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

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This paper describes the genesis and purpose of our geometry methods course, focusing on a geometry-teaching technology we created using NVIDIA® Chameleon demonstration. This article presents examples from a sequence of lessons centered about a 3D computer graphics demonstration of the chameleon and its geometry. In addition, we present data addressing the tools' effectiveness at helping preservice teachers learning geometric concepts, as well as changing preservice teachers' perceptions and attitudes about geometry.

The release of the National Council of Teachers of Mathematics' Focal Points has drawn renewed attention to the "big ideas" of geometry. Special emphasis is placed on K-8 students' learning of these concepts as well as the readiness of teachers to successfully guide students' learning. Kennedy, Tipps, and Johnson (2004) refer to elementary school geometry as spanning the basics of four geometrical systems: topological, Euclidean, coordinate, and transformational. In order for preservice teachers to be prepared to help their students learn geometry with understanding and proficiency, they must first have in-depth opportunities to engage with these ideas themselves, and develop connections between them, as well as gain skills in appropriate pedagogies. To assist our preservice teachers in learning geometry, we developed a specific geometry methods course organized around the "big ideas" of: 1) Location; 2) 2D Shapes and 3D Figures, 3) Transformations; 4) Visualization; and 5) Technology (NCTM, 2001). This paper focuses on the technological strand of this course and answers two fundamental questions:

1. How can instructors in a geometry methods course use technological tools effectively to help preservice teachers learn major geometric concepts and develop a better understanding of how they are applied in real-world settings?
2. What are some ways the use of technological tools impacts preservice teachers' proficiency in, and attitudes towards, geometry?

Our geometry-teaching technology was created using multimedia tools that required content created by 3D-graphics-intensive software as its input. It was used as a vehicle for exploring geometric concepts and demonstrating their relevance to different occupations. In this paper, we first describe the genesis and purpose of the geometry methods course. Second, we present examples from a sequence of lessons centered about a 3D computer graphics demonstration of a chameleon and its geometry.

The Geometry Methods Course for Elementary Education Majors

During a significant curriculum revision to the Elementary Education program in 1999, the mathematics education semester hours required for Elementary Education majors at Appalachian State University increased from 6 semester hours to 13. Part of the revisions included the design and implementation of a three-course sequence of mathematics education courses. Mathematics educators in the Departments of Mathematical Sciences and Curriculum and Instruction collaborated to develop the sequences that are taught jointly in the departments as shown in Table 1. The sequence of courses was designed to build upon the mathematics of the core curriculum course and incorporate current recommendations for the preparation of elementary school teachers (CBMS, 2001; NCTM, 1991; Ma, 1999). The sequence has several distinctive features:

- It is a cooperative venture between two departments in two different colleges.
- Mathematical content and pedagogy are integrated throughout the sequence.
- It builds upon an award-winning quantitative literacy course, which is part of Appalachian's core curriculum and involves extensive use of genuine data, written communication, and computer software.
- It is aligned with recommendations of the MAA, NCTM, and NCATE.
- It includes the five mathematics strands of the North Carolina Standard Course of Study: number and operations; measurement; geometry; data, probability, and statistics; and algebra.

The field of mathematics education predominately views students as active participants in learning, a view that is aligned with the conceptual framework of teaching adopted by Appalachian's Reich College of Education. This constructivist view of learning implies roles for teachers and students that are significantly different from the instructional practice that shaped the educational experiences of many prospective teachers. Research has shown that teachers tend to teach using the techniques by which they were taught (Ball & Bass, 2000; Shulman, 1986). This makes the argument for integrating mathematics content and pedagogy across courses and departments even more compelling and requires us to model the types of mathematics instruction we recommend.

The geometry methods course, CI 4030-Teaching Mathematics in the Elementary School, was planned as the last course in the sequence so preservice teachers would be engaged with geometric concepts immediately before entering the classroom as student teachers. Also, because of their growing familiarity with mathematics pedagogy across the course sequence, they would be in a greater state of readiness to study pedagogy in geometry. The course emphasizes the Van Hiele levels and the five "big ideas" previously noted. The central questions explored in the course are:

> *Knowledge of Mathematics*: What is my comfort level with the mathematics content I will be expected to teach? How do I improve in areas I know I need to learn more?
>
> *Expectations of Children*: Do I have realistic expectations concerning children's learning of mathematics that reflect appropriate understandings of normal child development as well as exceptionalities? Do I know how to create a learning environment that supports all students?

Knowledge of Pedagogy: Do I have a rich collection of strategies and examples to call upon in the teaching of mathematics? Do I understand how to use manipulatives and technology to achieve student learning? Do I have a plan for continued growth of my knowledge?

We were excited in 2004 to begin teaching this sequence, especially the geometry course. We were pleased that our preservice teachers had new opportunities to learn content and pedagogy. Below, we describe our continued efforts to improve their learning opportunities.

Connecting Geometry Curriculum and Teaching to the Workplace and Real Life

In developing the course, we applied a learner-centered, manipulatives-based approach to encourage our pre-service teachers to develop meaningful geometric concepts and to understand how their students might do so. Since 2004, as our group of four instructors has taught this course and analyzed preservice teachers' evaluations of the course, we saw a pattern whereby our preservice teachers: 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 own geometric conceptual development and their perceived preparation to teach geometry. Based on these perceptions, we modified the technology component of our course to include sequences of lessons featuring applied geometry. While we continue to value a learner-centered approach, and utilize activities to teach geometric concepts, we also identified the need to infuse the course with technology-based instructional activities that focus on helping preservice teachers see applications of geometry. This includes the following components:

1. Focus on preservice teachers as learners of geometry and prospective teachers:
   b. Preservice teachers perform a geometry activity, discuss the geometric concepts, and discuss, based on research, how students might learn the concept;
   c. Preservice teachers use technology-rich activities to motivate their own interest in, and their future students' interest, in geometry.
2. Focus on preservice teachers developing pedagogical skills and resources:
   a. Preservice teachers develop a project or collect a set of lesson plans and activities to illustrate Geometry in Our World;
   b. Preservice teachers teach a sequence of three lessons to a class and develop a case study about an individual student during a month-long internship.

During the fall semester of 2006, we surveyed 87 preservice teachers in four sections of the geometry methods course (Appendix 1). In an effort to explore preservice teachers' perceptions of their own geometric understanding and readiness to teach geometry, we designed a survey to administer to each preservice teacher pre- and post-course. The survey questions were clustered in groups of three, where the preservice teacher was asked: 1) about their content knowledge of key geometry concepts (i.e., 2D shapes, 3D shapes, similarity, symmetry, etc); 2) how prepared they felt to teach these concepts; and 3) to define or describe the concept in their own words. The first two questions of each cluster were evaluated using a 4 choice Likert scale where 1 is "not very well" and 4 is "very well". Additionally, we asked three open-ended questions: What is Geometry?; List three occupations that use geometry and specify how geometry is used.; and What do you hope to learn in this course? Data from our pre-course survey largely confirmed our impressions of preservice teachers' attitudes as evidenced below.

Five main areas of interest emerged from the pre-course survey. First, our preservice teachers, in general, rate themselves as not understanding geometry topics very well. Second, when asked to define geometry, they tend to simply provide lists of words, primarily names of geometric shapes, as opposed to explanations. There was little evidence of in-depth understanding of geometric topics from the lists, only that the preservice teachers could produce a group of words that are geometric in nature. These statements support Clements (2003), "the usual preschool to middle school curriculum includes little more than recognizing and naming geometric shapes (Porter, 1989). Through the grades, the curriculum tends to name more geometric objects but not require deeper levels of analysis (Fuys, Geddes, & Tischler, 1988)" (p. 151). A third trend that emerges from the data is the lack of geometric terminology. For example, when explaining what a two-dimensional shape is, a preservice teacher wrote, "a shape that is flat." The lack of geometric terminology is problematic in methods courses because, if preservice teachers do not know or understand the terminology, then they will not teach it accurately to students. Fourth, our preservice teachers indicated that they felt unprepared to teach geometry to children. Finally, they were unable to think outside the box when expressing how geometry is used in the real world. When asked about professions that used geometry, many listed the most obvious—teachers, carpenters, architects—and usually did not elaborate on how these professions used geometry.

We found these results to be disturbing because preservice teachers who are very weak in geometric content knowledge may also lack deep understandings of geometry's importance. This may, in turn, negatively affect their personal motivation to learn more about geometric concepts, may negatively affect the amount of time they spend on geometry in school (Porter, 1989), as well as impact the quality of instruction. Because only a small fraction of preservice teachers have used geometry professionally, and may not be cognizant of people who do, they are often unaware of its importance in many professions. What was promising from the data is that most of our preservice teachers wanted to learn more about geometry and how to teach it well. They understood their deficiencies and wanted to improve.

Seeing Geometry in Computer Graphics Applications

Based on our observations across numerous semesters of teaching the course and our pre-course survey data, we developed instructional materials and strategies in a project titled, *Using 3D Computer Graphics Intensive Technologies to Encourage Teachers and Students' Involvement in Science, Technology, Engineering, and Mathematics*, supported by a grant from Appalachian's Reich College of Education. The lessons and materials developed 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 to help preservice teachers 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 2). The primary challenge in developing these materials is that the majority of geometry/mathematics used in computer graphics is quite advanced. The goal is to select geometry/mathematics which is at a level accessible to prospective elementary teachers and depict it accurately. We also designed complimentary material for each component so that the preservice teachers could potentially use them with their future students.

The preservice teachers are guided through instructional materials that:

- Explain how the lessons are related to specific geometric concepts and to the North Carolina standard course of study in mathematics and the NCTM Standards;
- Describe a variety of careers related to geometry and computer graphics, including those in the computer gaming and movie industries, and point to information sources suitable for elementary-aged students, such as the U.S. Department of Labor's website Career Voyages;
- Illustrate a sequence of lessons to connect 2-D and 3-D geometry concepts to real-world examples and applications; and
- Direct pre-service teachers to additional technology support for learning.

We wanted to provide our preservice teachers with a geometric encounter in an unexpected setting. The next section describes how the Chameleon 3D computer graphics theme was applied to a sequence of lessons to help pre-service teachers understand the significance of elementary school instruction concerning 2D shapes and 3D figures.

The NVIDIA® Chameleon

Digital entertainment mediums such as movies, PC and Mac 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 programmable graphics processor technologies, including the graphics processing unit that is found in many personal computers and console gaming platforms such as the new Sony's Playstation 3. NVIDIA® regularly posts demonstrations (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. The Chameleon is interesting because one can view the Chameleon 1) in line view, also referred to as wireframe view, 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 preservice teachers understand the relevance of the information they are learning about 2D shapes and 3D figures. The class 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 shapes from Activity 2. They use Polydrons or other materials, such as gumdrops and toothpicks, in order 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 shapes 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.

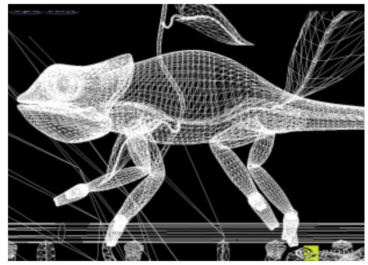
These activities provide preservice teachers with opportunities to see how geometric concepts are applied in a computer graphics setting, yet also appearing in contexts that are accessible to elementary school children.

The Chameleon Activity Plans

The following examples summarize each of the Chameleon class activities and provide some examples of how our preservice teachers responded to the activities.

Figure 1.
Chameleon rendered as textured solid

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



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 preservice teachers 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.

Discussion

This demonstration is useful for helping preservice teachers see how computer generated images are mathematically defined using a geometric skeleton called a wireframe mesh. It helps them develop awareness of the underlying polygons and clarifies that each of the individual polygons is flat (or planar) even though the 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, so the polygons are considerably smaller in these areas. While the demonstration movie points out this information, the paper activity allows preservice teachers 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 preservice teachers were surprised to learn that each individual polygon was planar.

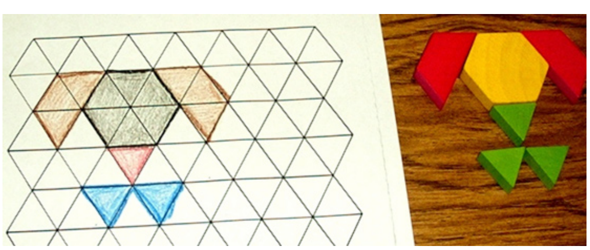
Creating 2D Creatures with Pattern Blocks

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 preservice teachers 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 preservice teachers during this activity (Figure 2).

Discussion

Preservice teachers observe that an infinite variety of creatures can be built using regular polygons such as triangles, squares, and hexagons. It is a mathematically valuable exercise for them to visualize the type

Figure 3.
2D Geometric Creatures made by Preservice Teachers



of creature that they want to make and to determine what polygonal shapes are required to create it. Preservice teachers 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. It is useful to instruct students to move throughout the classroom and view the creatures designed by their classmates. Our preservice teachers were surprised at their classmates' imaginations and the diversity of the creatures produced.

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 preservice teachers 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 preservice teachers during this activity (Figure 3).

Discussion

The preservice teachers 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.

Figure 4.
3D Polydron Models Based on 2D Designs

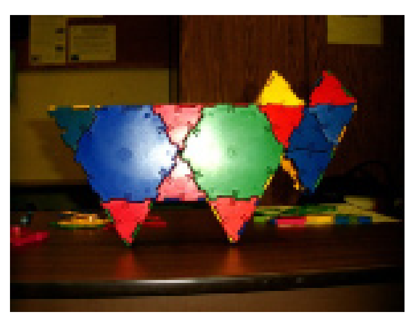
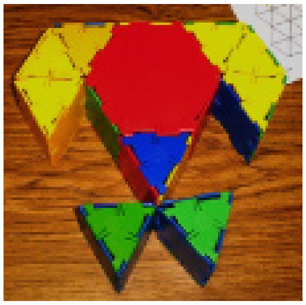


Figure 4 cont.
3D Polydron Models Based on 2D Designs



The instructor then asks preservice teachers 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 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 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. Preservice teachers 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 preservice teachers to move throughout the classroom and see the structures made by their classmates. Some of our preservice teachers were 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.

Transforming a 2D Drawing Across a Plane

After viewing the Chameleon computer graphics demonstration, preservice teachers are asked to pay particular attention to a figure as it moves across the screen. They are asked, "What happens computationally that makes the chameleon appear to crawl across the computer screen?" The goal of this activity is to help students learn about translations and to help older students connect these ideas to Cartesian coordinates.

Discussion

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. Preservice teachers are asked to translate the design of their 2D pattern block creature (developed in Activity 2) across the plane. They are asked to determine the coordinates of its points after it has been translated across a plane.

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

Preservice teachers 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 of this is to help them gain understanding of how 3D figures can be represented with 2D drawings.

Discussion

Isometric graph paper can be useful for teachers in learning how to draw 3D figures in 2D. In this activity, preservice teachers are shown a model of a cube and asked to attempt to draw the cube using isometric graph paper. They are then shown a prism model and asked to draw it. Preservice teachers see the instructor's 2D pattern block design, the 3D Polydron creature, and an example of how to draw the creature using isometric graph paper. They are then encouraged to draw their own 3D creatures on isometric graph paper. Our preservice teachers found this drawing exercise challenging but also exciting.

Conclusions

End-of-course survey results indicated modest increases in student teachers' knowledge of basic geometry and its applications. For example, when preservice teachers were asked "what is geometry?", even though most still compiled lists, the lists were more comprehensive and did not mainly focus on shapes. Our preservice teachers reported that they felt they knew much more about geometric topics, especially 2D shapes, 3D figures, transformations, tessellations, area, and perimeter. Their use of geometric terminology improved and was more evident than in the pre-survey. They also reported feeling more prepared to teach these topics to children. After viewing the Nvidia demonstrations, preservice teachers were better able to enumerate nontraditional professions that use geometry, e.g., computer graphics programmers, graphics chip makers, and geographers. However, some preservice teachers still only listed teachers and carpenters. We also asked them to respond to the question:

Do you think the Chameleon computer graphics demonstration we saw in class and the related activities we did, were useful to you in learning geometry and thinking about how to teach geometry to children? Please explain why or why not?

We received many thoughtful responses to this question such as:

> I thought the Chameleon technology program was very interesting. It was engaging and it was a great way to explain geometry to students. It shows students that math is integrated into other subjects and everyday life. I also thought the activities we did in class were helpful as well. The hands-on part of the 3D Polyhedron Creature made geometry easy to understand.

> 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.

> I thought that the chameleon activity was a good one. I think it really shows students how geometry is directly applied in the "real world." Plus it is pretty interesting. I think giving students the opportunity to come up and work with the software individually is a great way to involve students even more. I thought that the activities that went along with the chameleon program were good as well.
> I think that having students use math concepts such as polygons and polyhedra to create something by themselves is a great way to personalize learning. These activities got me thinking of other ways to make geometry more interactive and meaningful.

We were encouraged by these responses and continue to work to help preservice teachers see how and why geometry is relevant to the lives of their students. We found that using the Nvidia demonstrations in class helped them gain some perspective on the usefulness of geometry. It made them more aware of the importance of devoting adequate class time to geometry and the importance of learning proper geometric vocabulary. We do find, however, that even a semester long geometry methods course provides insufficient time to address the geometric learning needs of preservice teachers.

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Tables

Table 1.
Elementary education majors' coursework and experiences

College Year	Mathematics Education Courses	Other Courses Same Time Period	Field Experiences
Freshman or prior to MAT 2030	MAT 1010 Introduction to Mathematics (4 SH) Core Curriculum Course	· General Education Core Requirements	
Before Second Semester Junior Year	MAT 2030 Mathematics for the Elementary School Teacher [measurement, data analysis & probability, algebra] (3 SH)	· General Education Core & Program Requirements	
Second Semester Junior Year	MAT/CI 3030 Investigating Mathematics & Learning [number and operation] (3 SH)	· Learner Diversity · Integrating Media & Technology into Teaching · Foundations of Literacy · · Program Requirements	Practicum: 7-9 full days in a classroom
First Semester Senior Year	CI 4030 Teaching Mathematics in the Elementary School [geometry] (3 SH)	· Elementary School Curriculum & Instruction · Additional Methods Courses: - Social Studies - Literacy for Learning - Science & Science Teaching	Internship: 1 day per week first 10 weeks; 5 days per week last 5 weeks
Last Semester Senior Year	Student Teaching		Student Teaching

Tables Cont.

Table 2.
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? Preservice teachers explore how geometric "wireframe" mathematical models are used to create 3D computer graphics.	IV. How is Math Used? Preservice teachers explore where regular and non-regular polyhedra exist in the natural world and how they are applied to create items such as soccer and buckyballs.	IV. How is Math Used? Preservice teachers 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 scientist, 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 Chameleon. 2. Create 2D creature using pattern blocks. 3. Create a 3D creature using Polydrons. 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.

Appendices

Appendix 1.
Geometry CI 4030 Survey

Likert Scale:
1- Not very well   2   3   4- Very well

I. *When you hear the word geometry what do you think of?*

II. *(Content Knowledge)*

1. I understand two dimensional shapes (1-4)
2. I feel prepared to teach two dimensional shapes to elementary students (1-4)
3. Define two dimensional shapes
4. I understand three-dimensional figures (1-4)
5. I feel prepared to teach three dimensional figures to elementary students (1-4)
6. Define three dimensional figures
7. I understand area (1-4)
8. I feel prepared to teach area to elementary students (1-4)
9. Define area
10. I understand perimeter (1-4)
11. I feel prepared to teach perimeter to elementary students (1-4)
12. Define perimeter
13. I understand similarity (1-4)
14. I feel prepared to teach similarity to elementary students (1-4)
15. Define similarity
16. I understand symmetry (1-4)
17. I feel prepared to teach symmetry to elementary students (1-4)
18. Define symmetry
19. I understand transformations (1-4)
20. I feel prepared to teach transformations to elementary students (1-4)
21. Define transformations
22. I understand tessellations (1-4)
23. I feel prepared to teach tessellations (1-4)
24. Define tessellations
25. I understand congruence (1-4)
26. I feel prepared to teach congruence to elementary students (1-4)
27. Define congruence

III. *Uses of Geometry and Occupations*: List three occupations that use geometry. Identify the occupation and specify the geometry used.

IV. *Personal Learning Goals*: What do you hope to learn in this course?