Effective Medical Physics Educational Activities

Models and Methods

Perry Sprawls, Ph.D
Emory University
sprawls@emory.edu

and

Sprawls Educational Foundation
www.sprawls.org

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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
The Elements of A Highly Effective Educational Session

The Brain

Connection

Observe

Interact

The Physical Universe
(Physics of Medical Imaging)

Teacher / Guide

“Window”

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.

Sprawls
The Spectrum of Learning Activities For Medical Physics
The Spectrum of Learning Activities
For
Medical Physics

Effectiveness

Verbal  ←  Visual

Sprawls
The Spectrum of Learning Activities
For
Medical Physics

Passive Verbal → Interactive Visual

Effectiveness

Sprawls
The Spectrum of Learning Activities
For
Medical Physics

Easy Passive Verbal

Effort Interactive Visual

Effectiveness

Sprawls
The Spectrum of Learning Activities
For
Medical Physics

$  
Easy

Passive

Verbal

$\$\$\$\$
Effort

Interactive

Visual

Effectiveness

Sprawls
The Spectrum of Learning Activities for Medical Physics

Tradition → Innovation

$ $ $ $ $ Effort

Easy → Interactive

Passive → Visual

Verbal

Effectiveness

Sprawls
The Spectrum of Learning Activities

For Medical Physics

Tradition

Economy

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 EMORY
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 learn.
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
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.
Technology Enhanced Learning

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

Physics Education

Efficiency
Location, Resources, Human Effort, Cost

Clinical Imaging

Limited Experience

Sprawls
Your Mind
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

AAPM 2014 Austin
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

Observe

Physical Universe

Learner

Interact

Our Early Physics Learning Activities
One of Our First Physics Lessons

Sensory Ball Pit
Learning By Direct Observation

Interacting

A Natural Human Function

Sprawls
Teaching is helping someone
Building a Knowledge Structure in the Brain

A mental representation of physical reality
Connect  Organize  Guide

Physical Universe
Teaching Physics Is Not
The Role of Formal Education

Connect

Learner

Observe

Interact

Organize and Guide

Physical Universe
The Elements of A Highly Effective Educational Session

- The Brain
- Connection
- Interact
- The Physical Universe (Physics of Medical Imaging)
- Teacher / Guide
- "Window"

Sprawls
What do they need?

Learner

“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

Physical Universe

A mental representation of physical reality
Network of Sensory Experiences

Inputs

- Visual
- Smell
- Taste
- Sound
- Feel

Sprawls
Learning Medical Physics Requires Observation Medical Physics Universe

Interacting With
The Most EFFECTIVE way to Build Physics Knowledge Structures

Audio
Human (Teacher)
Guiding The Process

Visuals
Technology
Teaching Medical Physics

Observation

Medical Physics Universe

Interacting With

Is

Connecting and Guiding

Sprawls
Teaching Medical Physics

"Window"

Provide Window
Guide the Learning Process

Teacher must

Sprawls
A Traditional "Window" to the Physical Universe
The inverse square law is:

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

where:
- $I_1$ is the initial intensity of radiation,
- $d_1$ is the initial distance,
- $I_2$ is the final intensity,
- $d_2$ is the final distance.

The X-ray beam now covers four times the area, and the photon concentration (exposure) decreased to 1/4th.

Twice the Distance:

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

\[ E_2 = \frac{E_1}{(d_2/d_1)^2} \]
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)
X-ray beam now covers four times the area.

Twice the Distance

Photon Concentration (Exposure) decreased to 1/4th
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

\[ E_2 = \frac{E_1}{(d_2/d_1)^2} \]
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
- Evaluate
- Control and Optimize
- Anatomy and Pathology
- Risk

Sprawls
What do they need?

Learner (Resident)

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

Learner (Resident)

View

Action

Sprawls
The Brain...

Structure and Function

Image: AMA
Knowledge Structures in the Brain

A Complex Network

Concepts
Images
Language
Facts
Sprawls
Knowledge of the Learning & Teaching Process

We learn from the pioneers

- Gagne
- Dale
- Zull
- Kolb

Sprawls
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

1. Concrete experience
2. Observation and reflection
3. Forming abstract concepts
4. Testing in new situations

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

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

- Active testing
- Premotor and motor
- Sensory and postsensory
- Concrete experience
- Temporal integrative cortex
- Reflective observation
- Frontal integrative cortex
- Abstract hypotheses

Circular flow diagram illustrating the model of brain function.
Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex
- Where (Relationships)
- What (Characteristics)
- Language (Identification)

Emotions

Frontal Integrative Cortex
- Making Plans
- Evaluating
- Problem Solving

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

Visible Physical Objects

Sensory

Back Integrative Cortex

chow chow
poodle
schnauzer
collie
bulldog
German shepherd
Forming Knowledge Structures

Physical Universe

Visible Physical Objects

Sprawls
Forming Knowledge Structures

Physical Universe

Radiation
Electrons
Magnetic
Atomic
Nuclear

Sensory

Back Integrative Cortex

Invisible Physical Objects
The inverse square law is:

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

where:
- \(I_1\) is the initial intensity of radiation,
- \(d_1\) is the initial distance,
- \(I_2\) is the final intensity,
- \(d_2\) is the final distance.

When the distance is doubled, the photon concentration decreases to 1/4th. The X-ray beam now covers four times the area.
Forming Knowledge Structures

Physical Universe

Inverse Square Effect

Sensory

Back Integrative Cortex

Invisible Concepts Ideas

Visuals

Sprawls
Zull’s Model of Brain Function
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 About Learning Physics

Control

Sensory
Back Integrative Cortex
Records of the Past Knowing Reflection

Frontal Integrative Cortex
Preparation for the Future Doing Hypotheses

Motor

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.
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

Sprawls
Rich Learning Environments

Control

Sensory
Back Integrative Cortex
Records of the Past
Knowing Reflection

Frontal Integrative Cortex
Preparation for the Future
Doing Hypotheses

Emotions

Sprawls
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

LOWER

VISUALS

Clinical Images and Graphics

VISUALS

With Expert Guidance

SIMULATION

PHYSICAL REALITY

VERBAL

SYMBOLS

EQUATIONS

SKETCHES
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
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
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
Visuals for Learning and Teaching

The Imaging Process

Clinical Images

The Three Phases of CT Image Formation

Scan and Data Acquisition

Image Reconstruction

Digital/Analog Conversion and Display Control

Major Control Factors

Sprawls
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

Bitmap Digital Images

Paint Programs

Used for Editing
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
Collaborative Teaching is Sharing the Work

Resource Physicist

Create visuals and related resources

Share with the World

Medical Physics Universe

Local Physicist

Organizes
Guides
Shares Experience
Motivates
Role Model

Sprawls
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
The Imaging Process

Clinical Images

The Three Phases of CT Image Formation

Scan and Data Acquisition

Image Reconstruction

Digital/Analog Conversion and Display Control

Major Control Factors

- KV
- Pitch
- Slice Th.
- FOV
- Matrix
- Filter

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/

Visuals for Classroom, Conference, and Collaborative Learning
RIGHT CLICK on each visual to download and use in PowerPoint or other display programs.
# Modules for Self Study and Collaborative Learning in the Clinic

**Computed Tomography Image Quality Optimization and Dose Management**

Perry Sprawls, Ph.D.

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To step through module, [CLICK HERE](#). To go to a specific topic click on it below.
Effective Medical Imaging Physics Learning

...In The Clinic

The Real World  Motivating  Interactive  Collaborative

Radiologist

Resident

The Physicist Provides:
Learning Modules & Collaboration
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 Most EFFECTIVE way to Build Physics Knowledge Structures

Audio Human (Teacher) Guiding The Process

Technology

Visuals

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

Computed Tomography Image Quality Optimization and Dose Management

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

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

Computed Tomography

CT Image Characteristics

CT Image Characteristics

Objects in the Body

Anatomical Detail

Contrast Sensitivity

High Med Low

CT Image Characteristics

Reference

Sprawls

http://www.sprawls.org/resources/CTIQDM/
CT Image Characteristics

Spatial

Detail

Artifacts

Noise

Contrast Sensitivity

Major Protocol Factors

KV
Pitch
Slice Th.

MA
Beam Wid.
FOV

Time
Filter
Matrix

Window Width
Window Level
Zoom

Sprawls
CT Slice Divided into Matrix of Voxels

Field Of View (mm)

Matrix Size (voxels/pixels)

Slice Thickness (mm)

Voxel Size Controlled By

FOV ÷ Matrix = Slice Th.
Factors That Determine Image Noise

- KV
- MA
- Time
- Pitch

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

Scan Data

Filtered Back Projection

Filter

Voxel Size Determines Number of Photons

Slice Th.

FOV

Matrix

Digital Image
CT Dose Quantities

Effective Dose

Factors

DLP

Scan Length

KV

Time

MA

Pitch

CTDI_weighted

CTDI_volume

Sprawls
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.
Conclusion
Using Knowledge For
More Effective & Efficient Learning Activities
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)
The Elements of A Highly Effective Educational Session

The Brain

Connection

Observe

Interact

The Physical Universe (Physics of Medical Imaging)

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
Emory University
sprawls@emory.edu
and
Sprawls Educational Foundation
www.sprawls.org

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A Collaborative Model of Medical Physics Education Including Online Resources

Perry Sprawls, Ph.D
Emory University
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Effective
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