The Elements of
A Highly Effective Educational Session

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and
Sprawls Educational Foundation

Handouts and Resources
at
http://www.sprawls.org/ipad
The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.

Be EFFICIENT in our teaching

Challenges Opportunities
"I never teach my pupils, I only provide the conditions in which they can learn"

Albert Einstein
1879-1955
The Traditional Classroom

“A Box for Enclosing Students...”

And hiding them from the world about which they should learning.
WELCOME TO EMORY
My name is Perry Sprawls
I am your teacher
The Sprawls Resources
Sharing the Emory Experience with the World
With Emphasis on the Developing Countries

Emory

www.sprawls.org/resources

Open Access
Educational Resources

Visuals Books Modules

Global Impact

Enhancing Radiology Education in Every Country of the World

Radiology Residents

Physicist
The Elements of
A Highly Effective Educational Session

The Brain

The Physical Universe
(Physics of Medical Imaging)

Developing a knowledge structure.

Needs Analysis

Learning Objectives

Sprawls
Clinical Medicine

Imaging

Radiation Therapy

Physics

The Foundation Science
Effective and Safe Clinical Procedures

Imaging

Radiation Therapy

Require an extensive knowledge of Applied Physics and The Associated Technology
Who needs a knowledge of Physics applied to clinical imaging?

Radiologists, Residents and Fellows

Technologists

Medical Physicists

Each provides unique challenges and opportunities.
Physics Learning Objectives for Radiologists

Image Physical Characteristics
- Identify
- Relationship to Visibility
- Anatomy and Pathology
- Evaluate
- Risk
- Control and Optimize
Effective Medical Imaging Physics Education

Goals & Objectives

Medical imaging professionals with a knowledge of physics that will enable them to perform clinically effective imaging procedures with managed risk to both patients and staff.
The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.

Be EFFICIENT in our teaching

Challenges Opportunities

Sprawls
Learning Physics is Building a Knowledge Structure in the Brain

Physical Universe

A mental representation of physical reality

Sprawls
Learning is a Natural Human Process

We Learn by Experience

Learner ➔ Observe ➔ Physical Universe ➔ Interact
Learning is a Natural Human Process
We Learn by Experience

Learner

Observe

Physical Universe

Interact

Our Early Physics Learning Activities
Teaching is helping someone
Building a Knowledge Structure in the Brain

A mental representation of physical reality

Connect  Organize  Guide
The Role of Formal Education

Connect

Physical Universe

Learner

Observe

Interact

Organize and Guide
The Elements of A Highly Effective Educational Session

The Brain

Connection

Observe

Interact

The Physical Universe (Physics of Medical Imaging)

Teacher/Guide

“Window”
Five Dynamics

“It’s a new ball game!”

Capability & Complexity
Geographic Dispersion
Learning & Teaching Knowledge
Expanding Educational Resources
Increased Connectivity
Capability & Complexity
(Computed Tomography)
Continuing Growth in the Need for Physics Knowledge

- CT
- MRI
- Radionuclide Imaging
- Mammography
- Digital

Capability and Complexity

Time
Knowledge of the Learning & Teaching Process

We learn from the pioneers

Gagne → Dale → Zull → Kolb
Increased Connectivity
Digital Resources to Enrich Learning Activities

The Web: Connecting and Sharing

Textbooks, Modules, Visuals, Clinical Images, Modules, References, Teaching Files

Classroom, Clinical Conference, Small Group, “Flying Solo”
Clinically Focused Physics Education

Classroom  Clinical Conference  Small Group  “Flying Solo”

Learning Facilitator "Teacher"  Individual and Peer Interactive Learning

Each type of learning activity has a unique value.

Sprawls
Clinically Focused Physics Education

Classroom
Clinical Conference
Small Group
“Flying Solo”

Learning Facilitator “Teacher”

The Goal...

Increase the **EFFECTIVENESS** of each type of learning activity with the **necessary resources** and understanding of the process by the Learning Facilitators.

Sprawls
The Barrier

Physics Education

Clinical Imaging

Efficiency
Location, Resources, Human Effort, Cost

Limited Experience

Sprawls
The Elements of A Highly Effective Educational Session

The Brain

Connection

Observe

Interact

The Physical Universe
(Physics of Medical Imaging)

Teacher /Guide

“Window”

Sprawls
Knowledge Structures in the Brain

A Complex Network

Concepts

Images

Facts

Language

Sprawls
The Brain...

Structure and Function

Image: AMA
Zull’s Model of Brain Function

James Zull, Ph.D.
Professor of Biology
Professor of Biochemistry
Director of University Center for Innovation in Teaching and Education
Case Western Reserve

Reference:

THE ART OF CHANGING THE BRAIN
Zull’s Model of Brain Function
Brain Functions for Learning Physics

Control

Sensory
Back Integrative Cortex
  Where
    (Relationships)
  What
    (Identification)
  Language
    Comprehension

Frontal Integrative Cortex
  Making Plans
  Evaluating
  Problem Solving
  Language
    Assembly

Motor

Emotions
Sprawls
Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Records of the Past

Reflection

Frontal Integrative Cortex

Preparation for the Future

Hypotheses

Motor

Emotions
Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Records of the Past

Knowing

Emotions

Motor

Frontal Integrative Cortex

Preparation for the Future

Doing

Sprawls
Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex
Records of the Past
Knowing

Frontal Integrative Cortex
Preparation for the Future
Doing

Motor

Emotions

Balanced Education
Forming Knowledge Structures

Physical Universe

Back Integrative Cortex

Sensory

Visible Physical Objects

chow chow
poodle
schnauzer
bulldog
collie
German shepherd
Forming Knowledge Structures

Physical Universe

Sensory

Radiation
Electrons
Magnetic
Atomic
Nuclear

Back Integrative Cortex

Invisible Physical Objects

Sprauls
Forming Knowledge Structures

Physical Universe

Radiation
Electrons
Magnetic
Atomic
Nuclear

Invisible

Physical Objects

Sensory

Back Integrative Cortex

Binding Energy

33 keV
Iodine

Sprawls
Forming Knowledge Structures

Physical Universe

Inverse Square Effect

Sensory

Back Integrative Cortex

Invisible Concepts Ideas

Visuals

Sprawls
Forming Knowledge Structures

Intensity = Power / Area

Surface area of a sphere = \( \frac{4\pi r^2}{3} \)

So, the luminous intensity on a spherical surface a distance \( r \) from a source radiating a total power \( P \) is:

\[ I = \frac{3P}{4\pi r^2} \]

As \( P \) and \( \pi \) remain constant, the luminous intensity is proportional to the inverse square of distance:

\[ I \sim \frac{1}{r^2} \]

Visual

Verbal and Symbolic

Sprawls
Back Integrative Cortex
Integrating experience into existing knowledge structure

Sensory

Meaning
Back Integrative Cortex
Integrating experience into existing knowledge structure

Sensory

Meaning
Back Integrative Cortex
Integrating experience into existing knowledge structure

Medical Knowledge
Back Integrative Cortex
Integrating experience into existing knowledge structure

The image is the connection
Back Integrative Cortex

Integrating experience into existing knowledge structure

The image is the starting point for learning physics
COMPUTED TOMOGRAPHY
QUALITY CHARACTERISTICS

SPATIAL SPATIAL SPATIAL ARTIFACTS

DETAIL (BLURRING) CONTRAST SENSITIVITY NOISE

PROTOCOL FACTORS
SLICE TH. MAS Matrix

OPERATION
Forming Knowledge Structures

Physical Universe

Inverse Square Effect

Back Integrative Cortex

Intensity = Power / Area

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\]

Verbal and Symbolic
Zull’s Model of Brain Function
Brain Functions for Learning Physics

Active Experimentation and Testing

Control

Sensory
- Back Integrative Cortex: Records of the Past, Knowing Reflection
- Frontal Integrative Cortex: Preparation for the Future, Doing Hypotheses

Motor

Emotions

Sense and Experience

Observe

Interact and Affect

Physical Universe
Brain Functions for Learning Physics
Active Experimentation and Testing

Control

Sensory
Back Integrative Cortex
Records of the Past Knowing Reflection

Frontal Integrative Cortex
Preparation for the Future Doing Hypotheses

Motor

Emotions

Sense and Experience
Observe

Interact and Affect

Physical Universe
Brain Functions for Learning Physics
Active Experimentation and Testing

Control
- Back Integrative Cortex: Records of the Past Knowing Reflection
- Frontal Integrative Cortex: Preparation for the Future Doing Hypotheses

Emotions
- Sense and Experience
- Observe
- Interact and Affect

Physical Universe

Sprawls
Brain Functions for Learning Physics
Two brains are better than one!
Collaborative Learning

Problem Solving

Ben

Jerry
Brain Functions for Learning Physics

Two brains are better than one!

Collaborative Learning

Problem Solving
Brain Functions for Learning Physics
Two brains are better than one!
Collaborative Learning

Views
Perspectives
Experiences

Problem Solved!
Brain Functions for Learning Physics
Two brains are better than one!
Collaborative Learning

Analysis and Evaluation
Brain Functions for Learning Physics

Two brains are better than one!

Collaborative Learning

Problem Solving
Analysis and Evaluation
Developing Plans

Sprawls
The Learning Environment

Control

Sensory
Back Integrative Cortex
Records of the Past
Frontal Integrative Cortex
Preparation for the Future
Knowing Reflection
Doing Hypotheses

Emotions

Sprawls
Rich Learning Environments

Records of the Past
Knowing Reflection

Preparation for the Future
Doing Hypotheses
Challenging Learning Environments

Control

Sensory Cortex

Back Integrative Cortex

Records of the Past
Knowing Reflection

Frontal Integrative Cortex

Preparation for the Future
Doing Hypotheses

Emotions

Sprawls
Effective Learning

Rich Learning Environment

New and Different

Integrate into Existing Knowledge

Reflection

Sprawls
Effective Learning

Interact  Review  Reflect

Developing useful knowledge for the future
Brain Functions for Learning About Physics

Records of the Past Knowing Reflection

Preparation for the Future Doing Hypotheses

Sensory

Control

Emotions

Interact and Affect

Sense and Experience Observe

Our Teaching

Sprawls
Robert Gagne (1916-2002)

Best known for his Nine Events of Instruction

The Gagne assumption is that different types of learning exist, and that different instructional conditions are most likely to bring about these different types of learning.

Gagné was also well-known for his sophisticated stimulus-response theory of eight kinds of learning which differ in the quality and quantity of stimulus-response bonds involved. From the simplest to the most complex, these are:

- signal learning (Pavlovian conditioning)
- stimulus-response learning (operant conditioning)
- chaining (complex operant conditioning)
- verbal association
- discrimination learning
- concept learning
- rule learning
- and problem solving.
Gagne's Hierarchy of Learning

- Problem Solving
- Rule Learning
- Concept Learning
- Discrimination Learning
- Verbal Association
- Chaining
- Stimulus Response
- Signal Learning
Edgar Dale (1900-1985)

Educationalist who developed the famous Cone of Experience theory
Cone of Experience for Medical Imaging Education

- **Verbal**
- **Symbols**
- **Equations**
- **Sketches**
- **Visuals**
  - Clinical Images and Graphics
- **Visuals with Expert Guidance**
- **Simulation**
- **Physical Reality**
Cone of Experience for Medical Imaging Education

**Effectiveness**
- Low
- High

**Efficiency**
- High
- Low

- **Verbal**
- **Symbols & Equations**
- **Sketches**
- **Visuals**
  - Clinical Images and Graphics
  - With Expert Guidance
- **Simulation**
- **Physical Reality**

Sprauls
Effective Learning

Experience — Learning — Level

- Physical Reality
- Simulation
- Visuals (With Expert Guidance)
- Sketches
- Symbols and Equations
- Verbal

Level:
- Signal Learning
- Response
- Chaining
- Verbal Association
- Discrimination Learning
- Concept Learning
- Rule Learning
- Problem Solving
Clinically Focused Physics Education

Classroom
Clinical Conference
Small Group
“Flying Solo”

Highly Efficient
For General Physics and Related Topics

Highly Effective
Clinically Rich Learning Activities

Visuals Images Online Modules Resources and References

Sprauls
Rich Classroom and Conference Learning Activities

Learning Facilitator "Teacher"

- Organize and Guide the Learning Activity
- Share Experience and Knowledge
- Explain and Interpret What is Viewed
- Motivate and Engage Learners

Visuals

Representations of Reality
Technology Enhanced Learning

- Learning Guide
- Learner
- Visuals for Classroom
- Online Resources
- Notes and Text
Visuals for Learning and Teaching

The Imaging Process

The Three Phases of CT Image Formation

- Scan and Data Acquisition
- Image Reconstruction
- Digital/Analog Conversion and Display Control

Major Control Factors

- KV
- MA
- Pitch
- Beam Wid.
- Slice Th.
- FOV
- Matrix
- Filter
- Window Width
- Window Level
- Zoom

Clinical Images

Sprawls

Sprawls
Visuals
to be used by
Physicists in Classroom and Conference Discussions

SPRAWLS EDUCATIONAL FOUNDATION
Open Resources
for Learning and Teaching
The Physical Principles of Medical Imaging

Visuals
for
Classroom, Conference, and Collaborative Learning

RIGHT CLICK on each visual to download and use in PowerPoint or other display programs.

Computed Tomography Image Quality Optimization
and Dose Management
Companion Module
http://www.sprauls.org/resources/CTIQDM/

CT Image Characteristics
Contrast
Detail
Noise

Objects in the Body
Imaging Procedure
CONTRAST SENSITIVITY
High
Medium
Low

CT Image Characteristics
Contrast
Detail
Noise

Anatomical Detail
Image

CT Image Characteristics
Contrast
Detail
Noise

Reference
Sprauls

Computed Tomography
Image Characteristics
and Quality
Radiation Dose

Imaging Protocols
Technology
Science

Sprauls
Computed Tomography

Image Characteristics and Quality

Radiation Dose

Imaging Protocols

Technology

Science
CT Image Characteristics

Spatial

Detail

Artifacts

Noise

Contrast Sensitivity

Major Protocol Factors

KV
Pitch
Slice Th.
Window Width

MA
Beam Wid.
FOV
Window Level

Time
Filter
Matrix
Zoom

Sprawls
The Three Phases of CT Image Formation

Scan and Data Acquisition

Image Reconstruction

Digital/Analog Conversion and Display Control

Major Protocol Factors

KV
MA
Time

Pitch
Beam Wid.

Slice Th.
FOV
Matrix
Filter

Window Width
Window Level
Zoom

Sprawls
CT Slice Divided into Matrix of Voxels

Field Of View (mm)

Matrix Size (voxels/pixels)

Slice Thickness (mm)

FOV ÷ Matrix = Slice Th.

Voxel Size Controlled By
The Quantum Structure of the X-ray Beam

Photon
X-ray Photons Interact With Tissue in A Voxel

**Radiation Dose**
determined by
**Concentration**
of
**Absorbed Energy**
per voxel

**Image Noise**
determined by
**Number of Photons**
per voxel

**Dose is increased**
by
**increasing number**
of **photons**.

**Noise is reduced**
by
**increasing number**
of **photons**.
SPIRAL SCAN

CONTINUOUS

Distance per Revolution

PITCH = \frac{D}{W} Beam Width
CT Dose Quantities

Effective Dose

Factors

DLP

Scan Length

Pitch

CTDI_{weighted}

CTDI_{volume}
Decreasing Noise

Requires Increased Photons Absorbed Per Voxel

Produces Increasing Dose
Effect of Matrix Size on Image Noise

Small Matrix

Large Voxels

Low Noise

Large

Small Voxels

High Noise

The same radiation dose for both images.
Factors That Determine Image Noise

- KV
- MA
- Time
- Pitch

Concentration of Absorbed Photons and Energy at Each Location in the Body Tissue

Filtered Back Projection

Filter

Voxel Size Determines Number of Photons

Slice Th.

FOV

Matrix
Two Major Image Quality Goals

High Detail

Low Noise

Voxel Size

Small

Large

FOV

Matrix

Slice Th.

Protocol Factors
**Relationship of Radiation Dose to Image Detail**

**Lower Dose**

When detail is increased by:
- Decreasing **Slice Th.**
- Increasing **Matrix**
- Decreasing **FOV**

**Noise Increases**

Because of decreased voxel size

**Higher Dose**

Dose must be increased to reduce noise.

*Sprawls*
Factors That Determine Image Detail (Sources of Blurring)

Scan Data → Filtered Back Projection → Digital Image

Focal Spot
- Pitch
- Beam Wid.

Detector

Slice Th.
- FOV
- Matrix

Voxel Size
Reconstruction Filter Kernels

Filtered Back Projection

Noise Reduction: Filtered Image
Noise Reduction: Reference Image
Noise Reduction: Increased Blurring

Enhance Detail: Filtered Image
Enhance Detail: Reference Image
Enhance Detail: Increased Noise

(Effects exaggerated for illustration here)
THE LEARNERS
or
BARRIER

WINDOW

or

PHYSICAL UNIVERSE

Sprawls
The Elements of A Highly Effective Educational Session

The Brain

Perform

The Physical Universe (Physics of Medical Imaging)

Evaluation

Observation, Tests, and Exams

Sprawls
The Elements of A Highly Effective Educational Session

The Brain

Follow Up

Review
Refresh
Reflect
Recall
Remember
Re-inforce

The Physical Universe
(Physics of Medical Imaging)

Web-based Resources
(www.sprawls.org/ipad)
In Partnership with Other Medical Physics Teachers to be More Effective and Efficient in Providing Medical Imaging Education
Clinically Focused Physics Education

Classroom

Clinical Conference

Small Group

“Flying Solo”

Learning Facilitator
“Teacher”

Individual and Peer Interactive Learning

Each type of learning activity has a unique value.
Effective Medical Imaging Physics Learning...In The Clinic

The Real World Motivating Interactive Collaborative

Radiologist

Resident

The Physicist Provides: Learning Modules & Collaboration

Sprawls
Composed Tomography Image Quality Optimization
and Dose Management
Perry Sprawls, Ph.D.

To step through module, [CLICK HERE].
To go to a specific topic click on it below.

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Mammography Physics and Technology for effective clinical imaging
Perry Sprawls, Ph.D.

To step through module, CLICK HERE.

To go to a specific topic click on it below

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The x-ray beam spectrum is one of the most critical factors that must be adjusted to optimize a procedure with respect to contrast sensitivity and dose. One can think of it as a three-step procedure:

1. Select the appropriate anode (moly or rhodium)
2. Select the appropriate filter (moly or rhodium)
3. Select the appropriate KV (In the range 24 kV to 32 kV)

Increasing the KV has two effects on the x-ray beam. It increases the efficiency and output for a specific MAS value and it shifts the photon energy spectrum upward so that the beam becomes more penetrating.

While a more penetrating beam does reduce contrast sensitivity it is necessary when imaging thicker and more dense breast. Therefore compressed breast thickness is the principal factor that determines the optimum KV.

Mammography systems have indicators that display the thickness of the compressed breast. This along with a general assessment of breast density is used to manually select an optimum KV either from experience or an established technique chart.

The general goal is to increase the KV as necessary to keep the exposure time, MAS, and dose to the breast within reasonable limits as breast thickness increases.
The Values We Hold

The PHYSICIST is the TEACHER.

TECHNOLOGY is the TOOL that can be used for effective and efficient teaching.

Technology should be used to enhance human performance of both learners (residents, students, etc.) And teachers.
The Elements of A Highly Effective Educational Session

The Brain

Developing a knowledge structure.

The Physical Universe
(Physics of Medical Imaging)

Needs Analysis

Learning Objectives
The Elements of
A Highly Effective Educational Session

The Brain

Connection

The Physical Universe
(Physics of Medical Imaging)

“Window”

Teacher/Guide
The Elements of A Highly Effective Educational Session

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