TATA CONSULTANCY SERVICES | Discovery EDUCATION

IGNITE MY FUTURE

THINK | SOLVE | CREATE | CONNECT

SUBJECTS

Science
Computer Science

COMPUTATIONAL THINKING PRACTICE

Developing and Using Abstractions

COMPUTATIONAL THINKING STRATEGY

Abstract
Decompose

MATERIALS

Building Blocks of Smell capture sheet

Abstracting Scent capture sheet

Whiteboard, projector, or other central location

SuperScent: A Database of Flavors and Scents (background information for teachers)

The Science of Smell (background information for teachers)

Chemoreception: The Chemistry of Odors (background information for teachers)

Aroma Compounds (background information for teachers)

Flavors and Fragrances (background information for teachers)

LESSON TITLE

The Smell Test

Guiding Question: What will our future look like?

Ignite Curiosity

- What will movies be like in the future?
- How can we create smells to accompany movies?
- What smells would we need to create to cover any possible experience?
- How can we incorporate smells into virtual reality technology?

Three films at the 2017 Tribeca Film Festival integrated smells into their virtual reality movies. To do this, they sprayed chemical mixtures around viewers to mimic the smells of the scenes in their films. In the near future, it may be possible to use virtual reality headsets to create and dispense these smells without human aid. In this lesson, students will discover the chemical basis of smell by applying principles of chemistry and molecular structure to the growing field of virtual reality. In **THINK**, students act as chemists challenged to identify the chemical building blocks that make up everyday smells. In **SOLVE**, students brainstorm the smells that might enhance the experience of a moviegoer. They then cross-reference this list with the information they identified and integrated in Think. In **CREATE**, students make a table by using their lists of common smells to abstract the general categories and components of scent. In **CONNECT**, students identify how virtual reality connects to careers and the real-world problems of tomorrow.

Students will be able to:

- **Understand** the composition of smells by decomposing their chemical structure,
- **Apply** that knowledge by identifying patterns and extracting common features in the molecular structure of smells, and
- **Create** a table that abstracts common smells into categories.

Students act as chemists who have been tasked with identifying the building blocks (groups) of chemicals that produce scents.

1 **Read** the following scenario to students:
Imagine that you are a team of chemists challenged to create a virtual reality program in which you incorporate everyday smells into the moviegoing experience. To do this, you will first identify the building blocks (groups) of chemicals that produce scents. Then, you will hypothesize what combinations of these building blocks would produce certain results. If you are successful, viewers will have an incredibly realistic experience. If you are less accurate, viewers may experience some pretty unpleasant smells. Let's see what you come up with!

Elicit from students a few of their favorite scents and write these scents in a column on the board. Next, elicit several of their least favorite scents, and write these on the board in a separate column. Explain that no matter how pleasant or unpleasant we find certain scents, they all come from the same basic building blocks. At the smallest level, these building blocks are elements, which combine into compounds. Compounds are the molecules that we smell.

2 **Lead** students to consider the importance and basis of smell using the following guiding questions (if students are unfamiliar with elements and molecules or with the anatomy of the nose, you may wish to lead them through a presentation first):

- How many smells do you think there are? (Humans have identified over 10,000 smells.)
- How do humans to experience smell? (Inside the nose are olfactory epithelia, which contain millions of receptor cells. These fit together with scent molecules, like locks and keys.)
- How does an object "give off" a smell? (What we smell is actually evaporating molecules.)
- What objects don't have a smell? (those that don't evaporate)

3 **Distribute** the Building Blocks of Smell capture sheet to familiarize students with the basic aroma compounds. Guide students through Part I of the handout, in which they review each aroma and where it occurs in nature. Next, highlight Part II of the sheet. Review with students that to complete this part of the handout, they will combine categories of scent from Part I and hypothesize what resulting smells would emerge. Students should be able to identify that the ratios of one compound to another will affect the overall scent produced.

4 **With partners,** students should work through Part II of the Building Blocks of Smell capture sheet. When they have finished, regroup as a class and discuss student responses.

Students will brainstorms smells that could enhance a moviegoer's experience, cross-referencing their lists with the aroma categories listed in the Building Blocks of Smell capture sheet to abstract the most important components of common scents.

1. **Ask** students to consider scenes from their favorite movies. Invite students to brainstorm with a partner responses to the following guiding questions:
   - What smells might enhance the viewer's experience of these scenes?
   - What other common smells might enhance the moviegoer's experience?

2. **Return** to the larger group to discuss students' responses to the questions.

Students will abstract general categories and components of scents, creating a map of the Scientific Model to hypothesize how they could design a virtual reality headset that could generate many different smells.

Teacher note: If students struggle with concepts surrounding molecular compounds, you may wish to share a chart of scents classified by type with students. Ask: *What are the most common molecular structures for scents?* (Carboxylic esters, vinylogous esters, and alcohols are the most common groups. This could help us by letting us know which molecules to put the most of in the virtual reality headset because they will be the basis of the most scents.)

1. **Create** groups of five or six students, separating those who were partners in the previous activity. Tell students that they will now create a communal list of common smells a person might experience in a film, categorizing and abstracting the general categories and components of these scents based on their work in the previous task.

2. **Explain** to the groups that they will use the information they have abstracted to create a table of the chemical components and smells a headset must contain in order to provide an immersive moviegoing experience. They should work with the following guiding questions to direct their work:
   - What is the current state of virtual reality in this area?
   - What could make the scent experience more realistic?
   - How could you adapt the current equipment?
   - How could you fit the headset with the components for all possible smells?

3. **Guide** students to read the Abstracting Scent student capture sheet and invite them to work individually to categorize the scents they have listed. Their lists should include at least 30 smells. Ask students to turn to a neighbor and discuss their categorizations. Clarify with students that this process is called abstraction: it takes the details of phenomena to make generalizations that allow a solution to work in a variety of scenarios. Computer scientists use this technique to simplify complex computer systems.

4. **When students have completed** their individual lists, have them work in their groups to combine their individual lists into a master list, removing duplicates.

5. **When groups have completed** their master lists, reconvene as a class and create a master list on a whiteboard, on a projector, or in another central location, removing duplicates as you compile the list. Summarize the activity with the following critical thinking questions:
   - What steps would you take to begin designing a prototype of a virtual reality headset with scent capabilities?
   - Why are ratios important in creating realistic scent technology?
   - What are some other applications of virtual reality scent technology?
   - Considering that the senses of taste and smell are closely related, do you think this exercise could be modified to create virtual reality taste instead of smell? Why or why not?

Select one of the strategies listed below to help students answer these questions:

- **How do this problem and solution connect to me?**
- **How do this problem and solution connect to real-world careers?**
- **How do this problem and solution connect to our world?**

1. **Write** the three questions on PowerPoint or flip chart slides and invite students to share out responses.
2. **Display** pieces of chart paper around the room, each with one question written on it. Ask students to write down their ideas related to the questions on each sheet.
3. **Assign** one of the questions to three different student groups to brainstorm or research, and then share out responses.
4. **Invite** students to write down responses to each question on a sticky note, and collect them to create an affinity diagram of ideas.

How does this connect to students?

Students are likely familiar with moviegoing and advances in technologies in this area (e.g., 3D, IMAX). They may also be familiar with virtual reality, which is becoming increasingly popular in video games and other experiences. There are now virtual reality games for numerous devices: Android, iPhone, personal computers, and Playstation, among others. Virtual reality headsets and games have become less expensive as more companies produce them, making them more accessible to students. Even though students may be familiar with virtual reality through games and entertainment, the technology is already available for students to use for more practical matters—such as when their parents are ready to buy a house and can tour it virtually. Virtual reality is also currently used for social good, for example, to show the public what it would be like to experience the effects of climate change. This can affect students indirectly.

How does this connect to careers?

Chemists study the molecular structure of scents and the application of these scents to experiments and exploration.

Engineers create new technologies that allow us to experience virtual reality in increasingly realistic ways.

Perfumers explore scent combinations to identify the most tempting mixture for potential consumers.

Film Producers search for ways to keep movies relevant and exciting in an era of Netflix and high-quality TV programming.

How does this connect to our world?

Virtual reality is an emerging technology that is changing the way we work, watch movies, and play games. Video game designers, chemists, and computer engineers work together to transform 2D games into 3D (and even 4D) gaming experiences!

Today, scientists are working with virtual reality technologies to study everything from empathy to flexibility, from racism to environmental sustainability. Within their lifetime, it is likely that students will find virtual reality playing an important role in different aspects of their lives, from shopping for a home to traveling, as it continues to become more realistic and applied to different areas.

Furthermore, virtual reality may help shift society's perceptions of issues such as race or climate change, improve education, and make the human body more resilient, as researchers continue to explore the boundaries of the technology.

National Standards

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)	**ETS1.B Developing Possible Solutions** ▪ There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) **MS-PS1-3 Matter and its Interactions** ▪ Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.	**Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region.

COMMON CORE STATE STANDARDS CONNECTIONS

- **ELA RST.6.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)

K-12 COMPUTER SCIENCE FRAMEWORK

Practice 4. Developing and Using Abstractions
Abstractions are formed by identifying patterns and extracting common features from specific examples
to create generalizations. Using generalized solutions and parts of solutions designed for broad reuse simplifies the development process by managing complexity.

Building Blocks of Smell Part I

Review the following table of common smells and their chemical compound names. When you have finished, answer the questions following the table.

Smell	Where It Occurs in Nature	Compound Name	Molecular Structure Category
Fruity (rose)	Flowers	Geranyl acetate	Ester
Fruity (apple, pineapple)	Pineapple	Methyl butyrate, Methyl butanoate	Ester
Fruity (orange, pineapple)	N/A	Ethyl butyrate, Ethyl butanoate	Ester
Fruity (banana, pear)	Bananas	Isoamyl acetate	Ester
Fruity (pear, apricot)	N/A	Pentyl butyrate, Pentyl butanoate	Ester
Fruity (apple)	N/A	Pentyl pentanoate	Ester
Fruity (orange)	N/A	Octyl acetate	Ester
Fruity (grape)	N/A	Methyl anthranilate	Ester
Fruity (strawberry)	Strawberries	Benzyl acetate	Ester
Sweet (wine)	Wine	Ethyl acetate	Ester
Woody (complex)	Verbena	Myrcene	Linear terpene
Woody (lavender)	Lavender	Linalool	Linear terpene
Woody (bark)	Ginger	Nerolidol	Linear terpene
Flowery (rose)	Geraniums	Geraniol	Linear terpene
Flowery (sweet rose)	Neroli, lemongrass	Nerol	Linear terpene
Lemon	Lemongrass	Citral	Linear terpene
Lemon	Lemongrass	Citronellal	Linear terpene
Lemon	Lemongrass	Citronellol	Linear terpene
Orange	Oranges and lemons	Limonene	Cyclic terpene

Menthol	Menthol	Mentha	Cyclic terpene
Lilac	Lilacs	Terpineol	Cyclic terpene
Violet	Violets	Alpha-ionone	Cyclic terpene
Mint	Juniper	Thujone	Cyclic terpene
Almond	Bitter almond	Benzaldehyde	Aromatic
Clove	Clove	Eugenol	Aromatic
Cinnamon	Cinnamon	Cinnamaldehyde	Aromatic
Cooked fruit, caramelized sugar	N/A	Ethyl maltol	Aromatic
Vanilla	Vanilla	Vanillin	Aromatic
Anise (licorice)	Anise	Anisole	Aromatic
Anise (licorice)	Anise, sweet basil	Anethole	Aromatic
Tarragon	Tarragon	Estragole	Aromatic
Thyme	Thyme	Thymol	Aromatic
Fishy	N/A	Trimethylamine	Anime
Fishy	Belladonna	Pyridine	Anime
Rotting flesh	Rotting flesh	Putrescine	Anime
Rotting flesh	Rotting flesh	Cadaverine	Anime
Human waste	Human waste	Indole	Anime
Human waste	Human waste	Skatole	Anime

- Which smell is most common among the esters/can be produced by the most compounds?
- Which smell is most common among the linear terpenes/can be produced by the most compounds?
- Which smell is most common among the cyclic terpenes/can be produced by the most compounds?
- Which smell is most common among the aromatics/can be produced by the most compounds?
- Which smell is most common among the amines/can be produced by the most compounds?

Building Blocks of Smell Part I (answers)

- Which smell is most common among the esters/can be produced by the most compounds? (fruity, specifically apples and pineapples)
- Which smell is most common among the linear terpenes/can be produced by the most compounds? (lemon)
- Which smell is most common among the cyclic terpenes/can be produced by the most compounds? (No cyclic terpene scent appears more than once.)
- Which smell is most common among the aromatics/can be produced by the most compounds? (anise)
- Which smell is most common among the amines/can be produced by the most compounds? (They are equally divided: fishy, rotting flesh, and human waste.)

Building Blocks of Smell Part II

Using the table from Part I, create scent combinations from the smells given. Describe how much of each scent you would put in the mixture and what resulting smell—and possible uses for the movies—this combination could have.

Scent #1 Compound Name	Scent #2 Compound Name	Percentage of Scent #1 and Scent #2	Resulting Smell and Possible Uses
[Ethyl butyrate]	*[Methyl butyrate]*	*50%, 50%*	*Pineapple with apple and orange undertones: could be used for fruit salad or tropical environment.*

Abstracting Scent

In the following table, identify scents that could be used in movies to enhance the virtual reality experience. Then, hypothesize what categories of compounds these scents might fall into.

Useful Scent	Component Scents	Possible Compound/ Molecular Category
[Cookies]	*[Caramelizing sugar, vanilla]*	*[Aromatic]*