Standards-Aligned CaveSim Programs for Colorado High Schools

Thank you for your interest in CaveSim! The centerpiece of our program is our mobile cave. Housed in a 24' trailer, the cave contains 60' of passage filled with formations, cave biota, and ancient artifacts (all artificial), and students get a computerized score based on how carefully they avoid these objects as they explore.

Our programs are about much more than just fun. Students learn valuable content in biology, chemistry, physics, geology, engineering, and other subjects. To accomplish all this, students do much more than just explore a mobile cave. They do physics experiments on a 12' vertical caving tower. They learn about microbiology via labs with live cultures. Lessons with cave rescue phones and visualization equipment teach students about electromagnetics and engineering. Carbide lamp demos illustrate exothermic reactions, conservation of mass, and other chemistry concepts. In short, we provide an experience that is so interesting that students readily absorb valuable educational content without realizing that they're learning.

With engineering skills learned at MIT, I created the entire cave, including the electronics and software that give students feedback about their careful-caving skills. As a result, students learn that real people can create amazing things by excelling in school and following their passions. My staff and I are excited to help your students see the value of education in a whole new way.

High school students learn bat biology (and skeletal morphology)

— Dave Jackson, owner and inventor, CaveSim LLC.
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HS student quote, while working on a Petri dish during the CaveSim Biota Lab: "Mrs. Chaney [the HS biology teacher], why don't we get to do this kind of stuff in biology class?" CaveSim staff person: "This is biology class!" Student: "Oh, right." The students in this class were having so much fun learning that they forgot they were in class.

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Recent high school programs

Colorado Springs: The University School (Spring 2019, Spring 2018, Fall 2018)
Austin, TX: McCallum HS 4-day program (Spring 2019), Austin HS 1-day program (Spring 2018)
Grove, OK: Grove HS: 2-day program (Fall 2018), 1-day program (Spring 2018)

Standard Program Components (with Colorado standards[1] alignment)

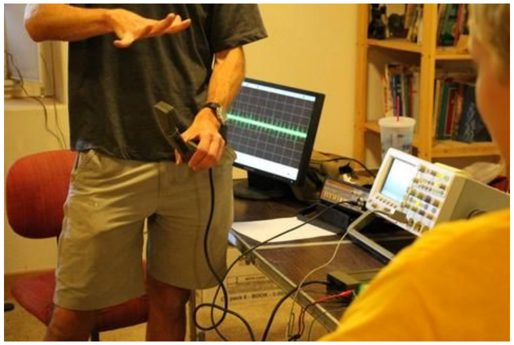
Standard components are included in the cost of the program. Students rotate through a series of different stations/lessons. Color key: Science Standards; Visual Arts Standards; Physical Education Standards

Program element: Explore CaveSim	Corresponding CDE Standards	Photos of CaveSim programs
<u>Horizontal caving</u> in CaveSim mobile cave (contains 60' of passage with multiple levels in a 24' trailer). While wearing helmets, students explore the cave and: ● Look for cave life (artificial) and discuss cave ecosystems.		 *A student at Austin High School explores CaveSim in 2018.*
● Look for indigenous artifacts & rock art, and discuss the importance of artifacts to native people, archaeologists, and anthropologists.		
● Try to avoid bumping into artificial cave formations. Students learn about the impact of skin oil on stalactites and other speleothems. The polar nature of water and the non-polar nature of skin oil are discussed to explain why touching destroys cave formations. Students learn about the relationship between the molecular-level characteristics and the macroscopic interactions of oil and water.	PS1:A Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.	
● Study the structure of the cave, and discuss how cave tunnels form. CaveSim staff talk about the role microorganisms (extremophile bacteria) play in metabolizing limestone using enzymes. ● CaveSim staff explain how aqueous cave formations (helictites, soda straws, gypsum) are formed. Fluid dynamics and the role of extremophiles are discussed.	PS1:B Chemical Reactions: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	
● Study the impact of diluted acid on various rock types. Discuss why and how carbonate rocks react with acid. Discuss the relative strength of chemical bonds in various rock types, and why the different rock types have different bond strength (based on how the rocks were formed).	HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	

[1] https://www.cde.state.co.us/coscience/2020cas-sc-p12

CaveSim program element: Vertical Caving	Corresponding CDE Standards	Photos of past CaveSim programs
Using the CaveSim portable 12’ A-frame w/ crash pads: ● While wearing helmets, students use a Bosun’s chair, ropes, and pulleys to learn about mechanical advantage afforded by 1:1 and 5:1 pulley systems, and learn that work is unchanged when a mechanical advantage is introduced. Students work together to lift a fellow student up the tower using the different systems. ● Students use water buckets on the tower to demonstrate Newton’s second law by making observations of balanced and unbalanced systems (with zero and non-zero net forces), recording rate of ascent/descent data, and drawing conclusions.		
● Students design a system to protect a wooden board from being destroyed when a water bucket is rapidly lowered from the top of the tower onto the board.		
● With the help of students, CaveSim staff demonstrate the power of friction to rapidly destroy Nylon rope. Staff work with students to develop models of the Nylon-Nylon interaction, and compare this to an interaction between Nylon rope and an aluminum or steel carabiner. ● With the help of students, CaveSim staff demonstrate the power of friction to allow a person to ascend a rope using the Prusik knot. Students learn to tie the Prusik, the Alpine Butterfly, the Lark’s Head, and other knots.	Colorado Essential Skills and Science and Engineering Practices: Use a model to predict the relationships between systems or between components of a system. PS1:A: Structure and Properties of Matter: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.... A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.	*Above, a Grove HS student uses mechanical advantage to lift herself up the A-frame. Below, Grove students & CaveSim staff destroy a rope in 20 seconds using another rope.*
● While wearing helmets, students use harnesses, mechanical ascenders, and footloops to ascend the 12’ A-frame. CaveSim staff discuss the ascender mechanics, as well as equipment safety and the important differences between caving and rock climbing equipment. ● Students engage in a discussion about vertical caving safety, and forces and vectors are discussed in the context of the 12’ A-frame.		

CaveSim program element: Carbide demonstrations	Corresponding CDE Standards	Photos of past CaveSim programs
To illustrate chemistry and physics concepts, CaveSim staff bring working carbide lamps and carbide to programs. Demonstrations include: ● CaveSim staff place carbide and ice in an open pan. As the ice melts, the water reacts with the carbide, producing the acetylene gas. CaveSim staff discuss the positive feedback associated with the reaction. Students investigate the interaction of the ice and the water heated by the carbide/water reaction. Students compare carbide (CaC_2) with road salt ($CaCl_2$) to develop a hypothesis about how carbide will react with water.	HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy levels of atoms. HS-PS1- 6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.	 *Above, carbide lamp demonstration by CaveSim staff at Grove high school in Oklahoma. Below, stock photo of the lamps we use.* 
● CaveSim staff light a working carbide lamp by placing carbide and water in the lamp to produce a small (and safe) quantity of flammable gas (acetylene). The acetylene burns to produce light and heat, but the lamp body also becomes hot because of the exothermic reaction between the carbide and water. The rate of reaction is controlled by the rate of dripping in the lamp (which controls the concentration of water in the reaction chamber). We discuss the concepts of limiting reactants.	HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	
● CaveSim staff mix carbide and water in a sealed container to demonstrate conservation of mass and energy. The container is placed on a gram balance, and the mass is recorded before and after the reaction. Students observe that the mass changes only after the resultant acetylene gas is released from the container. Students work with staff to draw models of the carbide-water chemical reaction.	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.	

Program element: cave rescue phones & waterproof speakers	Corresponding CDE Standards	Photos of past CaveSim programs
<u>Cave rescue phones</u> hands-on lessons: ● We bring two cave rescue phones to our programs. The phones are connected by wire, which allows us to discuss basic circuits, and demonstrate that a circuit requires at least one complete loop to function. Students can disconnect and reconnect wires for hands-on learning. Students talk with each other over the phones. CaveSim staff discuss the relationship between wire length, electrical resistance, electrical energy dissipation in the wire, and phone volume. Electrical circuits involving the earth as one of the conductor are discussed. The differences between analog and digital information transmission are also discussed.		 *High school students in Oklahoma enjoy using the cave rescue phones.*  *A CaveSim staff person teaches students about electricity and magnetism using cave rescue telephones and electronic test equipment (oscilloscopes).*
● Demonstrations with oscilloscopes (see https://whatis.techtarget.com/definition/oscilloscope) by CaveSim owner Dave Jackson, who has also designed high speed computer chips for oscilloscopes. The oscilloscope produces a graphical representation of voltage on the cave rescue phone wire vs. time, which allows students to visualize their vocal energy on a screen. We discuss graph axes, and the relationship between time-based and frequency based graphs. Resonances/oscillation of electrical and sound signals and the Fourier transform are also discussed. Students use tuning forks and water to demonstrate the relationships among frequency, wavelength, and speed.		
● Students use the aforementioned cave rescue phones to conduct electromagnetism experiments with analog meters, simple generators, and the aforementioned oscilloscope.		

Program element: Bat biology & epidemiology	Corresponding CDE Standards	Photos of CaveSim programs
<u>Bat skeleton and guano</u> demonstrations and lessons: ● Discussion of similarities/differences b/w bat wing morphology and human hand morphology. Discussion of evolutionary pressures that may have created the similarities/differences. ● Discussion of bat tail structure and usage of the tail in steering, balance, and in catching insects. ● Discussion of different types/sizes of bats, and the role that they play in helping humans. Real-life lesson about bat eradication by farmers and the impact on their crops. ● Discussions about history & the role caves played in the civil war (sources of saltpeter for the production of gunpowder).		 *CaveSim program lead Dave Jackson teaches high school students about bat biology in Oklahoma.*
● Photographic and/or video demonstration of the ongoing White Nose Syndrome (WNS) epidemic that has killed nearly 6 million bats in the last ~10 years. Lesson about the WNS fungus (Pseudogymnoascus destrucans) and how it metabolizes the bat alive. ● Discussion of bats' colonial behaviors, and the advantages and disadvantages of such behaviors.		
<u>Bat epidemiology activity</u>: As mentioned above, millions of bats are dying in the US from WNS. Students learn about the spread of this disease, and about the overarching epidemiological concepts, through a truly hands-on game. In this game, students apply powdered laundry detergent to their hands, and CaveSim staff use a blacklight to monitor the spread of the "disease" (i.e., fluorescent detergent) among the "bat" (i.e., student) population. Students play the game in multiple rounds, with the number of bat-bat interactions being equal to the round number. Students make a graph of interaction count vs. disease prevalence. Stochastic (i.e., random) processes are discussed.	Colorado Essential Skills and Science and Engineering Practices: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data. (e.g., number of trials, cost, risk, time), and refine the design accordingly	 *HS students in Oklahoma roleplay bats spreading WNS fungus.*

CaveSim program element	Corresponding CDE Standards	Photos of past CaveSim programs
<u>Cave rescue stretcher</u>: we bring an adult-sized cave rescue stretcher (Sked) to our programs. Students take turns getting into the stretcher. With the direct supervision of CaveSim staff, the student in the stretcher is carried through and around obstacles by fellow students. Students learn teamwork, communication, and leadership. <u>Space required</u>: any indoor or outdoor setting. May be done in classrooms or even hallways.		 *Austin High School student and football player gets ready to ride (successfully!) in the Skedco stretcher.*
<u>Squeezebox</u>: we bring an adjustable-height wooden box through which students can crawl to safely test their ability to navigate tight spaces. Students use a tape measure to quantify how tight a space they can move through. <u>Space required</u>: typically set up near the stretcher (see above). Any indoor or outdoor setting is fine.		 *Students at a 2018 Austin program use a tape measure to quantify their squeezebox skills.*

Special Program Components (aka labs)

Our standard programs (described above) can be enhanced with the addition of our labs. Our labs provide a very in-depth educational experience in a specific subject, such as biology or engineering. We never use kits because our goal is to teach students that engineering and science projects are accessible to them without the use of pre-prepared materials. We emphasize environmental conservation by including post-consumer recyclable materials in our engineering labs. Labs require:

- Classroom space

- Limited group size and sufficient time. Typically one class will spend 60 to 120 minutes on a lab (without doing other activities in that time), which may occur over a two-day period.
- Extra funding for lab materials and staff time.

<u>Engineering Lab:</u> Students create circuits using LEDs, switches, batteries, and other components to create an LED light system. They get hands-on experience with soldering (with supervision from CaveSim staff), and then design and make their own caving flashlight enclosure from recyclable materials. After creating their lights, students test their work in water to see if their lights are waterproof. Students have the chance to revise their designs if needed.

<u>Subjects/standards covered:</u> Electromagnetics, product design, material science, and mechanical engineering. **Technology Education Standard 8**: The student will apply the technology design process to create useful products and systems; **Standard 10**: The student will apply problem-solving and critical thinking techniques for troubleshooting, research and development, invention and innovation and experimentation and implement these strategies as a multidisciplinary approach; **Standard 11**: The student will apply creativity in developing technology products and systems. 1. Create a model to explain a solution to a problem. 2. Test and evaluate a design for improvement. 3. Identify quality controls necessary in a technology product or system process; **Standard 12**: The student will apply safe and proper use of tools, machines, materials, processes and technical concepts.


Students from The Colorado Springs School work on Engineering Lab (left) and Advanced Light Lab (right)

<u>Biota Lab:</u> Students culture cave biota in Petri dishes, and learn that single-celled organisms can demonstrate intelligence. Students choose from multiple experiments, and discuss the factors that impact the outcome of their experiments.

Students at a two-day high school program in Oklahoma get ready to inoculate their Petri dishes.

<u>Subjects/standards covered:</u> Experiment design, scientific method, and biology concepts. **HS-LS1-1**: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. **HS-LS1-2**: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. **HS-LS1-3**: Plan and conduct an investigation to provide evidence of the importance of maintaining homeostasis in living organisms. **HS-LS1-4**: Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms

<u>Karst Lab:</u> Students get to make their own cave formations and karst topography using safe household materials. Students learn hydrology, geology, basic chemistry, landforms, states of matter.

<u>Subjects covered:</u> Geology, hydrology, karst topography

<u>The value of education:</u> As an inventor and educator, Dave encourages students to study hard, find their passion, and understand that education is very important in life. During each program, Dave uses his personal story (including getting multiple degrees from MIT) to teach students that education leads to great success and adventure.

Keynote presentation in Lake George, CO.

Pricing and FAQ

How much do programs cost? This depends on factors like travel distance, number of days, and number of students. Our typical price is between $1408 and $1508/day, which usually works out to $7 to $10 per student. Discounts may be available. Please contact us for a quote.

Are deposits or contracts required? No. We will reserve your program date(s) once we agree on a price and you send us an email stating that you want us to visit your school at the agreed-upon price.

How are payments made? By check, made out to CaveSim LLC, as specified on the invoice that we'll email you. W9 available upon request.

Does CaveSim carry insurance? Yes. Once you commit to working with us, please let us know if you need a Certificate of Additionally Insured.

Are permission slips required? Yes. Paperless and printable versions in both English and Spanish are available: www.cavesim.com/waiver.

How much space is needed? Is power required? See www.cavesim.com/pages/site-logistics

Is this an outdoor activity? Typically yes. The cave stays inside the trailer (we don't move it into your school). Some activities can be moved inside in inclement weather (the tower can be moved indoors if you have 13+ foot ceilings in some part of your school). In light to moderate rain/snow, we put up tents to protect students and the cave.

Is the cave heated and air conditioned? Yes. Please provide access to 1 working 20A outlet in summer, and 2 outlets (15A and 20A) in winter.

How much setup and takedown time are needed? Typically 1.5 hours for setup, and 1 hour for takedown.

How many students can participate in a day? For elementary, 150-200. For MS/HS, 100-150. Educational value and number of students are inversely related. We're excited about working with you to size your groups for the best possible educational experience.

Does CaveSim do multi-day programs? Yes. We have done as many as six days in one school district.

Contact us: Email jacksondmit@cavesim.com or call 914-330-7824.

Safety and special needs

Teachers/staff can explore the cave, and students with special needs (physical or otherwise) may be assisted by school staff, students, and/or CaveSim staff. While each student is different, numerous wheelchair-bound students have explored CaveSim. Some students may have more difficulty avoiding cave formations, and our only requirement is that each student understand their goal of not touching the formations (for the safety of the system and students). Students who are unable to understand the careful-caving goal may participate in our other activities. CaveSim has night-vision cameras which allow us to check on students as they explore. We also have five access points to allow us to let participants out of the trailer if needed.

We follow the BSA's Youth Protection policy, which includes no 1:1 student/adult interaction.

Challenge by choice

Most students love exploring CaveSim. Occasionally we have a student who is unsure, uncomfortable, or afraid. We encourage him/her to set a goal for themselves and see if they can attain that goal. We teach challenge by choice, and have plenty of activities for students to try.

Classroom management

We've been doing our programs since 2010, and our staff includes former classroom teachers, so we have a good handle on classroom management. Because we spent over two years creating CaveSim, we set expectations at the start of the program: we expect students to respect the equipment and everyone involved in the program. We rarely experience discipline problems, but when we do we ask students to either change their behavior or take a break from the activity until they are ready to participate properly. Our goal is to work as a team with you, so please feel free to communicate with us about any issues that you foresee.