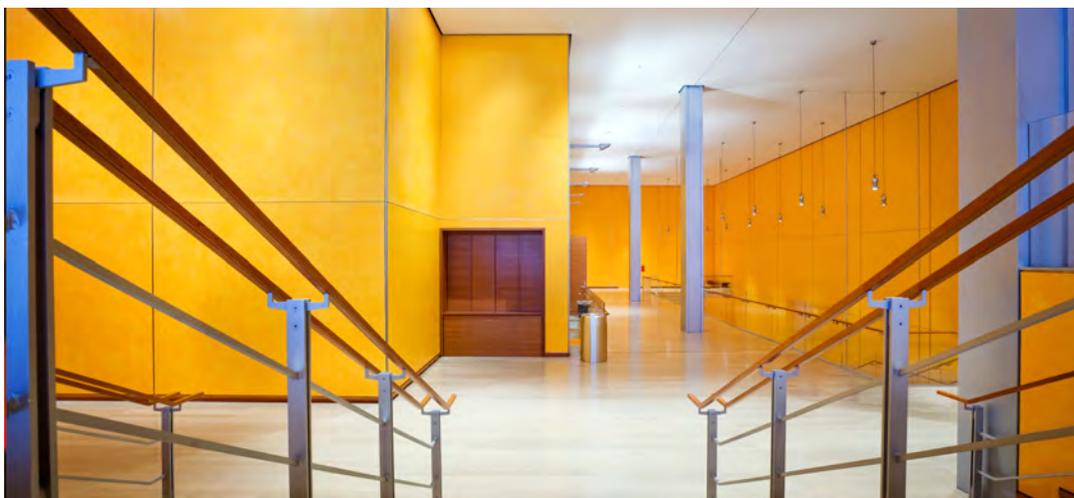


# DESIGNING SPACES



MATHEMATICS



GRADE 5

This guide links the *Designing Spaces* unit to the Texas Essential Knowledge and Skills (TEKS) for fifth graders. *Designing Spaces* is a mathematics unit that allows students to study the interconnectedness of mathematics and visual art in the field of architecture. *Designing Spaces* has interdisciplinary connections to Art, Social Studies, and English Language Arts and Reading disciplines. For example, students will develop and organize ideas from the environment, as outlined in the Fine Arts TEKS, compose original texts, as outlined in the English Language Arts and Reading TEKS, and understand the positive and negative aspects of modifications to an environment, as described in the Social Studies TEKS. The following document includes the applicable TEKS and the details of the *Designing Spaces* unit. The final section of this document presents the applicable Texas College and Career Readiness Standards adopted by the Texas Higher Education Coordinating Board (THECB) on January 24, 2008.

## Description of Unit

In this task, students study how mathematics applies to architecture and the creation of designed environments. Students explore how various designs relate to human needs and functions by observing their environments, drawing, graphing, and taking measurements. Students research a period of architecture, a particular style, or a famous architect of their choosing and analyze the way the architect uses geometric forms and mathematical patterns in his/her works. In small groups, students work together to design and build a variety of architectural spaces within the classroom using simple materials such as dowel rods and fabric. Finally, students present their works to an audience by leading guided tours through their structures during an event called the “Designer’s Showcase.”

## Goals

Students will meet these goals in their explorations:

- Become familiar with mathematical patterns found in nature and used in the design of everyday objects such as the Fibonacci Sequence and Golden Mean
- Gain awareness of the field of architecture

### *Designing Spaces* (Grade 5)

- Research styles of architecture and famous architects
- Design and build an original space using mathematical patterns
- Consider the impacts of architectural spaces on the surrounding areas
- Develop the essential skills of communicating, creative problem solving, and logical thinking

## Phase I. Learning Experiences

1. Introduce students to the unit by discussing the career path of an architect. In what ways is an architect like an artist? In what ways is an architect like a mathematician? Discuss the importance of both mathematics and aesthetics when designing spaces. Share images of architectural drawings and blueprints, describing each feature and how it relates to the real space. Introduce students to the concepts of positive and negative space and how these spaces can be described geometrically.
2. Break students into small groups and equip them with measuring tapes, yardsticks, or rulers and graph paper. Ask each group to construct a blueprint for the interior of the classroom by working backwards and measuring the interior of the current space as well as furniture and other features of the room. Students should indicate where windows and doors are on the blueprint. Provide students with hard-to-reach measurements, such as the height of the walls, and/or width and length of the ceiling. Student should include measurements and units on their drawings (e.g., 60 inches).
3. Write a journal entry for each of three different spaces (e.g., the student's bedroom, a favorite store or restaurant, and a library or gym). Describe the interior of each space:
  - What shapes exist in both the positive and negative spaces?
  - Describe the lighting in the space. How does natural light enter the room? How do artificial light sources provide illumination?
  - How might you describe your feelings when you are in the space? What characteristics of the space might contribute to evoking those feelings?
  - What physical materials do you see used in the construction of the space (e.g., wood, metal, carpet, fabric)?
  - What colors describe the space? What sensory information contributes to the space (e.g., sounds, smells, temperature)?
  - What are some of the activities that are most likely to occur in the space? How many individuals might the space reasonably accommodate at any one time? What features exist in the space?
  - If you were redesigning the space, what might you change and why?
4. Introduce students to the concept of mathematical patterns such as the Fibonacci sequence, and in particular how this sequence leads to the Golden Ratio or Golden Mean. Also known as phi, this number appears throughout nature, and has been used for centuries by artists, musicians, poets, and architects in designing/composing their works. View the animation of the Golden Rectangle at <http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibnat.html#spiral> or see <http://www.mathsisfun.com/numbers/nature-golden-ratio-fibonacci.html>. Guide students in constructing a Golden Rectangle on graph paper

by shading in the number of squares in the Fibonacci sequence. Students may want to use color codes to indicate the sequential order of the squares (e.g., the first (red) = 1, the second (yellow) = 1, the third (orange) = 2). Looking at a Golden Rectangle such as the one found in the Wikimedia Commons at <http://en.wikipedia.org/wiki/File:FibonacciBlocks.svg>, how might students predict the size of the next square, without looking at the Fibonacci sequence? When students add that square to the rectangle, what happens to the overall shape, and how are the new measurements related to the previous measurements?

5. Using the Fibonacci Rectangle as a visual aid, ask students to take the sequence of Fibonacci numbers and turn them into ratios (i.e., take the length of each square in the sequence over the length of the square that occurs just before it). In other words, for the squares represented by Fibonacci numbers 5 and 8, the length of the second square (8) becomes the dividend (numerator) and the length of the first square (5) becomes the divisor (denominator). Now, find the quotient (result) of dividing these ratios (see example at <http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibnat.html#golden>). Repeat this exercise with each of the color-coded squares in the Golden Rectangle. Plot the quotients on graph paper and describe the results.
6. Conduct a scavenger hunt looking for Fibonacci Rectangles (the Golden Mean) in the design of the classroom, furniture, or objects. How many designs, if any, come close to using these proportions? How would students redesign a piece of furniture in the classroom using the Golden Mean?
7. Conduct Internet research on the Fibonacci Sequence, the Golden Mean and architectural structures. A good resource to begin with is located at <http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibInArt.html#arch>.
8. Take students on a field trip to an interesting architectural structure and draw the structure's façade using a variety of drawing tools. Guide students in observing how light helps give the building or structure form. Help students identify mathematical terms in their drawings such as angles, arcs, and line segments.
9. Invite a guest speaker from a local architectural firm into the classroom to discuss the interconnections between mathematics and art in the designing of real buildings and spaces.
10. Discuss contemporary issues related to architecture such as the issues of private versus public space, and the architect's responsibility to the surrounding community. For example, the design of the Museum Tower project in Dallas, a high-rise condominium structure, is jeopardizing the surrounding museums and sculpture gardens of The Nasher in the Dallas Arts District due to major problems with reflected light and heat off of the Tower's glass windows. For information on the problem, read *Towering Inferno: How Arrogance and Greed Made Museum Tower a Threat to the Heart of Dallas* at <http://www.nashersculpturecenter.org/About-NSC/Press/D-MAGAZINE-TOWERING-INFERNO>.

## Phase II. Independent Research

### A. Research process

1. Selecting a topic. Form small groups based on the selected architectural styles or architects students wish to explore. Topics to consider may include:

- Frank Lloyd Wright
- Le Corbusier
- Walter Gropius
- Frank Gehry
- Philip Johnson
- Renzo Piano

Each group will design and construct a walk-through structure in the classroom using simple materials such as dowel rods and fabric. The teacher will provide the initial dimensions to each group for the structure's footprint and height allowances. These structures should:

- transform the space,
- incorporate the Golden Mean in some way, and
- reference the architectural style and/or architects studied.

How might you describe these various styles of architecture from a mathematics standpoint? What shapes do you observe? How many of the structures seem to employ the Golden Mean or another mathematical pattern?

2. Asking guiding questions. Once students have identified the period of architecture they wish to study, or the specific architect, they should think of three to five guiding questions to explore, such as:
  - What were the primary activities that occurred in these architectural spaces and how did the design lend itself to these functions?
  - How did the architect build the structure using geometric forms?
  - What types of materials were chosen to build the structure and why might the architect have selected these items?
  - How might you redesign this structure and what modifications might you make to it?
  - What elements of these designs will you incorporate into your original architectural design to be built within the classroom?
  - What sorts of modifications will you need to consider that allow for the simple materials available for your use?
  - How will you allocate resources for building the structure— human resources, material resources, and time resources?
  - What might a budget look like for your structure?
  - How will you design your structure so that it is safe to build and use within the classroom?

3. Creating a research proposal. Working in groups, students brainstorm and create drawings for the structure on graph paper and/or using a visualization software program such as Google Sketch Up. Students incorporate the Golden Mean in some element of the design and explain their decisions.
4. Conducting the research. Collaborate with the librarian to provide books and/or websites with visuals on architectural styles and famous architects. Observe the construction of local buildings, make sketches of building facades, and take tours of the insides of public/historic buildings such as capital buildings, courthouses, sports arenas or churches. Interview individuals who use these spaces to identify what they find most useful about the design and what they might change.
5. Sharing findings. Each group presents its building proposal to the class. The proposal should include:
  - drawings and prototypes,
  - an estimated budget and timeline for construction,
  - considerations for safety,
  - explanation of the function and purpose of the structure,
  - references to other architects or styles,
  - considerations on how their structure will impact the surrounding space (classroom), and
  - the intended look and feel of the space.

Once the students have made their presentations, the class may discuss the proposals, ask questions and/or make suggestions and finally issue “building permits” that allow the group to begin construction of the actual structural installation.

## B. The product

Each group will build the structure they designed using simple materials. Groups should observe safety practices such as wearing hard hats and eye protection, and observing classroom rules with regards to sharp tools, climbing, and/or standing on structures. Once all groups have completed construction, the class may hold a “Designer’s Convention” that serves as an open house for other classes or the public to come in and learn about the projects.

## C. Communication

Each group leads an audience through a tour of their structure, describing the function, features, the historical background or references, the mathematical patterns employed in the design, and the overall goal with regards to “look and feel” that they attempted to achieve.

## D. A completed project consists of:

1. A building proposal consisting of
  - project goal and function of the structure,
  - drawings/schematics,
  - prototypes of the structure,

- a budget,
  - a timeline,
  - impacts to the surrounding area,
  - references to other architects or styles, and
  - safety considerations.
2. Research notes
  3. Fibonacci Rectangle Maps and Golden Mean graphs
  4. Photographs or video of the structures
  5. Videos, audio files, or written transcripts of the student-led tours of the structures during the “Designer’s Convention” including student responses to the Q&A sessions.

## Internet Resources

### Fibonacci and the Golden Mean

<http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fib.html>  
<http://ualr.edu/lasmoller/fibonacci.html>  
<http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibInArt.html#arch>  
<http://www.mathsisfun.com/numbers/fibonacci-sequence.html>  
<http://www.fibonacci.name/index.html>  
<http://plus.maths.org/content/os/issue3/fibonacci/index>  
<http://illuminations.nctm.org/LessonDetail.aspx?id=L658>

### Architecture Resources

<https://sites.google.com/a/intlschool.org/julie-s-art-class-2011-2012/5th-grade>  
<http://www.austinfoundationforarchitecture.org/grants/architecture-in-schools/>  
<http://www.archcareers.org/website/article.asp?id=7>  
<http://ethemes.missouri.edu/themes/1704>  
<http://www.archkitecture.org/>  
<http://www.ischool.utexas.edu/~ifican/resources/pathfinders/architecture.html>  
[http://www.bc.edu/bc\\_org/avp/cas/fnart/fa267/contents.html](http://www.bc.edu/bc_org/avp/cas/fnart/fa267/contents.html)  
<http://www.bc.edu/content/bc/sites/artweb/architecture.html>  
<http://www.greatbuildings.com/>  
<http://www.math-kitecture.com/>  
<http://www.pbs.org/wgbh/buildingbig/>

*Thermal Delight in Architecture* by Lisa Hescong

*The Golden Ratio: The Story of PHI, the World's Most Astonishing Number* by Mario Livio

Visual Acoustics (documentary film exploring mid-century architecture/design/photographer Julius Shulman) (stream for free here:

[http://www.amazon.com/gp/product/B003NVMXXA/ref=atv\\_terms\\_dp#gc](http://www.amazon.com/gp/product/B003NVMXXA/ref=atv_terms_dp#gc))

## Texas Essential Knowledge and Skills

The unit may address the following TEKS:

### English Language Arts and Reading:

- 5.1 Reads grade-level text with fluency and comprehension
- 5.2 Understands new vocabulary and uses it when reading and writing
- 5.7 Understands, makes inferences and draws conclusions about the varied structural patterns and features of literary nonfiction and provides evidence from text to support their understanding
- 5.9 Reads independently for sustained periods of time and produces evidence of their reading
- 5.10 Analyzes, makes inferences and draws conclusions about the author's purpose in cultural, historical, and contemporary contexts and provides evidence from the text to support their understanding
- 5.13 Understands how to glean and use information in procedural texts and documents
- 5.14 Uses comprehension skills to analyze how words, images, graphics, and sounds work together in various forms to impact meaning
- 5.15 Uses elements of the writing process (planning, drafting, revising, editing, and publishing) to compose text
- 5.18 Writes expository and procedural or work-related texts to communicate ideas and information to specific audiences for specific purposes
- 5.20 Understands the function of and uses the conventions of academic language when speaking and writing
- 5.21 Writes legibly and uses appropriate capitalization and punctuation conventions in their compositions
- 5.22 Spells correctly
- 5.23 Asks open-ended research questions and develops a plan for answering them
- 5.24 Determines, locates, and explores the full range of relevant sources addressing a research question and systematically record the information they gather
- 5.25 Clarifies research questions and evaluates and synthesizes collected information
- 5.26 Organizes and presents their ideas and information according to the purpose of the research and their audience
- 5.27 Uses comprehension skills to listen attentively to others in formal and informal settings
- 5.28 Speaks clearly and to the point, using the conventions of language
- 5.29 Works productively with others in teams

### Mathematics:

- 5.1 Uses mathematical processes to acquire and demonstrate mathematical understanding
- 5.4 Applies mathematical process standards to develop concepts of expressions and equations
- 5.5 Applies mathematical process standards to classify two-dimensional figures by attributes and properties

5.9 Applies mathematical process standards to solve problems by collecting, organizing, displaying, and interpreting data

### Science:

5.2 Uses scientific methods during laboratory and outdoor investigations

5.3 Uses critical thinking and scientific problem solving to make informed decisions

5.4 Knows how to use a variety of tools and methods to conduct science inquiry

### Social Studies:

5.6 Uses geographic tools to collect, analyze, and interpret data

5.8 Understands the location and patterns of settlement and the geographic factors that influence where people live

5.9 Understands how people adapt to and modify their environment

5.21 Understands the relationship between the arts and the times during which they were created

5.24 Applies critical-thinking skills to organize and use information acquired from a variety of valid sources, including electronic technology

5.25 Communicates in written, oral, and visual forms

5.26 Uses problem-solving and decision-making skills, working independently and with others, in a variety of settings

### Fine Arts:

#### Art

5.1 Develops and expands visual literacy skills using critical thinking, imagination, and the senses to observe and explore the world by learning about, understanding, and applying the elements of art, principles of design, and expressive qualities

5.2 Communicates ideas through original artworks using a variety of media with appropriate skills

5.3 Demonstrates an understanding of art history and culture by analyzing artistic styles, historical periods, and a variety of cultures

5.4 Responds to and analyzes artworks of self and others, contributing to the development of lifelong skills of making informed judgments and reasoned evaluations

## Texas College and Career Readiness Standards

This unit may address the following Texas College and Career Readiness Standards:

### English Language Arts:

I.A.2 Generates ideas and gathers information relevant to the topic and purpose, keeping careful records of outside sources

I.A.3 Evaluates relevance, quality, sufficiency, and depth of preliminary ideas and information, organizes material generated, and formulates thesis

I.A.5 Edits writing for proper voice, tense, and syntax, assuring that it conforms to standard English, when appropriate

- II.A.1 Uses effective reading strategies to determine a written work’s purpose and intended audience
- II.A.2 Uses text features and graphics to form an overview of informational texts and to determine where to locate information
- II.A.11 Identifies, analyzes, and evaluates similarities and differences in how multiple texts present information, argue a position, or relate a theme
- II.B.1 Identifies new words and concepts acquired through study of their relationships to other words and concepts
- II.B.3 Uses reference guides to confirm the meanings of new words or concepts
- III.A.1 Understands how style and content of spoken language varies in different contexts and influences the listener’s understanding
- III.A.2 Adjusts presentation (delivery, vocabulary, length) to particular audiences and purposes
- III.B.1 Participates actively and effectively in one-on-one oral communication situations
- III.B.2 Participates actively and effectively in group discussions
- III.B.3 Plans and delivers focused and coherent presentations that convey clear and distinct perspectives and demonstrates solid reasoning
- IV.A.1 Analyzes and evaluates the effectiveness of a public presentation
- IV.A.2 Interprets a speaker’s message; identifies the position taken and the evidence in support of that position
- IV.B.1 Listens critically and responds appropriately to presentations
- IV.B.2 Listens actively and effectively in one-on-one communication situations
- IV.B.3 Listens actively and effectively in group discussions
- V.A.1 Formulates research questions
- V.A.2 Explores a research topic
- V.A.3 Refines research topic and devises a timeline for completing work
- V.B.1 Gathers relevant sources
- V.B.2 Evaluates the validity and reliability of sources
- V.B.3 Synthesizes and organizes information effectively
- V.C.1 Designs and presents an effective product
- V.C.2 Uses source material ethically

### Mathematics:

- III.A.2 Makes, tests, and uses conjectures about one-, two-, and three-dimensional figures and their properties
- III.B.1 Identifies and applies transformations to figure
- III.C.3 Makes connections between geometry and measurement
- IV.A.1 Selects or uses the appropriate type of unit for the attribute being measured
- VI.B.1 Determines types of data
- VI.B.2 Selects and applies appropriate visual representations of data
- VII.B.1 Understands and analyzes features of a function

- VII.B.2 Algebraically constructs and analyzes new functions
- VII.C.1 Applies known function models
- VIII.A.1 Analyzes given information
- VIII.A.2 Formulates a plan or strategy
- VIII.C.1 Formulates a solution to a real world situation based on the solution to a mathematic problem
- VIII.C.2 Uses a function to model a real-world situation
- VIII.C.3 Evaluates the problem solving process
- IX.A.1 Uses mathematical symbols, terminology, and notation to represent given and unknown information in a problem
- IX.A.2 Uses mathematical language to represent and communicate the mathematical concepts in a problem
- IX.A.3 Uses mathematics as a language for reasoning, problem solving, making connections, and generalizing
- IX.B.1 Models and interprets mathematical ideas and concepts using multiple representations
- IX.B.2 Summarizes and interprets mathematical information provided orally, visually, or in written form within the given context
- IX.C.1 Communicates mathematical ideas, reasoning, and their implications using symbols, diagrams, graphs, and words
- IX.C.2 Creates and uses representations to organize, record, and communicate mathematical ideas
- IX.C.3 Explains, displays, or justifies mathematical ideas and arguments using precise mathematical language in written or oral communications
- X.A.1 Connects and uses multiple strands of mathematics in situations and problems
- X.A.2 Connects mathematics to the study of other disciplines
- X.B.1 Uses multiple representations to demonstrate links between mathematical and real-world situations
- X.B.2 Understands and uses appropriate mathematical models in the natural, physical, and social sciences
- X.B.3 Knows and understands the use of mathematics in a variety of careers and professions

### Science:

- I.C.1 Collaborates on joint projects
- I.D.1 Demonstrates literacy in computer use
- I.D.2 Uses computer models, applications, and simulations
- I.E.1 Uses several modes of expression to describe or characterize natural patterns and phenomena. These modes of expression include narrative, numerical, graphical, pictorial, symbolic, and kinesthetic
- I.E.2 Uses essential vocabulary of the discipline being studied
- II.A.3 Understands ratios, proportions, percentages, and decimal fractions, and translates from any form to any other
- II.A.4 Uses proportional reasoning to solve problems

- II.C.1 Understands simple vectors, vector notations, and vector diagrams, and carry out simple calculations involving vectors
- II.C.4 Understands basic geometric principles
- II.D.1 Uses dimensional analysis in problem solving
- III.A.1 Uses correct applications of writing practices in scientific communication
- III.B.3 Recognizes scientific and technical vocabulary in the field of study and uses this vocabulary to enhance clarity of communication
- III.B.4 Lists, uses and gives examples of specific strategies before, during, and after reading to improve comprehension
- III.C.1 Prepares and represents scientific/technical information in appropriate formats for various audiences
- III.D.1 Uses search engines, databases, and other digital electronic tools effectively to locate information
- III.D.2 Evaluates quality, accuracy, completeness, reliability, and currency of information from any source
- V.E.2 Uses scale to relate models and structures
- X.E.1 Describes the different uses for land

### Social Studies:

- I.A.1 Uses the tools and concepts of geography appropriately and accurately
- I.A.2 Analyzes the interaction between human communities and the environment
- I.A.3 Analyzes how physical and cultural processes have shaped human communities over time
- I.A.6 Analyzes the relationship between geography and the development of human communities
- IV.A.1 Identifies and analyzes the main idea(s) and point(s) of view in sources
- IV.A.2 Situates an informational source in its appropriate contexts
- IV.A.3 Evaluates sources from multiple perspectives
- IV.A.4 Understands the differences between a primary and secondary source and uses each appropriately to conduct research and construct arguments
- IV.A.5 Reads narrative texts critically
- IV.A.6 Reads research data critically
- IV.B.1 Uses established research methodologies
- IV.B.3 Gathers, organizes, and displays the results of data and research
- IV.B.4 Identifies and collects sources
- IV.C.1 Understands/interprets presentations critically
- V.A.1 Uses appropriate oral communication techniques depending on the context or nature of the interaction
- V.A.2 Uses conventions of standard written English
- V.B.1 Attributes ideas and information to source materials and authors

### Cross-Disciplinary Standards:

- I.A.1 Engages in scholarly inquiry and dialogue

- I.A.2 Accepts constructive criticism and revises personal views when valid evidence warrants
- I.B.1 Considers arguments and conclusions of self and others
- I.B.4 Supports or modifies claims based on the results of an inquiry
- I.C.1 Analyzes a situation to identify a problem to be solved
- I.C.2 Develops and applies multiple strategies to solving a problem
- I.C.3 Collects evidence and data systematically and directly related to solving a problem
- I.D.1 Self-monitors learning needs and seeks assistance when needed
- I.D.2 Uses study habits necessary to manage academic pursuits and requirements
- I.D.3 Strives for accuracy and precision
- I.D.4 Perseveres to complete and master tasks
- I.E.1 Works independently
- I.E.2 Works collaboratively
- I.F.1 Attributes ideas and information to source materials and people
- I.F.2 Evaluates sources for quality of content, validity, credibility, and relevance
- II.A.2 Uses a variety of strategies to understand the meanings of new words
- II.A.3 Identifies the intended purpose and audience of the text
- II.A.4 Identifies the key information and supporting details
- II.A.5 Analyzes textual information critically
- II.A.6 Annotates, summarizes, paraphrases, and outlines texts when appropriate
- II.A.7 Adapts reading strategies according to structure of texts
- II.A.8 Connects reading to historical and current events and personal interest
- II.B.1 Writes clearly and coherently using standard writing conventions
- II.B.2 Writes in a variety of forms for various audiences and purposes
- II.C.2 Explores a research topic
- II.C.3 Refines research topic based on preliminary research and devises a timeline for completing work
- II.C.4 Evaluates the validity and reliability of sources
- II.C.5 Synthesizes and organizes information effectively
- II.C.6 Designs and presents an effective product
- II.C.7 Integrates source material
- II.C.8 Presents final product
- II.D.1 Identifies patterns or departures from patterns among data
- II.D.3 Presents analyzed data and communicates findings in a variety of formats
- II.E.1 Uses technology to gather information
- II.E.2 Uses technology to organize, manage, and analyze information
- II.E.3 Uses technology to communicate and display findings in a clear and coherent manner
- II.E.4 Uses technology appropriately