In this context, a *visual repository* is any website that publishes visuals that are available for medical physics educators to download and use in their teaching. These include universities, medical physics organizations, and industry that post images for other purposes but are available for teaching. Of special value are websites that provide for the publication of visuals created by individuals to share with other educators and teachers.

There are two general methods for finding visuals on the web. One is to search the entire internet (World Wide Web) by a specific topic for a visual and the other is to go to designated repositories where visuals are organized and indexed.

A. *Searching Throughout the Internet*

There are several internet search programs, sometimes referred to as "search engines", that can be used. Google Image Search is illustrated here for searching by several specific topics. Go to **http//www.images.google.com** and insert a subject to search for. Examples are shown here.

x-ray spectrum: x-ray spectrum - Google Search

x-ray tube: x-ray tubes - Google Search

Mammography Procedure: mammography procedure - Google Search

B. *Searching Specific Repositories*

These are repositories with visuals that are organized by subject and can be viewed before selecting.

- *The e-Encyclopaedia of Medical Physics*

An extensive text with visuals covering all areas of medical physics on the web at:
http://www.emitel2.eu/emitwwwsql/encyclopedia.aspx .

- *The Sprawls Visuals*

Visuals for teaching the physics of medical imaging for medical physics students and physicians, especially Radiology Residents in training.

On the web at: www.sprawls.org/SprawlsVisuals .

IX. Conclusions

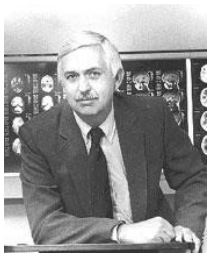
Teaching medical physics in the classroom has both advantages and disadvantages. A major advantage is the efficiency of getting classes together as a group for presentations and discussions led by a knowledgeable and experienced teacher. A major limitation and disadvantage is that the traditional classroom separates the students from real-world physics, especially in the medical clinics that they should be learning about. Classrooms are adequate for teaching the mathematical representation of physics relationships and interactions along with verbal descriptions but does not provide sensory, especially visual interactions that are critical for developing the conceptual knowledge that is necessary for many medical physics activities, evaluating the quality characteristics of an image is an example. This requires visuals (images, diagrams, etc.) in the classroom to provide a sensory interaction with the physics applications.

There is now the opportunity to enhance the value of visuals for teaching medical physics with more individuals becoming "teachers" by using their knowledge and experience to create and share visuals for all to use.

X. REFERENCES

1. Sprawls, P. Historical Evolution Of Physics Classroom Learning And Teaching. A Personal Perspective and Journey Perry Sprawls. Medical Physics International Journal, Special Issue, History of Medical Physics 8, 2022 968 http://www.mpijournal.org/pdf/2022-SI-08/MPI-2022-SI-08-p968.pdf
2. 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
3. Sprawls, P. Effective Physics Knowledge For Diagnostic Radiologists. Medical Physics International Journal, vol.7, No.3, 2019. Search http://www.mpijournal.org/pdf/2019-03/MPI-2019-03-p257.pdf
4. Sprawls, P. Maps For Developing Medical Physics Concept Networks in The Mind. Medical Physics International Journal, vol.10, No.1, 2022 http://www.mpijournal.org/pdf/2022-01/MPI-2022-01-p019.pdf
5. Sprawls, P. Enhancing Medical Physics Teaching with Image Repositories And Shared Resources Medical Physics International Journal, vol.8, No.3, 2020 http://www.mpijournal.org/pdf/2020-03/MPI-2020-03-p479.pdf

ABOUT THE AUTHOR



The long career of Perry Sprawls combines two activities, that of a clinical medical physicist in medical imaging and as an innovative educator. His work along with radiologists and technologists in the clinic provides an understanding of the *physics knowledge* they needed to conduct imaging procedures (mammography, CT, MRI, etc.) that were adjusted and optimized to produce images with the necessary diagnostic information with managed risk to patients. These are the specific educational needs that he addresses in his educational activities, including textbooks, courses, and especially visuals that he creates and makes available to medical physics educators around the world to enhance their classroom presentations and discussions, in the spirit of Collaborative Teaching. Throughout his career he has recognized the limitations of the traditional classroom as an effective learning environment for medical physics, especially clinically applied physics, and has applied a series of innovations to address this, using the technology available at the time. [Ref. 1]. The development of digital technology (especially computer graphics and the internet) now provides the opportunity to collaborate with other medical physics educators/teachers by creating and sharing high-quality and effective visuals for their use in classrooms, anywhere in the world: www.sprawls.org/SprawlsVisuals .

Contact of the corresponding author:
Author: Perry Sprawls, Ph.D.
Institute: Sprawls Educational Foundation
www.sprawls.org
Email: sprawls@emory.edu
Country: USA