Student Journeys for Understanding Radiation & Radioactivity

Ryan Anderson, Anna Hafele (Andy Johnson) CAMSE, Black Hills State University, Spearfish SD 57799-9005

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Recent renewed interest in nuclear power and the public response to the Fukushima disaster highlight the need for radiation literacy.

The Inquiry into Radioactivity Project (IiR) is developing and testing course materials for non-science majors to understand basics of nuclear radiation and radioactivity.

Students' initial ideas strongly hamper their understanding radiation - they think of it as "bad stuff that makes other objects radioactive." [1, 2, 3] Understanding the basics of radiation is essential to learning the ionizing process. [4]

The IiR materials successfully move most students to conceptualize radiation as high speed subatomic particles. This is called the "differentiated view". [1, 2]

When does it happen? How difficult is this conceptual transformation?

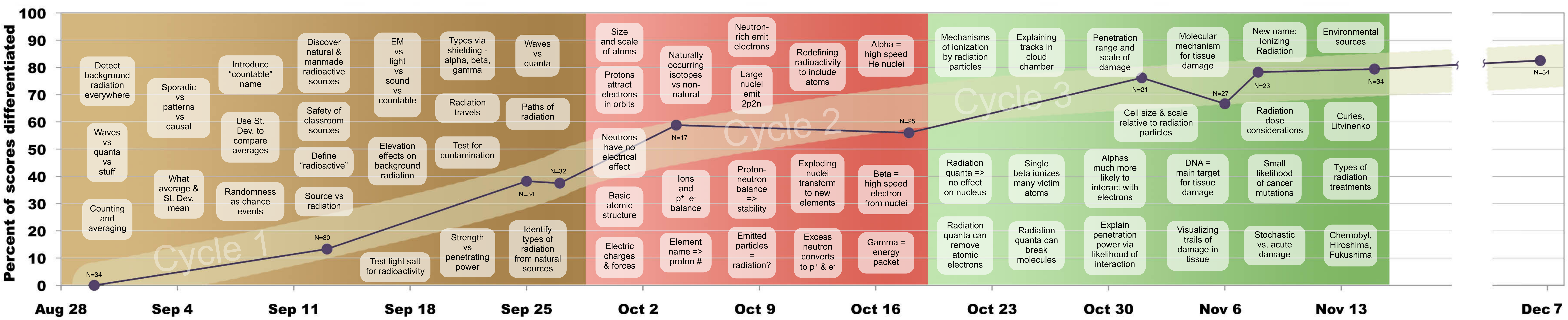
The IiR materials are being trial tested in a Survey of Physics course for non-science majors. Research data consisted of conceptual evaluations, homework, exam responses, etc. Not all data sets were complete. We examined all student work for evidence of undifferentiated thinking in three categories:

- **Radiation as "stuff":** Radiation can be 'on' or 'in' objects.
- **Contamination:** Radiation makes other objects radioactive.
- **Radiation = radioactive:** No distinction between the two.

Figure 1 shows the percent of students for which we have data who showed evidence of fully differentiating radiation from radioactivity in all three categories - if it was possible to tell - at various points during the semester.

Rounded boxes list significant content and concepts addressed by the course materials (usually worked out by students). Numbers next to data points are the numbers of students for whom codes could be assigned in that data set.

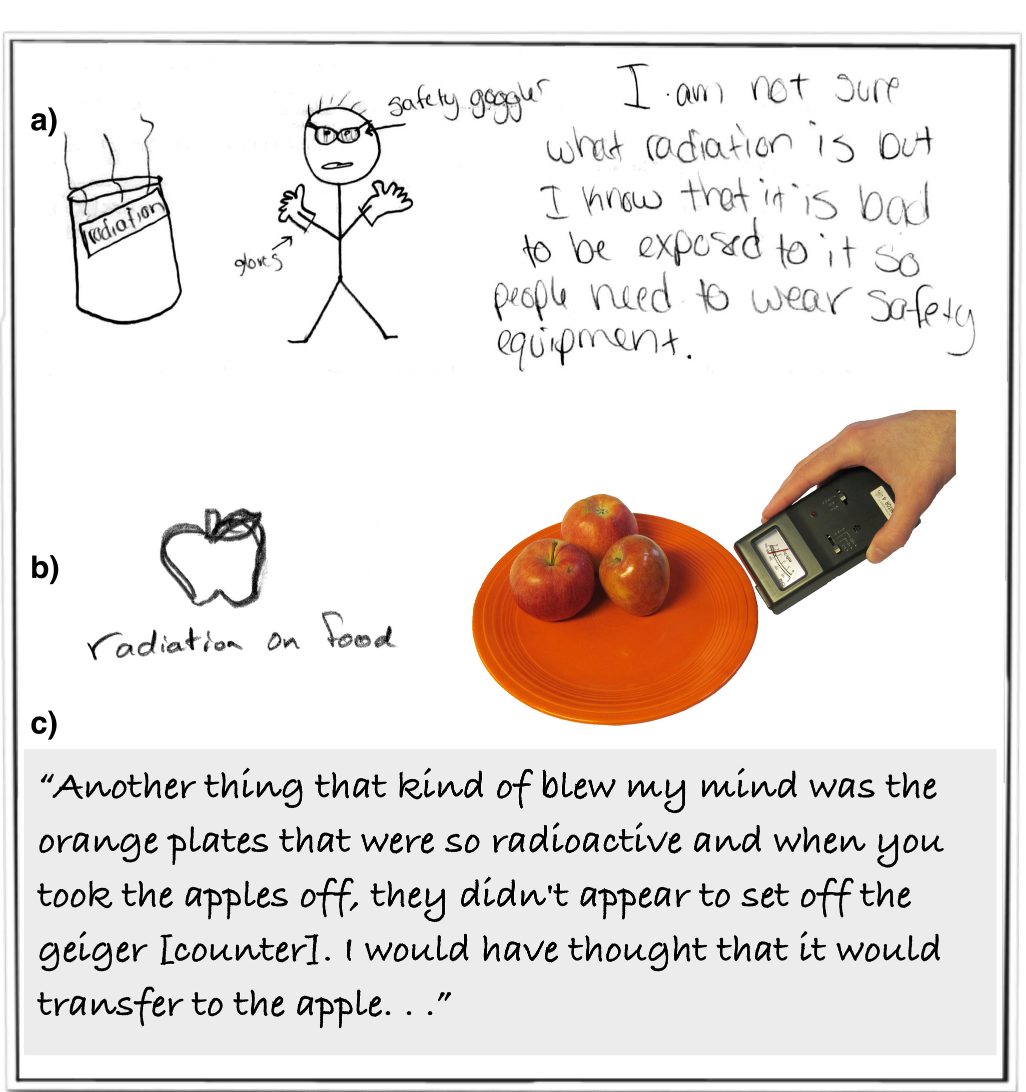
Fig. 1: Percent of students differentiating vs. time



Initial Ideas

- Nearly all students (88%) initially gave radiation stuff-like characteristics. An additional 11% appeared to have mixed ideas about stuff.
- 65% of students said that radiation makes other objects radioactive and an additional 34% gave conflicting answers.
- 94% of the students mentioned waves in their initial descriptions of radiation.
- Most students did not differentiate between nuclear and electromagnetic radiation sources.

Fig. 2: Example data of students initial thinking showing Stuff, Contamination, and Radiation = Radioactive



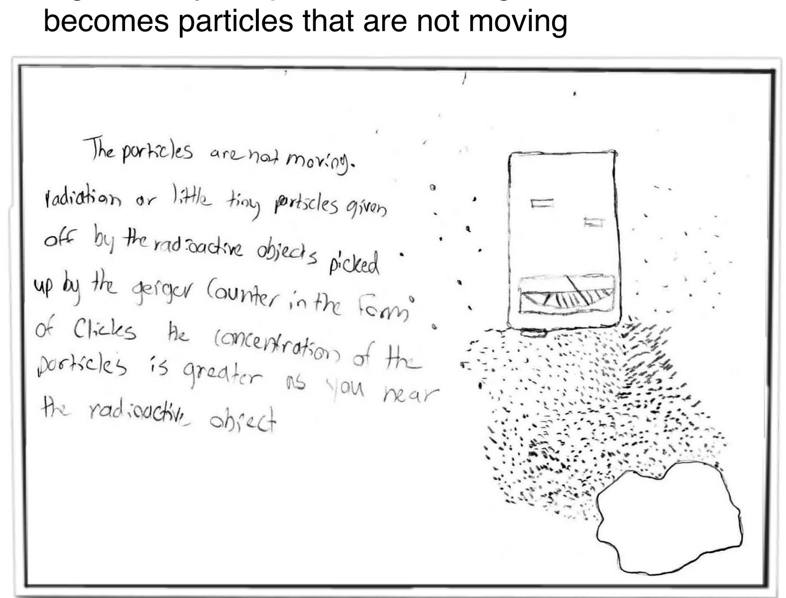
a) Fumes above the drum imply **stuff**, as does "radiation on food".

b) The labels "radiation" imply **no differentiation** between "radioactive" and "radiation".

c) "Blew my mind" implies a belief that the apples should have been radioactive (**contamination**).

Ideas in Transition

Fig. 3. Early adaptation of thinking: Radiation becomes particles that are not moving



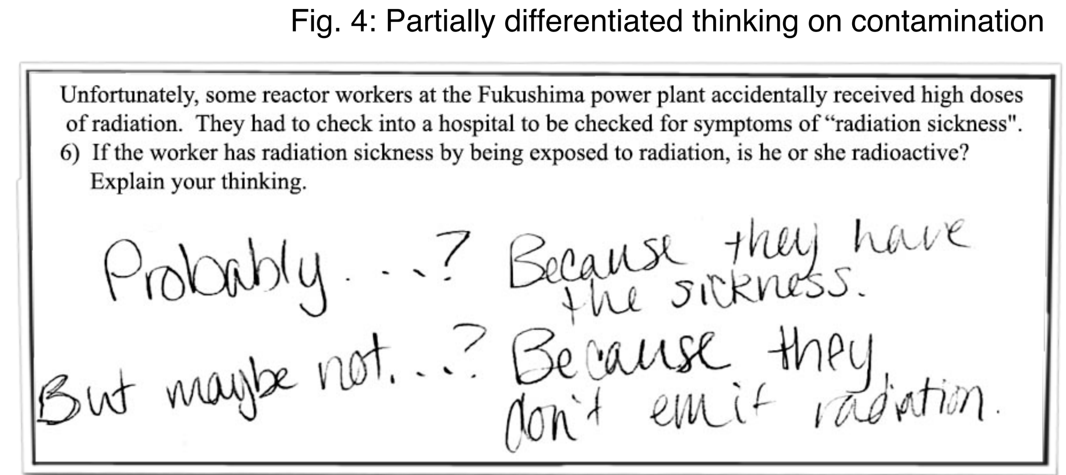
As students encountered new evidence they had to modify their initial ideas. However, their new ideas were often not yet fully consistent with accepted scientific ideas.

The learning process involved students answering questions that mattered to them in ways that were increasingly consistent with all the evidence.

Before the third cycle on radiation effects on living things, students were uncertain about how radiation can harm someone since it did not make them radioactive.

Many hedged their statements, uncertain about their answer.

Fig. 4: Partially differentiated thinking on contamination



References:

1. Eijkelhof, H. M. C. (1990). *Radiation and Risk in Physics Education*. Utrecht, University of Utrecht. Web resource: http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/22/010/22010294.pdf Accessed March 30, 2012

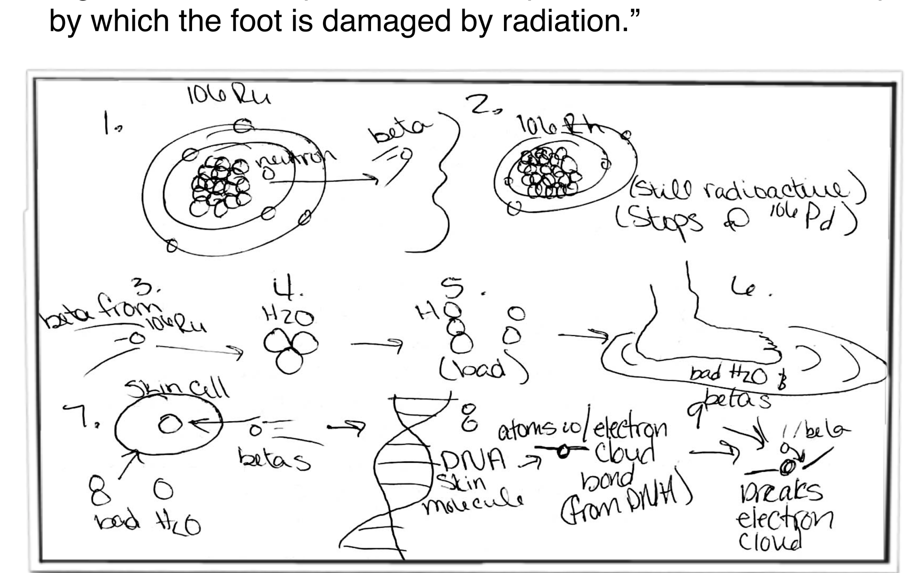
2. Millar, R. and J. S. Gill (1996). "School students' understanding of processes involving radioactive substances and ionizing radiation." *Physics Education* **31**(1): 27 - 33.

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. Hafele, A. and Johnson, A. (2012) "Exploring Learning Difficulties Associated with Understanding Ionizing By Radiation." NCUR 2012 Proceedings, Ogden Utah.

Final Ideas

Fig. 5: Student response to exam question "Describe the steps by which the foot is damaged by radiation."



This example shows a nearly complete line of reasoning from an unstable ^{106}Ru nucleus to beta emission to the beta breaking molecules in a worker's foot, to DNA damage. Many students developed this range of reasoning which is necessary for a full understanding of radiation's origins, behavior, and effects on the body.

Conclusions

Each student seemed to need different amounts of time to change their thinking about radiation and radioactivity. The differentiation process appears to be gradual, and to require extensive thinking about many related issues, often simultaneously.

Roughly 80% of the students differentiated by the end of the semester. The remaining 20% appeared to be in transition but were reluctant to abandon their initial ideas. Undifferentiated students had greater difficulty understanding the ionizing process.

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