Cinderella Separates a Mixture

An investigation uses a classic fairy tale to teach students about the properties of substances.

By Sabine Streller

Scientific investigations are usually introduced to children by referring to phenomena and occurrences that they already know about from their environment. The goal is that children learn to understand everyday observations and experiences from a scientific perspective, pose questions, express and test simple hypotheses by planning and performing experiments or investigations, present their results, and question explanations. Not only children's everyday experiences but also situations and characters from stories can be useful for encouraging children to pose questions that can be answered through scientific investigations. The following lesson sequence, "Cinderella," was conducted several times in different fifth-grade classes by me and my colleagues. To accommodate different learning conditions, my colleagues decided to adapt parts of the lessons for their classes. I will describe these adaptations at the end of relevant sections. The lessons provide opportunities for students to encounter the NGSS crosscutting concept Scale, Proportion, and Quantity (NGSS Lead States 2013). The structure of the lesson sequence follows the 5E model (Bybee et al., 2006),

As stated in the Framework, "The concept of scale builds from early grades as an essential element of understanding phenomenon. Young children can begin by understanding scale with objects, space and time related to their world" (NRC 2012, p. 90).

Lentils in the Ashes: Room for Discoveries

Engage

In the fairy tale Cinderella, Cinderella's evil stepmother stops her from going to a dance by throwing lentils into ash and instructing her to pick the lentils out again. Cinderella chooses a special method to finish the task. She asks birds for help. After students listened to the fairy tale, they were presented with a large bowl (around 40 cm in diameter) containing ashes and lentils. I posed the following question to my students: What if the birds had not done the separation for Cinderella? Which alternatives would she have had?
FIGURE 1.

Materials.
First activity
- ash (e.g., from burnt newspaper), lentils
- large cloth or flat bowl, sieve, hairdryer or bellows
- beakers, water, spoons

Second activity
- sand, salt, plastic beads (alternatively wooden beads, foam rubber), iron filings (available at metal-working shops or to order from chemical traders)
- several bowls (e.g., Petri dishes), magnets, kitchen towels, glasses, spoons, funnels, filter paper
- scales

Practical tips
Iron filings are difficult to remove from the magnet. For this reason, magnets should be wrapped with a paper towel (see images on p. 52).

Some plastic beads do not float on water. Try them in advance.

The sand has to be very dry before the weight can be measured. This is the most common source of error.

The evaporation of the salt solution on a hot plate can lead to severe water splashing. Slower evaporation on a radiator is preferable.

Students must use caution when working with ashes, not only wearing goggles but also taking care to not breathe in the ashes. Tell students to make sure other students are out of the way when using a blow dryer or bellows to move the ashes.

Explore
The students spontaneously gave answers and wanted to try out their own ideas. Most frequently, they suggested sifting. Apart from that, the following ideas were mentioned: The mixture should be put into a big, flat bowl or on a cloth. If it is thrown up outside, the wind will blow away the ash, and the lentils will fall back into the bowl. The ash could also be blown away with a hair dryer or bellows (see safety tips in Figure 1). Another suggestion was to add water to the mixture. The students expected the lentils to sink and the ash to float so that the ash could be poured off with the water. The students wrote down their ideas on a record sheet.

Students were almost ready to test their ideas but first, some safety concerns needed to be addressed. Ashes can contain respiratory and eye irritants as well as toxins, so students wore safety goggles and aprons while working with the mixture. This portion of the activity was done outdoors to reduce the risk of exposure, especially for students with respiratory or allergy issues.

After the activity, students were required to wash hands with soap and water. If you use hair dryers, they must be used with GFI-protected electrical circuits under adult supervision.

Students worked in groups of three, and each group got a small portion (3 tablespoons) of the mixture from the large bowl and tried out the idea they recorded on their record sheets (mentioned above)—some groups sifted; others tried throwing the mixture up from a large bowl or cloth, hoping the ashes would be blown away outside while the lentils returned to the bowl; some tried using a hair dryer or bellows to blow the ashes away; others tried submerging the mixture in water.

Explain
In a discussion, the students shared their different ideas and experiences with the class and discussed which ideas
Four substances: iron, salt, sand, and plastic beads

achieved the best results. Students remarked that blowing and sifting worked well. However, adding water to the mixture was not successful because a part of the ash sinks in water as well, making this approach unsuitable. Together, we reflected on the various separation methods. They have in common that they take advantage of different properties of the ash and the lentils—i.e., the particle size when sifting, the difference in weight when blowing. After discussing and comparing different methods, the students finally agreed on sifting as the most successful method because it does not result in a mess and is fast and effective. They then recommended this method to Cinderella.

To sum up, in this first part of the lesson sequence, the students used simple separation methods that most of them already knew and transferred them to a scientific context. Students learned to choose separation methods according to the properties of substances and size of objects (5-PS1 Matter and Its Interactions).

**Elaborate**

In the beginning of the next part, the following question was raised: "What could we have done if the evil stepmother had been particularly mean and asked her to separate a mixture of salt, iron, plastic, and sand into its components?" Given the task of separating this complex mixture of everyday substances, the students were encouraged to make observations to distinguish the provided materials based on their properties, such as particle size, magnetism, and solubility, which relates to the performance expectation 5-PS1-3 of the Next Generation Science Standards: "Make observations and measurements to identify materials based on their properties" (NGSS Lead States 2013, p. 43). They collaboratively planned and conducted a sequence of investigations in which the number and order of steps is essential (see NSTA Connection).

I designed this separation task as a competition: I gave every group a defined amount of the mixture—4 g of salt, sand, plastic beads, and iron filings (available at metal-working shops or to order from chemical traders; see Internet Resources). Keep in mind: The smaller the amount, the harder the task! The goal for the students was to recover the given amount of the substances in a pure form, having no other substances present (see "Evaluate"). Students were instructed to avoid touching their eyes, skin, and clothing while working with the iron filings. Students should wear gloves in addition to their chemical-splash goggles and aprons.

Before starting the competition, the students learned to use a scale. The scale was necessary to compare the results of the recovered amounts of salt, sand, iron, and plastic with the original amounts. Using scales is connected to the cross-cutting concept Scale, Proportion, and Quantity: "Standard units are used to measure and describe physical quantities such as weight" (NGSS Lead States 2013, p. 43).

I used digital scales in my class and demonstrated the tare function for the students. My colleagues used manual scales and practiced the proper handling with their students. By using manual scales, the children learned to calculate the difference between the empty container and the container filled with the substance to find out the amount of the substance.

The separation of this four-compound mixture was conducted in small teams of two or three students. The provided record sheet (see NSTA Connection) offers a plan to separate the substances: separating the iron by
Children separate the four-component mixture with a magnet.

using a magnet, adding the mixture to a small amount of water (I gave each team 100 ml of water in a beaker) and skimming off the plastic beads, filtering the mixture to separate the sand, and finally heating the salt water to recover the salt. By doing so, the complex task is simplified to fit the students’ ability. Students were supervised closely while using the hot plates and instructed to wipe up any spilled or splashed water immediately. The sheet also provides instructions on how to document the results. Despite this support, the students are still required to think, as the record sheet does not provide all details of the separation process. All of my students followed the instructions easily and solved the task in 40 minutes.

Depending on the students’ ability to plan and experiment, there are several possibilities to adapt the given task. A colleague of mine, who had mostly high achievers in his class, did not hand out the record sheet. Instead, the students planned the separation on their own: In groups of two or three students, they decided how they wanted to separate the four substances. They composed a list of materials and wrote down their planned procedure. The teacher provided the required materials in the next lesson (see Figure 1). The students then carried out and documented their procedure and compared the results and the procedure with other groups. This option is very challenging for many students, and therefore, more lesson time was required than with the guided instruction approach. However, the feeling of success was very rewarding for the students when they accomplished a clean separation of their mixture. One advantage of this option is the possibility to have students work independently and cooperatively, and therefore learn from each other.

Another possibility to accommodate the different learning conditions was used by another colleague. The students received the record sheet cut in pieces and were asked to bring them into a logical order, thereby designing a well-grounded plan in a guided but at the same time involving way.

Evaluate

To find out how well the students managed the task of separation, I handed out cards with the original amount of each substance. In a table, the students compared the original amount with the amount that they were able to regain. The amount that the students regained was smaller (for sand and salt) and bigger (for iron and plastic beads) than the original amount. Because, as disciplinary core idea PS1.A states, “the amount (weight) of matter is conserved” (NGSS Lead States 2013, p.43), it is actually impossible for children to have more of a specific substance than before. Losing an amount of a substance, however, is possible if they did not work properly. This observation—a smaller or larger amount than the given amount—was a good reason to talk about measurement errors and the pureness of the substances. The increase of mass can only be caused by contamination with some of the other substances. For example, iron was often tainted with sand, and plastic beads were covered with salt.

The students’ success with the separation task was measured as follows: First, it was checked whether the four recovered substances were pure. If a substance still contained traces of another, the separation was not successful. Only if the substance was pure, the weight of the regained substance could be considered. Therefore, the group with substances that appeared pure to the eye and had the smallest deviations from the original amount won.

In the variation in which the students planned the entire separation on their own, another objective was added. In addition to the pureness and the weight of the substances the number of needed steps was a criterion for the assessment.
Children skim plastic beads from the mixture.

Requirements, Anticipated Difficulties, and Further Aspects

Use plastic beads that float on water. These allow students to experience another separation method when adding the mixture to water: skimming. If the plastic beads do not float on water, they first must be separated with a sieve before the mixture of sand and salt is added to water. However, the method of sifting was already introduced in the separation of ashes and lentils. Most children found it easy to separate iron with a magnet, skim off floating plastic beads, and filter sand as they know these methods from their everyday life. A difficulty for my students was the recovery of salt, even though it relates to everyday life as well. The salt is dissolved in water and can only be recovered when the water has evaporated. This separation method is related to performance expectation 5-PS1-1: Develop a model to describe that matter is made of particles too small to be seen (NGSS Lead States 2013, p. 43). When salt is added to water, it dissolves into particles that are too small to be seen. The salt seems to vanish. Therefore, the separation method of dissolving salt in water and evaporating the water was used to introduce or revise a simple particle model in subsequent lessons.

Summary

In my experience, this lesson sequence is well-suited to introduce, develop, and practice separation methods of substances and characteristics of scientific investigation. Instructive moments and direct guidance with the record sheets can be applied variably. In this sequence, the students planned and experimented independently according to their abilities, which means they could put their own ideas into action. After trying out their ideas, the students discussed them in class and evaluated success and limits. The core of this sequence was understanding that a separation of substances is based on their different properties, and using standard units to measure and describe physical quantities (NGSS Lead States 2013, p. 43). One fifth-grade student of an elementary school in Berlin, Germany, put her quintessence into the following words: "We wanted to regain the pure substances from a mixture of four substances. As all the pure substances differ in certain properties, we were able to separate them."

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References


Connecting to the Standards

Standard: 5-PS1Matter and Its Interactions

Performance Expectation: 5-PS1-3 Make observations and measurements to identify materials based on their properties.

Science and Engineering Practice: Planning and Carrying Out Investigations


Crosscutting Concept: Scale, Proportion, and Quantity

NGSS Table 5-PS1 Matter and Its Interactions www.nextgenscience.org/5ps1-matter-interactions

NSTA Connection

Visit www.nsta.org/SC1412 for the record sheets.