Making complex concepts accessible through hands-on analogs: An example teaching Radioactive Decay & Dating – the 2nd phase of the study

Lily L. Claiborne & Calvin F. Miller

Department of Earth and Environmental Sciences

VANDERBILT UNIVERSITY

Context

Dynamic Earth 111 is the laboratory section for the introductory geology course. Students in these labs are primarily freshmen or sophomores fulfilling their science core requirement, although all future geology majors pass through these labs as well. The labs are intended to clarify and compliment what is taught in lecture by employing student-centered and hands-on activities. At the end of the semester, we would like students to have a deep and intuitive understanding of the processes that form and alter the earth and the tools scientists use to investigate these processes, with the ultimate goal of helping them to make informed decisions as citizens or serving as a strong foundation for further scientific study. Radioactive Decay and its use in dating is an excellent example for this study, as it is relevant to many scientific disciplines and to a variety of current issues including radioactive power as an energy source and controversies over evolution and the age of the earth. It is also one of the more complex concepts for students to grasp, as it involves processes with which they have no previous experience (unlike studying stream science or erosion) and is not entirely intuitive. Even upper level geoscience students often struggle with the nuances of both the decay process and its use in dating rocks and minerals.

LEARNING GOALS for this Lesson on Radioactive Decay

- What controls radioactive decay?
- How do we use radioactive decay for dating?
- Make Predictions about decay/dating
- Understand (and use) the decay equation

Questions

Can students learn complex, non-intuitive scientific concepts better when they can work hands-on with an analog experiment than through traditional lecture?

Can they appropriately transfer the things they learn from the analog experiment to the original concept?

Specifically, do the students develop a deeper understanding of radioactive decay and dating by experimenting with more intuitive and familiar fluids and hydrostatic principles than they did from lecture on atomic processes?

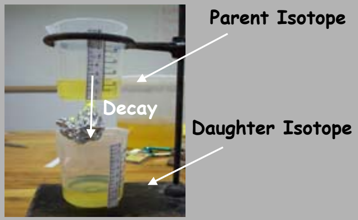
Study Design

1. Students attend the lecture on radioactive decay and dating at some time before the lab.
2. At the beginning of lab, students take a pre-test to determine their level of understanding of the concept, including a statement of confidence.
3. Students perform the analog activity.
4. Students take a post-test identical to the pre-test to assess the success of the activity on their understanding and their confidence.

Student Activity

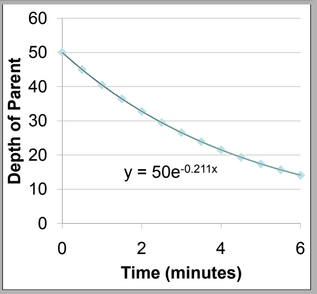
- Students perform 4 runs of the experiment, varying amount of initial parent and size of the hole.
- Students record their data, graph it, and find the equation of their fluid 'decay'
- Students dissect their equations, figuring out what each term represents, then construct a general decay equation
- Students start a run of the experiment, plug the hole at some time of their choosing, write down the time and put it face down by the experiment, then <u>move to another group's setup and use their equation to 'date' the other group's experiment!</u>

Beakers with <u>different sized holes</u> represent parent isotopes with <u>different decay constants</u>



Example Student Data

time (min)	parent depth (cm)
0.0	50.0
0.5	45.0
1.0	40.5
1.5	36.5
2.0	32.8
2.5	29.5
3.0	26.6
3.5	23.9
4.0	21.5
4.5	19.4
5.0	17.4
5.5	15.7
6.0	14.1



Excerpt from Lab Handout

Considering how the 3 runs varied and which were faster/slower, what 3 things determine how much decay occurs in an isotopic system?
decay constant, amount of parent, time

For your Run 1:

What is the decay equation? <u>$y=50e^{-0.211x}$</u>

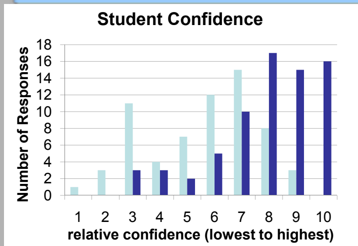
What is the initial parent (N_0)? <u>50</u>

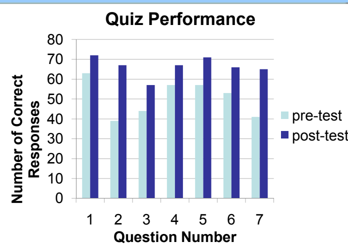
What is the decay constant (λ)? <u>-0.211</u>

Now, write a GENERAL decay equation that would fit all systems:
$N=N_0e^{-\lambda t}$

Now, move to another table and use your equation from your run 1 to "date" their experiment (determine how long they let it run before plugging the hole)! Check your answer!

Phase I Results





Phase I Conclusions

- Student learning and confidence can be increased using hands-on analog activities.
- Students can transfer the ideas from the analog experiment to the original concept without confusion.
- Students do learn about radioactive decay and dating more successfully by analog experiments using fluids and basic physical principles than from lectures on atomic processes.

Problems revealed by Phase I study

- Although discussions and questions asked during the activity indicated deep understanding and **high level thinking**, on the post-test students tended to reproduce answers that were part of their activity, rather than thinking deeply about the processes they explored. This could be due to ambiguity in the wording of the questions or that they were not asked to think on this level during the lab activity.
- **Misconceptions** introduced during lecture and transferred to lab came to light in the post-test, and should be addressed. (Student thought all radioactive decay involved gasses that could easily escape rocks and minerals. This is the rare, not common, case).

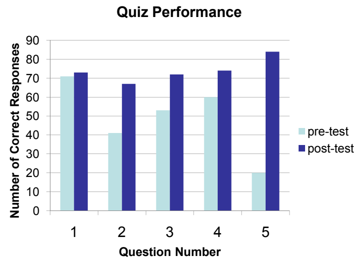
Phase II Revisions

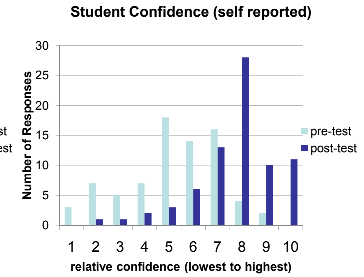
To promote higher level thinking during assessment, we

(1) Revised the post-test open-ended questions for clarity.
(2) Had students answer high level open-ended questions DURING the lab, working with their groups. We hoped this would encourage them to continue to think outside the box on their own.
(3) Removed questions 6 and 7, which did not deal with concepts directly addressed in the lab.

To address misconceptions revealed on the post-test during phase I, we
Created questions on the lab activity that directly address these misconceptions

Phase II Results





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Having students perform high-level synthesis in their groups after the lab activity increased their performance on open-ended synthesis questions on their post-test.

While the previously recognized misconceptions did not surface, new misconceptions were revealed on the phase II post test that were not an issue during phase I. We believe this is due to the fact that a different professor taught the lecture on radioactive decay each semester, using different wording and providing a different perspective.

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