

Using 3D Computer Graphics Multimedia to Motivate Teachers' Learning of Geometry and Pedagogy

Tracy Goodson-Espy
Associate Professor
Department of Curriculum & Instruction
Appalachian State University, Boone, NC
goodsonespyt@appstate.edu

Samuel L. Espy
Viz Multimedia
Boone, NC 28607
samespy@pobox.com

Kathleen Lynch-Davis
Assistant Professor
Department of Curriculum & Instruction
Appalachian State University, Boone, NC
lynchrk@appstate.edu

Pamela Schram
Professor
Department of Curriculum & Instruction
Appalachian State University, Boone, NC
schrampk@appstate.edu

Art Quickenton
Associate Professor
Department of Curriculum & Instruction
Appalachian State University, Boone, NC
quickentonaj@appstate.edu

Abstract

This paper describes the implementation of 3D computer graphics multimedia, developed with an institutional technology grant, in a geometry methods course for elementary teachers. Computer graphics demonstrations, in conjunction with related 2D and 3D mathematics manipulative activities, were used to improve preservice teachers' (PSTs) motivation to learn geometry and help them learn geometric content. The paper focuses on the question: *How can instructors in a geometry methods course use 3D computer graphics multimedia effectively to motivate PSTs' learning of major geometric concepts and their understanding of how these concepts are applied in real-world settings?*

The Geometry Methods Course

Since 1999, we have taught a geometry methods course for prospective elementary teachers and have analyzed their evaluations of the course. During fall semester of 2006, we surveyed 87 PSTs in four sections of the course. The survey explored PSTs' perceptions of their own geometric understanding and readiness to teach geometry both pre- and post-course. We saw a pattern whereby our PSTs: 1) were not gaining an appreciation for how geometry is applied in real-world professions; 2) did not see how geometry relates to modern technology; 3) did not fully recognize how geometry taught in elementary school related to what students need in high school geometry; and 4) were making only limited gains in their geometric conceptual development and in their perceived preparation to teach geometry. What was promising from the data is that most of our PSTs wanted to learn more about geometry and how to teach it well. Based on this information, we modified the technology component of our course to include sequences of instruction featuring applied geometry.

Seeing Geometry in Computer Graphics Applications

We developed instructional materials via a technology grant from Appalachian's Reich College of Education. The lessons and materials focused on three themes: 1) Using 3D computer graphics demonstrations to illustrate how 2D and 3D geometry is applied to create computer-generated figures; 2) Using 3D computer graphics demonstrations to help PSTs visualize and understand 3D geometric figures, such as regular and non-regular polyhedra, and to help them

gain an appreciation of where these figures occur in the natural world or how they are applied; and 3) Using techniques for creating 3D multiplayer online role playing games to illustrate the importance of perimeter and area—even when creating a virtual world (See Table 1). The challenge in developing these materials is that the majority of the mathematics used in computer graphics is quite advanced. The goal is to describe topics at a level accessible to PSTs and depict it accurately. We also designed complimentary materials for each component so that the PSTs could potentially use them with their future students. We wanted to provide our PSTs with a geometric encounter in an unexpected setting. The next section describes how the *Chameleon*

Table 1. Demonstration CDROM Content

Demo 1 NVIDIA Chameleon: Using Geometry to Create 3D Computer Graphics	Demo 2 3D Figures in the Real World: Seeing Geometry in Crystals, Prisms, and Soccer Balls	Demo 3 Game “Mods”: Using Perimeter and Area to Create Virtual Worlds
I. North Carolina Standard Course of Study Goals & Objectives	I. North Carolina Standard Course of Study Goals & Objectives	I. North Carolina Standard Course of Study Goals & Objectives
II. NCTM Standards	II. NCTM Standards	II. NCTM Standards
III. Math Concepts: Polygons, 2D Shapes, 3D Figures & Transformations	III. Math Concepts: Polygons, Regular Polyhedra, & Non-regular Polyhedra	III. Math Concepts: Polygons, Area, and Perimeter.
IV. How is Math Used? PSTs explore how geometric “wireframe” mathematical models are used to create 3D computer graphics.	IV. How is Math Used? PSTs explore where regular and non-regular polyhedra exist in the natural world and how they are applied.	IV. How is Math Used? PSTs explore how area and perimeter are applied in a game setting in the planning and creation of a virtual game world.
V. Related jobs: Software engineer, computer graphics artist, movie/game industry jobs	V. Related jobs: Microbiologist, virologist	V. Related jobs: Software engineer, computer graphics artist, movie/game industry jobs
VI. Class Activities: 1. Identify 2D geometric shapes in a wireframe model of the <i>Chameleon</i> . 2. Create 2D creature using pattern blocks. 3. Create a 3D creature using <i>Polydrons</i> . 4. Transform a 2D creature across a plane. 5. Draw a 3D figure using isometric paper.	VI. Class Activities: 1. Build regular polyhedra. 2. Build non-regular polyhedra.	VI. Class activities: 1. Apply a game “mod” tool to create a model virtual world. 2. Use game tiles to create a virtual world with a given perimeter and area.
VII. Geometer’s Sketchpad activities: 1. Complete computer graphics tutorial 2. Create figures/animate	VII. GSP activities: 1. Create regular and non-regular polyhedra.	VII. GSP activities: 1. Complete computer graphics tutorial 2. Draw polygons, find perimeter and area.

3D computer graphics theme was applied to a sequence of lessons to help PSTs understand the significance of elementary school instruction concerning 2D shapes and 3D figures.

The NVIDIA® Chameleon

Digital entertainment mediums such as movies, PC computer games, and video consoles easily capture children's attention partly through their use of advanced 3D computer graphics. NVIDIA® Corporation is an international company, headquartered in California, which develops graphics processing units like those found in console gaming platforms such as Sony's Playstation 3. NVIDIA® regularly posts short graphics programs on their website to illustrate the power of their latest graphics processor:

http://www.nzone.com/object/nzone_downloads_nvidia.html. One of the downloadable demonstrations from the NVIDIA® website is the *Chameleon*, developed to illustrate the capabilities of their GeForce3 graphics chip that was released in 2001. It is important to note that the *Chameleon* demo is completely interactive—meaning the chameleon can be observed from any view while the demo is running—which means that the graphics processor is calculating all the visual information displayed on the screen in real time. The first demonstration on our multimedia CDROM is a movie of the computer-generated chameleon. One can view the *Chameleon* 1) in line view, also referred to as wireframe view (Figure 2), which enables one to see the polygons used to define the figure or mesh; 2) in point view, which allows one to see the intersection points among all the polygons (vertices of the polygons); 3) in solid form with a single, simple solid texture applied; and 4) in normal view which shows the chameleon with multiple 2D complex textures applied (Figure 1). We used the *Chameleon* demonstration as a centerpiece for a series of lessons directed at helping PSTs understand the relevance of the information they are learning about 2D shapes and 3D figures. The activity plans for the *Chameleon* demonstration include:

1. Seeing Primitive Shapes in the Chameleon

Students view the *Chameleon* demonstration and then identify geometric figures within paper copies of the chameleon shown in point view.

2. Creating 2D Creatures with Pattern Blocks

Students examine an example of a 2D creature using pattern blocks, create their own pattern block 2D creatures, and record the designs on pattern block graph paper.

3. Creating 3D Creatures with Polydrons and other Materials

Students build 3D figures such as cubes, prisms, and their own invented creature based on their 2D designs from *Activity 2*. They use *Polydrons* or materials, such as gumdrops and toothpicks, to explore how 3D shapes can be formed using polygons.

4. Transforming a 2D Drawing Across a Plane

Students explore transformations, such as translations and reflections using pattern blocks and Cartesian coordinates for older students. This activity is also based on their 2D designs created in *Activity 2*.

5. Learning How to Draw 3D Figures Like the Chameleon in 2D

Students explore how to draw 3D figures such as cubes, prisms, and the creatures they created in *Activity 3* in 2D, using isometric graph paper.

These activities provide PSTs with opportunities to see how geometric concepts are applied in a computer graphics setting, yet also appearing in contexts that are accessible to elementary school children.

The Chameleon Activity Plans

The following examples summarize each of the *Chameleon* class activities and provide some examples of how our PSTs responded to the first three activities.



Figure 1. Chameleon rendered as a textured solid (over geometry).

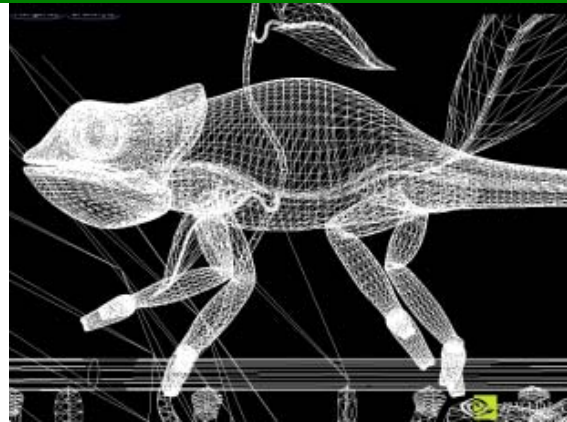


Figure 2. Chameleon rendered in wireframe only to show geometry of objects in virtual scene

1. Seeing Shapes in the Chameleon

The goal of this activity is to explore geometric shapes, such as triangles and quadrilaterals, and see how these shapes can be used to create more complex shapes. First, the *Chameleon* computer demonstration is viewed. Next, the PSTs examine the chameleon in point (vertex) view on an overhead transparency and observe how the points may be connected to create various geometric shapes. They then perform this activity on a paper copy of the point view of the chameleon. Computer graphics 3D models such as the chameleon are actually made using a variety of geometric shapes as determined by a specialized type of artist called a modeler. This demonstration is useful for helping PSTs see how computer generated images are mathematically defined using a geometric skeleton called a wireframe mesh (Figure 2). It helps them develop awareness of the underlying polygons and clarifies that each of the individual polygons is flat (or planar) even though the complete wireframe mesh is a curved surface in 3D space. The areas of the mesh that have more detail and/or higher curvature have larger numbers of polygons for a given mesh area, so the polygons are smaller in these areas. While the demo movie points out this information, the paper activity allows PSTs to explore these concepts using an approach that is as familiar to children as playing the game “*Connect the Dots*”. After viewing the movie and seeing the chameleon in wireframe view, many PSTs were surprised to learn that each individual polygon was planar.

2. Creating 2D Creatures with Pattern Blocks

Preservice teachers first review the *Chameleon* demonstration. They observe that in this example, the chameleon is made of quadrilaterals. The instructor notes that while the chameleon is a 3D figure, on paper we can also represent it in 2D. The instructor shows the PSTs an example of a 2D shape made from pattern blocks. The goal for this activity is for them to create their own 2D creatures using pattern blocks and record their designs on a grid. These are some examples of 2D creatures made by PSTs during this activity (Figure 3). PSTs observe that a variety of creatures can be built using regular polygons such as triangles, squares, and hexagons.

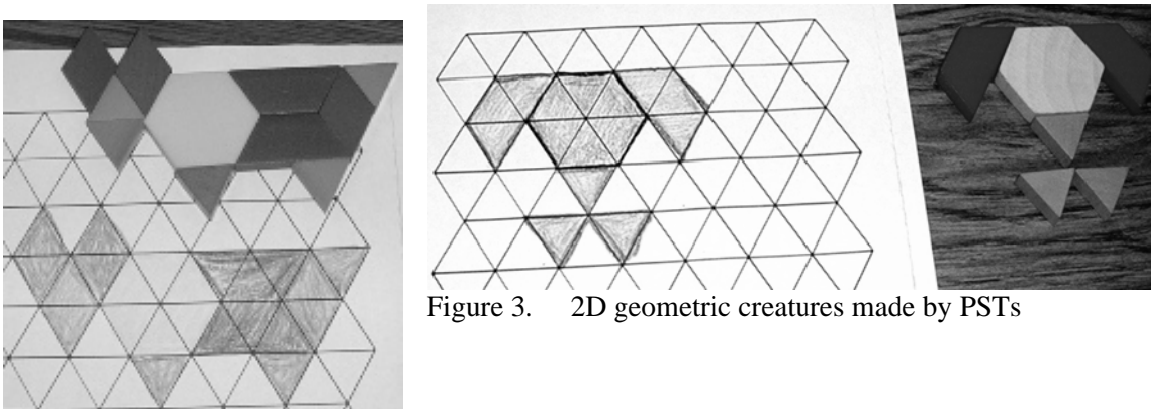


Figure 3. 2D geometric creatures made by PSTs

It is a mathematically valuable exercise for them to visualize the type of creature that they want to make and to determine what polygonal shapes are required to create it. PSTs are advised that while younger children will be able to create some shapes with the pattern blocks, children in the upper grades may create more complex designs. They will also be able to use more advanced geometric vocabulary to describe their design and should be encouraged to do so. It is useful to instruct students to move throughout the classroom and view the creatures designed by their classmates. Our PSTs were surprised at their classmates' imaginations and the diversity of the creatures produced.

3. Creating 3D Creatures with *Polydrons* and other Materials

Preservice teachers view the *Chameleon* computer graphics demonstration and observe that the creature is made of polygons, specifically, quadrilaterals. The goal of this activity is to help PSTs practice spatial visualization skills by exploring how a 2D shape can be expanded into a 3D figure. The instructor explains that the class will learn how to create a 3D creature by first working with some more familiar shapes. These are some examples of 3D figures made by PSTs during this activity (Figure 3). The PSTs are first asked to compare the structure of a square to a cube and that of a triangle to a pyramid. Then the course instructor displays a 3D model made from *Polydrons* that is based on the 2D figure the instructor created in *Activity 2*. The instructor then asks PSTs to look carefully at the drawings of the 2D creatures that they developed in *Activity 2*. They are asked to attempt to create 3D figures based on the 2D creatures. Can they visualize how the creature would look in 3D? While computer graphics figures in wireframe are usually represented using only one type of polygon, there are circumstances where more than one type of polygon is used. Because classroom sets of *Polydrons* have limited numbers of each polygonal shape, it is more practical in the classroom to use different types of polygons to create the 3D models. However, most figures can be efficiently made with triangles, squares, and/or rectangles. PSTs are reminded of the process for identifying the faces, edges, and vertices of a figure and are asked to count and record each of these features on a table. During this activity it is also beneficial for PSTs to move throughout the classroom and see the structures made by their classmates. Some of our PSTs were easily able to visualize the creation of a 3D figure from their 2D pattern and quickly completed the task. Others had great difficulty with this type of visualization but were eventually successful.

4. Transforming a 2D Drawing Across a Plane

PSTs are asked to pay attention to the *Chameleon* as it moves across the screen. They are asked, "What happens computationally that makes the chameleon appear to crawl across the screen?" The goal is to help students learn about translations and to help them connect these ideas to

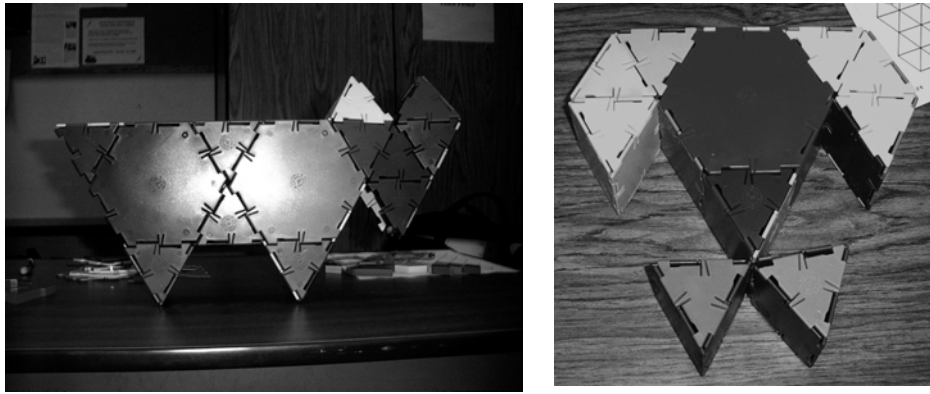


Figure 3. 3D Polydron Models Based on 2D Designs

Cartesian coordinates. The instructor explains that while the chameleon is shown as a 3D figure in the demonstration, it is also useful to describe the motion of a 2D figure across a plane (a visualization made easier when one realizes that the 3D virtual chameleon is always rendered (drawn) in 2D on the computer screen). PSTs are asked to translate the design of their 2D pattern block creature across the plane and to determine the coordinates of certain points.

5. Learning How to Draw 3D Shapes Like the Chameleon in 2D

PSTs explore how to draw 3D figures such as cubes, prisms and the 2D creatures they created in *Activity 3* using isometric graph paper. The purpose is to help them gain understanding of how 3D figures can be represented with 2D drawings. Isometric graph paper can be useful for teachers in learning how to draw 3D figures in 2D. PSTs are shown a model of a cube and asked to attempt to draw the cube using isometric graph paper. Then, PSTs see the instructor's 2D pattern block design, the 3D *Polydron* creature, and a model of the creature drawn on isometric paper. They are then encouraged to draw their own 3D *Polydron* creatures on isometric paper.

Conclusions

End-of-course survey results indicated modest increases in PSTs' knowledge of basic geometry and its applications. They reported feeling that they knew much more about geometric topics, especially 2D shapes, 3D figures, transformations, tessellations, area, and perimeter. Their use of geometric terminology improved compared to the pre-course survey. They reported feeling more prepared to teach these topics. A typical comment included:

I think that the chameleon lesson that we did in the class was useful and very interesting. Before seeing this I had never really thought about how geometry and computer graphics were related. I knew that they were of course, but this demo let me see how the realistic graphics were possible because of the arrangement of the shapes. Since so many kids today are into technology and video games I think this demo will allow them to see the connection between geometry and something that they are interested in.

We continue to encourage PSTs to see how and why geometry is relevant to the lives of their students. We found that using 3D computer graphics multimedia in class helped them gain some perspective on geometry's usefulness.