Development and Refinement of Biomedical Labs: Magnetic Resonance Imaging and CT Scans

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Physics Education Research

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Outline

- Overview of MMMM project
- MRI activity
- CT activity

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Modern Miracle Medical Machines

- NSF sponsored program
- Project to develop learning activities based on medical applications
- Activities typically incorporate both a hands-on activity and a computer-based visualization

Modern Miracle Medical Machines

- Wavefront Aberrometry
- Positron Emission Tomography (PET)
- Magnetic Resonance Imaging (MRI)
- X-rays and Computed Tomography (CT) Scans
- Alexander Graham Bell's Experiment

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http://web.phys.ksu.edu/mmmm

Outline

- Overview of MMMM project
- MRI activity
- CT activity

Approach

- Develop a hands-on activity
- Locate supporting visualizations
- First draft of worksheet
  – Use knowledge of research base
  – Use experience
  – Have other experienced researchers/teachers read through materials
- Testing and refinement

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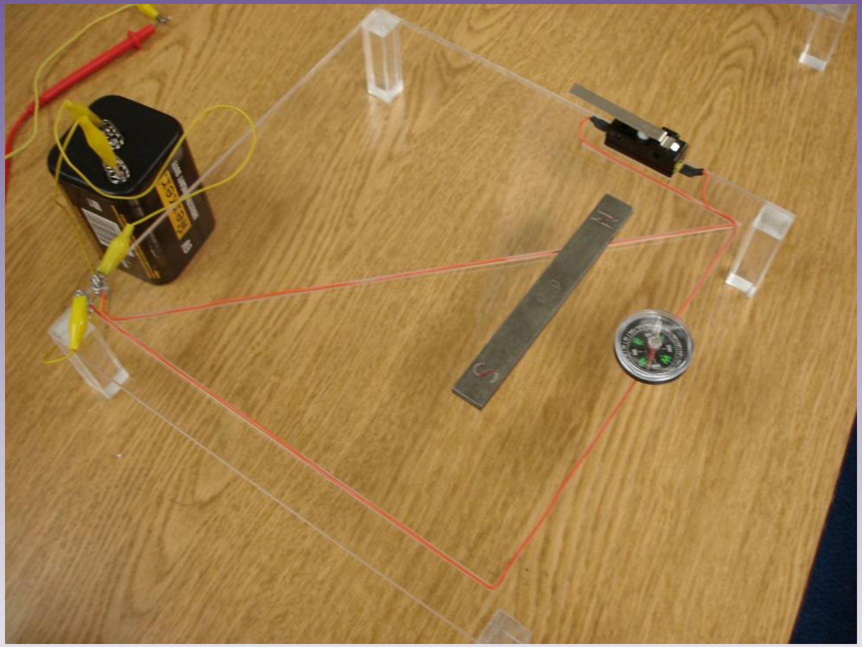
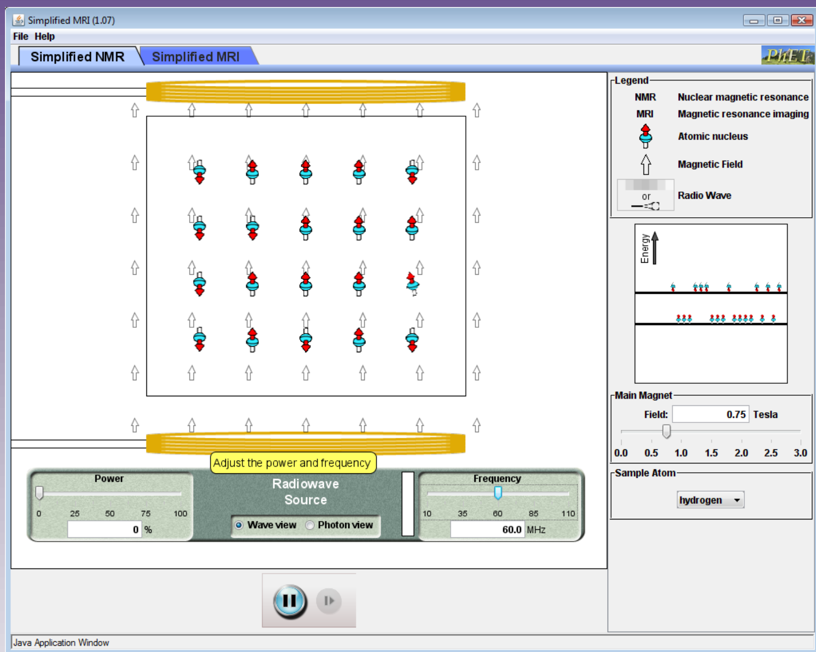
Hands-On Activity

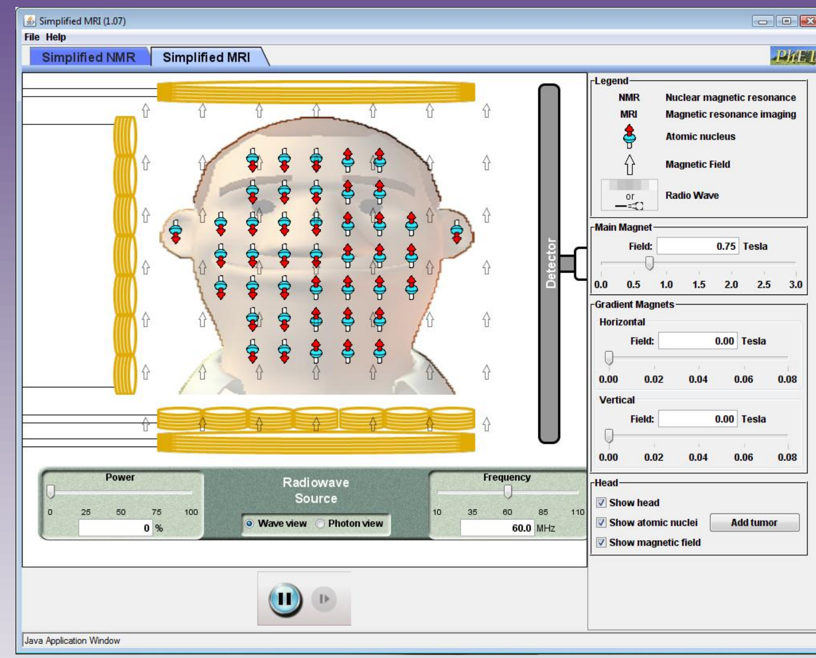


- Compass => Atoms
- Electromagnetic Field => Electromagnetic Wave
- Field from Magnet/Earth => Fields from Magnets

Visualization



NMR



MRI

http://phet.colorado.edu/en/simulation/mri

What's Needed…

- In order to understand the hands-on activity and the visualization, students must:
  – Understand magnetism and electromagnetism
    - Field due to a bar magnet
    - Field due to a wire
    - Effect of a magnetic field on compass orientation
  – Understand resonance
    - Dependence of frequency on physical parameters of the oscillator, external field and initial amplitude

Activity Outline

1. Magnetism Basics
2. Electromagnetism
3. MRI Magnets
4. Resonance
5. NMR
6. MRI
7. Summary

Research Base -- Magnetism

- D. P. Maloney, *Phys. Educ*. **20,** 310–316 (1985).
  - Magnetic poles are "charged"
- A. B. Arons, *A Guide to Introductory Physics Teaching*, (John Wiley and Sons, 1990)
  - Advice on how to teach Oersted's experiment
- L. C. McDermott *et al.*, *Tutorials in Introductory Physics*, (Prentice Hall, 1998)
  - Research-based curriculum for teaching the basics of magnetism

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Experience Base -- Resonance

- Students don't know what it means to be resonant
  - Have them work through what it means to be resonant
- Students have not experienced the novel resonant system in our hands-on activity
  - Have them start with a (more) familiar system – the pendulum

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Experience Base -- Resonance

- Students think that a pendulum's frequency depends on mass, amplitude, and length
  - Have them measure for mass and length.
  - Add an anchor point.
- Students tend to miss the frequency dependence on gravity
  - ?????
- Now address the novel resonant system

To This Point…

- First draft written
- Discussed and worked with during a seminar
- V3: tested with graduate students
  - All the materials
- V4: tested with undergraduate students
  - As far as possible in 1-hour (typically to resonance)
- V5: tested with REU students
  - All the materials

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Change #1

- Switched from a quantitative to a qualitative measurement of compass oscillation frequency
  - Hard to measure accurately
  - Easy to compare the motion of two compasses
  - Focus on the measurement distracted from what was actually happening
- Modification: added "by eye" to the instructions

Change #2

- Found that students were not noticing how the block arrows in the visualization were changing when the strength of the magnetic field was adjusted.
- Modification: moved a question on this to an earlier point in the activity

MRI_v5a 19

♦ In the table below, you are given three main magnet strengths. Using the visualization, determine what is the smallest possible strength of the vertical gradient magnet can be used to make the atoms at the top (and bottom) of the head resonate.

Part of Person's Head	Main Magnet (T)	Vertical Gradient Magnet (T)
Top	1.19	
	1.15	
	1.11	
Bottom	.89	
	.86	
	.82	

MRI_v5a 20

♦? Now click the "Add Tumor" button on the lower right. Can you cause only the part of the person's head that contains the tumor to resonate? How?

? In your own words, explain what you have learned about MRI and how the image is formed.

MRI_v5a 21

V5

MRI_v6 19

Earlier you learned that there is a range of magnetic field strengths over which the atoms will resonate for a given frequency. As a reminder, if the frequency is set to 42.5 MHz, then the atoms will resonate when the strength of the main magnetic is set anywhere between 39.5 T and 45.5 T.

MRI_v6 20

♦ Now unclick "Show atomic nuclei" and then click the "Add Tumor" button on the lower right.

The part of the head with the tumor will behave differently than the parts without the tumor. But, because you can no longer see the atomic nuclei, you, like a real doctor, can only use the emission from the MRI process to determine where in the head the tumor is.

♦Describe the process you will use to try to find the tumor.

♦? Did you find the tumor? If so, in which quadrant of the head is the tumor located?

If not, try setting the frequency and adjusting first the main magnet and the vertical gradient field, keeping the horizontal gradient field at zero. This allows you to scan the head from top to bottom. Then, repeat the process scanning from side-to-side by adjusting the main magnet and the horizontal gradient field with the vertical gradient field at zero.

♦? After you have made your best attempt to find the tumor, reclick "Show atomic nuclei." Were you correct?

? What about the emission from the area containing the tumor allowed you to determine the tumor's location?

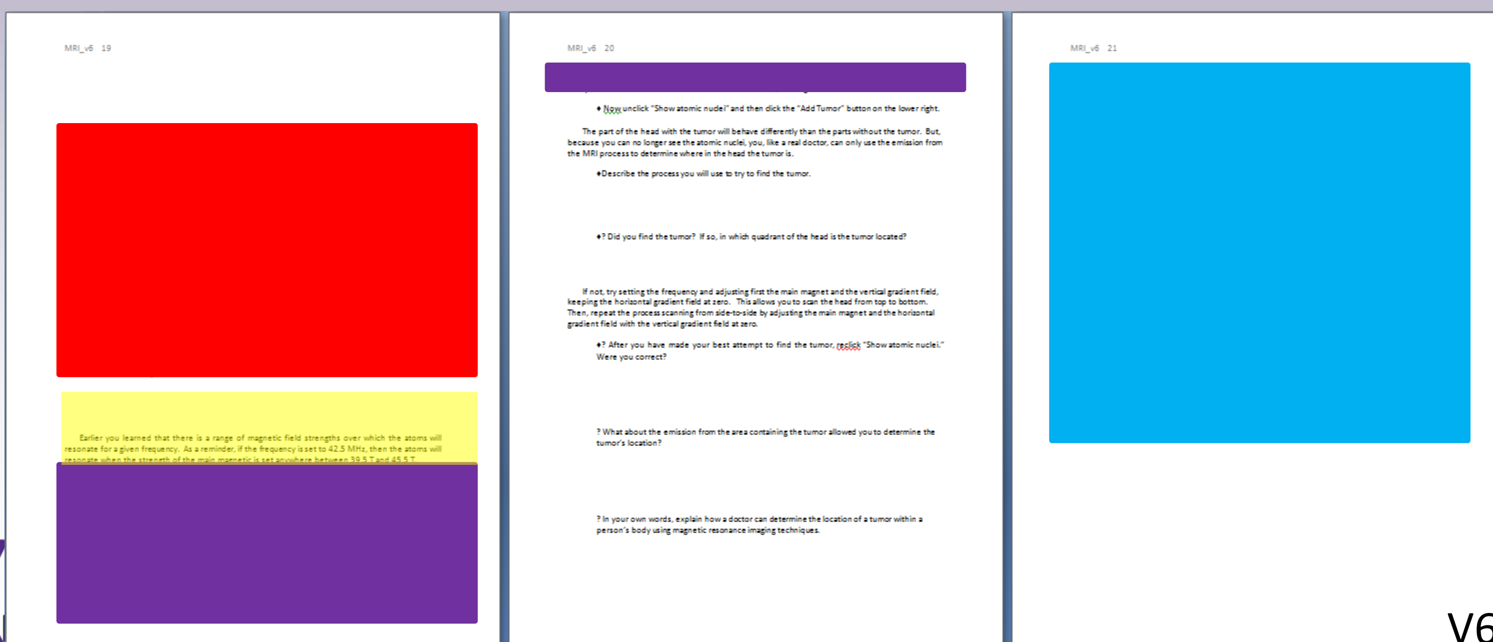
? In your own words, explain how a doctor can determine the location of a tumor within a person's body using magnetic resonance imaging techniques.

MRI_v6 21

V6

Added Portion

- Anchor – reminds students of something they already learned in the activity



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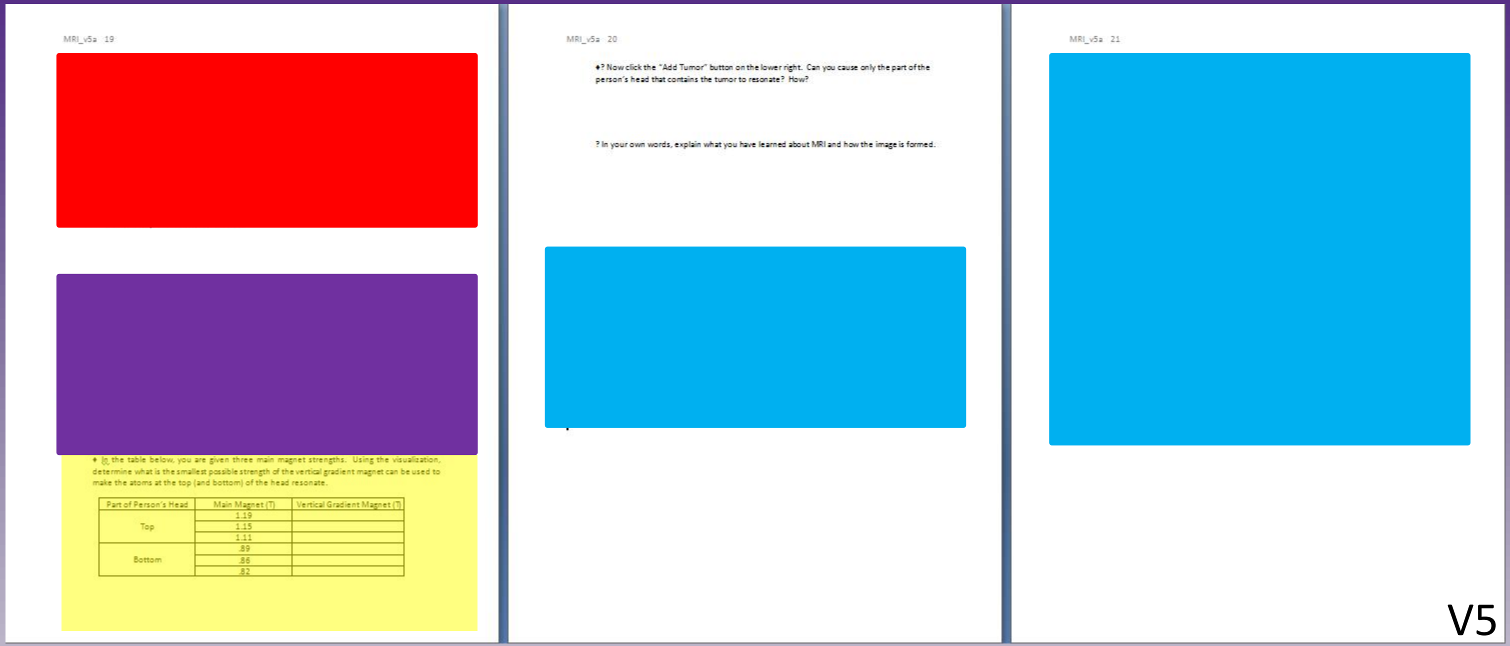

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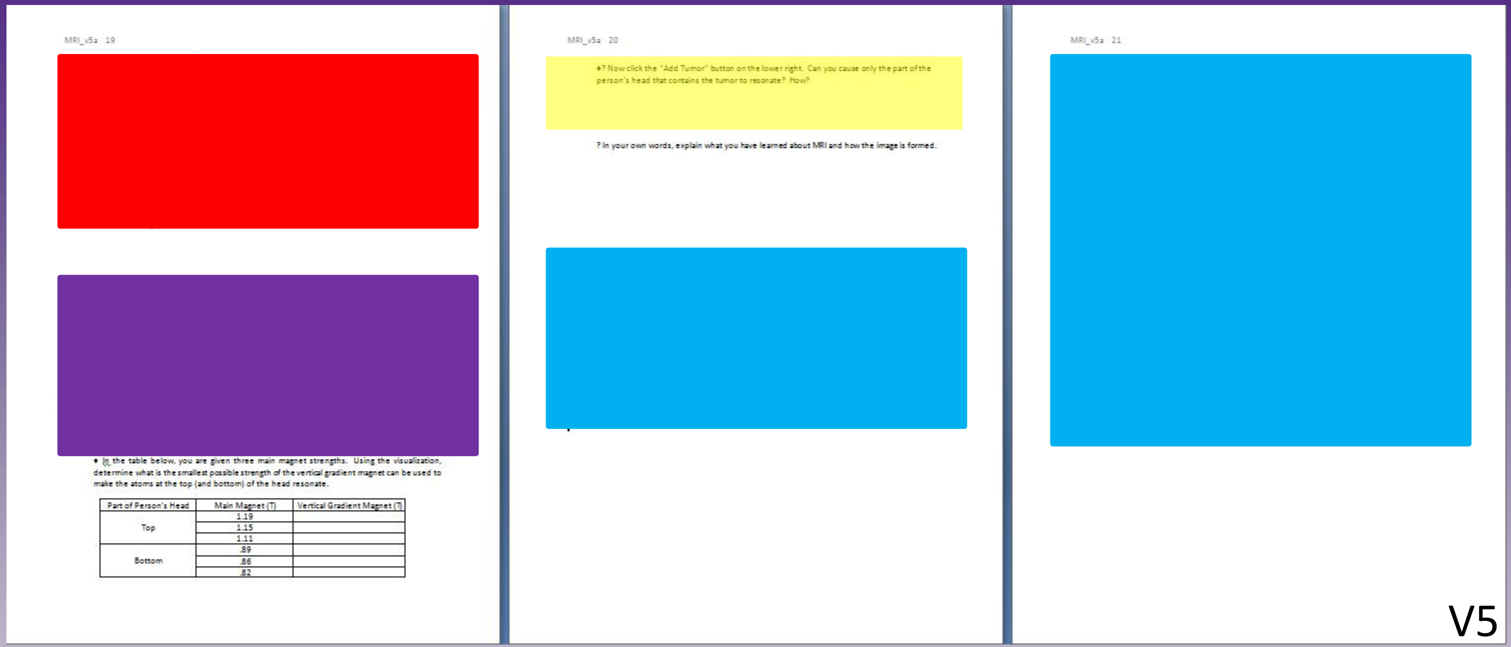
Removed Portion

- Multiple "measurements" within the visualization
- Time consuming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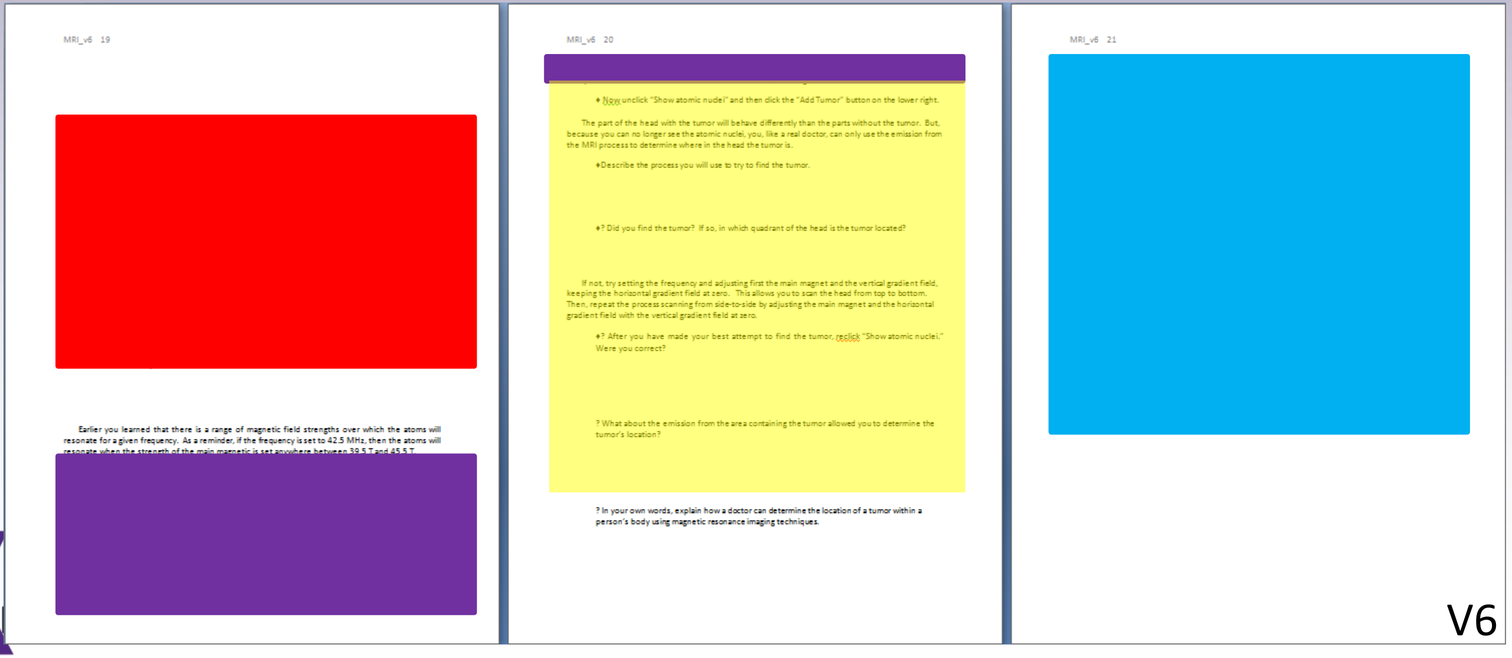
Removed Portion

- Focus on making only area with the tumor resonate
- Students could see the tumor

Added Portion

- Tumor is now hidden
- Students describe the process
- Students look for tumor on own first
- Describe process for finding the tumor



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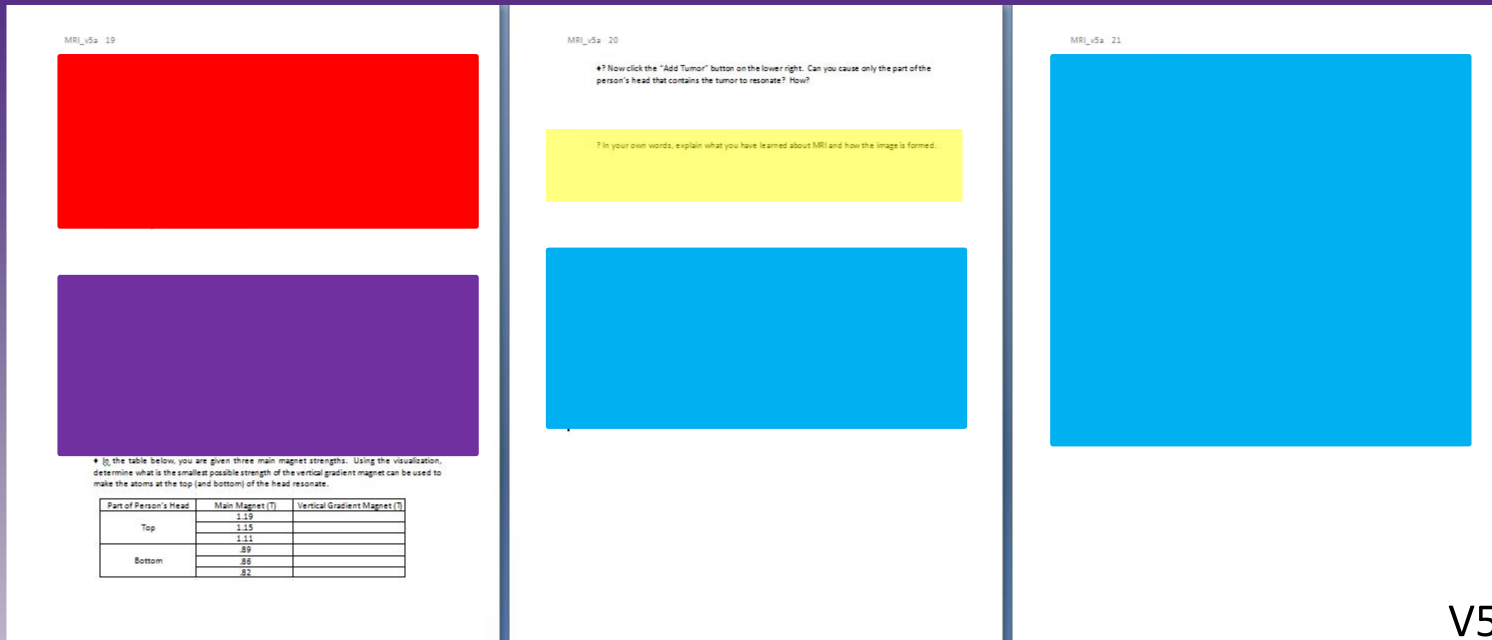

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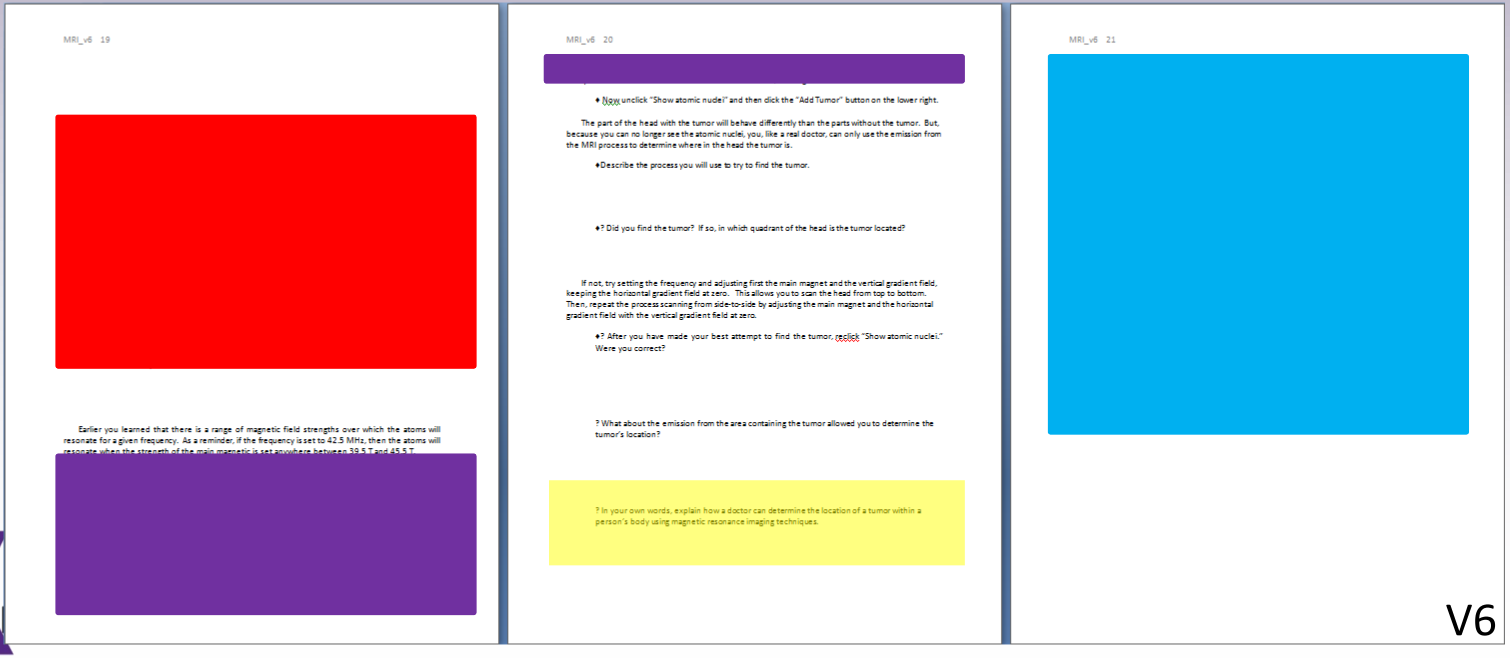
V5

Original Final Thought

- "In your own words, explain what you have learned about MRI and how the image is formed"

Reworded Final Thought

- “In your own words, explain how a doctor can determine the location of a tumor within a person’s body using magnetic resonance imaging techniques?”



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MRI_v6 21

V6

V6 Classroom Implementation

- At Mercyhurst College
- Spring 2010
- 22 students in 8 self-selected groups

- Submitted to PERC.

V6 Classroom Implementation

- Students had difficulty identifying the factors influencing the period of a pendulum
- Students had difficulty measuring the compass's oscillation frequency

In the Next Draft…

- Modify the worksheet to …
  - Further assist with the understanding of frequency.
  - Help see the link between the hands-on activity and the visualization.
- Modifications will include:
  - Additional scaffolding.
  - Rewording/rephrasing of questions.

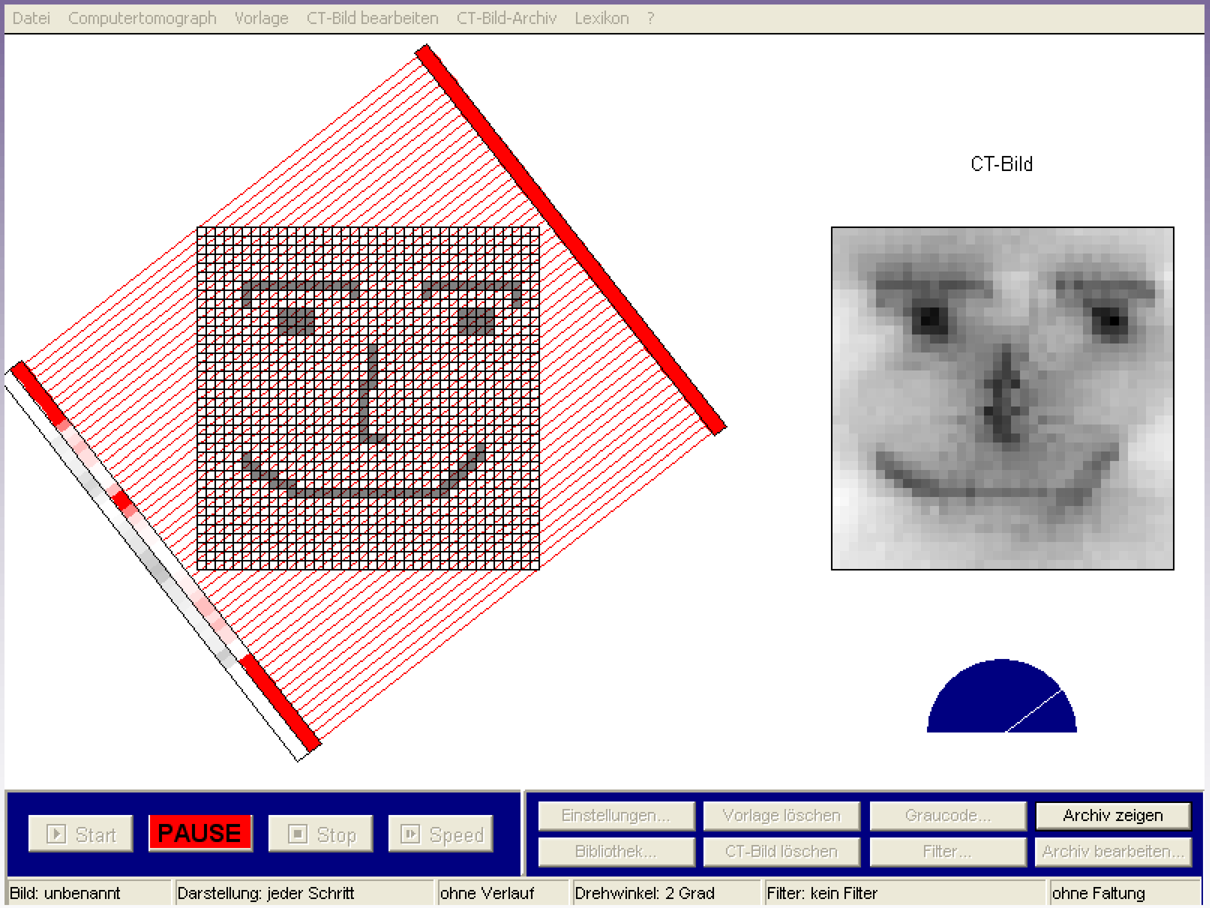
Outline

- Overview of MMMM project
- MRI activity
- CT activity

Current Status

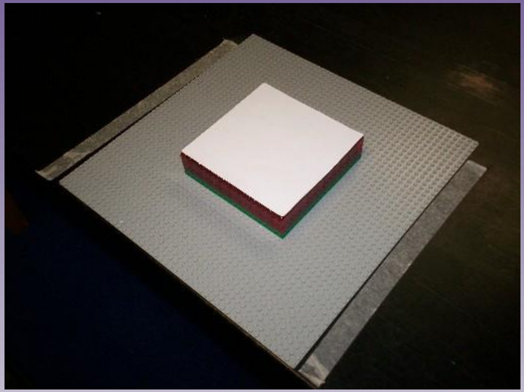
- Research base in the form of a PhD dissertation
- Visualization written
- New hands-on activity has been developed
- Need to write and test the worksheets combining these elements.

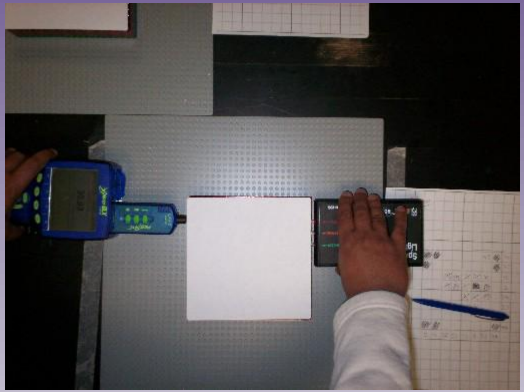
Visualization

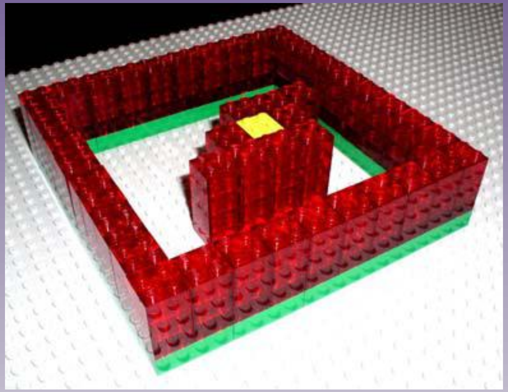


Program written by Monica Ring Muthsam, 1999

The Original Activity



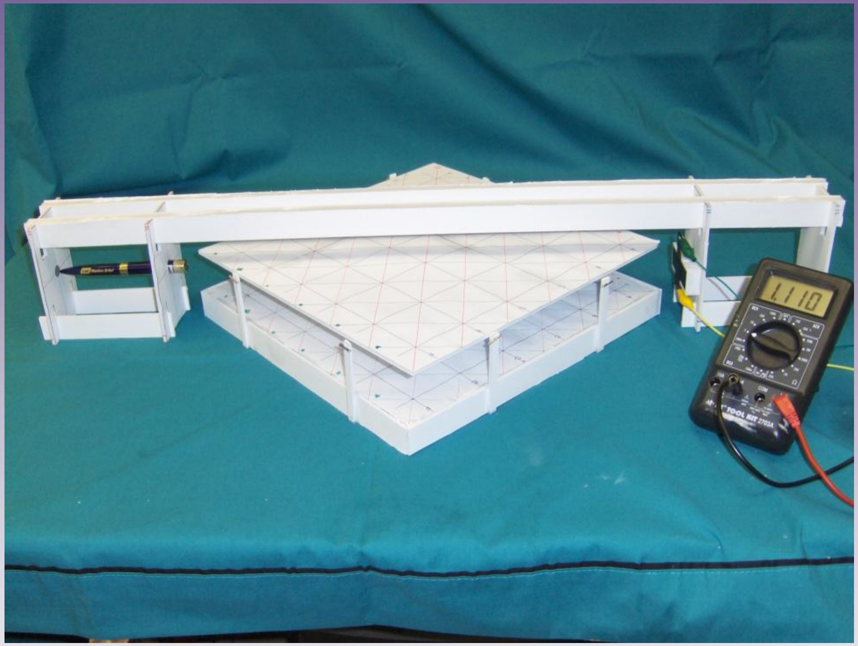




Pictures from Kalita (2008)

- Legos and detector are expensive
- Measurements were dependent on relative positions of laser, Lego, and detector
  - Time of manufacture of Legos determines optical properties

The New Activity



- Laser => X-ray source
- Solar cell => X-ray detector
- Filter => Tumor

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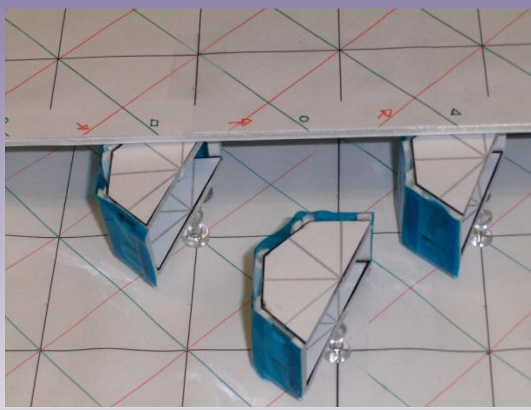
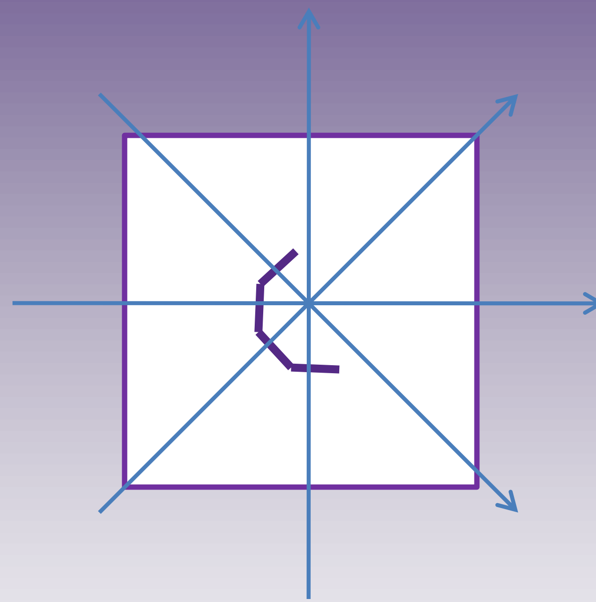
This hands-on activity is on display at the apparatus competition in the Grand Parlor B/C at the Hilton.

The New Activity





	A	B	C	D	E	F
1	4	1	3	2	3	3
2	4	2	3	2	3	5
3	3	2	3	2	3	1
4	2	3	6	5	2	3
5	2	2	7	4	4	3
6	4	4	4	6	6	4

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Final Thoughts

- Overview of development/refinement process of two activities
  - Begin with hands-on activity
  - Use of experience and research as basis of activity
  - Further testing to refine
- Knowledge and experience are not enough!
  - Always room for improvement!

Acknowledgements

- MRI: B. N. Meera and Josh Gross
- CT: Spartak Kalita and Brandon Sargent
- Members of KSUPER
- Munich PER group
- National Science Foundation

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