Inquiry into Radiation - IiR

Radiation Literacy for Non-Science Majors and High School students

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Direct Experiments With Radiation

Students perform experiments with geiger counters to determine:

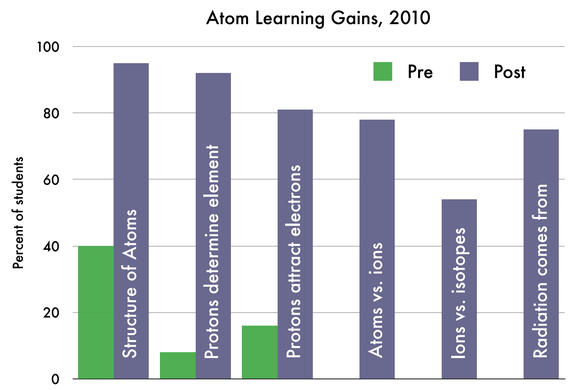
- Rate and statistics of background radiation
- Ubiquity & variation of background radiation
- Particulate character of readings
- Types of radioactive objects
- Relative hazard of classroom sources
- Types of radiation (alpha, beta, gamma)
- No contamination/transfer of radiation
- Penetrating power of alpha, beta, gamma
- What a half-life is, using ^{137}Ba

Other experiments:

Differentiating EM from Ionizing radiation

Stochasticity of dice and coins

Atoms Learning Results



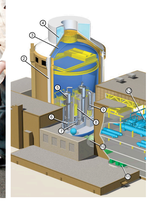
Data from 2010:

Students showed substantial improvement in understanding of atomic structure and conditions related to radioactivity.[5]

More recent versions of the materials give better isotope learning results.

Radiation Literacy?

A nuclear powered world needs a nuclear-literate populace. Recent efforts to initiate a nuclear renaissance and the disaster in Fukushima highlight the need for broad-based understanding of basic ideas about radiation.[1]



Unfortunately, most people have very limited understanding of radiation. Problems include:

- Not distinguishing EM from ionizing radiation
- Thinking of source and radiation as the same[2]
- Thinking of radiation as material or chemical
- Thinking radiation causes radioactivity[3]
- Believing harm comes from becoming radioactive
- Not understanding atoms as sources and victims of radiation
- Complete unawareness of the process of ionization

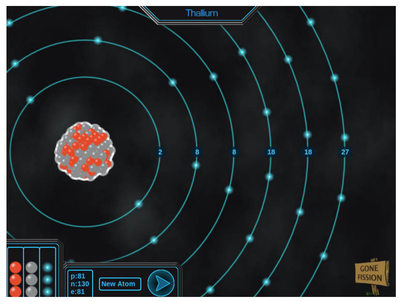
With the IiR course materials, HS and college non-science students can:

- Use ideas of atoms as sources & victims of radiation (80%)
- Develop a model of radiation as subatomic particles (70%)
- Describe ionization as the tissue damage mechanism (70%)
- Understand atoms, emission, fission products, half lives, types of radiation, contamination vs. irradiation, etc.
- **Enjoy learning about radioactivity!!**

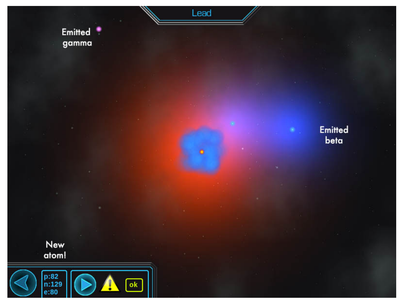
Atom Builder Simulator

Students investigate the structure and behavior of atoms using the specially designed Atom Builder.

Students build atoms in schematic view and send their atoms to Testing to identify ion behavior and later discover radioactive nuclei. They build multiple atoms to make sense of naturally occurring vs. manmade isotopes. Students identify nuclear processes involved in alpha and beta emission.[5]



^{211}Thallium in builder view



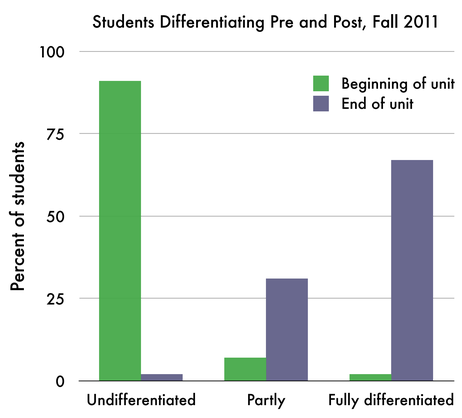
^{211}Thallium exploded in Testing and emitted a beta!

Developing a Viable Model of Radiation and Radioactivity

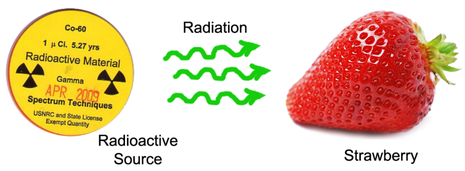
One of the major conceptual issues is ***differentiation*** of radioactivity from radiation. Students initially believe that radiation is "bad stuff", that it contaminates objects making them radioactive, and they use the words "radioactive" and "radiation" interchangeably.

Students must change from the "undifferentiated" view to the "differentiated" view in order to understand radiation as scientists do.

In 2011 we examined student thinking and found that the majority of students started out undifferentiated, but successfully changed![4]



Conceptual Difficulties - The Strawberry Question

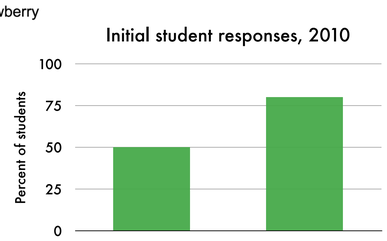


"A strawberry is placed near a radioactive source. Which of the three shown are radioactive?"

"After the source is removed, did the strawberry become radioactive?"

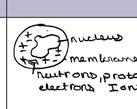
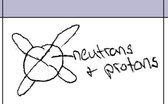
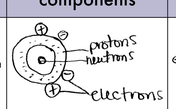
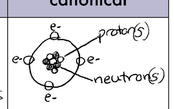
When asked whether radiation will make a strawberry radioactive, most students initially believe it is or could become radioactive, depending on the strength of the source and/or the amount of time.[4]

Strawberry question from Prather & Harrington, 2001[3]



Difficulties With Atoms

Pre-instruction, 74 students were asked to draw pictures of atoms. Only 40% drew useful diagrams.[5]

Circles/Molecules	Cell-Like	Orbital Unlabeled	Misplaced components	Reasonably canonical
				
8%	8%	11%	32%	40%

What determines which element an atom is?

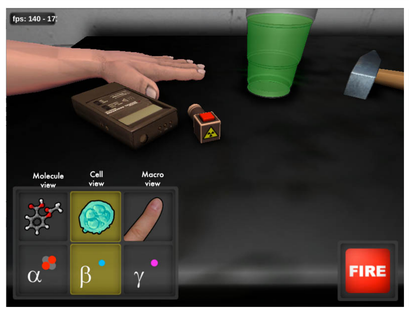
- Number of protons - 11%
- Number of something - 32%
- Other answer - 8%
- No answer - 50%

What holds electrons in atoms?

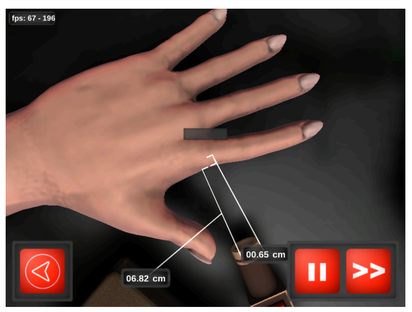
- Protons attract electrons - 11%
- Bonds or nucleus - 30%
- Gravity - 11%
- Walls or membranes - 9%
- Other - 40%

Tracks Simulator

Students investigate effects of radiation at three size scales using the Tracks simulator. Understanding the health effects of radiation requires "zoom scale" thinking - students must think on three size scales (macro, cellular, molecular) and combine ideas from each scale level.

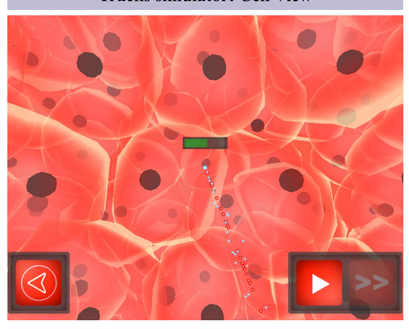


Overview of the Radiation Lab



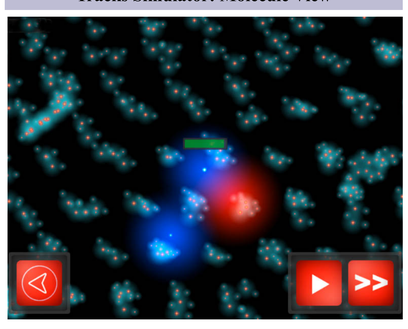
Path of a beta particle in macro view

Tracks simulator: Cell View



A beta leaves a trail of ions (red dots) through cells in the hand

Tracks Simulator: Molecule View



A beta removes an electron from a molecule inside the hand

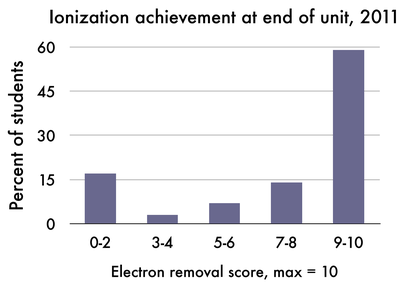
Students use their observations in the Tracks simulator to develop a theory of radiation ionizing atoms and breaking molecules, which causes chemical damage to DNA and other parts of cells.

This new model of molecular damage displaces the initial idea of radiation as "bad stuff".

Understanding Ionization by Radiation

Radiation-literate students must recognize that radiation ionizes atoms and breaks molecular bonds, potentially harming living cells or inanimate materials. This is not easy.

In 2011 we found that understanding atoms and differentiating appear to be prerequisites for developing and using a viable mental model of ionizing by radiation.[6]



Future directions:

We are now studying the process of differentiation and finding that students do not readily differentiate radiation from radioactivity.

Differentiation seems to require extensive development of new concepts and repeated, significant challenges to the old undifferentiated view. This aspect of promoting radiation literacy may not be easy or straightforward!

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References

1 Wallace, R. (2011). Discrimination increases torment of Fukushima. The Australian. Sydney, News Limited, June 11, 2011.

2 Millar, R. and J. S. Gill (1996). "School students' understanding of processes involving radioactive substances and ionizing radiation." Physics Education 31 (1): 27 - 33.

3 Prather, E. and R. Harrington (2001). "Student Understanding of Ionizing Radiation and Radioactivity: Recognizing the Differences Between Irradiation and Contamination." Journal of College Science Teaching 31(2): 89-93.

4 Maidl, R., N. Dekay, et al. (2012). Identifying & Resolving Problematic Student Thinking About Ionizing Radiation. National Conference on Undergraduate Research, Weber State College, Ogden, UT, UNC Asheville.

5 Johnson, A., Hafele Anna (2010). Exploring Student Understanding of Atoms and Radiation With The Atom Builder Simulator. 2010 Physics Education Research Conference, Portland OR, American Institute of Physics.

6 Hafele, A. and A. Johnson (2012). Exploring Learning Difficulties Associated with Understanding Ionizing By Radiation. National Conference on Undergraduate Research, Weber State College, Ogden, UT, UNC Asheville.