Ancient TL

Research Article

A simple activity to teach 4th–8th graders about OSL dating and its applications

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Abstract

I have developed a simple hands-on activity for 4th–8th grade children (10–14 years old), with the goal to teach about the need for geochronology and the basic principles of OSL dating. The children are first introduced to the basic concepts of OSL dating, and participate afterwards in an activity to answer a scientific question. In our case they are asked to answer the question "Do islands move?". In the hands-on part of the activity, children playfully simulate the process of dating a sample. They use measuring spoons to fill clear plastic cups with beads to a pre-determined fill level. By counting the number of spoon-loads needed, students can determine the "age" of the sample. Ages are entered into a map and the results are discussed. The activity has been designed to be suitable for varying group sizes and different settings. It can easily be adopted by other researchers, we recommend however that the scientific question be modified to fit the regional setting of each laboratory. This manuscript describes the different stages of the outreach event – i.e., introduction, hands-on activity and discussion – and the rationale behind each step, as well as the materials needed.

Keywords: Outreach activity, Science communication, Didactics

1. Introduction

In an era where scientific misinformation is rampant and public trust in science is often eroded, it has become crucially important to bridge the gap between complex scientific knowledge and the public. It is particularly important to reach out to school children, many of whom have never met a scientist in person. Their idea of a scientist is formed by TV and movies, where scientists are portrayed either as brilliant miracle-workers, who conjure up problem solutions completely out of the blue, or alternatively as social oddballs who use complex jargon and are mostly good for a laugh. To dispel these myths, we need to allow school children to come to our labs, introduce them to our every-day work, and explain how we interpret data to learn about the world around us. We need to help them build trust in science and encourage their participation in science.

For this reason, my lab, just like many others, is increasingly participating in outreach events for school children, some as young as elementary school. School classes come to visit our university, or we visit schools. The target age range of the children – in this manuscript also referred to as "students" – is 4th–8th graders, i.e., ∼10–14 years. These younger children do not have the attention span to enjoy a lengthy guided tour or to listen to a presentation. They are looking for hands-on activities. The purpose of the project presented in this manuscript was to develop a hands-on activity for 4th–8th graders to teach about luminescence dating and its applications. Basic requirements were: (i) The activity must be age appropriate; (ii) it must accommodate groups of up to 50 children; (iii) the whole event should take less than an hour. The development of the activity was predominantly based on experience and interactions with children. However, in many ways it follows the strategies of active learning (e.g., Edwards, 2015). The hands-on aspect ensures that the children are actively involved and have the opportunity for playful learning in a group setting. The activity builds on prior knowledge and uses real-world connections. Last but not least, an aha-moment at the end is intended to reinforce the experience (e.g., Pilcher, 2015).

The primary objective of the learning activity was for the children to gain a basic understanding of the purpose of geochronology and how results are interpreted. The secondary goal was to introduce luminescence dating as an example of a geochronological method. To best familiarize and engage the students with the material, I considered our geographic location on the East Coast of the United States, close to the Atlantic Ocean. The activity centers on the surprising question "Do islands move?".

In the hands-on part of the activity, students playfully simulate the process of dating samples "collected" from islands. They use measuring spoons (symbolizing the quantity of radiation damage per time) to fill clear plastic cups (i.e. the sediment sample) with beads (symbolizing radiation damage) to a pre-determined fill level. By counting the number of spoon-loads needed, students can determine the "age" of the sample. Ages are entered into a map and the results are discussed. Students determine from the results that an island is experiencing coastal erosion on its east side and depositing erosive outwash on the west side. This gives the impression that the island is "moving" west, and provides students insight on local geographic processes along the coast, and how geochronology helps measure and predict the outcome of such processes. I have tested the activity in a variety of settings and I have found the project to work well in general. This manuscript describes the different stages of the outreach event – i.e. introduction, hands-on activity and discussion – and the rationale behind each step, as well as the materials needed. Based on this description it is easily possible to adapt the activity for more advanced audiences or other geographic settings.

2. Materials needed

The materials needed fall under two main categories: (1) objects for the lesson introduction, to explain the basic principle of luminescence dating; and (2) materials for the hands-on activity. Materials in the first category can be found in most OSL labs, while materials for the second category were selected to be widely available and inexpensive.

Materials for Part 1 – explanation of radioactivity and luminescence dating:

- Geiger counter with the speaker tuned on
- materials with various levels of radioactivity that are also of general interest: e.g. uranium ore, Fiesta™ dinner ware, watches with a radium dial, a mammoth bone, piece of granite, sand samples, etc.
- fluorescent minerals and a UV flashlight (e.g. calcite, fluorite, sodalite)

Materials for Part 2 – hands-on activity:

- clear plastic cups
- measuring spoons of different sizes
- plastic beads or wood beads
- sticky notes and pens
- one or two posters showing sites and locations for collected samples

3. Part 1: Explanation of radioactivity and luminescence dating (∼15 min)

The introduction includes multiple demonstrations and should not exceed 15 min, in order to leave enough time for the activity. The purpose of this part is for the students to understand why we need geochronology, and they should gain a very simple understanding of OSL dating. To establish continuous interaction with the students, I ask leading questions and give students the chance to contribute. In the hands-on part of the activity, which is explained in Section 4 in more detail, students use plastic cups, beads and measuring spoons to simulate the process of dating a sample. While I explain the basic principles, I frequently refer to the materials they will use later in their activity, and I demonstrate how they relate to the dating process. This process is illustrated in Figure 1.

The explanation of the basic principles is broken down into three steps which are outlined in the following:

1. **Explain the need for sediment and rock dating:** Purpose of the first step is to connect our activity to the real world and explain why we are doing luminescence dating. I choose regionally relevant examples for landscape change. Examples include the flooding events of September 2024 in Western North Carolina, or hurricanes and the resulting destruction of structures and roads. In a discussion we establish together that each event leaves behind a characteristic sediment layer. We can observe sequences of these sediment layers and see how often these events happen. To answer the question "how often", we need to know the age, and this is why we use methods such as luminescence dating.
2. **Introduction to radiation:** Children of the target age range have generally heard about radiation and radioactivity and the associated dangers. Using the Geiger counter and different materials, I demonstrate how radioactivity can range from high to low (this aspect is further discussed in Section 5). To explain the concept of dose rate, I take one of the clear cups, which represents a sample. Every time the counter clicks, radiation damage is done to the sample, and this is represented by the beads. For every click I throw a bead into the cup. If there is a lot of radioactivity more beads are thrown in. We discuss that, how quickly a cup fills, depends on the radioactivity of the sample. And the longer a sample is exposed to radioactivity, the more damage is accumulated. Thus, amount of damage can be used to measure time.
3. **Simplified introduction to luminescence:** Having established that damage can be used to measure time, we need to find a way to measure the damage. Children of the target age range have generally no knowledge

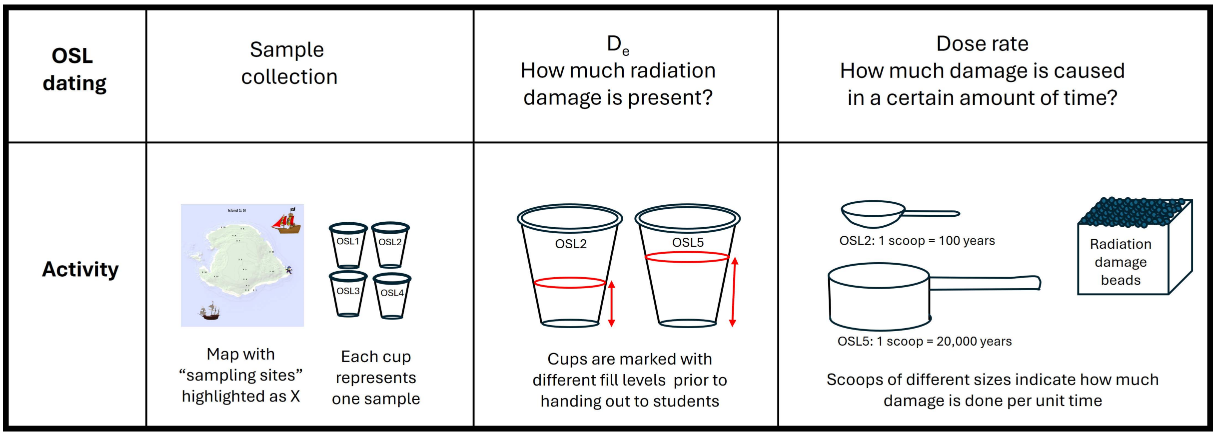

Figure 1: Various steps of the OSL dating process and illustration how the materials used in the hands-on activity relate to each step.

of atomic structure or crystal structure. It was therefore necessary to simplify the explanation of the luminescence process. Fluorescent minerals are used to demonstrate the basic idea behind the OSL measurement: we stimulate with light of one "color" (UV flashlight), which causes the damage to heal; we obtain light of a different "color" (here fluorescence, which symbolizes the emitted luminescence). The more damage the sample had accumulated, i.e. the fuller the cup is, the brighter it glows. This is also a good moment to explain the need for collecting the samples in the dark and for working in a dark laboratory.

At the conclusion of part 1, the students should understand that we need two pieces of information in order to obtain an age: (1) How much radiation damage did the sample experience? / How full is the cup? (2) How much damage is done by radiation every year? / How big is the spoon that fills the cup?

4. Part 2: Hands-on activity (30–45 min)

In this part of the lesson, the students take on the role of the scientists. They are given a scientific question that requires geochronometry and they apply the principles learned in the introduction. They will first "date" samples and subsequently interpret the results to answer the question. So as not to exceed the 1-hour time limit, part 2 is designed to take 30–45 min.

4.1. Presenting the scientific question (∼5 min)

Due to our location on the East Coast of the USA and our closeness to the ocean, I developed an activity that centers on the guiding question "Do islands move?". The message of the question is easy to grasp for younger audiences - children will of course think that islands do not move.

My selection of the scientific question was informed by my aim to build on prior knowledge of the children. The Outer Banks are barrier islands along the NC Atlantic Coast. They are familiar to students in Eastern North Carolina, as they are popular vacation and weekend spots, and most of the children have been there. The islands have become famous through movies, such as *Nights in Rodanthe*, and have drawn attention due to major damage caused by the last hurricanes. The children are generally aware of these facts. They do not usually know, however, that the islands formed at the end of the last ice age and experience a complicated pattern of overwash and long-shore transport (Riggs et al., 2011). Overwash acts like a conveyor belt and slowly moves the islands to the west, towards the mainland. These islands move!

At the beginning of the hands-on activity, the students are shown the two maps in Figure 2. They are told that one island (Island 1, Fig. 2 left) is a typical island that could be found somewhere in the ocean. Island 2 (Fig. 2 right) mimics an island on the Outer Banks of the North Carolina coast. I explain that I have already collected sediment samples from these locations and the sites are indicated on the maps with an X and a number. Their job is to "date" the samples and to enter the ages on the maps.

4.2. Dating the samples (15–20 min)

The materials for the dating activity are shown in Figure 3 and an outline of the process is given in Figure 4. I explain that the measurement of the radiation damage, i.e. the fill levels of the cups, has to be performed in the dark and requires specialized instrumentation. Therefore, I have already performed this task for every sample and every cup is already marked with sample number and a fill level. The spoons show us, how much damage is done in a certain amount of time. Each sample has a different spoon and the sample numbers on cups and spoons must match. The task is to find out, how many spoon loads are required to reach the respective fill level. From the label on the spoon, the age can be calculated as demonstrated in Figure 4. The sample number and age are then written on a sticky note and added to the correct spot on the map.

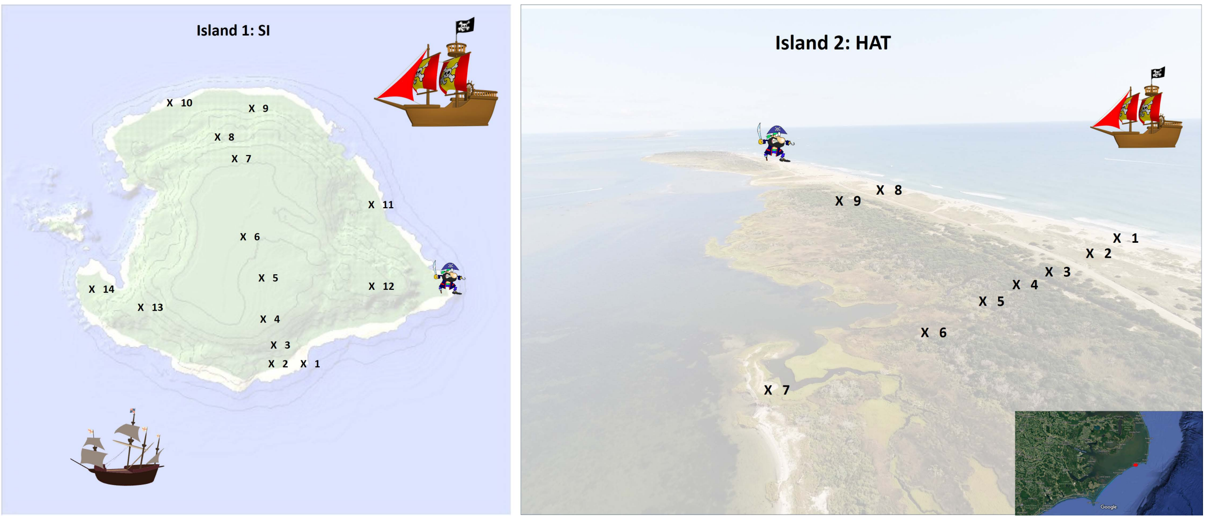

Figure 2: The two locations from which samples have been "collected" and which need to be "dated" by the students. Island 1 on the left represents a generic island that does not display major change over time ("SI" – Static Island). Island 2 on the right ("HAT" – Hatteras Island) is representative for the Outer Banks along the coast of North Carolina. These islands show dynamic behavior. They move! Sample locations are indicated with X and a sample number.

First, we work on one example together, to ensure that all students understand the task. The students are then divided into groups. Group sizes can range from two students up to six students, depending on the total number of children present. Each group is given a set of samples, which can vary from two to five samples, and the students have 15–20 min to complete their task.

4.3. Data analysis and discussion (10–15 min)

Once all ages have been entered into the map, the results are discussed, and the class answers the question "Do islands move?".

Island 1 is intended to be a generic non-changing island. Ages in years are shown in Figure 5. The discussion first focusses on the modern samples with age 1 year. These modern ages are used to re-affirm the concept that age refers to the time since the last light exposure. We discuss, why samples at the beach are so young. Next, we focus on the ages in the center, 250,000–300,000 years. These show that the largest part of the island is old and has not changed. Lastly, we discuss the intermediate ages (200, 500 and 5000 years). We discuss storm events and tsunamis that do not reach the higher parts of the island.

Island 2 represents the dynamic Outer Banks (Fig. 6A). A modern sample is located directly at the beach. All other samples show that the island is older on the eastern side, i.e., the ocean side, and younger towards the west, i.e., landwards. I let the children come up with ideas, how such an age sequence could happen. Some groups make creative suggestions (e.g., tsunamis), and we discuss if those could be possible. In general, the groups need to be guided towards the answer with leading questions. At the end I explain how wind and waves transport sand across the island, eroding the east side and depositing on the west side, similar to a conveyor belt (Fig. 6B). This island moves!

5. Discussion

5.1. Did I meet my original aims and objectives?

The basic requirements and aims for my activity were: (i) The activity must be appropriate for 4^{th}–8^{th} graders and build on their prior knowledge; (ii) it must accommodate groups of up to 50 children; (iii) the whole event should take less than an hour; (iv) there must be "aha-moments" for the students to make a meaningful connection of the new concepts to the world around them. After the activity the children should have a basic understanding of the purpose of geochronology, of how results are interpreted, and of luminescence dating as an example of a geochronological method.

I have tested the activity with more than ten school classes, ranging in age from 4^{th} to 8^{th} grade, with groups ranging from 15 to 50 students, in my lab and in school classrooms. I did not attempt to formally assess the efficacy of the activity. However, I have been able to obtain feedback from the students and the teachers through conversations and unsolicited e-mails, which are discussed in more detail in the next paragraph. While minor tweaks are necessary to accommodate each individual setting, I have found the project to work well in general.

The time frame of below one hour ensures that students do not lose interest. While it is possible to reduce the time to 45 min, it seemed rushed, and I had to urge the children to complete the hands-on activity as fast as possible. During the activity students are divided into groups. To address varying class sizes, I have maps with different numbers of samples and I also have to adjust the number of samples per

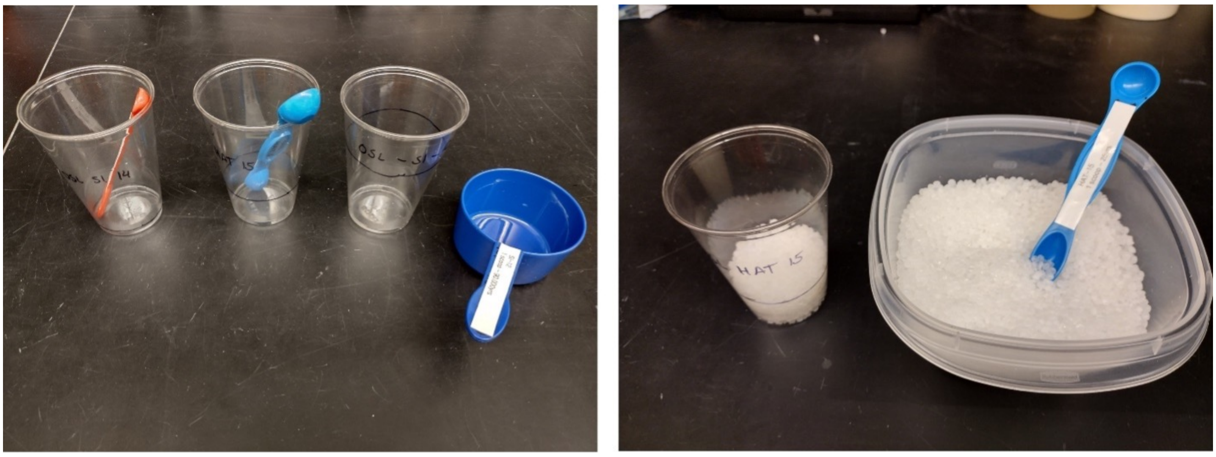

Figure 3: Sample cups and associated measuring spoons. Each sample comes with a dedicated spoon. Children use the spoon to fill the cup to the marked level with plastic beads. The label for sample spoon HAT 15 reads "1 scoop = 25 years".

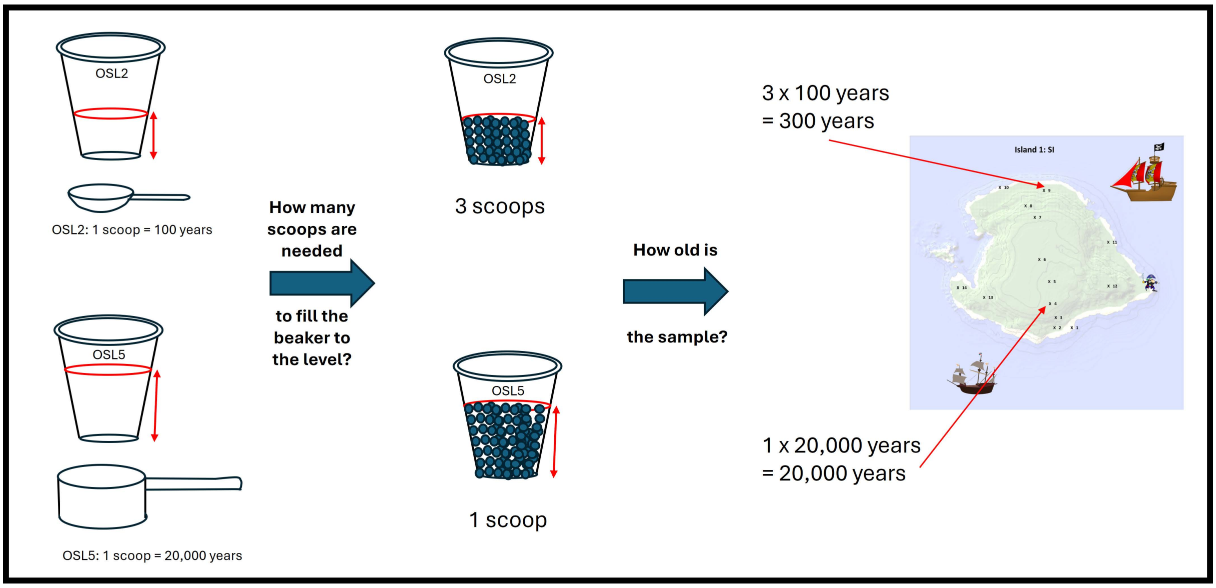

Figure 4: The steps taken to "date" a sample. Students count the number of spoons required to fill the cup to the indicated level. From the number of spoon loads and the label on the spoon the age is calculated and entered on the map.

group, which can range from two to five samples. Students generally like to see a real Geiger counter and unusual radioactive materials such as Fiesta^{TM} dinner plates. They like looking at fluorescent minerals and if time allows at the end, they get the opportunity to try the UV flashlights themselves. Students particularly like the hands-on aspect of the event. While the plastic beads can be quite messy (having a broom at hand is imperative), students also consider them the most fun part of the activity.

The first step in developing the activity was the selection of the scientific question. As mentioned earlier, I wanted the children to be able to relate to the geographic location for a real-world connection. But I also wanted to introduce an aha-effect. The fact that almost all the kids are familiar with the Outer Banks, but likely do not know that these islands move, fulfilled both requirements. This part of the activity is the only part that would have to be changed, when adopted by other laboratories. I did not aim at getting the ages and the geologic setting perfectly correct. On the contrary, I tried to simplify the age chart as much as possible. The static island is completely generic. Students of the target-range cannot yet visualize the difference between 100 million years and 100,000 years (e.g., Trend, 1998; Dodick and Orion, 2003). Both represent a large number, which translates into "old," which was completely sufficient for my purpose. For Island 2, the island representing the Outer Banks, I tried to stay within the approximately correct age range, but I did not perform a detailed literature search or use actual published ages. My main goal was to demonstrate an age gradient from east to west. I ignored long-shore transport, effects of inlets, etc.

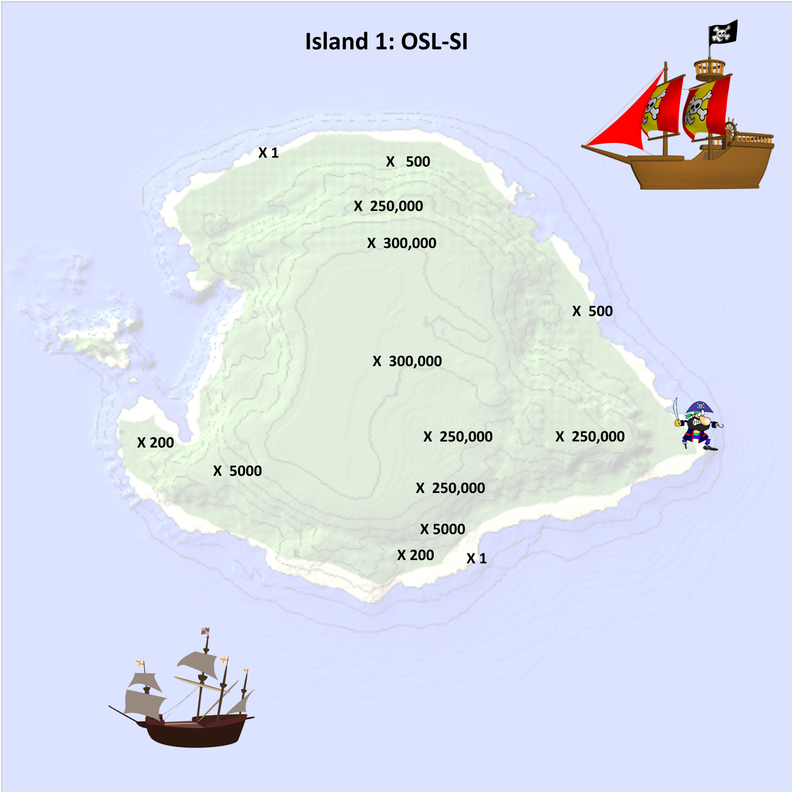

Figure 5: Results for Island 1. The numbers indicate ages in years.

For older audiences more detailed maps with actual research results could be used and more detailed geologic processes could be discussed. Some groups needed nudging to understand that this island moves, others – including 4th graders – were able to draw this conclusion by themselves. But all classes were surprised by the fact that islands can and do move and that there are even such islands near-by!

5.2. Considerations for the hands-on activity

I always ask ahead of time how many students and teachers will participate. I determine how many groups should be formed and I pre-arrange "kits" with cups, spoons and beads. Part 1 involves all students at the same time. If necessary, for example in a larger room, I stand on a table or chair, to ensure that all children can see the demonstrations. The same is true for the discussion at the end. For the hands-on activity, the children are divided into smaller groups. For this purpose, I rely on the help of teachers, who have proven very effective in forming groups and making sure that the children follow the instructions. The transition from Part 1 to the hands-on activity usually takes no more than a few minutes. The boxes with the materials are handed out at the beginning of the hands-on part. Distributing the materials before the children arrive was not a good idea. The children did not pay attention to the explanation in Part 1 and played with the plastic beads instead. The activity requires little space. As long as enough separate tables are available, each individual group can easily work around a single table. Alternatively, students can sit on the floor. The teachers generally work together with the children. At the end, the children are asked to put all materials back in the boxes. I modified the activity several times to address reactions of students and to ensure that they really understood how the hands-on part relates to luminescence dating.

Most students were excited to see a real Geiger counter in use, in particular the feature of the loudspeaker that allows them to "hear" the radioactivity. They were fascinated by the low click-rate for sediment samples and the much higher click-rate for the mammoth bone. Quite a few students became apprehensive about the high count-rates for a piece of uranium ore. At this point I try to add small pieces of historic information about the years after the discovery of radioactivity. I mention the fact that radioactive toothpaste was sold, because it made the teeth glow at night, and I demonstrate the radioactivity of the Fiesta^{TM} dinner plates. I tell them that for a while it was not uncommon to X-ray children's feet upon buying new shoes. And I explain about the women who painted radium-dials on clocks. All this highlights that we are now much more aware of the risks of radioactivity, and it serves to re-assure the students that I would not expose them to dangerous levels of radiation.

I tried illustrating the principle of luminescence by using dosimeters with a bright TL signal that is visible with the naked eye, such as TL from doped $CaSO_4$. I irradiated the dosimeters to saturation and used a laboratory heating

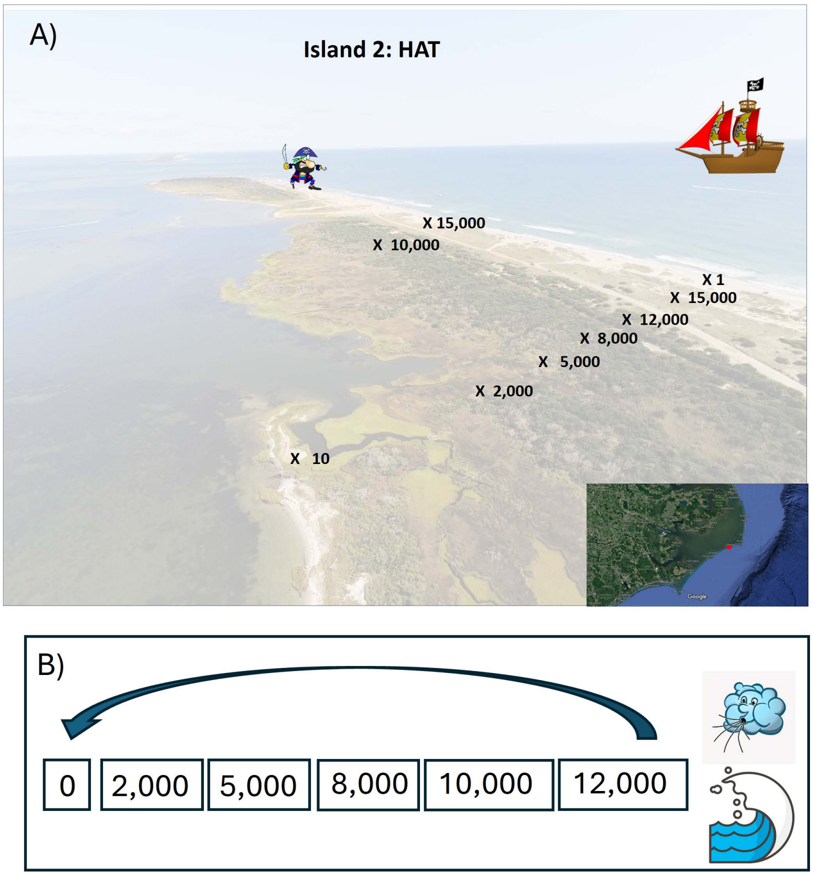

Figure 6: A) Results for Island 2. The numbers indicate ages in years. B) Illustration of the conveyor belt model to explain the age sequence.

plate. Unfortunately, even these very bright dosimeters appear very dim to the eye. The demonstration required a completely dark room, which is rarely available. Students did not have the patience to allow their eyes to become sufficiently adapted to the dark, I had to prevent them from touching the heating plate or pulling out their cell-phones. Many students were not able to see the dim TL emission. For these reasons I decided that UV-induced fluorescence is a more suitable proxy. I am using common and bright fluorescent minerals such as calcite and fluorite. It is not necessary to make the room completely dark, but it is advisable to close blinds or, at a minimum, to turn off lights, so that all children can see the glow. One of my samples is brighter, which I use to highlight that this reflects more radiation damage. For the activity the children only need to understand that radiation damage correlates with age. To avoid confusion, I keep the explanation of the luminescence process as simple as possible. For example, I do not mention that different minerals have different intrinsic brightness.

The materials for the dating activity are inexpensive and easy to find. Plastic beads can be replaced with more environmentally friendly materials such as wood beads. I originally used small pebbles to represent radiation damage, but students were confused about the difference between the actual sediment samples that we collect for OSL dating, and the pebbles that were meant to merely represent radiation damage. I decided to use an artificial material to avoid confusion. It is imperative to keep cup-and-spoon pairs together and to emphasize that the students need to match the sample numbers before starting the "dating process". Labelling the cups and spoons was somewhat time-consuming. I first had to decide on an age for that specific sample, then the cup had to be filled with an easy to measure number of spoon-loads, the level was marked, and last I had to convert age and number of loads to a "dose rate" for the spoon label. I chose simple numbers for both, number of spoon loads and the dose-rate, to ensure that the calculation did not pose a challenge for 4^{th} graders. Marker labels on the spoons smudged after the first use and I decided to re-label them with printed labels. This might also be advisable for the labels on the cups, although the marker has held up well on the cups.

Instead of using printed maps and sticky notes, Powerpoint maps could be projected, and ages could be entered directly on the map. This depends on the facilities provided. When visiting schools, I found myself in a gym without the option to use a computer or projector. I also found that sticky notes give the students the feeling, that they actually contributed to this work and that they are looking at their own data. They were more engaged than when projectors were used. Overall, it is helpful to know ahead of time, how many students will participate and what facilities are available if the event is held off-campus. It is also advisable to warn the teachers ahead of time about the radioactive materials and the Geiger counter to ensure that these items are not in conflict with school regulations.

6. Conclusions

I developed a simple hands-on activity for 4^{th}–8^{th} grade children with the goal to teach them about the need for geochronology and the basic principles of OSL dating. The children are first introduced to basic concepts and participate afterwards in a "dating" activity to answer a scientific question. In the hands-on part of the activity, students use measuring spoons to fill clear plastic cups with beads to a predetermined fill level. By counting the number of spoon-loads needed, students can determine the "age" of the sample. Ages are entered into a map and the results are discussed. The scientific question, in our case "Do islands move?", was selected to be regionally relevant while also providing a moment of surprise that would re-inforce the lesson. The whole activity lasts approximately one hour and can accommodate groups with as many as 50 students. While minor tweaks are necessary for each individual case, I have found the project to be versatile and suitable for a variety of school settings. The activity can easily be adopted by other researchers. I recommend however that the scientific question be modified to fit the regional setting of each laboratory.

Data availability. No original data have been acquired for this study.

Conflict of interest. The author declares that she has no conflict of interest that could have biased her scientific work.

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