Informatics for Medical Physics Education

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

Sprawls Educational Foundation
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

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Informatics for Medical Physics Education

Learning Objectives

Use Technology to Enhance Human Performance for both Learners and Teachers

Use technology to enrich medical physics learning activities making them more effective and efficient
The Traditional Classroom

“A Box for Enclosing Students...”

And hiding them from the world about which they should learning.
The Barrier

Physics Education

Clinical Imaging

Efficiency
- Location, Resources, Human Effort, Cost

Limited Experience

Sprawls
Learning Physics is Building a Knowledge Structure in the Brain

A mental representation of physical reality
Let’s look into our brain.
Let’s look into our brain.

Look for balls.
Let's look into our brain.
Feel the ball.
The Physics of Balls
Knowledge Structure
The Classroom Lecture About Balls
One of Our First Physics Lessons

Sensory Ball Pit
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

Physical Universe

Learner

A mental representation of physical reality

Connect  Organize  Guide

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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

Observe

Interact

The Physical Universe (Physics of Medical Imaging)

Teacher /Guide

“Window”

Sprauls
Our Plan for Today

Human Brain
Knowledge Structures
How We Learn
What we need to know

Learning Activities
Effectiveness
Efficiency

Medical Physics Universe
Clinical Applications

Technology Tools & Applications

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Informatics for Medical Physics Education Works in Progress
Development of Applications

Evolution of Technology
WELCOME TO EMORY
My name is Perry Sprawls
I am your teacher
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” Sprawls
The Sprawls Resources
Users, April 2013

Global Impact
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

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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
- Risk
- Anatomy and Pathology
The Elements of A Highly Effective Educational Session

The Brain

Connection

Observe

Interact

The Physical Universe
(Physics of Medical Imaging)

Teacher/Guide

“Window”
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.
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” Sprawls
Educational Informatics

A Large Umbrella

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Educational Informatics

Technology

Human Brain

Impact

Does it enhance or deteriorate human performance?

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Educational Informatics

Warning
There are risks of adverse effects for both
Learners and Teachers

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My Value...

Technology is a Tool it is not The Teacher
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

Concrete experience

Observation and reflection

Forming abstract concepts

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

Reflective observation

Temporal integrative cortex

Frontal integrative cortex

Abstract hypotheses
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

Language
- Comprehension
- Assembly

Motor

Sprawls
Brain Functions for Learning Physics

Control

Sensory

Back Integrative Cortex

Records of the Past

Reflection

Motor

Frontal Integrative Cortex

Preparation for the Future

Hypotheses

Emotions

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

Sensory

Visible Physical Objects

Sprawls
Forming Knowledge Structures

Physical Universe

Visible Physical Objects

Sensory

Back Integrative Cortex

Sprawls
Forming Knowledge Structures

Physical Universe

Radiation
Electrons
Magnetic
Atomic
Nuclear

Sensory

Back Integrative Cortex

Invisible Physical Objects

Sprawls
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

Verbal

Sensory

Mathematical

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The Inverse Square Law

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

Where:
- \( I_1 \) is the initial intensity of radiation,
- \( d_1 \) is the initial distance, and
- \( I_2 \) is the final intensity,
Forming Knowledge Structures

Physical Universe

Inverse Square Effect

Sensory

Back Integrative Cortex

Invisible Concepts Ideas

Visuals

Sprawls
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
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

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

Sense and Experience Observe

Interact and Affect

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

1. Problem Solving
2. Rule Learning
3. Concept Learning
4. Discrimination Learning
5. Verbal Association
6. Chaining
7. Stimulus Response
8. Signal Learning
Challenging Learning Environments

Records of the Past
Knowing Reflection

Preparation for the Future
Doing Hypotheses

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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

VERBAL
SYMBOLS
EQUATIONS

SKETCHES

VISUALS
Clinical Images and Graphics
VISUALS
With Expert Guidance

SIMULATION

PHYSICAL REALITY

EFFICIENCY

HIGH

LOW
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

Visuasl 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

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Technology Enhanced Learning

Learning Guide

Learner

Visuals for Classroom

Notes and Text

Online Resources

Compton Scatter Interactions

X-ray photon

Energy

Weak

Nucleus

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Technology Tools

Connectivity
Technology Tools
Developing Digital Images

I’m a bitmap. I’m a vector.
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

Paint Programs

Used for Editing
The Three Phases of CT Image Formation

Scan and Data Acquisition
- KV
- MA
- Time
- Pitch
- Beam Wid.

Image Reconstruction
- Slice Th.
- FOV
- Matrix
- Filter

Digital/Analog Conversion and Display Control
- Window Width
- Window Level
- Zoom

Major Protocol Factors

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Decreasing Noise

Requires Increased Photons Absorbed Per Voxel

Produces Increasing Dose
Technology Tools
Web Conferencing

WebEx

GoToMeeting

Use in “share desktop” mode.
The Model

Online Courses
  Modular Courses  MOOC

Reduce the need and opportunity for local faculty

Local Universities
The "radio university" that Prof. Michael Pupin, of Columbia University, believes is sure to come with the further development of the loudspeaker. From the classroom where the university professor lectures to a group of his students—

A COLLEGE education for every one who wants it.
A university in the home, in the factory and mill, and in the public hall.
An "aerial soapbox" for the forces of economic progress and right.

A complete course in practically any of the subjects now named in the college curriculum—for five dollars; an elementary course in these subjects for one dollar, and

Radio will carry a wealth of authoritative information and scientific knowledge to hundreds of town halls, factories, and firesides, offering a higher education to thousands of men and women to whom such training has hitherto been denied.

"In each of the 100 halls 1000 persons—100,000 persons in all—are receiving an education without even leaving the limits of their own neighborhoods!"

"Such a picture represents, to my mind, what radio may mean soon as a broadcaster of useful knowledge and as a disseminator of vital information."

"Go a step further. Enter a factory or mill of the future. It is lunchtime and,

Prof. Michael Pupin
Professor of physics; head of the Phoenix Research Laboratory at Columbia University, and inventor of the Pupin coil, which made possible transcontinental telephony
The Collaborative Teaching Model

Online Resources
- Modules
- Books
- Visuals

Enhance the performance of physics faculty

Knowledge Experience Guidance Role Model

Local Universities

Sprawls
The Elements of A Highly Effective Educational Session

The Brain

Connection

Observe

Interact

The Physical Universe
(Physics of Medical Imaging)

Teacher / Guide

"Window"
The Collaborative Teaching Model

Sprawls Online Resources
Modules Books Visuals

Enhance the performance of physics faculty
Residents & Radiologists

Local Universities

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.
# 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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<th>Contrast Sensitivity</th>
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Effective Medical Imaging Physics Learning...In The Clinic

The Real World  Motivating  Interactive  Collaborative

The Physicist Provides: Learning Modules & Collaboration

Radiologist

Resident

Sprawls
# 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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KV Values for Mammography

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.

We 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 forward 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.
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
- Pitch
- Slice Th.
- FOV
- Matrix
- Filter
- Window Width
- Window Level
- Zoom

Clinical Images
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

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CT Slice Divided into Matrix of Voxels

Field Of View (mm)

Matrix Size (voxels/pixels)

Slice Thickness (mm)

FOV \div \text{Matrix} \rightarrow \text{Slice Th.}

Voxel Size Controlled By
Factors That Determine Image Noise

- **KV**
- **MA**
- **Time**
- **Pitch**

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

- **Slice Th.**
- **FOV**
- **Matrix**

**Digital Image**

**Filtered Back Projection**

**Scan Data**

**Voxel Size Determines Number of Photons**
CT Dose Quantities

Effective Dose

Factors

DLP
Scan Length

CTDI weighted

CTDI volume
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.*
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 Sprawls Resources
Users, April 2013

Global Impact
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.
In Partnership with Other Medical Physics Teachers to be More Effective and Efficient in Providing Medical Imaging Education
Conclusion
In This Session
Building Knowledge Structures

Human (Teacher)

Visuals

Informatics

Technology

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.spawrls.org/ipad)
Conclusion
After This Session
Enhancing Knowledge Structures
Review & Refresh
Technology
Create
Sprawls
Sprawls References for Additional Viewing

AAPM Virtual Library Presentations

1. The Elements of a Highly Effective Educational Session
2. Medical Physics and Technology Education for Society: Adults, Teenagers, and Elementary Students
3. Effective Medical Imaging Physics Education
4. Clinically Focused Physics Education
5. Education Council Symposium - Effective Use of Web-Based Resources to Enrich Classroom and Collaborative Learning Activities
6. Models and Resources for Intergrated Teaching and Learning of Medical Imaging Physics and Technology

Published in Medical Physics International (www.mpijournal.org)

Physics Education for the Optimization of MRI Clinical Procedures: Visualizing the Invisible and Collaborative Teaching

Effective Physics Education for Optimizing CT Image Quality and Dose Management with Open Access Resources
Conclusion
Using Knowledge For
More Effective & Efficient Learning Activities
The Physicist as an Educator and Teacher

Our Objectives

Provide more EFFECTIVE learning activities.

Be EFFICIENT in our teaching

Challenges Opportunities

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Informatics for Medical Physics Education

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