Effective Medical Physics Educational Activities Models and Methods

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www.sprawls.org

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The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.

Be EFFICIENT in our teaching

Challenges Opportunities

Sprawls
The Elements of A Highly Effective Educational Session

The Brain

Connection

The Physical Universe
(Physics of Medical Imaging)

Observe

Interact

"Window"

Teacher/Guide

Sprawls
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.
The Spectrum of Learning Activities
For
Medical Physics

Effectiveness

Sprawls
The Spectrum of Learning Activities For Medical Physics

Verbal - Effectiveness - Visual

Sprawls
The Spectrum of Learning Activities For Medical Physics

Passive Verbal

Interactive Visual

Effectiveness
The Spectrum of Learning Activities
For
Medical Physics

Easy
Passive
Verbal

Effort
Interactive
Visual

Effectiveness
The Spectrum of Learning Activities
For
Medical Physics

- Easy
- Passive
- Verbal

$\rightarrow$ Effort

$\rightarrow$ Interactive

$\rightarrow$ Visual

Effectiveness

Sprawls
The Spectrum of Learning Activities for Medical Physics

Tradition <-> Innovation

$ <-> $$$$

Easy <-> Effort

Passive <-> Interactive

Verbal <-> Visual

Effectiveness
The Spectrum of Learning Activities

For

Medical Physics

Tradition

Easy

Passive

Verbal

Ionnivation

Effort

Interactive

Visual

Effectiveness

Sprawls
The Spectrum of Learning Activities
For Medical Physics

Where do you fit in?

Effectiveness
The Spectrum of Learning Activities

For

Medical Physics

Effectiveness
Large Classroom
Effective or Efficient?
Large Classroom
Effective or Efficient?

More passive than interactive

Individuals have different backgrounds and needs
Effective Medical Physics Education is like a Giant Puzzle
What do you bring to the table?
What do I bring to the table?

A Lecture
To Talk To You
Tell You What I Know

Share Experience
and
Some Resources
WELCOME TO EMMORY
My name is Perry Sprawls
I am your teacher
The Traditional Classroom

"A Box for Enclosing Students..."

And hiding them from the world about which they should learning.
THE LEARNERS
or
BARRIER

WINDOW

PHYSICAL UNIVERSE

Sprawls
THE LEARNERS

or

BARRIER

PHYSICAL UNIVERSE

Visuals

A MAGNETIC FIELD
GRADIENT

FIELD STRENGTH
GRADIENT COILS

UNIFORM

Physicists

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The Sprawls Resources
Sharing the Emory Experience with the World
With Emphasis on the Developing Countries

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Open Access Educational Resources
Visuals Books Modules

Global Impact

Enhancing Radiology Education in Every Country of the World
The Collaborative Teaching Model

Sprawls Online Resources
Modules Books Visuals

Enhance the performance of physics faculty
Residents & Radiologists
Local Universities
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 Barrier

Physics Education

Efficiency
- Location, Resources, Human Effort, Cost

Clinical Imaging

Limited Experience
Your Mind

Network of A Lifetime of Experiences
Network of Sensory Experiences

Inputs

- Visual
- Smell
- Taste
- Sound
- Feel

Sprawls
Network of Sensory Experiences

Inputs

- Visual
- Smell
- Taste
- Sound
- Feel
Exploring Your Mind
What Can You See?
Network of Sensory Experiences

Inputs

- Visual
- Smell
- Taste
- Sound
- Feel

Sprawls
**Chocolate Cake**

**Ingredients**

- Baking spray, for spraying custard cups
- 1 stick butter
- 2 ounces bittersweet chocolate
- 2 ounces semisweet chocolate
- 1 1/4 cups powdered sugar
- 2 whole eggs
- 3 egg yolks
- 1 teaspoon vanilla
- 1/2 cup all-purpose flour
- Vanilla ice cream, for serving

**Directions**

Preheat the oven to 425 degrees F. Spray four custard cups with baking spray and place on a baking sheet.

Microwave the butter, bittersweet chocolate and semisweet chocolate in a large bowl on high until the butter is melted, about 1 minute. Whisk until the chocolate is also melted. Stir in the sugar until well blended. Whisk in the eggs and egg yolks, then add the vanilla. Stir in the flour. Divide the mixture among the custard cups.

Bake until the sides are firm and the centers are soft, about 13 minutes. Let stand 1 minute. Invert on individual plates while warm and serve with vanilla ice cream.

**CATEGORIES:** Chocolate, Dessert, Cake | View All
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

Interact

Physical Universe

Our Early Physics Learning Activities
One of Our First Physics Lessons

Sensory Ball Pit
Learning By Direct

Observation

Interacting

A Natural Human Function
Teaching is helping someone
Building a Knowledge Structure in the Brain

Physical Universe

A mental representation of physical reality

Connect  Organize  Guide

Sprawls
Teaching Physics Is Not
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

The Physical Universe
(Physics of Medical Imaging)

Observe

Interact

Teacher/Guide

“Window”
What do they need?

Learner

Medical Physics Universe

“Know” or to “Do”
What do you need?

You As An Educator

Provide a highly-effective learning experience
Here is our challenge!

Learner

Medical Physics Universe

How are you going to do it?

Sprawls
Learning Medical Physics is building a Knowledge Structure in the Mind
Learning Physics is Building a Knowledge Structure in the Brain

A mental representation of physical reality
Knowledge Structure of Medical Physics
Network of Sensory Experiences

Inputs

Visual
Smell
Taste
Sound
Feel

Sprawls
Learning Medical Physics Requires

Observation

Medical Physics Universe

Interacting With

Sprawls
The Most **EFFECTIVE** way to Build Physics Knowledge Structures

- **Audio**
- **Human** (Teacher)
- **Visuals**
- **Technology**

*Sprawls*
Teaching Medical Physics

Observation

Interacting With

Is

Connecting and Guiding

Sprawls
Teaching Medical Physics

"Window"

Medical Physics Universe

Provide Window

Guide the Learning Process

Teacher must

Sprawls
A Traditional "Window" to the Physical Universe
The Physical Universe

The inverse square law is......

Twice the Distance

Photon Concentration (Exposure) decreased to 1/4th

X-ray beam now covers four times the area

The Inverse Square Law

\[ \frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2 \]

- \( I_1 \) is the initial intensity of radiation,
- \( d_1 \) is the initial distance,
- \( d_2 \) is the final distance, and
- \( I_2 \) is the final intensity.
Medical Physics Knowledge Structures

Sensory

Linguistic

The inverse-square law states that the exposure decreases inversely to the square of the distance from the source.

Quantitative

\[ E_2 = \frac{E_1}{(\frac{d_2}{d_1})^2} \]
The X-ray Beam

Magnified View

Photons

Energy

Sprawls
Image Of An X-ray Beam

A Random Distribution of Photons

This is visible in an x-ray image as noise (quantum noise).

High

Medium

Low

— Photon Concentration (Exposure) →
Twice the Distance

Photon Concentration (Exposure) decreased to 1/4th

X-ray beam now covers four times the area
The inverse-square law states that the exposure decreases inversely to the square of the distance from the source.

Quantitative

\[ E_2 = \frac{E_1}{(d_2/d_1)^2} \]
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

Control and Optimize

Risk
What do they need?

Learner (Resident)

Optimize CT image quality and manage dose.
What do they need to DO?

Learner (Resident)

View

Action

Sprawls
Your Mind
Knowledge Structures in the Brain

A Complex Network

Concepts
Images

Facts
Language

Sprawls
Knowledge of the Learning & Teaching Process

We learn from the pioneers

Gagne
Dale
Zull
Kolb
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
Kolb’s Experiential Learning Model

David A. Kolb, Ph.D.
Professor of Organizational Behavior
Case Western Reserve

Website:  http://www.learningfromexperience.com
Zull’s Model of Brain Function

Abstract hypotheses

Frontal integrative cortex

Premotor and motor

Temporal integrative cortex

Sensory and postsensory

Reflective observation

Active testing

Concrete experience
Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Records of the Past

Reflection

Emotions

Frontal Integrative Cortex

Preparation for the Future

Hypotheses

Motor

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

Sprawls
Forming Knowledge Structures

Physical Universe

Back Integrative Cortex

Sensory

Visible Physical Objects

chow chow
poodle
schnauzer
collie
German shepherd
bulldog
Forming Knowledge Structures

Physical Universe

Back Integrative Cortex

Visible Physical Objects
Forming Knowledge Structures

Physical Universe

Radiation
Electrons
Magnetic
Atomic
Nuclear

Sensory

Back Integrative Cortex

Invisible Physical Objects
Forming Knowledge Structures

Physical Universe
- Radiation
- Electrons
- Magnetic
- Atomic
- Nuclear

Invisible
Visuals
Physical Objects

Back Integrative Cortex

Sensory

 BINDING ENERGY

33 keV

IODEINE

Sprauls
The Physical Universe

The inverse square law is......

The Inverse Square Law

\[
\frac{I_i}{I_f} = \left(\frac{d_i}{d_f}\right)^2
\]

- \(I_i\) is the initial intensity of radiation.
- \(d_i\) is the initial distance.
- \(I_f\) is the final intensity.
- \(d_f\) is the final distance.

Verbal

Twice the Distance

Photon Concentration (Exposure) decreased to 1/4th

Sensory

X-ray beam now covers four times the area

Mathematical

Sprawls
Zull’s Model of Brain Function
Brain Functions for Learning Physics
Active Experimentation and Testing

Sense and Experience

Observe

Interact and Affect

Emotions

Control

Sensory

Back Integrative Cortex

Records of the Past Knowing Reflection

Frontal Integrative Cortex

Preparation for the Future Doing Hypotheses

Motor

Physical Universe

Sprawls
Brain Functions for Learning About Learning Physics

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

Our Teaching
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.
Challenging Learning Environments

Control

Sensory

Back Integrative Cortex

Records of the Past
Knowing Reflection

Frontal Integrative Cortex

Preparation for the Future
Doing Hypotheses

Emotions

Motor

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Rich Learning Environments

Records of the Past
Knowing Reflection

Preparation for the Future
Doing Hypotheses

Control

Sensory
Back Integrative Cortex

Frontal Integrative Cortex

Emotions

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Edgar Dale (1900-1985)
Educationalist who developed the famous Cone of Experience theory
Cone of Experience for Medical Imaging Education

1. Verbal
2. Symbols
3. Equations
4. Sketches
5. Visuals: Clinical Images and Graphics
7. Simulation
8. Physical Reality
Cone of Experience for Medical Imaging Education

**EFFECTIVENESS**

LOW

**EFFICIENCY**

HIGH

1. **VERBAL**
2. **SYMBOLS EQUATIONS**
3. **SKETCHES**
4. **VISUALS Clinical Images and Graphics**
5. **VISUALS With Expert Guidance**
6. **SIMULATION**
7. **PHYSICAL REALITY**

Sprawls
Cone of Experience for Medical Imaging Education

LEARNING OUTCOMES

Define
List
Describe
Explain
Demonstrate
Apply
Practice
Analyze
Create
Evaluate

VERBAL
SYMBOLS
EQUATIONS
SKETCHES
VISUALS
Clinical Images and Graphics
VISUALS
With Expert Guidance
SIMULATION
PHYSICAL REALITY
Effective Learning

Experience

Learning

Level

1. Physical Reality
2. Simulation
3. Visuals
   - Clinical Images and Graphics
   - With Expert Guidance
4. Sketches
5. Symbols
6. Verbal
Technology Enhanced Learning and Teaching

Experience

Learning

Level

- Physical Reality
- Simulation
- Visuals with Expert Guidance
- Sketches
- Symbols and Equations
- Verbal

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

Classroom
Clinical Conference
Small Group
“Flying Solo”

Highly Efficient
Highly Effective
Clinically Rich Learning Activities

For
General Physics
and
Related Topics

Visuals Images Online Modules Resources and References
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

Sprawls
Technology Enhanced Learning

Learning Guide

Learner

COMPTON SCATTER INTERACTIONS

X-RAY PHOTON

ENERGY

WEAK

NUCLEUS

Visuals for Classroom

Online Resources

Notes and Text
Visuals for Learning and Teaching

The Imaging Process

The Three Phases of CT Image Formation

1. Scan and Data Acquisition
2. Image Reconstruction
3. Digital/Analog Conversion and Display Control

Major Control Factors

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

Clinical Images
Technology Tools
Developing Digital Images

“Paint”
Bitmaps
This illustration is a raster file, made up of pixels.

“Draw”
Vectors
This illustration is a vector file. The paths have been highlighted for comparison.
Technology Tools
Vector Digital Images

draw programs
Technology Tools

Bitmap Digital Images

Used for Editing

Paint Programs
The Sprawls Resources
Sharing the Emory Experience with the World
With Emphasis on the Developing Countries

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www.sprawls.org/resources

Open Access Educational Resources

Visuals Books Modules

Global Impact

Enhancing Radiology Education in Every Country of the World

Physicist

Radiology Residents
Collaborative Teaching is Sharing the Work

Resource Physicist

Create visuals and related resources
Share with the World

Local Physicist
Organizes
Guides
Shares Experience
Motivates
Role Model

Medical Physics Universe
Collaborative Teaching is
Sharing Experience, Perspectives, and Opportunities

Physicist

Radiologist

Clinical Applications

Factors That Determine Image Noise

Radiology Residents

Principles and Concepts
What do they need?

Learner (Resident)

Optimize CT image quality and manage dose.
What do they need to DO?

Learner (Resident)

View

Action

Sprawls
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
- Beam Wid.
- Time
- Pitch
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- FOV
- Matrix
- Filter
- Window Width
- Window Level
- Zoom

Clinical Images
Computed Tomography Image Quality Optimization and Dose Management

Companion Module

http://www.sprawls.org/resources/CTIQDM/
# Modules for Self Study and Collaborative Learning in the Clinic

**Computed 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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Effective Medical Imaging Physics Learning...In The Clinic

The Real World Motivating Interactive Collaborative

Radiologist

Resident

The Physicist Provides: Learning Modules & Collaboration

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

To step through module, CLICK HERE.

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The Most EFFECTIVE way to Build Physics Knowledge Structures

Audio
Human (Teacher)
Guiding The Process

Visuals
Technology

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

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

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

Computed Tomography
- Imaging Protocols
- Technology
- Science

CT Image Characteristics
- Contrast
- Detail
- Noise

CT Image Characteristics
- Contrast
- Detail
- Noise

Objects in the Body
- Physical Contrast
- Imaging Procedure
- Contrast Sensitivity
  - High
  - Medium
  - Low

Anatomical Detail
- Reference
- Image
CT Image Characteristics

Spatial

Detail

Artifacts

Noise

Contrast Sensitivity

Major Protocol Factors

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

Sprauls
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

Sprawls
Factors That Determine Image Noise

Scan Data → Filtered Back Projection → Digital Image

Filter

K V
M A
Time
Pitch

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

Slice Th.
FOV
Matrix

Voxel Size Determines Number of Photons

Sprawls
CT Dose Quantities

Effective Dose

Factors

DLP

Scan Length

Pitch

CTDI \_\text{weighted}

CTDI \_\text{volume}

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Relationship of Radiation Dose to Image Detail

Lower Dose

Higher Dose

When detail is increased by

- Decreasing Slice Th.
- Increasing Matrix
- Decreasing FOV

Noise Increases

Because of decreased voxel size

Dose must be increased to reduce noise.
Conclusion
Using Knowledge For
More Effective & Efficient Learning Activities

Evaluate

Apply
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.spawls.org/ipad)
The Elements of A Highly Effective Educational Session

The Brain

Connection

The Physical Universe
(Physics of Medical Imaging)

Observe

Interact

Teacher /Guide

"Window"
What is my contribution to effective medical physics education?

I do windows.
Enriching Medical Physics Education by Visualizing the Invisible

Perry Sprawls, Ph.D
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and
Sprawls Educational Foundation
www.sprawls.org

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A Collaborative Model of Medical Physics Education Including Online Resources

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Effective
Medical Physics Educational Activities
Models and Methods

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