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What is a Virtual Lab?

A Virtual Lab is intended to give your students real-life problems to solve in a “virtual lab” that they find on their classroom computer. For an engineering design problem, such as the *Vehicle Design Virtual Lab*, students must define the problem, determine the design criteria and constraints, brainstorm solutions, build and test a prototype, and collect data in a systematic way. They will need data in order to evaluate their designs and perhaps make design changes and retest until they are satisfied that they have filled the design “need.” An important skill for students to master is that of developing a plan before they begin testing. Virtual engineering labs are complex. Students will find that a haphazard approach can produce a bewildering set of results.

One further goal of a Virtual Lab is for students to act as a community of research professionals (engineers, scientists, mathematicians, designers) working together toward the solution of a problem. For this reason, students are asked to communicate their process and results to you and to their classmates.

The Vehicle Design Virtual Lab

Overview

In this Virtual Lab, high school students are able to design and test vehicles that are suitable for different consumer needs. Based on an initial challenge to create a vehicle with as many advantages as possible, the students may choose to attempt to create vehicles that cost the least amount to manufacture, buy, or drive. They might also try to create vehicles that release the least amount of harmful carbon dioxide into Earth’s atmosphere or they may design vehicles that get the best mileage from their fuels. Many students will want to design vehicles that meet all of these conditions at once. However, good engineering process requires an understanding of each of the many variables involved and their complex interactions. You may choose to organize students into groups based on a design goal, or allow the groups to determine their own goals.

Students first decide what the purpose is for their vehicle (e.g. family trips, hauling loads, commuting to work). Entering the Design Lab, students choose an energy source that the vehicle will use, the vehicle’s size and shape, the motor size, the materials from which the vehicle frame and vehicle chassis are made, and finally the tire size. (For detailed lists of the design options available within the Design Lab, see the *Virtual Lab Procedure* section below.) When the vehicle is complete, students are presented with the curb weight, materials cost, and selling price for their first vehicle. They can then test that vehicle, revise their design, or go back and try designing a different vehicle.

Next, in the Test Lab. students decide how to test their vehicle. They are presented with options for test drive length, average speed, and for additional weight. Once these choices are made, the car is driven on the test track and students are automatically taken to the Review area where they are able to see their test results.

The Review area also shows a record of their design and test input choices for each vehicle design and test run.

Students may then decide whether to test the same vehicle under different conditions or take the vehicle back to the Design Lab where they can revise their design. Each time students make a design change in a vehicle, that design is given a new number, so that the data from the earlier test can be compared.

Learning Process

The Virtual Lab is designed to be open-ended in order to foster inquiry-based STEM learning. Students follow a scaffold version of the engineering design process. They determine their own design plans based their interpretation of the design challenge. The students identify the design need and the criteria and constraints that affect the vehicle they will design. They next develop a design plan and create a prototype vehicle using the tools provided in the Virtual Lab. Students then test their vehicle, evaluate the data, and revise their designs. Students are responsible for coming up with an efficient method for recording their own process, decisions, and data.

There is no one right inquiry question, no one right procedure, and no one right answer. Given the number of variables available within the Design and Test Labs, students or groups of students should be encouraged to investigate different vehicle design needs with the idea that all students will come together as a class at the end to compare designs and discuss which designs offer the most advantages for a particular vehicle use and targeted user.

In the Classroom

As a Teacher Demonstration

You may choose to use the Virtual Lab as a tool to demonstrate basic principles of advanced vehicle design to a class. For example, it is relatively simple to design three cars with similar weights and sizes, but which have different body shapes. Comparing these three cars will reveal that the Wing shape (tapered both front and back) has less air drag than a similar car with a Wedge shape (tapered in front, chopped off in back). This opens up class discussion about why cars aren't built with more aerodynamic shapes. What are the trade-offs facing engineers in designing vehicles?

Getting Students Started Using the Lab

Before allowing students to work on the lab, you may wish to demonstrate the lab functionality to students. The same demonstration above is a good example. Taking them once through the design process will help to reduce the amount of "messing around" time they will need in order to figure out how the lab variables work. The student guide also provides an in depth review of the lab, should you wish to assign the lab as a completely independent activity.

Collaboration

The Virtual Lab can be used successfully by students working alone. However, collaboration in pairs or in small groups increases the likelihood of success and fosters 21st Century skills. When they collaborate, students can divide the work according to their skills and interests. One student may feel more comfortable interacting with the screen while another may want to record data. One student may want to lead the small-group discussion while another may want to present the group's results to the class. Of course, the social interaction involved in teamwork has its own value. If your students collaborate in the Virtual Lab, it is up to you to decide whether they should write their experiment plans and summaries separately or together.

Sharing Results

One goal of the Virtual Lab is for students and student groups to act as a community of researchers working together toward the solution of a problem. For this reason, students are asked to share their design plans and summaries with their classmates. You may wish to direct this class discussion in one of these ways:

- Discuss any differences in the students' procedures. Ask them what kinds of thinking led to their different approaches.
- All students started with the same challenge, but students will have identified different needs as they interpret that challenge and which advantages to address with their vehicle design. Discuss differences in the product need and target users identified by students.
- List all of the criteria and constraints identified by student groups. Are there constraints common to everyone's design?
- Ask your students to analyze the trade-offs involved in bringing a vehicle to market. What need would a manufacturer not meet if it brought the cheapest vehicle to market? What are the trade-offs in producing the most fuel-efficient vehicle?

Allocating Class Time

This Virtual Lab can be completed by students in three or four class periods. One suggested use of the time is as follows:

Period 1: Introduce the challenge problem. Give students the Student Guide. This is when you may choose to demonstrate the functionality of the Design and Test Labs or allow students very limited time in the Design and Test Labs to just become familiar with the variable settings. Students may do research in class or as homework on some of the factors involved in the design. For example, what are the relative costs for different materials that they will be using to “make” their vehicle(s).

Period 2: Students brainstorm. They identify the design criteria and constraints. Students then write a design plan. This plan will include which data students will need to compare from multiple tests.

Period 3: Students design vehicles in the Design Lab and test them in the Test Lab. The virtual lab does not save data from session to session, so it is important that students design and test all of their vehicles, and gather all data during the same class session.

Period 4: Students share results and participate in class discussion.

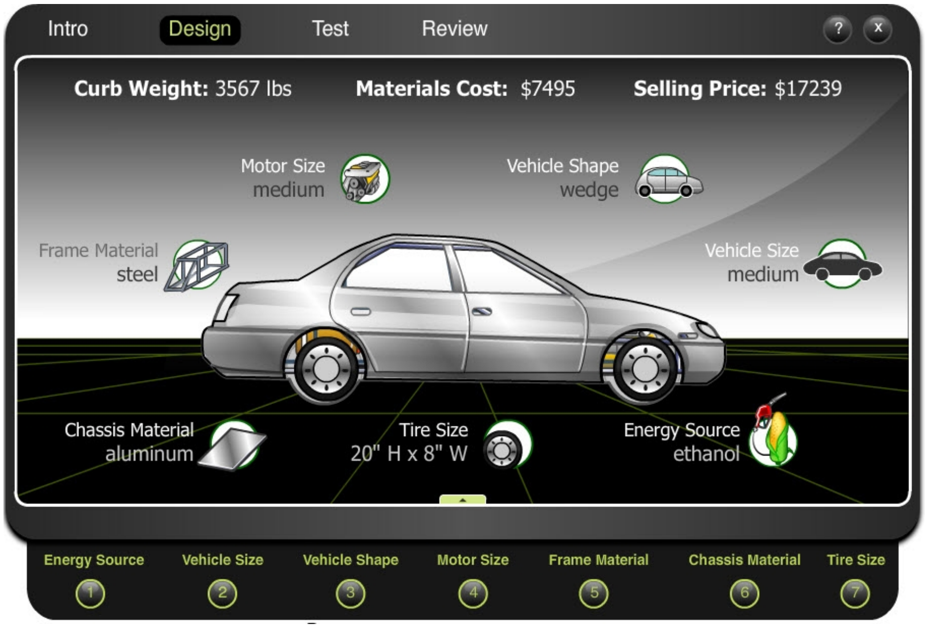
Virtual Labs Procedure

There are four sections in the Virtual Lab. Students navigate from section to section using the links at the top of the screen:

These four sections are intended to be read, explored, and completed in order, left to right. Briefly, they are as follows:

1. **Intro:** Students are introduced to a real-world problem and presented with the design challenge.
2. **Design:** Students go here to the Design Lab to design their vehicle(s). Cost will be automatically calculated once their choices are made.
3. **Test:** Students go to the Test Lab to drive their vehicles around a test track and gather additional data.
4. **Review:** Students go to the Review area to see summaries of all of the input choices they have made for each vehicle design, plus the data outputs for that vehicle. Students are able to print data summaries from inside the Review area. It is also possible to save a spreadsheet version of the data for analysis.

After reading the Intro, students can use either Design button at the top of the screen or the slide-up navigation bar along the bottom of the screen to go to the Design Lab. Here they can use a vehicle design simulator to design a vehicle for testing.



Curb Weight: 3567 lbs **Materials Cost:** $7495 **Selling Price:** $17239

Motor Size medium

Vehicle Shape wedge

Frame Material steel

Vehicle Size medium

Chassis Material aluminum

Tire Size 20" H x 8" W

Energy Source ethanol

Here are the design options students will find in the Design Lab:

- **Energy Source** Choose from electric, hybrid, natural gas, ethanol, gasoline, diesel, or biodiesel. These choices are based on current technologies and different fuels as they are most commonly available for sale in consumer vehicles.
- **Vehicle Size** Choose from small, medium, or cargo van. Small and medium-sized cargo van settings might be used to approximate SUVs.
- **Vehicle Shape** Choose from boxy, wedge, or wing. A boxy vehicle shape is blunt in both the front and back. A wedge-shaped vehicle is tapered in the front, but is often blunt in the back. A wing-shaped vehicle is tapered in both the front and back like an airplane wing
- **Motor Size** Choose from small, medium, or large. These are engines that are intended to work with the vehicle size you have already chosen. A small car's small engine is smaller than a medium car's small engine. Weight differences here also reflect larger or smaller transmissions, etc.
- **Frame Material** Choose from steel, aluminum, or carbon fiber. All three materials are strong and durable enough to use in vehicle frames, so consider other factors in choosing the material.
- **Chassis Material** Choose from steel, aluminum, or carbon fiber.
- **Tire Size** Choose from 6 different tire sizes. The tire heights are the diameter of the wheel and its tire when inflated and on the vehicle. The width is the width of the inflated tire tread in contact with the ground.

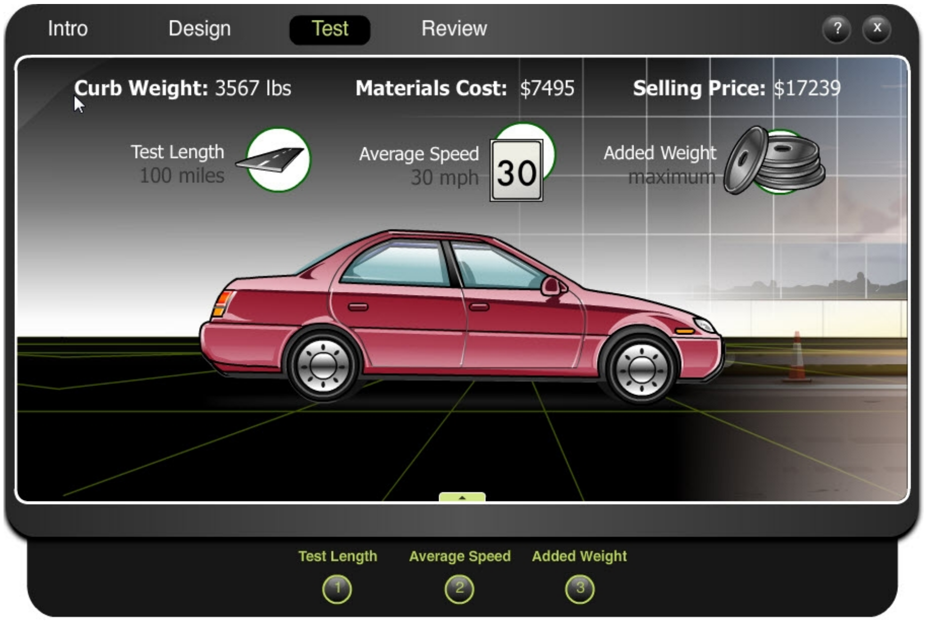
In the Design Lab, students will see the following data outputs, representing the outcomes of their design decisions:

- **Curb Weight** This is how much the vehicle weighs with a full tank of fuel. The curb weight will not be final until students have made choices for all 7 design inputs.
- **Materials Cost** This is how much the raw materials cost to build the vehicle.

- **Selling Price** This is how much the finished vehicle will cost at a dealer (the “sticker price”). It includes labor to make the vehicle, shipping costs, and, of course, profit to the vehicle maker and the dealer. Tags, title and taxes are not included.

Once a vehicle is designed, students will take it to the Test Lab to drive it on the test track. Here are the test options students will find in the Test Lab:

- **Test Length** Choose a test drive length of 50, 100, or 200 miles.
- **Average Speed** Choose to drive a vehicle at 30 or 65 miles per hour (mph).
- **Added Weight** Choose from minimum or maximum. A minimum added weight only adds the weight of a driver (200 lbs). Choosing maximum adds weight equivalent to: 1) a driver, passenger, and 100 lbs of cargo for a small vehicle (500 lbs total); 2) a driver, 4 passengers, and 300 lbs of cargo for a medium vehicle (about 1200 lbs total); and 3) a driver, 1 passenger, and 1000 lbs cargo for a cargo van (1400 lbs total).


Curb Weight: 3567 lbs
Materials Cost: $7495
Selling Price: $17239
Test Length 100 miles
Average Speed 30 mph
Added Weight maximum

Once the vehicle has been tested, students will automatically be taken to the Review area where they will see the following data outputs, representing how the tested vehicle performed on the test track:

- **Loaded Vehicle Weight** Total weight of vehicle’s curb weight plus added cargo weight
- **Time to Complete Test** How long it takes the vehicle to complete the test drive
- **Drag Force (air)** Drag force on the vehicle due to friction from air moving over the vehicle’s surface during the test drive (in pound feet)
- **Drag Force (tires)** Drag force on the vehicle due to friction from the tires rolling over the track during the vehicle’s test drive (in pound feet)
- **Fuel Use** Amount of fuel (in miles per gallon gasoline equivalent (MPGe*)) used by the vehicle during the test drive
- **Fuel Cost** Cost to drive the vehicle (in cents per mile)
- **Carbon Emissions** Pounds carbon dioxide released into Earth’s atmosphere by the vehicle during the test drive

* If the vehicle does not burn gasoline, MPGe is the equivalent miles per gallon of gasoline that it would use. This value is a way for engineers to compare the efficiency of gasoline and non-gasoline vehicles. You may wish to have students read the Progressive Automotive XPRIZE Prize Blog on this measure: http://autoblog.xprize.org/axp/2009/08/gms-claims-cast-doubt-on-fuel-economy-rating.html

The Review area allows students to examine the results of different tests they have run on either the same or different vehicle designs. Students can choose a vehicle and flip through the different tests run on that vehicle by using the left or right arrows. Students also have the option in the Review area to either: 1) print their results using the Print button; or 2) save their results as a spreadsheet. **Note:** Data is not saved between sessions. If students reload the virtual lab or return to run it again on a second day, their results from the first session will be lost. Therefore, remind students to record, print, or save their data when they are finished each time they work on the virtual lab.

Engineering Design Process

Nearly all products that come to market have gone through an engineering design process. Some products, such as cars or washing machines or even ballpoint pens, have gone through this process. In the Vehicle Design Virtual Lab, students are asked to follow a variation on the engineering design process. Below are some general thoughts on the critical parts of the engineering design process presented to the students in the Student Guide:

Identify the need

The first thing students need to do is reword the challenge given in the Virtual Lab so that it expresses what it is specifically that the target user of the product needs. They should express the challenge as a statement that follows the general format: "I am designing a (product) for (target user) so that they may (a useful function that satisfies the target user's need)." For the Vehicle Design Virtual Lab, one design need might be: "I am designing a vehicle for small families that gets high mileage, is affordable, and does not pollute."

There are many good design need statements that students might pose in this lab. The best results are achieved when individuals or groups each investigates a different need or evaluates the same need using different design plans. This strategy makes good use of scarce resources and promotes collaboration. Toward the end of the lab time, as part of the sharing process, the students can put together the evidence from their separate designs and tests and arrive at a common solution to the larger question.

Do research and brainstorm ideas

Encourage students to do research *before* they begin writing their design plan. Students should focus their research and brainstorming on what makes a "best" vehicle to meet the design need. Students may choose to brainstorm before they do their research, after they do research, or even do some research before and after brainstorming. Available time is a limiting factor and you should remind them of the schedule for the activity.

There are three other resources that are important in doing this lab:

Student Guide

The Virtual Lab has its own Student Guide that provides students with information needed to carry out the work of the lab. The Student Guide document is an Acrobat PDF file that can be viewed online or printed. It is found in the Intro section of the Virtual Lab itself. You may want to print out the Student Guide for students ahead of time. This document walks students through the lab sections and gives suggestions on using the engineering design process with the Virtual Lab to solve the design challenge.

Fuel Our Future Now Additional Resources

The Additional Resources page on the Fuel Our Future Now web site (http://fuelourfuturenow.com/resources.cfm) has links to useful data resources from the U.S. Department of Energy (e.g., alternative fuels http://www.afdc.energy.gov/afdc/fuels/index.html), the Environmental Protection Agency (e.g., vehicle mileage comparison http://www.fueleconomy.gov/feg/findacar.htm), and many other sources. Students may also want to revisit video clips and activities from both the Middle School and High School areas of the Fuel Our Future Now site, as the content presented is helpful as prior knowledge for completing this Virtual Lab.

Additional Online References

At first, students will have more than enough variables to test and data to examine without seeking additional information. However, depending on available time, you may encourage students to do additional research online to clear up any questions they may have about such topics as drag due to rolling resistance, drag due to air friction, the costs involved in manufacturing a vehicle, etc.

Identify design criteria and constraints

In order to write a design plan, students must next take their identified design need and identify the design criteria and constraints for that need. Criteria are those things against which the student can measure the success or failure of the final design. For example, if a vehicle is designed to be an economical family car, is it inexpensive to purchase (i.e., sticker price)? Does it get good mileage? Do you think the vehicle has sufficient cabin space for passengers and trunk space for groceries?

Students must also determine what constraints exist on their design. The first and most obvious constraint on the design is the limited number of design choices available within the virtual lab. The student cannot select an option for a variable if that option is not available within the lab. In the real world, available technology, resource availability, time, and cost are almost always design constraints.

Develop a design plan

It is suggested that you have students write down their design plan either using a text processor or pencil and paper. The design plan should also include a statement of the design need, a list of identified design criteria and constraints, a description of their preliminary design including choices for variables within the Design Lab, and a description of their testing plan including choices for variables within the Test Lab. You may want to read and approve students' design plans before letting them enter the Design Lab. Challenge students to tell you why their proposed vehicle design "best" meets the need of the target user. Ask how they will know if their vehicle does not "best" meet the needs of the target user.

Students may also not understand how different variables are linked and affect each other. One of the strengths of the Virtual Lab is that it makes these misunderstandings explicit and forces students to struggle with them. For instance, choosing lighter materials for the vehicle's frame and chassis does decrease the vehicle's weight and increases its efficiency (miles per gallon); however, those raw materials cost more and drive up the sticker price of the vehicle.

Implement the design plan and test the design

Students next enter the Design Lab and, following their design plan, construct their first vehicle. Students may revise their initial design before taking it to the Test Lab; however, students should know that there will not be any data saved for any vehicle that does not get tested in the Test Lab. Once students are satisfied with their vehicle, they should move to the Test Lab and carry out their testing plan.

Evaluate test results, revise design and retest

Unlike the commonly accepted scientific method, the engineering design process is iterative. Within the constraints of time and budget, design prototypes can be built, tested, and then modified to create better designs. Students may modify a design before taking it to the Test Lab. They can test the same vehicle design under different conditions in the Test Lab or return to the Design Lab to modify their original design and then test the revised model. At each stage, it is important for the students to understand and document their decisions and explain what data (e.g., data outputs, test results) led them to make changes. Students should be able to answer the question, "In what way did this change better meet the design criteria?" As with science investigations, students will be tempted to change more than one variable at a time. You may wish to caution against this, or let them discover on their own how that confounds their results. It is possible for students to print the results or to save them as a spreadsheet file and manipulate or graph the data.

Communicate process, results, and recommendations

Finally, students should be prepared to share their work with you and with their classmates. Students should be prepared to present their written summary, which includes the design need, their design criteria and constraints, a description of their design process, a summary of data including how it may have caused them to revise their designs, and their conclusions/recommendations.

About Lab Results

The Vehicle Design Virtual Lab is a simulation. The calculations performed behind the scenes are based on real numbers from vehicles currently in commercial production, but are not meant to suggest that they are real numbers. That is, the Virtual Lab may say that the car your student has designed weighs 2250 pounds. In reality, that only approximates the weight of a car of that general description or with the characteristics matching what the student has selected. What's more important is that the relative numbers are accurate. Changing the vehicle's frame or chassis materials from aluminum to steel will make the vehicle heavier; changing them to carbon fiber will make the vehicle lighter. Numbers are meant to be interpreted relative to other vehicles and to variations in the same vehicle.

Here are a few examples of results your students should find:

- The same vehicle will run father (greater MPG) on diesel and biodiesel than on other fuels. However, the carbon dioxide output (in lbs/gallon) is significantly greater for these fuels.
- The cheapest car to drive in terms of fuel is the all-electric vehicle. However, at current costs, an all-electric car that goes more than 40 miles between charges is too expensive for most consumers to purchase.
- Drag resistance from air increases with vehicle speed. Drag from the rolling resistance of the tires increases slightly with increased tire width, but does not change with increases in vehicle speed.

Inquiry in the Virtual Lab

Most of students' work in the Virtual Lab is done on a computer. Students are given a problem situation (e.g., design an affordable, fuel efficient vehicle), some information, and a virtual laboratory with some resources (e.g., a vehicle design lab and a test track) with which they can test their ideas. What happens next is up to them. They must identify the design need, evaluate design criteria and constraints, develop a design plan, build and test their design, analyze how their initial design meets their stated goals, and then revise and retest their design if necessary. The amount of guidance you provide will depend on how much experience your students have in designing good investigations.

Remember that this Virtual Labs is an inquiry-based activity. It is as much concerned with curiosity and investigation as it is with specific engineering, mathematics, or science content.

How will you know inquiry when you see it? Look for the following:

- Students plan and carry out their own investigations.
- Students behave as engineers, scientists, and mathematicians.
- Students work cooperatively with their peers and collaborate with other student researchers to find solutions to problems.
- Students take opportunities to try out their own ideas, to question or verify findings, and to revise and retest less-than-successful designs.
- Students are interested in unexpected results and regard "failure" in the lab as an invitation to rethink assumptions and try again.
- Students exhibit curiosity, skepticism, open-mindedness, and "what-if" thinking.
- Students listen actively and communicate their ideas using a variety of methods.

Conclusion

Your role as the teacher in an inquiry classroom is not to impart factual information or even to tell students what to do. Your role is to promote inquiry and manage the learning environment. When your students are doing a Virtual Lab, you serve as a facilitator. You offer support and head off the occasional wild notion, but you mostly observe. When your students collaborate and share their results, you encourage engagement and point out that they are building their own knowledge. Again, your role is facilitation. Your students' goal is discovery.

This is a very empowering kind of teaching. It may be as much a challenge for you as for your students. But, like all discovery, it is also very exciting, and it will lead you and your students in many new and productive directions.

Meeting the Standards

This Virtual Lab, along with the written student and teacher materials, addresses the following science, technology, engineering, and math (STEM) standards, as well as the 21st Century Skills:

Science:

NSES Standards	
Code	**Standard**
12ASI1.3	Use technology and mathematics to improve investigations and communications.
12ASI2.3	Scientists rely on technology to enhance the gathering and manipulation of data
12ASI2.4	Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results
12EST1.1	Identify a problem or design an opportunity. Students should be able to identify new problems or needs and to change and improve current technological designs.
12EST1.2	Propose designs and choose between alternative solutions. Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes.
12EST1.3	Implement a proposed solution.
12EST1.4	Evaluate the solution and its consequences. Students should test any solution against the needs and criteria it was designed to meet. At this stage, new criteria not originally considered may be reviewed.
12EST1.5	Communicate the problem, process, and solution.
12EST2.3	Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
12BPS2.4	The physical properties of compounds reflect the nature of the interactions among its molecules.
	The magnitude of the change in motion can be calculated using the relationship F=ma, which is independent of the nature of the force.
12BPS3.1	Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.
12FSPSP3.2	The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes

	those resources that cannot be renewed
12FSPSP6.2	Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science - and technology - related challenges. However, understanding science alone will not resolve local, national or global challenges.

AAAS Project 2061 Benchmarks	
Code	**Standard**
4E/H1*	Although the various forms of energy appear very different, each can be measured in a way that makes it possible to keep track of how much of one form is converted into another. Whenever the amount of energy in one place diminishes the amount in other places or forms increases by the same amount.
4F/H1*	The change in motion (direction or speed) of an object is proportional to the applied force and inversely proportional to the mass.
4D/H10**	The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.
7C/H2	The decisions of one generation both provide and limit the range of the possibilities open to the next generation.
7D/H1	Benefits and costs of proposed choices include consequences that are long-term as well as short-term, and indirect as well as direct. The more remote the consequences of a personal or social decision, the harder it usually is to take them into account in considering alternatives. But benefits and costs may be difficult to estimate.
7D/H2	In deciding among alternatives, a major question is who will receive the benefits and who (not necessarily the same people) will bear the costs.

Technology:

AAAS Project 2061 Benchmarks	
Code	**Standard**
3A/H1	Technological problems and advances often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend

	their research in new ways or to undertake entirely new lines o research. The very availability of new technology itself often sparks scientific advances.
3A/H2	Mathematics, creativity, logic, and originality are all needed to improve technology.
3A/H3a	Technology usually affects society more directly than science does because technology solves practical problems and serves human needs (and also creates new problems and needs).
3A/H4	Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge provides a means of estimating what the behavior of things will be even before they are made. Moreover, science often suggests new kinds of behavior that had not even been imagined before, and so leads to new technologies.
3B/H1	In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
3B/H2	The value of any given technology may be different for different groups of people and at different points in time.
3B/H4	Risk analysis is used to minimize the likelihood of unwanted side effects of a new technology. The public perception of risk may depend, however, on psychological factors as well as scientific ones.
3C/H1	Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives.
3C/H3	In deciding on proposals to introduce new technologies or curtail existing ones, some key questions arise concerning possible alternatives, who benefits and who suffers, financial and social costs, possible risks, resources used (human, material, or energy), and waste disposal.
8C/H2*	When selecting fuels, it is important to consider the relative advantages and disadvantages of each fuel.
8C/H5*	Decisions to slow the depletion of energy resources can be made at many levels, from personal to national, and they always involve trade-offs involving economic costs and social values.

ITEA Standards

Code	Standard
Standard 1	**Students will develop an understanding of the characteristics and scope of technology.** • In order to understand the scope of technology, students in Grades 9-12 should learn that: o L. Inventions and innovations are results of specific, goal-directed research. o M. Most development of technologies these days is driven by the profit motive and the market.
Standard 2	**Students will develop an understanding of the core conce technology.** • In order to recognize the core concepts of technology, students in Grades 9-12 should learn that: o W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems. o Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. o AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development. o BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.
Standard 4	**Students will develop an understanding of the culture, soc economic, and political effects of technology.** • In order to recognize the changes in society caused by the use of technology, students in Grades 9-12 should learn that: o I. Making decisions about the use of technology involves weighing the trade-offs between positive and negative effects.
Standard 5	**Students will develop an understanding of the effects of technology on the environment.** • In order to discern the effects of technology on

	the environment, students in Grades 9-12 should learn that: o G. Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling. o H. When new technologies are developed to reduce the use of resources, considerations of trade-offs are important. o L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.
Standard 6	Students will develop an understanding of the role of society in the development and use of technology. • In order to realize the impact of society on technology, students in Grades 9-12 should learn that: o I. The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures. o J. A number of different factors, such as advertising, the strength of the economy, the goals of a company, and the latest fad contribute to shaping the design of and demand for various technologies.

Math:

NCTM Standards	
Code	**Standard**
	Judge the reasonableness of numerical computations and their results
	Evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions
	Solve problems that arise in mathematics and in other contexts.
	Understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each
	Know the characteristics of well-designed studies, including the role of randomization in surveys and experiments

	Compute basic statistics and understand the distinction between a statistic and a parameter
	Use representations to model and interpret physical, social, and mathematical phenomena

AAAS Project 2061 Benchmarks	
Code	**Standard**
2B/H1*	Mathematical modeling aids in technological design by simulating how a proposed system might behave.
2B/H3*	Mathematics provides a precise language to describe objects and events and the relationships among them. In addition, mathematics provides tools for solving problems, analyzing data, and making logical arguments.
2B/H6** (SFAA)	Mathematics is useful in business, industry, music, historical scholarship, politics, sports, medicine, agriculture, engineering, and the social and natural sciences.
9C/H6**	Both shape and scale can have important consequences for the performance of systems.
9B/H4	Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another.

21st Century Skills

Code	**Standard**
Global Awareness	Using 21st century skills to understand and address global issues
Financial, economic, business and entrepreneurial literacy	Knowing how to make appropriate personal economic choices
	Understanding the role of the economy in society
Creativity and Innovation	Demonstrating originality and inventiveness in work
	Being open and responsive to new and diverse perspectives
	Developing, implementing, and communicating new ideas to others
	Acting on creative ideas to make a tangible and useful contribution to the domain in which the innovation occurs
Critical Thinking and Problem Solving	Exercising sound reasoning in understanding
	Making complex choices and decisions
	Understanding the interconnections among systems
	Identifying and asking significant questions that clarify various points of view and lead to better solutions

	Framing, analyzing and synthesizing information in order to solve problems and answer questions
Communication and Collaboration	Articulating thoughts and ideas clearly and effectively through speaking and writing
	Demonstrating ability to work effectively with diverse teams
	Exercising flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal
	Assuming shared responsibility for collaborative work
Information Literacy	Accessing information efficiently and effectively, evaluating information critically and competently and using information accurately and creatively for the issue or problem at hand
Flexibility & Adaptability	Adapting to varied roles and responsibilities
Initiative & Self-Direction	Monitoring one's own understanding and learning needs
ICT Literacy	Using technology as a tool to research, organize, evaluate and communicate information, and the possession of a fundamental understanding of the ethical/legal issues surrounding the access and use of information
	Going beyond basic mastery of skills and/or curriculum to explore and expand one's own learning and opportunities to gain expertise
	Defining, prioritizing and completing tasks without direct oversight
	Utilizing time efficiently and managing workload
	Demonstrating commitment to learning as a lifelong process
Social & Cross-Cultural Skills	Working appropriately and productively with others
Productivity & Accountability	Setting and meeting high standards and goals for delivering quality work on time
	Demonstrating diligence and a positive work ethic (e.g., being punctual and reliable)
Leadership & Responsibility	Using interpersonal and problem-solving skills to influence and guide others toward a goal
	Leveraging strengths of others to accomplish a common goal
	Demonstrating integrity and ethical behavior
	Acting responsibly with the interests of the larger community in mind