

The Art of Computer Animation and the Mathematics that Moves It

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Overview

The goal of the course is to teach both introductory computer animation techniques and the mathematics working in the background to make this animation possible. The curriculum unit will start with a brief history of animation and basic drawing and animation techniques. The computer aspect of the course will develop from programming on a TI-83 Plus graphing calculator, to animation using Geometer's Sketchpad. From there, the course will move on to simple Flash computer animation. The majority of classroom activities will be hands-on. Field trips to the University of Pennsylvania will enrich the students' experience. Guests may visit the classroom, and students from local university animation programs will be invited to work with students in the course.

This unit will be taught to middle school students in sixth, seventh and eighth grades. It will be taught as part of an elective that meets every other day for one report card period (about thirty one-hour classes). The elective course is not graded and is seen as enrichment. Approximately ten students will be enrolled in the class. In the classroom there are networked desktop computers and also available are wireless laptops so that each student can have his or her own workstation. We also have a classroom set of TI-83 Plus graphing calculators.

It is assumed that the instructor using this unit is a mathematics teacher who would like to add a visual arts element to their curriculum. Familiarity with coordinate geometry and transformations is important, and knowing how to use a graphing calculator and dynamic geometry software would be helpful.

Rationale

Kids need constant reminders of the utility of mathematics. My students are always asking, “Are we ever going to use this in real life?” Computer animation is based both in art and mathematics. The programs that create animation are based on logic and complex mathematical algorithms. If middle years students can be given an example of something that they use in daily life (cartoons, computer games, Web sites) that relates to mathematics, it will nurture an appetite for learning mathematics. A teacher in Indiana who developed a high school course in computer animation said that his students “were not intimidated by the new technology; they simply embraced it as a new way of life. I never heard them say, ‘This is too hard,’ or ‘I can’t do this.’...the curriculum allows for a wide range of ability levels because the students are so motivated by the technology.” (Cain, 2003)

When the young French lawyer Rene Descartes wrote “La Geometrie” he showed that algebraic equations could be represented as geometric shapes. (Descartes, 1637) What we now call Cartesian coordinates can direct digital devices to create drawings and the appearance of motion. Thus, one of the primary goals of the course is to make the connection between coordinate geometry and visual representation.

Spatial visualization is a difficult task for school geometry students. Middle years students are grappling with the difference between perimeter and area, between angle and side, and they are trying to make sense of similar figures. Animation is a good way to develop spatial visualization skills. Figures are outlined and shaded, angles must change to create the sense of motion from frame to frame, and scaling is necessary to give a sense of forward and backward motion.

Although much of the mathematics behind computer animation software is well beyond the reach of middle years students, they are learning the fundamental concepts. In grades six, seven and eight, students learn to graph points, lines and curves on the coordinate plane. They are learning the essential vocabulary of plane and solid geometry. Students can begin to analyze the shapes of objects in the world as combinations of lines, polygons, circles, polyhedra, cylinders and spheres. They are also learning some of the basic logical constructs like equality, and “if-then” statements. They can take what they are learning in their mathematics classes and find immediate applications to the art of animation.

Pennsylvania State mathematics standards require students by Grade 8 to be able to solve problems using graphing calculators and computer spreadsheets. Learning the mathematical requirements for creating images on graphing calculators will enhance students’ ability to manipulate technology, and importantly will introduce middle years students to programming language.

Middle school students also need to begin to develop a sense of the college admissions process. The School District of Philadelphia’s new curriculum focus on career and

college awareness for this age group recognizes this (Rich, 2005). Computer animation programs at colleges are becoming more elaborate and competitive. Students need to start early in high school to position themselves for acceptance into top college programs. Making sensible decisions in middle school about high school is easier if students have a clear goal—if they understand the relationship between a scholarly discipline like mathematics and practical applications.

Convincing students that they could make a contribution to a real life discipline is difficult. To become practitioners of a discipline, students need to understand that this discipline is a human construct and they, too, could eventually become part of that community. If they know something of the development of the art and technology and the people involved – especially if they can identify with computer artists – the discipline will seem more real to them.

Finally, the creation of a piece of animation represents the solution of a very complex problem. Solving problems is the essence of mathematics, and requires us to make new connections based on our previous knowledge. In completing this curriculum unit, students will need to learn new skills and to use old skills in new ways. The mathematician G. Polya said of problem solving (Polya, v):

A great discovery solves a great problem but there is a grain of discovery in the solution of any problem. Your problem may be modest; but if it challenges your curiosity and brings into play your inventive faculties, and if you solve it by your own means, you may experience the tension and enjoy the triumph of discovery. Such experiences at a susceptible age may create a taste for mental work and leave their imprint on mind and character for a lifetime.

Background on Animation, Computers, and Math

Animation is the creation of a sense of movement based on repetition of still images. When our eyes are presented with a series of still images shown at a fast enough rate, our brain merges them together and interprets them as being in motion. This phenomenon is called persistence of vision, based on the inability of the retina to follow rapid fluctuations in brightness (Gregory, 116). About 50 flashes per second will be perceived as a steady light, and this “Critical Fusion Frequency” in bright light may be as high as 100 flashes per second. There are three basic ways to present still images this quickly to our eyes: “cameraless” animation by a variety of mechanical devices, images photographed onto film, and electronic images shown on television or computer monitors.

Mechanical devices can make drawings appear to merge. Some of the earliest ways to create cameraless animation were clever toys. One, the thaumatrope, is a disk held by a string on either side (Laybourne, 1979). When the disk is spun on the string, the picture

on the “heads” side blends with the picture on the “tails” side. An 1826 version placed a bird on one side and an empty cage on the other. Spinning the thaumatrope puts the bird in its cage. Creating a thaumatrope will be one of the first assignments of the course.

Other devices were the phenakistoscope, the zoetrope and the praxinoscope. They all found ingenious ways of moving images and more importantly laid the groundwork for the development of motion picture film.

Motion picture filming is made possible by taking many still photographs in succession on a continuous roll of film. Inventors in France developed the beginnings of this technology. The first photograph was taken in 1826 by Joseph Niepce, a French physicist. In 1839 Louis Daguerre patented his “daguerrotype,” a picture fixed onto a sheet of silver-coated copper.

Financed by industrialist Leland Stanford, San Francisco photographer Edward Muybridge was the first to successfully photograph motion in a series of animal studies in 1877. (Taft, 1955) In a later study begun in 1884 at the University of Pennsylvania Muybridge continued to improve his methods. As a result of Muybridge’s popular public lectures showing his work, “he was certainly the first to bring the moving picture international attention and to use it as a method of instruction.” (Taft, ix)

In 1888 American George Eastman introduced the Kodak box camera system which recorded still photographs on a roll of gelatin-coated film. Thomas Edison and his assistant William Dickson used Eastman’s film in the kinetoscope, a cabinet with a peephole through which the pictures were viewed. Motion pictures were projected on a screen for the first time in 1895 in Paris. Edison used his projecting kinetoscope for the first public exhibition of motion pictures projected on a screen in New York City in 1896. By 1900, motion pictures had become a popular international attraction.

The first animated films had their origins in vaudeville and newspaper cartooning. In 1900 James Stuart Blackton filmed his “Komikal Kartoontist” vaudeville routine to make the film “The Enchanted Drawing.” He was photographed doing his “lightning sketches” on a large easel pad. “Blackton draws a man’s face with a bottle and glass above his head. Then he reaches toward the easel and ‘lifts off’ the bottle and glass – now actual three-dimension objects – to pour himself a drink. This displeases the cartoon man, whose facial expression turns sour at the same moment the bottle and glass are removed.” {Maltin, 1980) These images were created by stopping the camera between frames and making substitutions. (Lund, 1999). While it did not use true animation, the effect was funny and imaginative. Six years later, Blackton made what is considered the first animated cartoon, “Humorous Phases of Funny Faces” by drawing the faces of a man and a woman on a chalkboard. These two early examples of animation and many others can be downloaded for viewing from the Library of Congress website, “Origins of American Animation.” This curriculum unit will base a lesson plan on this website. Students will be amused and inspired by these early efforts.

The technical and artistic development of animation proceeded rapidly in the first decades of the 20th century. In 1914 newspaper cartoonist Earl Hurd patented a process employing layered transparencies on celluloid – the origin of the cel – as a labor saving method. Many popular newspaper comic series were translated to cinema.

One of the early pioneers of animation was Walt Disney who got his start in 1919 animating cartoon ads for theaters in Kansas City. Leonard Maltin says, “It is impossible to overstate the impact that Walt Disney had on the development of animated cartoons.” (Maltin, p 29) In addition to pioneering numerous technical innovations, Disney was an educator. In 1932 he hired artist Don Graham to teach his young animators. In Graham’s classes animators studied the dynamics of movement and developed an esprit-de-corps at the studio. One artist said, “It was like a marvelous big Renaissance craft hall. We were just all so excited about anything that happened; almost every day, something was new.” (Maltin, p. 43) Out of this research Disney’s studio created “twelve animation principles” for hand-drawn cartoon animation, which can be adapted for computer animation production techniques. (Rhalibi and Shen, 2004)

1. Squash and stretch -- Use shape distortion to emphasize movement.
2. Anticipation – Apply reverse movement to prepare for and bring out a forward movement.
3. Staging – Use the camera viewpoint that best shows an action.
4. Straight-ahead vs. pose-to-pose action – Apply the right procedure.
5. Follow through and overlapping action – Avoid stopping motion abruptly.
6. Slow-in and slow-out – Allow smooth starts and stops by spacing frames appropriately.
7. Arcs – Allow curved motion in paths of action.
8. Secondary actions – Animate secondary actions to bring out even more life.
9. Timing – Apply time relations within actions to create the illusion of movement.
10. Exaggeration – Apply caricature to actions and timing.
11. Solid drawing – Learn and use good drawing techniques.
12. Appeal – Create and animate appealing characters.

The twelve principles will be presented to students in the curriculum unit as we discuss the Disney class film “Fantasia.”

Reading more about the history of filmmaking and animation would be very helpful to teachers who hope to use this curriculum unit. A lively and detailed account of animation is given in Leonard Maltin’s “Of Mice and Magic.” A possible source of film history is Kenneth Macgowan’s “Behind the Screen, the History and Techniques of the Motion Picture.”

In 1822, the British scientist Charles Babbage started work on the first computing machine which he called the Difference Engine. Up to this time, complex calculations were carried out by hand, aided by published tables of values. Babbage's machine was never completely finished in his time, but he defined procedures that anticipated modern computer algorithms.

Over the course of the next 100 years, tabulating machines were developed that analyzed data mechanically. Tabulating machines borrowed the technology of the Jacquard weaving loom which was programmed by means of punched cards. Results of calculations could be printed by means of electromagnetic printing devices. The IBM Corporation began as a manufacturer of tabulating machines for business. Banks of IBM tabulating machines with their punch cards were used at Los Alamos, New Mexico during World War II in research leading to the atomic bomb. (Feynman, 102)

Other calculation needs of the military in World War II drove the development of the electronic computer. In England, code breakers working to decode messages written on the German Enigma machine created a calculating machine that is credited with saving the lives of many Allied soldiers. And in the United States, on the University of Pennsylvania's ENIAC, the first truly electronic calculator, complex calculations were performed in order to compute ballistics trajectories. After the war, the research and development of the electronic computer proceeded quickly.

The rise of commercial television after World War II did not initially impact the development of electronic or computer animation. In the beginnings of television, the only way to pre-record images was on film that was shown on a special type of camera linked to a film projector. So, the cartoon series that became the staple of children's television continued to use film technology.

The cathode ray tube began to be used as an input/output device for computers in the early 1950s. In 1963, Ivan Sutherland developed the "Sketchpad" drawing system. "This system included input and interactive techniques for creating line drawings, including pointing, dragging, and icons, that are still in use today." (McConnell, p. 370)

Initially, computer monitors used a technology like broadcast television. An electron beam swept across the screen in rows, refreshing the picture 30 times a second. This method slows down as an image gets more complex, leading to "flicker." In the 1970's raster graphics solved this problem by lighting individual picture elements or "pixels." Pixels are laid out in a grid and the computer instructs the monitor to produce the right amount of voltage at the right pixel location. The computer uses Cartesian coordinates – specifying a horizontal and vertical address – to locate each pixel.

The mathematical structure that makes computer graphics possible was developed in the early 17th century by the French lawyer and philosopher René Descartes. In "La

Geometrie,” an appendix to the longer philosophical treatise Discours de la Methode, Descartes showed how a pair of numbers could determine a position on a surface: “The length of any such line can always be expressed by three terms, one of which consists of the unknown quantity y multiplied or divided by some other known quantity; another consisting of the unknown quantity x multiplied or divided by some other known quantity; and the third consisting of a known quantity.” (Descartes, p. 33) In other words, Descartes had defined what we now call the standard equation of a line -- $ax + by + c$. So, algebraic equations could be represented as a series of points. He showed how these equations could define geometric shapes -- straight lines, circles, ellipses, parabolas or hyperbolas – the conic sections. The philosopher John Stuart Mill said that “La Geometrie” represented “the greatest single step ever made in the progress of the exact sciences.” (Bergamini, p. 83)

In middle school, students are introduced to the concept of linearity as represented on the coordinate plane. They learn to plot single points and lines and start to define slope. It is important for them to begin to understand that a constant rate of change graphs a line, and that an increasing or decreasing rate of change creates a curve.

Polygons can be drawn as line segments plotted on an x-y coordinate grid, and middle school students are now required to be able to state the coordinates of vertices and identify when these figures have been translated, reflected and rotated.

Cartesian coordinates are used by computers in several ways: identifying a horizontal and vertical location enables the computer to make an image with pixels, basic geometric shapes can be drawn, and algebraic functions can define paths for both straight and curved motion. Vector graphics use Descartes’ analytic equations to make scalable images, capable of growing and changing.

Objectives:

Students will learn the general techniques of animation that are common to all media. In particular, they will be introduced to storytelling concepts and making storyboards to plan animation. Making a flip book is a fun and easy way to introduce animation; this course will have students make flip books on paper and on an internet website.

Students will explore the relationship between mathematics and animation by creating and modifying points, lines, curves and closed figures on the coordinate plane, both on paper and electronically.

Students will learn to draw figures on TI-83 Plus graphing calculator and how to program the calculator. They will use the Cabri Jr. Geometry application on the TI-83 Plus to animate basic geometric shapes. Students will learn how to construct geometric objects in Geometer’s Sketchpad and how to animate them in that program.

Students will also learn basic computer animation techniques using programs like Macromedia Flash.

Students will learn how geometry/math can help to improve their artwork by drawing the underlying shapes – that the human body, for example, can be described as a group of solid figures. Using appropriate ratio, proportion, and perspective can make drawings more realistic.

Finally, students will experiment with current drawing fashions used in games and films like Japanese Manga and current Hip-Hop styles.

Strategies:

Some of the most important tools in this computer animation curriculum are paper, pencils and rulers. It is important to have the students graph points, lines and polygons on graph paper before they attempt the same actions on a graphing calculator or computer.

For hands-on activities, techniques will be described in teacher-authored handouts and taught by demonstration. Students will be able to work on these activities in pairs or small groups. The instructions will suggest ways in which students can explore on their own after they have learned the basic techniques. Some lessons are available as black-line masters published in books available through on-line bookstores or textbook publishers. These are noted in the lesson plans and bibliography.

The graphing calculator is a powerful tool that teaches both graphing on the coordinate plane as well as basic programming language. Working with the calculator is also a good introduction to the Geometer's Sketchpad software. This curriculum unit assumes that the instructor has some familiarity with these technology tools, but both Texas Instruments and Key Curriculum Press offer publications that would help a teacher learn to use them. For additional information on how to use technology, the School District of Philadelphia has a site-license to Atomiclearning.com. The technology leader in a Philadelphia school can provide a teacher with the username and monthly password. Atomiclearning.com has excellent tutorials for many different software programs like Flash and HyperStudio as well as the graphing calculator

Students will view classic and current animated films and discuss them based on prompts. Watching films like Fantasia or Toy Story will provide examples and inspiration. There are also many "how-to" books that give good examples of how to draw animated characters. Some titles are listed in the bibliography.

Several lessons are based on websites, such as Drexel University's MathForum, FlipBook! and Intel's "Journey Inside."

Other educational and cultural institutions will offer enriching experiences, like field trips and visits from computer animation artists.

Classroom Activities:

This list of classroom activities is in roughly chronological order and some may be completed in more than one class hour. Detailed lesson plans are given for some, but not all, of the activities. Not all lessons in the course are listed here. Students who work quickly will be encouraged to explore and extend the lessons. Teachers who are using this unit under different time constraints may omit lessons.

1. View Early Animation

Some of the earliest animation films made are available for download from the Library of Congress website: <http://www.loc.gov/loc/lcib/9906/animate.html>

These include: “Humorous Phases of Funny Faces” by the Vitagraph Company; producer and animator J. Stuart Blackton. Running time: 3:00. Digital file includes a piano score composed and performed by Philip Carli. “Krazy Kat and Ignatz Mouse at the Circus” by International Film Service, Inc.; animator Leon Searl. Running time: 3:00. Digital file also includes a piano score composed and performed by Philip Carli.

2. Make a Thaumatrope – “Plastic Surgery”

Subject: Cameraless Animation

Grade Range: 6 to 8

Description: Students will create a simple thaumatrope, a device that creates an optical illusion which makes two images appear to merge.

Duration: 60 minutes

Objective: The object of this lesson is to have students create a thaumatrope and to use the thaumatrope to explore and understand persistence of vision.

Assessments: The creation of a thaumatrope which successfully makes two images merge.

Procedures:

1. Take a digital photo of each student and print a copy for the student. The face should be 2” to 3” high. Have students follow these steps.
2. Trace the outlines of your face either on tracing paper or on regular paper over a light source. Draw a circle around your drawing about 4” in diameter with a compass or a

round object. It's important to make registration marks on the original photo and transfer them to the tracing. Cut it out around the circle.

3. Place tracing paper over the photo to add comical "plastic surgery" to your appearance – beards, glasses, punk hair, dreads, etc. For the effect to work, the final pencil drawings should be traced over with a fresh sharp tipped black marker. Make sure to include the registration marks in pencil to be erased later.

4. Mount the tracing paper drawings on a circle of heavy paper with either glue or tape. Include the registration marks on the heavy paper circle. The drawing of the face should be upside down compared to the "plastic surgery" side.

5. Use a small holed paper punch to cut two holes on either side. These punch holes should be carefully placed directly opposite each other, rotated 90 degrees from the vertical line of symmetry.

6. Loop a rubber band through each hole.

7. Hold each side of the thaumatrope by the rubber band, wind it up by twisting, and let go!

Materials:

Photograph, pencils, markers, tracing paper, scissors, glue or tape, hole punch, compass, heavyweight paper or cardstock, rubber bands and a light box.

Remarks:

Although this lesson suggests using a drawing of a face as the basis of the thaumatrope, any two simple line drawings would work.

3. Visit the University of Pennsylvania Archives to see Eadward Muybridge's Animals in Motion photographs.

The staff at the Archives of the University of Pennsylvania has kindly agreed to allow students in this course to visit and view Muybridge's actual photographs of animals in motion.

4. Discuss the 12 Disney principles of animation and view classic animated Walt Disney film Fantasia

In the 1930s animators at the Walt Disney Studios defined "Twelve Animation Principles" for hand-drawn cartoons that became the basis for the Disney cartoon empire. (El Rhalibi and Shen, 14-15) The following lesson plan is based on these twelve principles.

Title: The Sorcerer's Apprentice

Subject: Classic Disney Animation

Grade Range: 6 to 8

Description: Students will view the “Sorcerer’s Apprentice” section of Walt Disney’s classic animated film “Fantasia” and identify animation and drawing techniques used in the film.

Duration: 60 minutes

Objective: The object of the lesson is for students to learn the basic elements of the Disney animation vocabulary and to identify the use of these techniques in the “Sorcerer’s Apprentice” section of “Fantasia.”

Assessments: Completion of handout; class discussion.

Procedures:

1. First, view the film segment. It is about 9 minutes long.
2. Introduce the vocabulary of the twelve principles by giving the students the handout for the lesson and read the rules together (see Appendix C for handout).
2. Divide the students into groups of two, three or four and ask them to choose the topics they will search for while watching the film again. In the handout, each student is asked to choose three topics to identify in the film.
3. Watch the film again and have the students list the examples they have found. Give the students pieces of post-it notepaper on which to write individual examples.
4. Hang sheets of poster paper with one or two of the twelve principles listed on each. Have the students attach their post-its under the topic on the poster.
5. Allow the students to do a “gallery walk” and circulate around the room reading each other’s comments.
6. Discuss their observations. Be prepared with some questions for the discussion: what do they think is the most important rule for making believable animation? How do these principles make an animated film more entertaining? Which rules, if any, do they disagree with? How are the drawings influenced by the musical track?

Materials:

VHS or DVD copy of Fantasia (DVD version makes it easier to view one chapter), player, speakers and screen. Copies of handout, poster paper, post-it notepaper, markers, pencils.

Remarks:

Save the posters for future use when viewing other films or discussing animation techniques. The Little Golden Book illustrated version of The Sorcerer’s Apprentice is juvenile in format, but uses drawings from the film and could be used to jog memories of the film’s scenes.

5. Make a flip-book

1. Introduce concept of storyboard.

2. Suggestions for three types of stories for flip book: “A Journey,” “Metamorphosis,” or “Introduce a Personality.”
3. Make a book by putting about twenty-five 3 x 5 index cards together with a strong clip.
4. Stack the cards at a very slight angle to make it easier to flip the pages.
5. Create your animation by starting on the bottom card and working up.
6. You can edit your flip book by inserting or deleting cards.

6. Make drawings on x-y coordinate grid paper by plotting line segments and then translating, dilating and reflecting them.

A nice activity for this lesson is available as a blackline master in Algebra Tools (Encyclopedia Britannica, p. 28)

7. Make drawings via programming x-y coordinates on TI-83 Plus graphing calculator. Program translations and dilations of drawings. Detailed lesson plan follows.

Title: Animations on TI-83 Plus Graphing Calculator

Subject: Mathematics

Grade Range: 6 to 8

Description: Students will program two animations on the TI-83 Graphing Calculator

Duration: One or two 50 minute class periods

Text: TI-83 Plus Graphing Calculator Guidebook

Author(s): Texas Instruments

Publisher: Texas Instruments

Objective: Students will learn to create two programs on the TI-83 Plus Graphing Calculator that animate line segments and polygons. The first animation will employ translations to move a line segment on the screen; the second will use dilations to enlarge a square on the screen.

Assessments: Students will show programs on the calculator and discuss results as a group.

Procedures:

1. Discuss work from preceding class that asked students to graph transformations of line segments and polygons on graph paper using translations, reflections and dilations.

2. Review calculator basics: In our school, 7th and 8th grade students will have had experience with the calculator, some 6th graders may need extra time. off/on, clear, quit, mode, window set-up, insert, delete, second, alpha.
3. Go through programming menus: CTL (Control), I/O (In/Out), Vars (Variables), Test, Logic
4. Go through draw menus: DRAW, POINTS, STO (Store)
5. Give students handouts of these menus copied from TI-83 Plus Guidebook menu maps for reference.
6. Give students copy of first program and lead them through entering program commands.
7. Discussion: How do you think this program is related to animation? What happens to the two line segments? Do you think it would be easier to tell the program to plot certain specific points or to ask it to translate points by adding or subtracting from the coordinates?
8. Give students copy of second program and lead them through entering the program commands.
9. Discussion: What kinds of activities could be animated by using dilation commands?
10. Further exploration: Suggest that students edit their programs to add additional transformations of line segments or to try dilating a different polygon, like a triangle or a concave polygon.

Materials: Handouts: menu maps and copies of MVLN program and DILSQ program (See Related Materials), TI-83 Plus overhead graphing calculator and overhead projector, classroom set of TI-83 Plus graphing calculators, TI-83 Plus graphing calculator poster showing enlargement of keys is helpful. For students who would like to try to program different drawings, it may be helpful to have graph paper available for planning.

Remarks: For this exercise, students will be copying a supplied list of program commands. The lesson is not expected to teach them the details of programming language or logic, although they hopefully will begin to observe the effects of the commands. It is possible that students will need more than one class session to complete these activities.

Related Materials:

Handout/Worksheet: See Appendix B for lists of program commands to be copied as handouts for the lesson.

8. Pixels

Create pixel drawings on Intel website.

The Intel Education website “The Journey Inside” offers lessons about the “technologies, processes, and methods that make your computer and the Internet work.”

<http://www.intel.com/education/journey/index.htm>

The Journey InsideSM is a collection of 35 interactive, online lessons for students to complete. The curriculum is divided into six sections: Introduction to Computers, Circuits and Switches, Digital Information, Microprocessors, The Internet, and Technology and Society. Many of the lessons include interactive Flash* activities, virtual field trips, and videos demonstrating the ideas discussed. You will also be able to use the other Intel® Innovation in Education thinking tools such as *Visual Ranking* and *Seeing Reason* to further enhance your students' learning.

In particular there is a lesson on how pixels work that has the students drawing pictures based on a grid of squares:

http://www97.intel.com/discover/JourneyInside/TJI_DigitalInfo_lesson3_1/default.aspx

9. Create drawings and animate them with Geometer's Sketchpad.

Title: Animating a Ferris Wheel with Geometer's Sketchpad Software

Subject: Geometry/Animation

Grade Range: 6 to 8

Description: Using Geometer's Sketchpad to draw and rotate a ferris wheel

Duration: 60 Minutes

Author(s): Jim King

Publisher: The Math Forum

Objective: Students will learn how to create a path to animate a figure and to translate the figure by a marked vector.

Assessments: When complete, each student should be able to show a completed animated sketch of a "Ferris Wheel."

Procedures:

The plans for this lesson come from the web page, The Math Forum Corner for Interactive Geometry Software "Modeling a Ferris Wheel" by Jim King (King, 2006).

The lesson should be downloaded and copied for the class, or students may read the instructions directly from the website with Sketchpad opened in another window.

When the students have completed the lesson, suggest that they try to create and animate their own amusement park ride.

Materials:

Geometer's Sketchpad Software (Key Curriculum Press, 2006)

Remarks:

Previous to this lesson, students will have had a lesson in traditional geometric construction and a lesson to familiarize them with Geometer's Sketchpad's menus and capabilities.

Related Materials:

Website: http://mathforum.org/dynamic/jrk/ferris_dir

Annotated Bibliography

Resources for Teachers

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Descartes, René. "La Geometrie." Trans. David Eugene Smith and Marcia L. Latham. New York: Dover Publications. 1954. A helpful side by side translation of the original text by Descartes.

Disney, Walt. Walt Disney's The Sorcerer's Apprentice. Adapted by Dan Ferguson. Illus. Peter Emslie. Little Golden Book. Racine, Wisconsin: Western Publishing Co., Inc., 1994. This little book contains charming illustrations based on the cels from the film. It can be used to support students' memories of the film.

Dunham, Ken. "Helping students design HyperCard Stacks." *Learning and Leading with Technology* v. 23 (October 1995) p. 6-7. Strategies for helping students to design HyperCard stacks are provided. HyperCard is a powerful authoring tool that can be used for a range of communication formats, from simple animations to complex multimedia with user interaction capabilities. The design of storyboards for Hypercard animations and the creation of these animations are described.

Dunham, Ken. "Learning the basics of HyperCard with Animations." *Learning and Leading with Technology* v. 23 (November 1995) p. 29-30. The second in a series of articles on strategies for teaching HyperCard focuses on the use of animations. Students can learn how to paint, edit, navigate, and program in the HyperTalk language when they make their own flip-card animations in HyperCard. Advice on introducing HyperCard to students, teaching it in the computer lab, and evaluating students' work is provided.

El Rhalibi, Abdennour and Shen, Yuanyuan. "Animation." Berkshire Encyclopedia of Human-Computer Interaction. Volume 1. p. 13-17. Berkshire Publishing Group. Great Barrington, Massachusetts. 2004. Excellent articles about computers.

Encyclopedia Britannica, ed. Algebra Tools. Mathematics in Context. 2005. Blackline masters to accompany the Mathematics in Context textbook series.

Feynman, Richard. "Surely you're joking, Mr. Feynman" : adventures of a curious character. W. W. Norton. New York. 1984

Gregory, Richard L. Eye and Brain, the Psychology of Seeing. 5th edition. Princeton University Press. Princeton, New Jersey. 1997. This book is an introduction to the psychology of vision.

Hinshaw, C. "One Approach to Elementary Computer Art." *Arts & Activities*. v. 130 no. 2 (October 2001) pp. 40 – 41.

Iovinelli, Robert. "Animating graphs." *Mathematics Teacher* v. 93 no. 5 (May 2000) p. 408-11. Advice for teachers and students on using animation in their mathematics demonstrations is presented. The advice focuses on the use of computer animation programs, graphing calculators, and the Internet.

King, Jim. "The Geometer's Sketchpad Modeling a Ferris Wheel." The Math Forum Corner for Interactive Geometry Software. http://mathforum.org/dynamic/jrk/ferris_dir/

This lesson is simple, but illustrates how animation can follow a path created by a geometric figure.

Laybourne, Kit. The animation book : a complete guide to animated filmmaking--from flip-books to sound cartoons. Preface by George Griffin ; introduction by Derek Lamb. New York : Crown Publishers, c1979. Newer editions are available of this compendium of animation information. This is a must-have reference for the teacher and student of this curriculum unit.

Lund, Karen. "Origins of American Animation." The Library of Congress Information Bulletin. June 1999. <http://www.loc.gov/loc/lcib/9906/animate.html> This website has lots of animation history and includes streaming video of historic animations.

Macgowan, Kenneth. Behind the Screen. The History and Techniques of the Motion Picture. Dell Publishing Company. New York, New York. 1965. A classic film history.

Maltin, Leonard. Of Mice and Magic. A History of American Animated Cartoons. McGraw-Hill Book Company. New York, New York. 1980. Another classic history of animation.

McConnell, Jeffrey J. "Computer Graphics." Encyclopedia of Computer Science, 4th Edition. John W. Wiley & Sons, Ltd. Chichester, England. 2003. An excellent article with technical information about how computers produce graphics.

Ospina, Juan. Flipbook. 18 Feb. 2006. Fabrica, the Benetton research center on communication. 11 June 2006 <<http://www.fabrica.it/flipbook/faq.php>>. This website, sponsored by the Benetton corporation, allows users to easily create and publish simple flipbooks online.

Patmore, Chris. The Complete Animation Course : The Principles, Practice and Techniques of Successful Animation. Barron's Educational Series (August 15, 2003) This is another how-to book, an excellent in-class guide.

Polya, G. How to Solve It, A New Aspect of Mathematical Method. Second Edition. Princeton University Press. Princeton, New Jersey. 1985. Professor Polya's readable analysis of problem solving in mathematics, originally published in 1945, remains a wonderful guide to teachers. His heuristics are applicable to other disciplines as well.

Rich, Jessica. First Steps to College. Philadelphia Futures. Philadelphia, PA. 2005. The School District of Philadelphia's new pamphlet that teaches middle years students early what to expect in the college application process.

Roach, R. "Sony Establishes Visual Effects Program for U.S. Art and Design Schools." *Black Issues in Higher Education* v. 22 no. 13 (August 11, 2005) p. 32 This article lists curriculum topics related to computer animation.

Taft, Robert. Introduction. The Human Figure in Motion. By Eadweard Muybridge. New York: Dover Publications. 1955. vii-xiv. Taft's introduction to Muybridge's photographs is an excellent overview of the photographer's accomplishments.

Schantz, Thomas. "Animation in the Classroom." Video review *School Arts* v. 98 no. 2 (October 1998) p. 55. *Animation in the Classroom* (\$24.95), from Crystal Video, is a 20-minute video that provides detailed how-to demonstrations and fascinating examples of animation devices that students at any level can make without the need for a camera. The secrets and principles of motion magic such as squash-and-stretch, movement rates, easing in-easing out, key poses, and in-betweens are fully explained. This excellent introduction to the art of animation also shows the use of time-saving techniques such as rubber stamps and the photocopier.

Wolff, K. C. "Elementary Graphics and Animation with Your Calculator." *Mathematics Teacher*. v. 95 no. 3 March 2002. pp. 172 – 176.

An annotated reading list for students

Hart, Christopher. Manga Mania Chibi and Furry Characters. Ed. Anne McNamara. New York: Watson-Guption Publications, 2006. How to draw the adorable mini-people and cool cat-girls of Japanese comics.

Krefta, Ben. The Art of Drawing Manga. 2003. New York: Barnes & Noble, Inc. by arrangement with Arcturus Publishing Limited, 2004. Shows how to draw Manga figures, starting with basic geometric shapes like circles, polygons and ellipses.

Laybourne, Kit. Canemaker, John (Introduction). The Animation Book : A Complete Guide to Animated Filmmaking--From Flip-Books to Sound Cartoons to 3- D Animation. 1998. Three Rivers Press. New York. A great reference guide to all aspects of animation.

Scott, Damion and Ex, Kris. *How to Draw Hip-Hop*. Watson-Guption Publications, New York, New York. 2006.

Annotated list of materials for classroom use

Key Curriculum Press. Exploring Geometry with the Geometer's Sketchpad. Key Curriculum Press. Berkeley, California. 1996. Blackline masters for more than 100 activities at all levels using The Geometer's Sketchpad software program.

Lund, Charles. TI-82/83 Graphing Calculator Activities for Middle School Math. Mathware. Urbana, Illinois. 1995. This book has many creative lessons for use with the TI graphing calculators, including some animation activities.

<<http://www.atomiclearning.com>> The School District of Philadelphia pays for a site license to this very helpful website. It includes tutorials for all the major software packages. Each lesson in a tutorial is brief, and narrated so that students who are not strong readers can benefit from the lesson. When logging in from a School District server, it's not necessary to have the user name and password available, but if a student or parent would like to use Atomic Learning from home, a teacher can get the monthly password from the Technology person in their building.

Appendix A Content Standards

This curriculum unit addresses Pennsylvania State Standards in three content areas: mathematics, visual arts and technology.

Mathematics

- 2.1.8.D Numbers, Number Systems and Number Relationships
- 2.3.8.A-G Measurement and Estimation
- 2.4.8.A Mathematical Reasoning and Connections
- 2.5.8 Mathematical Problem Solving and Communication
- 2.6.8.F Statistics and Data Analysis
- 2.8.8 Algebra and Functions
- 2.9.8.B Geometry
- 2.10.8 Trigonometry
- 2.11.8 Concepts of Calculus

Visual Arts

- 9.1.8.K Production, Performance and Exhibition of Dance, Music, Theatre and Visual Arts
- 9.2.8 Historical and Cultural Contexts
- 9.3.8 Critical Response
- 9.4.8 Aesthetic Response

Science and Technology

- 3.6.7 Technology Education
- 3.7.7 Technological Devices

Appendix B Lesson Handouts

The following instructions can be copied to create handouts for the Graphing Calculator lesson plan:

Commands for MVLN (Move Line) Program on TI-83 Plus Graphing Calculator

| Instructions | Remarks |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Program, New, Create New, Name=MVLN | Names new program MVLN |
| :CoordOff | Format menu, turns coordinates off |
| :AxesOff | Format menu, turns axes off |
| :ZStandard | Zoom menu; sets viewing window |
| :Zsquare | Zoom menu |
| :ClrDraw | Draw menu, clears screen |
| :-10Sto->A | Sets value of A to -10 |
| :-10Sto->B | Sets value of B to -10 |
| :0Sto->C | Sets value of C to 0 |
| :0Sto->D | Sets value of D to 0 |
| :Lbl 99 | Identifies beginning of while loop |
| :Line(A,B,C,D) (C,D) | Draws line from point (A,B) to point (C,D) |
| :Pause pressed | Pauses program until ENTER is pressed |
| :ClrDraw | Clears screen |
| :A+1Sto->A | Increases value of A by 1 |
| :B+1Sto->B | Increases value of B by 1 |
| :C+1Sto->C | Increases value of C by 1 |
| :D+1Sto->D | Increases value of D by 1 |
| :While A#6 | While is from program control CTL menu, less than or equal sign is from TEST menu – establishes duration of loop |
| :Goto 99 | From CTL menu, identifies loop location |
| :End | From CTL menu, ends program at completion of loop |

To run MVLN program, select PRGM, EXEC, MVLN, ENTER. To advance through the program, press enter until the line is off the screen.

Commands for DILSQ (Dilate Square) Program on TI-83 Plus Graphing Calculator

| Instructions | Remarks |
|--------------------------------------|------------------------------------|
| Program, New, Create New, Name=DILSQ | Names new program DILSQ |
| :CoordOff | Format menu, turns coordinates off |
| :AxesOff | Format menu, turns axes off |

| | |
|-------------------------|------------------------------------------------------------------------------------------------------------------|
| :-70Sto->Xmin | From VARS, window menu |
| :70Sto->Xmax | These commands establish the size of the viewing window |
| :-70Sto->Ymin | |
| :70Sto->Ymax | |
| :Zsquare | Zoom menu |
| :ClrDraw | Draw menu, clears screen |
| :1Sto->A | Sets value of A to 1 |
| :1Sto->B | Sets value of B to 1 |
| :1Sto->C | Sets value of C to 1 |
| :-1Sto->D | Sets value of D to -1 |
| :-1Sto->E | Sets value of E to -1 |
| :-1Sto->F | Sets value of F to -1 |
| :-1Sto->G | Sets value of G to -1 |
| :1Sto->H | Sets value of H to 1 |
| :Lbl 99 | Identifies beginning of while loop |
| :Line(A,B,C,D) (C,D) | Draws line from point (A,B) to point (C,D) |
| :Line(C,D,E,F) (E,F) | Draws line from point (C,D) to point (E,F) |
| :Line(E,F,G,H) (G,H) | Draws line from point (E,F) to point (G,H) |
| :Line(G,H,A,B) (A,B) | Draws line from point (G,H) to point (A,B) |
| :Pause pressed | Pauses program until ENTER is pressed |
| :ClrDraw | Clears screen |
| :A*2Sto->A | Doubles value of A |
| :B*2Sto->B | Doubles value of B |
| :C*2Sto->C | Doubles value of C |
| :D*2Sto->D | Doubles value of D |
| :E*2Sto->E | Doubles value of E |
| :F*2Sto->F | Doubles value of F |
| :G*2Sto->G | Doubles value of G |
| :H*2Sto->H | Doubles value of H |
| :While A#64 | While is from program control CTL menu, less than or equal sign is from TEST menu – establishes duration of loop |
| :Goto 99 | From CTL menu, identifies loop location |
| :End | From CTL menu, ends program at completion of loop |

To run DILSQ program, select PRGM, EXEC, DILSQ, ENTER. To advance through the program, press enter until the square is off the screen.

Handout for Sorcerer’s Apprentice Lesson (Expand space for students to enter examples before this is printed.)

Name:

Date:

The Twelve Golden Rules of Classic Film Animation

The legendary Walt Disney worked with the artists in his company to develop these twelve principles of animation. He believed that following these rules would make a successful animated film.

1. Squash and stretch – Use shape distortion to emphasize movement.
2. Anticipation – Apply reverse movement to prepare for and bring out a forward movement.
3. Staging – Use the camera viewpoint that best shows an action.
4. Straight-ahead vs. pose-to-pose action – Apply the right procedure.
5. Follow through and overlapping action – Avoid stopping motion abruptly.
6. Slow-in and slow-out – Allow smooth starts and stops by spacing frames appropriately.
7. Arcs – Allow curved motion in paths of action.
8. Secondary actions – Animate secondary actions to bring out even more life.
9. Timing – Apply time relations within actions to create the illusion of movement.
10. Exaggeration – Apply caricature to actions and timing.
11. Solid drawing – Learn and use good drawing techniques.
12. Appeal – Create and animate appealing characters.

Discuss all of these topics with the other students in your group. Each student in the group should choose three different principles and find at least one example of each as we watch “The Sorcerer’s Apprentice.” List the principles below that you have chosen and describe the examples of each that you observed in the film.

A. Principle: _____

Example(s):

B. Principle: _____

Example(s)

C: Principle: _____

Example(s)