Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2006 Volume IV: Math in the Beauty and Realization of Architecture

Gingerbread Architecture: An Exploration of Architecture and Engineering

Curriculum Unit 06.04.01
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Introduction

In this unit students will combine math, technology and art in the creation of gingerbread houses. Students will use math and basic engineering skills to test various gingerbread house building materials for strength and other important building characteristics. Students will also study various building techniques and the materials to which they have been applied throughout human history. Using information gained from these two exercises, students will design and construct gingerbread houses.

This unit will be very good for a class with many different types of learners. It will have strong visual elements to it, but it will also have very kinesthetic aspect to it as well as spatial and mathematical elements. Because of the many skills required, this unit will lend itself well to a class that can work in small teams. All of the projects involved in this curriculum unit could be accomplished by individuals, but most of them could also be done in small groups or teams. In this way, this unit can be adapted to use in a much larger class setting than the one for which I am designing it.

Correspondence with Curriculum

This unit corresponds with parts of the science curriculum for the city of New Haven as well as parts of the science curriculum for the state of Connecticut. Both curricula are based on recommendations in the National Science Education Standards. The Connecticut and New Haven Standards may be found in the appendix at the end of this unit. Essentially, though, both standards call for students to be able to explain how forces act on materials, why certain materials are chosen rather than others, and how technology is used and has been used to improve living standards.

In this unit, students will study the forces that act on structures. The method of study recommended by the State of Connecticut for these phenomena is to study bridge construction. However, the same forces apply to house construction, and there are far more houses than bridges to study in the neighborhood where my school is located. I am in favor of taking a walk to see actual phenomena in action rather than reading about them in books whenever this is possible, so this unit is focused on houses and other similar structures rather than on bridges. The students will, therefore, be experimenting with various materials that in some way

resemble housing construction materials to test the ways that the materials react to stresses that might be typically found in buildings. They will be learning about the same forces that act on bridges, but they will be using a different medium, gingerbread houses.

In this unit, the students will observe the choices that builders have made in their selections of building materials in the houses in our neighborhood. The students will then use their observations of the buildings to evaluate the choices that they make in choosing building materials for their gingerbread houses. There are hundreds of different gingerbread recipes and each one has its own strengths and weaknesses. In addition, "gingerbread" houses can be made from many other materials. In this curriculum unit, students will have certain guidelines, but they will have to decide what materials they wish to use to construct their houses. Of course, the students will be expected to defend their decisions.

Finally, the students will also study the advances that have occurred in building construction. We will look at the basic problem of enclosing a space while still leaving a usable space underneath the roof. After all, young children are very good at building castles out of sand at the beach, but there isn't a whole lot of living space inside a sand castle. The student will consider how different societies have used different technologies to solve the problem of supporting a roof without taking up all of the space underneath.

Student Population

A word about my student population is essential in the introduction to this unit as my students are very unique. Students are not admitted to my school without a proof of pregnancy. As a result, all of our students are female and most are in high school. We admit students as they come to us at all times during the year, so in planning units, including this one, I plan for several contingencies. The most common contingency is that there will be more students at the end of the unit than are present at the beginning. This generally means that students will need to be able to work on some parts of the unit independently while I work with the student who just entered. This sort of planning is also useful when some students work more quickly than others. The second major contingency is that students will legitimately be out of school for various reasons relating to their pregnancies. This means that any classroom work needs to have a similar component suitable to be sent home. The third contingency is caused by our policy that we will take any student who lives in the district and has proof of pregnancy. This means that my classes are small, but they tend to have very diverse levels of ability. For example, this unit is aimed at an eighth grade level. This class typically has fewer than five students, but they may or may not have been in eighth grade before and may or may not have already covered the particular material that is being covered on a given day. As a result, the five students in the room may all need different levels of instruction. So, in writing a curriculum unit, I try to include variations on the theme which would allow the unit to be taught at different levels. Furthermore, I try to teach the material in the curriculum in a way that is unique in the district, so the students who have covered the material before are not bored and therefore disruptive.

What is Architecture

Architecture is many things to many different people. This unit will focus on architecture, that is buildings, their materials, their structures, and their artistry, in which people live. Architecture is a holistic discipline which combines structural engineering with art. It combines the mundane necessities of building sturdy buildings with the necessity of making the buildings comfortable living spaces. Buildings must not collapse, but they also must not be irritating to the eye, mind or body. Architecture is the discipline which improves basic structures with pleasing aesthetics.

In this unit, we will study architecture as a discipline, but we will also study the results of this discipline. We will study buildings which have been built over the ages in various parts of the world before building our own houses. We will study structural principles, but we will also study aesthetics. The students will be required to use information from both aspects in their final constructions.

Why Gingerbread Houses

This project obviously could have been done with any of a number of different building materials. Tooth pick constructions are common, as are popsicle sticks and balsa wood, but their frequent occurrence in curricula around the country and around the world is one of the reasons I have chosen not to use them. Many of the students have been in eighth grade before coming to my class. Many teachers have written or used curricula which build bridges with the above mentioned materials, and students tend to resent having to redo work that they have done before. Gingerbread is not a common material, and, therefore, it is unlikely to have been used before.

Furthermore, gingerbread houses are a traditional winter holiday construction. It is a tradition of which many students may have heard, but most of my students will not have built a gingerbread house before. This project has the potential to expand the experience of students beyond what they might get at home. It also gives my students a chance to experience a project which, if simplified, they might share with their child when he or she is older. This project will be timed to finish just before the winter holiday break. The project will give students something that they can contribute to their families during the holidays.

Finally, gingerbread is fun. It combines learning with one of students' favorite activities, eating. The students will have lab reports to write and will have other assessments, but they will do most of the learning while "playing". This approach encourages laughter and a relaxed atmosphere, both of which promote healthy pregnancies, while still engaging in education. In this way both of my school's missions, educated mother and healthy babies, are accomplished.

Observations

All good science begins with observations. This curriculum unit is no exception. We will begin by exploring building styles throughout history and around the world. I realize that this is a very broad topic, but we will approach it looking for trends and common features. This piece of the observation will be done via a PowerPoint slide show. We will continue our observations by observing the architecture of the world around us. We are fortunate in that New Haven is a city rich in very diverse architecture. Finally, we will also observe how buildings are put together.

Building Styles: a history of architecture

Students at the eighth grade level need concrete examples to help them start on creative projects. In this case the concrete example to help the students design their gingerbread houses will be buildings as they have been built in the past. This serves several purposes. First, it introduces the idea that there are many ways to solve the fundamental problem of enclosing a hollow space. In order to live in a space, the area must be reasonably free of columns, walls and other support structures that might impede free movement of people and objects; hence it must be a hollow space. The challenge in building a space is this: any child can build a

solid sand castle but the building task becomes more challenge when the interior space needs to be reasonable empty of support structures. This part of the unit will introduce the idea that there are many resolutions for this task.

Another reason to begin with this overview is that the students may be introduced to the vocabulary associated with architecture. Vocabulary is essential for comprehensible discussion of any topic. As such, vocabulary needs to be introduced as early as possible in any discussion, so it is begun here in this introduction. However, the specific vocabulary terms will be discussed in more detail later in this document.

The overview of architecture allows information to be presented using technology. Traditionally, this section probably would have involved slides, a slide project, a darkened room, and a droning voice. The information does not have to be presented this way, though. In my case, I will put together an electronic slide show. If this is done properly, students will be able to go through the captioned images at their own pace and possibly even at home, for the students on bedrest. Ideally, this slide show can be done using local buildings as examples, which will help show the relevance of this study by connecting architectural concepts to local landmarks. Incidentally, if you have technology use requirements for your classroom, this is one way to meet them. By allowing students to go through the information on their own, I solve two problems: differentiation of instruction, and the issue of students working on different sections of the unit at different times.

As always, this section of the unit will require some sort of assessment. In this case, the assessment will take two forms. The students will have a vocabulary sheet which they will be expected to update as the vocabulary terms come up in class, and the students will be expected to start a sketch book showing various styles or pieces of buildings that interest them. This sketch book will continue with our walk. The vocabulary sheet will be checked for progress a few times per week. The sketch book will be assessed in a similar manner.

Neighborhood Walking Activity

The neighborhood in which our school is situated is very interesting in its diversity of architecture. We are located on a park which is surrounded primarily by residences. However, there are two major exceptions. The first exception is our school. The second is a large church. Both of these buildings provide several architectural elements which are different from the other buildings in our neighborhood. All of this means that we can see a wide array of architecture without walking more that a block. However, if the nature of a class allows for a longer walk, (sometimes there are medical issues that prohibit longer walks), we are only a few blocks from downtown New Haven, which has a wealth of architecture as well. This walk is an activity that could be adapted to most urban settings, but which might be a bit more complicated in a suburban or rural setting.

Essentially, this activity consists of observing buildings in situ. There is a fair amount that can be learned from a picture of a building, but the picture can not necessarily show you that a front is a false front, or that a porch is made of a composite material, not real wood, etc. Seeing a building in situ allows the students to see much more. This activity will allow students to see that buildings are part of the environment around them. They will be able to see what happens to materials in shady areas that might not happen to the same materials in sunny areas. This activity will allow the students to see how tree roots can push up side walks and crack masonry walls. All of the students' observations will be recorded in the students' sketch books. This walk will also allow students to develop a visual reference containing the ways that different building materials are used and how they are joined.

Building Materials

The choice of building material is one of the most important decisions made in the construction of a building, or any other large object. This decision determines many of the limitations of a project. For example, a building made of stone will need to be built on a foundation that can hold the weight of the stone. A building with glass walls will have to account for sunlight in a different way than a building made of primarily brick walls would. Buildings made of old oil drums in the Caribbean are uncomfortably hot because of the nature of the metal drums. Similar Caribbean buildings made of adobe are far more comfortable. All of these types considerations are essential in the planning process.

In this part of the unit, students will be observing the types of materials that are being used for various parts of the buildings we will see on our walks and in the electronic slide show. For example, the students will observe the types of materials being used for roofs, doors, or siding.

There are several reasons for these observations. First, the observations provide concrete examples which illustrate the many ways there are to solve common architectural problems. For example, there are many ways to create an entrance to a building. Some ways present an imposing "keep out" sort of feeling. Other ways may present an inviting "welcome" sort of feeling. The students will be expected to record their reactions to some of the different solutions they encounter on our walks.

Second, the observations provide concrete examples which illustrate that more than one type of material is used in almost every building. The combination of materials is another important decision in building construction because a good combination will make a building stronger. A poor choice will weaken the overall structure. The students need to understand that different materials are chosen to do different jobs in a structure because of the particular strengths of the different materials. We will look at this more fully in the experimentation section of this unit, but the students will be making some observations about why they think certain materials are frequently chosen for particular parts of the building. Later they will consider the implications of the choices they observe and apply the implications of their observations to their own decisions about material choices for their gingerbread houses.

Finally, the students will also observe how the materials in the buildings they are observing are attached to one another. For example, students will try to figure out how a wooden window is inserted into a brick wall. These observations will be useful later when the students build their own houses.

Architectural Vocabulary

Vocabulary is essential to carrying on a conversation about any topic. In science it is especially necessary because scientist tend to use a very specialized vocabulary, with very specialized meanings to the words. Architects also have a very specialized vocabulary. My students tend to enter school with an impoverished vocabulary, so even at the highest levels of my classes it is necessary to do some vocabulary building exercises with the students. In this case, the words will be terms used to describe architecture. We will look at the names for different styles of buildings, but we will also look at names for the different parts of buildings. Part of the reason for this insistence on proper names is that the students will then be able to describe the buildings they wish to build.

The students will have a list of vocabulary, but it will not be a traditional list with definitions copied from the dictionary. Architecture is a visual medium, so the vocabulary list will have big empty spaces after the words, so that students can sketch and describe the style or building part being discussed. At the end of this unit, in

the appendix, you will find a list of words which will be used with the students.

Experimentation

Experimentation is at the heart of modern science education. Many non-scientist consider experimentation to be the only true aspect of science. In fact, this is only one part of science. However, it is the part that is most frequently tested at the secondary school level.

As such, this curriculum unit has students performing experiments. They are not, however, traditional hypothesis driven experiments. These experiments are designed to produce observations which will be used in the later construction of the gingerbread house. These experiments will test the strengths of the materials the students propose to use in their houses under conditions which will simulate those that the materials will suffer in the actual building. Aside from being good science, these experiments save time and a good bit of heartache during the final construction phase of the building.

Begin Researching Gingerbread House Materials

Gingerbread houses are traditionally built of gingerbread. However, there are a number of modern substitutes for the gingerbread, and there are, of course, all of the decorations to consider. Because it is important for the students to learn how to do basic research, the students will do some research into the various materials that are used to make gingerbread houses. This research will also help guide the students in their later design efforts as it will help them to establish parameters for size and other design features.

Most of this research will be conducted online; however, the books listed in the gingerbread section of the resources are also good resources for this section of the unit. There are many excellent websites exclusively dedicated to gingerbread houses. Additionally, there are many more sites dedicated to recipes and cooking. Furthermore, many children's craft sites also have sections on gingerbread houses. Some sites even allow the user to plan decorations for their houses online. In my class, a number of these online sites will be collected together on a webpage which the students will use as a webquest in this particular activity. There are a number of free web hosting sites that are easy to use and could be used in other classrooms. Incidentally, this is another way to introduce technology into the classroom. It could even be a project that some students could do on their own.

From this activity the students will exit with a list of potential gingerbread house materials. It will probably include gingerbread, graham crackers, wafer cookies, icing, and various candies. These materials will then be used in the materials strength testing.

The Stonehenge Experiment

All buildings are made up of different elements. Most doorways, for example, are made of two posts and a lintel. Many porches consist of columns supporting a roof. Understanding basic building elements like these will help students to understand the slightly more complex materials strength testing that will follow. Most of these basic elements may be made from a simple set of children's wooden blocks. In fact, some, like the arch, are traditionally included in the set. These blocks are very useful in showing how a building is made up of various elements. Furthermore, if these blocks are combined with uniform slabs of playdoh, it is easy to

demonstrate were the weight from applied loads ends up in various different structures.

In this experiment, or demonstration, tell the students that they are building a circle of standing stones like Stonehenge. These stones must also support stone lintels over the stone posts. All of this stone is going to produce a huge weight, officially called a "load". The students have to figure out the path that the load is going to travel from the lintels into the ground so that standing stones, aka posts, will be placed to provide enough support to carry the load. Feel free to make up your own back story here, if you don't like mine. In this experiment a fairly thick slab of playdoh, about a quarter of an inch thick, is placed between pieces of the structure. The slabs of playdoh will be indented at the places where a force is being exerted when a load is applied to the structure. Good spots for the playdoh slabs include the bottom side of the lintel, on the table under the posts, and anyplace else that two pieces of the structure come into contact. Once the posts and lintel are set up, you add weight to the lintel until you start to get impressions in the playdoh. The experiment is a bit more interesting if your posts are not perfectly vertical, but instead are slightly tilted.

A similar experiment can be done for almost any type of basic building element. The most important things to remember about this experiment are: get blocks that playdoh will peel off, and make the slabs of playdoh a uniform thickness.

Materials Strength Testing

Materials exhibit strength in many different ways. The two most common ways, though, are stress and strain. Stress is the amount of load, or weight or force, that is born over a certain area of material. It has the same units as a measure of pressure. For example, a car tire might be under a stress of 33 pounds per square inch. Strain is the measurement of how much a material stretches. It is the increase or decrease in length divided by the original length. In other words, it is the percent increase in the size of a material. For example, when the car tire is inflated to 33 psi, it may expand from its original size. Precisely how much it expands is a measure of strain. J. E. Gordon has a very good explanation of these concepts in his book Structures: or why things don't fall down.

In the context of gingerbread houses, stress makes gingerbread walls crumble and bow outward causing strain at the joints of the house. So, the experimentation that must be done on the gingerbread materials must focus on these two issues. This is also a very good place to introduce some of the engineering terms like tension and compression.

One of the easiest ways to study the effects of stress and strain on gingerbread house materials is to use a setup similar to the Stonehenge experiment. In this experiment, two upright pieces of some material like wood support a span of gingerbread material. Small weights are then added to the center of this span. As the weights are added, the material should begin to bend. In fact, it is stretching. The amount of stretch should be measured after each addition of weight. Furthermore, any thinning of the material should also be measured. The division of the weight, which is actually force, by the cross sectional area of the material under the weight will yield the stress on the material. This stress will change as more weight is added because both the load and the cross section will change. The division of the change in length of the material by the original length will yield the strain on the material. Gingerbread tends not to be very elastic, so very small weights should be used.

Another way to measure stress and strain is to suspend a piece of material from a spring scale. As weight is added to the bottom of the material, the material will stretch and eventually break. The same data that was collected in the last experiment may also be collected in this one. The choice depends on the materials

available to the particular class.

Experimental Vocabulary

Vocabulary is essential for sensible conversation. Engineering terms in some ways are actually more important than many other forms of scientific vocabulary. The reason for this is that many of the term used in structural engineering are also used differently in common parlance. Therefore, it is essential to student comprehension of their experimental results that they understand the engineering version of the terms that they will be using. This vocabulary list, unlike the architectural one, will be more language based, but it will probably still also have room for sketches. Like the architectural terms, the structural engineering terms also have a strong visual and spatial element to them. Unlike architectural terms, engineering terms often have a very specific meaning which can easily be put into words. So, in this case, the vocabulary list is likely to be a combination of words and some pictures. As with the architectural list, a list of suggested words may be found in the appendix.

Building

The building part of this unit is the culminating project of this curriculum unit. It ties together all of the prior aspects of the project and adds in the challenge of transforming something two dimensional into something three dimensional. Finally, this building allows the students to express their innate creativity, as they will design and build it themselves. Creative outlets are increasingly rare in the new standardized test driven school culture and are, therefore, all the more precious when they are available.

Design and drawings

The design is one of the most important parts to any project. It lays the groundwork for everything else to come. As such, it requires quite a bit of thought and supervision.

My intent is that the students will have a sketch book full of interesting bits and pieces by this point in time. They should have been gathering ideas for their houses from the neighborhood walk and from the architectural overview. I would also encourage the students to sketch things that they see and like as they walk through the city. By this time, the students should also have a good idea about the building properties of their potential building materials from their experiments. All of this information should go into their designs at this point.

Students will use pieces of buildings that they have seen and liked to create sketches of a few different ideas. Then, in consultation with their classmates and teacher they will choose one of their initial sketches to use as the basis of their design. Once a sketch is chosen, the students will draw some elevations of the house. This stage is extremely important because the elevations will form the basis of their cardboard constructions. You may want to have the students draw their houses to scale at this point, too. Incidentally, this is also a very good place to reiterate the ideas of proportion and balance that will have been introduced in the observations section. Creating drawings to scale is also a good way to introduce fractions.

If you have time, the inclination, or an especially interested or gifted class, there is quite a bit that can be done at this stage of the project. Mechanical drawing, or drawing according to a fixed set of rules, is a

fascinating topic and is a useful way to transition between two and three dimensions and could be introduced at this time. Section and plan views, while not really necessary for gingerbread houses, are another facet of architecture which could also be introduced at this time. Isometric views and other sorts of perspective drawings would also be fun to play with, again, if there is time and ability.

There are a number of books on this topic to assist teachers who may be unfamiliar with the concepts. Frank Ching's book, which I have listed below in the resources, leans more towards architectural drawing than engineering drawings, which makes it especially useful in the context of this unit.

Research building techniques

This is another piece which may or may not be appropriate for all classes. In classes which have a number of individuals interested in construction, shop classes, technical science classes, or other similar groups, this might be a good place to introduce research techniques. In classes that do not have enough time to devote to this or that lack interest or inclination to these topics, this research might be better done by the teacher.

One of the most difficult parts of building a gingerbread house is getting the piece to stick together. This is where the building techniques come in. In regular construction, there are many different ways to convince different materials to stick together. For example, in wood working everything from nails pegs, bolts and screws, to specialized joints like dovetails, to glues, to lashings is used. In gingerbread architecture, the thickness of the pieces tends to limit the range of attachment procedures. Traditionally, large dollops of royal icing are used to hold everything together, but this does not necessarily have to be the way a particular house is made. Furthermore, particularly where the roof is concerned, this may not be the best way to attach the pieces. As a result, I strongly recommend researching various attachment techniques from both the traditional gingerbread world as well as the wider construction world. I find techniques that are used to make boxy things like drawers and book cases are useful. Finally, this research is also useful in that it ties in nicely with the spirit of the Connecticut standard on which this unit is based.

Cardboard construction

This stage of the project can be very difficult for students who do not have very good spatial abilities. It involves moving from a two dimensional pictures to a three dimensional object, which can be very difficult for a student who has trouble with geometry or with poor spatial abilities. I strongly recommend building a model that can be fitted together which shows how you get from a piece of cardboard, essentially two dimensional, to a house, which is three dimensional.

This stage can be practice for the actual gingerbread house. This will probably be the case in my class. However, this can be the final project if gingerbread, for whatever reason does not work in a particular classroom. In any case, it is very important.

There are two possible approaches to this stage of the project. The first involves corrugated cardboard. The second requires a thinner cardboard like oaktag or cardstock. Both have merits which will be discussed below. In both cases piece of the house are drawn without decorations on the cardboard, are cut out, and fitted together. This is where the research into construction techniques begins to pay off.

Corrugated cardboard has several factors going for it. First, it is readily available and can almost always be obtained free. Food service employees will frequently give you the big boxes that lunch and/or breakfast came in if you ask nicely. If that doesn't work, many stores will give you the boxes that they would otherwise throw

away. Liquor stores are almost always a good place to get cardboard, but some school districts may have a problem with the liquor logo on the box, so check first. Another advantage of corrugated cardboard is that is approximates many of the properties of gingerbread. It is approximately the same thickness as gingerbread, which is especially helpful if you are building a practice house. This thickness is an important consideration, particularly where pieces join together, which is frequently neglected in the calculations of first time house builders. Another advantage of corrugated cardboard is that its stiffness is similar to that of gingerbread. If the house stands in corrugated cardboard, then it will probably stand in gingerbread. However, an important consideration in this respect is that cardboard is much lighter than gingerbread; it is much less dense. It is important to remember that while the cardboard is stiff like gingerbread, it may not be supporting quite as much weight as the gingerbread will, particularly if frosting and candies are to be added to the final house.

A lighter weight cardboard like oaktag or cardstock is also a possibility for a practice house. This can also be obtained free, but it is more difficult to get in large pieces. Shoe boxes are a good source of this type of cardboard and can be obtained from some shoe stores. Boxes from boots are especial useful because they have bigger pieces of cardboard. Old manila file folders are another good free source of this cardboard, but they are again limited in size. While, light weight cardboard does not have the thickness or stiffness that corrugated cardboard has, it is much easier to use when you actually cut out the gingerbread. It also may be easier to decorate if the cardboard house is to be the final project.

The cardboard construction phase is a good time to make revisions to the original plan. It will be come increasingly obvious to the students that simpler is easier to build. However, the students should not be allowed to get too discouraged because there is quite bit that can be done with icing in the later decoration of the house.

Make the gingerbread

There are many different recipes for gingerbread, but most contain the basic ingredients or flour, eggs, spices, sugar (including molasses), and some other liquid like milk or water. Whatever recipe you choose, there are several good ones in the books in the gingerbread section of the references, I recommend that you try the recipe first because some work well for cookies, but they are too crumbly for houses.

Essentially, the process of making the gingerbread houses is the same for almost all of the recipes. First, you mix up the dough. Then, the dough is rolled out to a thickness generally specified in the recipe. The pieces are then cut out, transferred to a baking sheet, baked and cooled. Then, the pieces are assembled into the house.

There are a few tip and tricks that I found that seem to help in this process. First, allow several days to complete the building of the house. Most gingerbread dough will have to be chilled before it is rolled out, so this kills quite a bit of time. Additionally, the icing can take quite a while to dry, and the icing must be dry to hold. This means that the icing on the walls needs to be given time to dry before the roof can go on. Furthermore, if decorations for the house walls are elaborate, they may need to be done and allowed to dry before the house is put together.

There are several things that can be done to make baking and decorating easier. Parchment paper is very useful because the dough can stay on it from the time it is rolled out to the time it is cooled. A piece of parchment paper may be used below the dough and on top of it while the dough is being rolled. The paper helps to keep the dough from sticking to the rolling pin. One the dough has been rolled, the top sheet of parchment may be used to trace the shapes of the house pieces that need to be cut out. If the pieces are cut carefully, the excess dough may be peeled away and the entire bottom piece of parchment can be transferred

to the baking sheet. After baking, the entire piece of parchment, gingerbread and all, can be transferred to the cooling rack. Finally, when the time comes to clean up, the baking sheets will not have bits of gingerbread dough stuck to them because the parchment will have protected the baking sheets. Parchment is also a useful material when it comes to decorating. Parchment is easily made into cones which can be filled with different colors of icing. At the end of the decorating session, the parchment cones are disposable. There are several cooking sites online that give instructions for making parchment paper cones. Finally, soup cans or blocks may be helpful in supporting walls or the roof while the icing dries.

Finally, while there are some necessities for baking such as mixing bowls and an oven, there are a number of simple substitutions that can be made to help cut the cost of this unit. For example, rolling pins are expensive, so if they are not available, almost any smooth, round, long object can be used. Wooden dowels are a good substitute, as are tall glass containers that resemble wine bottles. Many recipes suggest that the cook buys special rubber bands to get the dough to roll out to a specific thickness. These are unnecessary. Instead, guides of the proper thickness may be used. Meter sticks will probably work for most recipes. The meter sticks are laid parallel on the table on either side of the dough. The dough is then rolled out until the rolling pin can rest on the two guides.

Construct the house

The last piece is, of course, putting the house together. This can be a complicated process, but if you have built the house out of cardboard first, it is much easier. One of the complications of this process is that it takes time for the icing to dry, so the house must be built slowly. For example, the wall joints need to be dry and solid before the roof goes on. Otherwise, the house collapses. Overall though, this is one of the most fulfilling parts of this project and will be an amusing and exciting experience to watch. This is when the magic happens; this is when the students' dreams and imaginings become reality.

Because most modern school districts frown upon grades based on magic and dreams, I recommend a rubric for grading the final project. I find that it helps my students if I give them the rubric before they start projects like this one because it helps them to focus their ideas. Some suggestions for the rubric might include a final finished size, a certain number of design elements, or a theme for their houses. The final grading might also involve an essay explaining how certain decisions were made in the design and construction of the house or a discussion of how the student's plans had changed based on what they learned as they went through the process. After all, science is all about communicating the results of experience.

Appendix

Connecticut standards

Connecticut State Science Standard 8.4

> "In the design of structures there is a need to consider factors such as function, materials, safety, cost and appearance."
> Performance Standard C 30

"Explain how beam, truss and suspension bridges are designed to withstand the forces that act on them."

New Haven Standards

New Haven Standard 5.1
"Students will develop understanding of technological designs, which solve problems and improve the quality of life."
New Haven Standard 7.1
"Students will study the history of science as a human endeavor."

Resources

Vocabulary list

(table available in print form)

Building Materials observations sheet

Building Materials

1. Choose a building that you like.

2. What is the predominant material in the building? If there are two or three main materials, include them too.

3. Why do you think this material was used to construct this building?

4. What is the overall shape of the building? (eg. square, round, rectangular, domed, etc) How does the building's shape change as the building gets taller?

5. Why do you think this building was built in this shape?

6. Give an example of another building material that could have been used to build this building. Explain why your material would have been better or worse than the material chosen by the original builders.

7. Give on example of how the primary material is connected to one of the other materials used in the structure.

8. Based on the construction techniques and the materials used, how long do you think this building will last? Explain your answer.

Roof

1. What material was chosen for the roof of this building?
2. Would you have chosen this material to roof this building? Why or why not?

Doors

1. Find a door that you like. This can be any type of door (house, school, fence gate, animal door, etc.) Sketch the door and its surroundings here.
2. What is it that makes this door different?
3. What is it about this door that you like?
4. What does the door appear to be made from?
5. What is the door frame made from?
6. Are the hinges on the inside of the door, the outside of the door, or next to the door?
7. Can you see how the door is connected from its frame? If you can see how it is connected, draw or describe it below. If you can not see how the door is connected to the frame, make your best guess.
8. What type of material is the wall that the door is built into?
9. How is the door frame connected to the surrounding wall? If you can not actually tell, make your best guess.
10. What do you think this door will look like in ten years time?

Windows

1. Find two windows that you really like; they do not have to be from the same building. Sketch them here.

2. What is it that you like about these windows?

3. What are the windows made from? Are they clear glass, plastic, stained glass, louvered, etc? If they are mullioned or latticed windows, don't forget to describe the materials used to create the mullions and lattice.

4. How are these windows connected to their frames? Can they be opened?

5. What material is the wall surrounding the windows made from?

6. How are the frames set into the surrounding wall?

7. What mood do you think these windows create inside the building? How do you think different windows would change the mood of the room?

Books

Architecture

Ching, Frank Architectural Graphics, Van Nostrand Reinhold, New York, New York, 2nd edition. 1985

This book is a good reference on architectural drawings.

Mainstone, Rowland J., Structure in Architecture: History, Design, and Innovation, Ashgate, Brookfield, VT, 1999

This book is an interesting reference. Parts of it are useful in leading students through the design phases of this project.

McAlester, Virginia and Lee, A field Guide to American Houses, Alfred A Knopf, New York, New York, 2002

This book has a very nice pictorial key for students who struggled with drawing pieces of buildings that they liked. It is also a good source of pictures of houses.

Speicher, J, et al, Reader's Digest Home Improvements Manual, The Reader's Digest Association, inc., Pleasantville, New York, 1982

This book is a somewhat unorthodox choice, but the descriptions of various housing styles at the beginning are very well done. This is also a good reference for researching joinery techniques.

Tzonis, Alexander, Santiago Calatrava: The Poetics of Movement, Universe Publishing, New York, New York, 1999

This is an inspiring book containing beautiful pictures and enlightening descriptions of Santiago Calatrava's work.

Engineering

Engel, Heino, Structure Systems, Deutche Verglas-Anstalt GmbH, Stuttgart, Germany, 1967

This is a good book, but it is difficult to find.

Gordon, J.E., Structures: or Why Things Don't Fall Down, Penguin Books, Ltd, London, 1978

This is a wonderful book, written in easily accessible language.

Levy, Matthys and Salvadori, Mario, Why Buildings Fall Down: how structures fail, WW Norton & Co., New York, New York, 1982

This is a good book to read before doing the experiments in this unit. It goes through the causes of structural failure for many interesting structures.

Salvadori, Mario, Why Buildings Stand Up: the Strength of Architecture, WW Norton & Co., New York, New York, 2002

This book is similar to Gordon's book, but it contains more diagrams and gives concrete examples of the concepts as they are applied in actual buildings.

Salvadori, Mario, The Art of Construction: projects and principles for beginning engineers and architects, Chicago Review Press, Chicago, Illinois, 1990

This book is an excellent resource for teachers. It gives lots of good examples and suggests simple, inexpensive projects and experiments.

Watson, Donald, Crosbie, M., Time-saver Standards for Architectural Design Data, McGraw-Hill, New York, Eighth Edition, 2005

This is a good reference book

Zalewski, Waclaw and Allen Edward, Shaping Structures: Statics, John Wiley & Sons, Inc., New York, New York, 1998

Gingerbread

Cargas, Nonnie, Gingerbread Houses: Baking and building memories, Krause Publications, Iola, WI, 1999

This is a very well written book. It has descriptive photographs and a very tasty recipe for gingerbread. My only criticism is that the gingerbread is a bit softer than I would like for building a house; however, the gingerbread may be better if it bakes a bit longer than mine did.

Currie, Christa, Gingerbread Houses: a complete guide to baking building and decorating, Doubleday, New York, New York, 1992

This is a good book as a starter book. It is easy to read and goes through the process well.

Layman, Theresa, Gingerbread for all seasons, Abradale Press, New York, New York, 1997

This book has a recipe for a very durable gingerbread. It is a slightly more advanced book than some of the others listed, but it will still be accessible to most readers.

Morgan, Aaron, Gilchrist, P. Making Great Gingerbread Houses: delicious designs from cabins to castles, from lighthouses to tree houses, Lark Books, New York, New York, 1999

This book is full of beautifully designed gingerbread houses. It is a wonderful book for ideas and it comes with templates for all of it designs.

Perry, Sara, Great Gingerbread, Chronicle Books, San Francisco, California, 1997

This book takes a general approach to the gingerbread flavor, including such things as gingerbread waffles and gingerbread cakes. It does a have a few ideas gingerbread houses and might be good for enrichment activities, particularly in a cooking class.

Rogers, Juliet, Chief Executive, The Essential Guide to Cake Decorating, Murdoch Books Pty Limited, Sydney Australia, 2005

As the title indicates, this book is intended for cake decorating; however, most of the techniques used to decorate cakes are also useful in decorating gingerbread houses. This is a more advanced book, but it includes many useful tips and tricks.