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Geometry Sketching Software for Elementary Children: Easy as 1, 2, 3

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This paper discusses insights for using geometry sketching software to teach geometric concepts for kindergarten to grade 4. The authors created hands-on resources that incorporate technology in a user-friendly environment. When working with *Geometer's Sketchpad* with middle and high school students, the teacher educators noticed the ease of student use after creating such activity sheets and felt such activities may be used at the K-4 grade levels as well. The second graders who participated in the activities commented on the fun and ease of such software and compared it to the software *Paint*. The paper provides a literature review and appendices with geometry worksheets that can easily be used by elementary teachers to excite students about mathematics while incorporating the technologies reflected in the National Council of Teachers of Mathematics *Standards* (1989) and *Principles and Standards for School Mathematics* (2000).

Keywords: Elementary, Geometry, Mathematics, Sketchpad, Spatial Visualization, Semi-concrete

INTRODUCTION

The importance of using technology in the teaching of mathematics has been advocated by the National Council of Teachers of Mathematics (NCTM) for many years (NCTM, 1989 and 2000). Computers are an integral part of everyone's life, and students need to be prepared to use the technology to solve problems and access information as young adults. Currently, there exists many Internet websites and mathematics software for learning math concepts K-12 and beyond in an interactive and dynamic manner. What was once considered sophisticated software is now being used even by elementary students as the advanced technology of yesterday is slowly being brought down to the lowest levels of learners in our classrooms.

In particular, the K–4 grade students are excited when using the computer. By harnessing this excitement, teachers need to expose their students to such educational activities that employ "best practices" such as incorporating technology while helping construct students' understanding of important mathematics concepts. The National Council of Teachers of Mathematics has placed a great deal of importance on technology usage in the teaching of mathematics by making technology once of its six principles for teaching and learning mathematics (NCTM, 2000). NCTM is well aware of the role of technology in our advancing global society and wants students to learn and understand the mathematics while using the software which may be similar to such software a career person may use on the job as an architect, nurse, X-Ray Technician, and perhaps someone at the DMV who produces driver licenses. Educators are better preparing their students for their futures when they incorporate technology in their teaching. Math teachers can better help students construct their understanding when they allow them to investigate semiconcrete and abstract ideas using both concrete manipulatives and current geometry-sketching software. Bridging the gap between hands-on manipulatives and computer simulations helps to better create understanding for the learner. One dynamic math

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software is *Geometer's Sketchpad (GSP,)* which promotes the exploration of geometric concepts. Reys, Lindquist, Lambdin, Smith, & Suydam (2006) and Perkins, Schwartz, West, & Wiske, M. S. (1997) advocate that geometry is best learned in a hands-on active manner, one that should not rely on learning about geometry by reading from a textbook. Instead, as Reys, Lindquist, Lambdin, Smith, & Suydam (2006) point out, based on research by Piaget, young learners of mathematics need to (1) experience hands-on (concrete) use of manipulatives for geometry such as geoboards, pattern blocks and tangrams, (2) connect the hands-on to visuals or semiconcrete models such as drawings or use the sketching software on a computer, and (3) comprehends the abstract understanding of the concepts by seeing and operating with the picture or symbol of the mathematical concept.

MAKING IT INTERESTING FOR STUDENTS TO LEARN

As educators, we need to make mathematics interesting for students to learn and enjoy while also providing a focus on important mathematical concepts. While developing their confidence and ability to do math, learning such math skills using the technology may impact their lives in positive ways creating good attitudes toward mathematics and developing substantial mathematical content knowledge. By preparing them to learn and understand mathematics using existing technology**,** we are preparing our students to compete and function in our high-tech world. It is our obligation, as an educational community, to make the difference for the future of our students in an ever-growing, competitive global environment, which in today's society depends so heavily on mathematics, science, and technology (Furner, 1998).

Students today are motivated to learn when activities are presented in a dynamic hands-on engaging manner. The *GSP* software is an excellent interactive tool that allows students to create their own understanding of geometry and mathematical ideas. By utilizing "best practices" in mathematics instruction (Zemelman, Daniels, & Hyde, 2005; NCTM, 1989, 1995, & 2000*)* such as incorporating emerging technologies, educators can see greater gains in math achievement among their students; hence, eradicating much math anxiety and fear of using computer software and learning mathematics. The use of such technology also prepares young people to feel confident to use such sophisticated software as adults on the job. Almeqdadi (2000) has found in a controlled/experimental study that children who learned geometry using both a textbook and *GSP* software had significant gains in achievement over students who used only a textbook without software use. *GSP* makes the learning of geometry exciting and dynamic where one constructs his or her own understanding of geometry, not just reading it passively from a textbook.

TRANSITION FROM HANDS-ON MANIPULATIVES TO SOFTWARE

Research suggests that in elementary school classrooms students should learn shape recognition through hands-on manipulatives (Reys, Lindquist, Lambdin, Smith, & Suydam; 2006). In Pre-K and first grade, students should experience activities that involve shape recognition with real-life examples. They should recognize that the shape of the table-top is a rectangle and that the shape of a pizza is a circle or a honey comb is like the hexagon in the pattern block set. A problem occurs when three-dimensional real-life objects are represented in a two-dimensional computer screen environment. One study by McClintock, Jiang, & July (2002) found *GSP* provides opportunities to have a distinct positive effect on students' learning of three-dimensional geometry when using the sketching software.

Students have difficulty moving from the three-dimensional world to a two-dimensional world. Experiences that bridge this gap will help students move from concrete to abstract examples of shapes. Reys, Lindquist, Lambdin, Smith, & Suydam (2006) feel that teachers need to emphasize the stages of concrete (manipulatives), semiconcrete (the sketching software), and the symbolic (the paper and pencil).

One such example is found in the Appendix A using *Geometer's Sketchpad* (Recognizing Shapes). This activity shows the two-dimensional representation of real life objects and asks the students to use the tools of *GSP* to outline various geometric shapes. The culminating activity asks the students to find their own examples on the Internet to include with their projects.

Another activity in the Appendix A, Triangle Shapes, helps students learn about the different classifications of triangles. They experience the triangle classifications by sides and then by angles. As a review, students classify selected triangles by sides and angles and then check their answers. Geri Anderson-Nielson (n.d.) has complied an extensive set of activities entitled, *Sketchpad Activities for the Little Ones,* which like the activities above emphasize exploration of geometrical ideas using the *GSP* software. Many other activities for primary grades can be found in the *Websites Related to Geometer's Sketchpad Activities* section found below.

Many activities can be created to introduce students to the tools of *GSP* and to help students with the transition from real-life objects into the two-dimensional computer graphics (See Appendix C for *GSP* Software Website Resources). *Geometer's Sketchpad's* initial activities were created for high school and college students, but recently more *GSP* activities have been

created for elementary and middle school levels. As many young students have used *Window's Paint* on their own home computers to create designs and pictures, it also provides a smooth transition into the *GSP* environment.

It is important for students to move gradually into the computer environment by relating hands-on manipulatives to two-dimensional computer shapes. These hands-on manipulatives include items collected in the real world and translated into free hand drawings and designs (two-dimensions). These drawings could be used to recognize and classify shapes and then construct them in *GSP* to analyze mathematical relationships. Teachers can help students first by using the commercial manipulatives like pattern-blocks, geo-boards, and tangrams as well as daily life items like buttons, CD's, books, cans, and cones. By introducing students to these activities at an early age, they will be able to proceed to more abstract mathematical concepts in the upper elementary grades and beyond (McClintock, Jiang, & July, 2002). When primary age children are learning mathematics concepts, Berlin and White (1986) found that computer simulations provide a smooth transition from concrete manipulation of objects to their abstract understanding. Colker (1990) contends that using a multi-media videodisc system allows children to manipulate real-world objects in order to acquire concrete knowledge about abstract concepts. Teachers should of course do concrete activities first using such manipulatives, teachers may first lead their students into using software like *MS Paint*, which most students are familiar with prior to enter school, for drawing, from this, students can easily be lead into using GSP for creating shapes, exploring properties, and even doing animations which most young students enjoy with GSP. GSP is much more sophisticated than *MS Paint* and exposing students to this software early on better prepares them for use with it in the middle and high school grades. Teachers can lead the instruction of GSP as a whole class demonstration, or walk around to monitor student progress using such activities sheets (See Appendix A). Allowing students to work together in groups/partners or individually doing such activities while the teacher observes and interacts during the activities serves also as another form of assessment for the teacher to see if students really understand and apply the concepts they are learning, the activity sheets can serve as both a guide and an assessment for the students (see Figure 3).

GEOMETRY SKETCHING SOFTWARE

Geometer's Sketchpad (by Key Curriculum Press) is one of the dynamic construction and exploration tools that exists to enable students to explore and understand mathematics in ways that are simply not possible with traditional tools. With *GSP*, students can construct an object and then explore its mathematical properties by dragging the object with the mouse. All mathematical relationships are preserved, allowing students to examine an entire set of similar cases in a matter of seconds, leading them by natural course to generalizations. *GSP* encourages a process of discovery in which students first visualize and analyze a problem and then make conjectures before attempting a logical proof.

Geometer's Sketchpad, although stated in its user's manual that it is geared toward Grades 5 through college level, can be lowered to a level of use and understanding for younger children. With its active, visual approach, *Geometer's Sketchpad* allows younger students to develop the concrete foundation to progress into more advanced levels of study (Hannafin, Burruss, & Little, 2001; Key Curriculum Press, 2001; Marinas, 2003). The features of the software invite exploration and play and enable users to define their own roles in shaping and crafting their understanding of mathematics using *GSP* (see Figure 1, Figure 2). In 1998, Manouchehri, Enderson, and Pugnucco shared their observations about teaching and learning geometry by describing how the *GSP* software program allows for the implementation of many recommendations from the National Council of Teachers of Mathematics (NCTM) *Standards* documents, as NCTM advocates the use of technology and a dynamic approach to teaching/learning, such recommendations include: developing spatial sense, the use of manipulative materials, questioning and making conjectures, justification of thinking, use of calculators and computers, teachers as facilitators of learning, and using multiple assessment techniques, including written, oral, and demonstration formats. These recommendations are all aspects of a child applying and using the GSP software when learning mathematics.

There are many elementary geometry concepts that could be explored using some fairly basic features of GSP: identifying congruent figures, giving reasons using sides, angles, etc.; drawing and describing parallelograms, rhombuses, trapezoids; characteristics of parallel and perpendicular lines; finding areas of shapes by dividing them into basic shapes such as rectangles and triangles; discovering formulas for perimeter and area; observing that rectangles with the same area can have different perimeters, etc. Some of the special features of GSP would make it a powerful tool for dealing with these topics. Their main value may be to serve as a catalyst which motivates teachers to create their own GSP activities that engage students in ways not previously feasible. Such uses of GSP would be significant and useful and better prepare our youngsters for middle and high school mathematics.

Geometer's Sketchpad works well in a variety of classroom settings with an overhead projector, with one or two classroom computers, or in a computer lab. Students can work on assigned explorations independently or collaboratively. Teachers can use *GSP* to create worksheets, exams, and reports by exporting *GSP* figures and measurements to spreadsheets, word processors, other drawing programs, and the Web (Key Curriculum Press, 2001). When primary age students have mastered the basic sketching tools, they then are curious to explore the measurement tools and even animations. Young children can play for hours using this software to create their own understandings of mathematics. Many benefits can occur as young students use the GSP software, many of the elementary students compared *GSP* to *MS Paint* and thought it was very easy to use, benefits such as the following are key to student learning: hands-on, practice drawing, visualizing, comparing to real-life objects, being artists, verbalizing the geometry as they draw, ease of interacting with the software, etc. See Appendix B for photos of second graders using the *GSP* software. In addition to *Geometer's Sketchpad*, Key Curriculum Press has recently added *TinkerPlots*. This product can be used in the primary grades for data collection and analysis which provides a foundation for Probability and Statistics concepts. *KaleidoMania!* is also another unique tool by Key Curriculum Press developed for dynamically creating and analyzing symmetric designs and for exploring the mathematics of symmetry which offers a comprehensive, interactive unit on transformational geometry and symmetry. Students build important mathematical analysis skills that give them a deeper understanding of, and appreciation for, the patterns they see all around them.

SUMMARY

Using math software, such as *Geometer's Sketchpad*, encourages elementary students to take an active role in their own learning. These experiences provide a foundation for future math classes that build these ideas into abstract mathematical relationships. This software is no longer just for the middle school, high school, or college student; primary age learners can also benefit from employing such sketching software. Today's children are more advanced technologically than they were five or ten years ago. One can see this advancement by observing young students using the sketching software.

Technology is forever advancing, and our young students need to continue to keep abreast of the latest technology for learning. The authors have found that although geometry sketching software is most frequently used with middle, high school, and college students, such software may also be brought down to the age and developmental level of primary-age learners as well. While young children benefit from using hands-on manipulatives to construct their own understanding of geometry, the sketching software creates the bridge needed for children at a young age to connect their concrete understanding to more abstract mathematical ideas.

Teachers often need to review the existing software and resource materials to adapt to their curricular goals. Geometry-sketching software, such as *Geometer's Sketchpad*, serves as a dynamic motivating tool to help students learn for understanding while lessening any math anxiety or reluctance to do mathematics. As educators**,** we would be remiss if we did not expose our students to the technology. By using geometry-sketching software**,** the teachers are implementing NCTM's *Standards* into the curriculum and better preparing young people for using the emerging technologies that surround us in an ever-advancing, globally competitive world.

APPENDIX A: A SAMPLE OF GEOMETRY SKETCHING SOFTWARE ACTIVITY SHEETS KINDERGARTEN – GRADE 4

Name_____ Date_____

(**Note**: These activities assume students have had some prior experiences using the *GSP* Tools to draw, measure, and explore geometry shapes. Teachers may need to demonstrate these steps.)

Audience: Grade 1

Geometer's Sketchpad

Recognizing Shapes

1. The teacher should download this *GSP* file prior to bringing students to the computer lab for easy access of students (http://mcs-cmarinas.barry.edu/net/gsp/clip.gsp) to the hard drive (zip drive or CD). [See Note below]
2. Open *Geometer's Sketchpad* and then open clip.gsp.
3. This file has many pages. At the bottom, you will see tabs called: Intro, Triangles, Quadrilaterals, Circles, Mixed Shapes, Create Your Own Shapes.
4. Click on the Triangles tab. Remember a triangle has 3 sides.
    a. Use the **STRAIGHTEDGE TOOL** of *GSP* to create outlines of triangles around these shapes.
    b. In order to see the outline clearly, the segments can be selected using the **SELECTİON ARROW TOOL** and then use the Display pull-down menu and change the color and/or thickness of the line.
    c. Find at least 5 triangles that are sides of theses shapes.
5. Next, click on the Quadrilaterals tab. A quadrilateral has 4 sides.
    a. Use the **STRAIGHTEDGE TOOL** to create outlines of quadrilaterals.
    b. Change the outlines colors or shapes so they are clearly seen.
    c. Find 5 quadrilaterals on this page.
6. Click on the Circles tab next.
    a. Circle are round so we will use the **COMPASS TOOL** (the circle) to outline the circles.
    b. Change the outlines colors or shapes so they are clearly seen.
    c. Find 5 circles on this page
7. Click on the next tab: Mixed Shapes. You will see many triangles, quadrilaterals, and circles on this page.
    a. Find 3 examples of each shape.
    b. Make sure that the outlines are clear.
8. Click on the final tab: Create Your Own Shapes. On this page, you will find pictures on the Internet to show these shapes.
    a. Minimize your GSP program, using the **–** box in the upper right corner of this window.
    b. Go to http://www.google.com and click on the IMAGES tab. Put **triangle** in the Search Box and click on the Google Search button.
    c. Find a triangle that you like. Right click with your mouse and then copy. Minimize your Google site, using the **–** box in the upper right corner of this window.
    d. Open the *GSP* program, by clicking on *GSP* in the Task Bar area. In the Create Your Own Shapes page, use the pull-down menu **Edit** and then **Paste Picture**.
    e. The **SELECTİON ARROW TOOL** can then move the picture into position. Do the same steps for **quadrilateral** and **circle**.
    f. When you have your pictures, outline the shapes.
9. Save the file as clipart [yourname].gsp. Example: clipart bob.gsp

NOTE: clip.gsp contains graphics that make this file large. It will not fit on a 3.5" diskette. Also it is suggested that you do only one shape per day. This gives the students the time to get used to the *GSP* environment. Many young children who have used the software *Window's Paint* will see that *GSP* is very similar and will find *GSP* easy to use. You may want to ask the class how many have used *Paint* before on their computers.

Name_____ **Date**_____

Audience: Grade 4

Geometer's Sketchpad

Triangle Shapes

1. The teacher should download this *GSP* file prior to bringing students to the computer lab for easy access of students (http://mcs-cmarinas.barry.edu/net/gsp/Triangles.gsp).
2. Open *Geometer's Sketchpad* and then open Triangles.gsp.
3. This file has many pages. At the bottom, you will see tabs called: Intro, Triangles by Sides, Triangles by Angles, What Kind of Angles?, Create the Following Angles.
4. Click on the tab Triangles by Sides. Click on the **Show Definitions** button to get an explanation of the shapes. Click on Show Shapes button to see some triangles in each group. Look at the definitions and compare to the shapes.
5. Click on the tab Triangles by Angles. Click on the **Show Definitions** button to get an explanation of the shapes. Click on **Show Shapes** button to see some triangles in each group. Look at the definitions and compare to the shapes. Click on the Animate Point A button to see that the shapes remain the correct classification.
6. Click on the tab What Kind of Triangles? Classify each shape by Sides. Classify each shape by Angles. Click on the **Show Classifications** button to check your answers.
7. Click on the tab Create the Following Angles. Use the hint buttons to help you construct these triangles. Click on the **Show Shapes** button to check your answers. For more help use, the Show All Constructions button.
8. Save this file as triangles [your name].gsp. Example: triangles bob.gsp
9. Students can use the TEXT TOOL to label their triangles.

NOTE: Many young children who have used the software *Window's Paint* will see that *GSP* is very similar and will find *GSP* easy to use.

APPENDIX B: PHOTOS OF 2ND GRADERS USING GEOMETRY SKETCHPAD

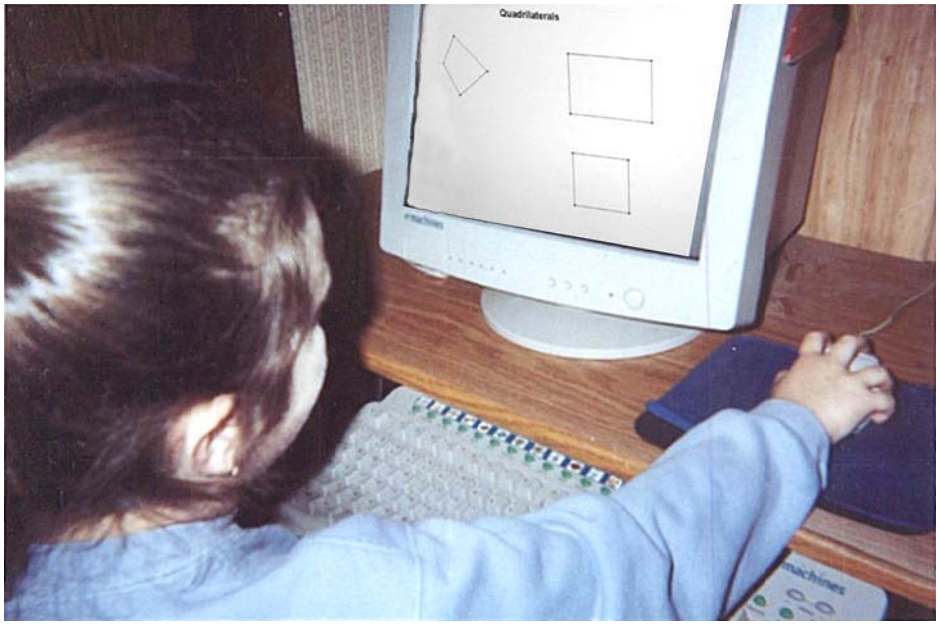

Figure 1. Student A with GSP quadrilaterals

Figure 2. Student B with GSP quadrilaterals

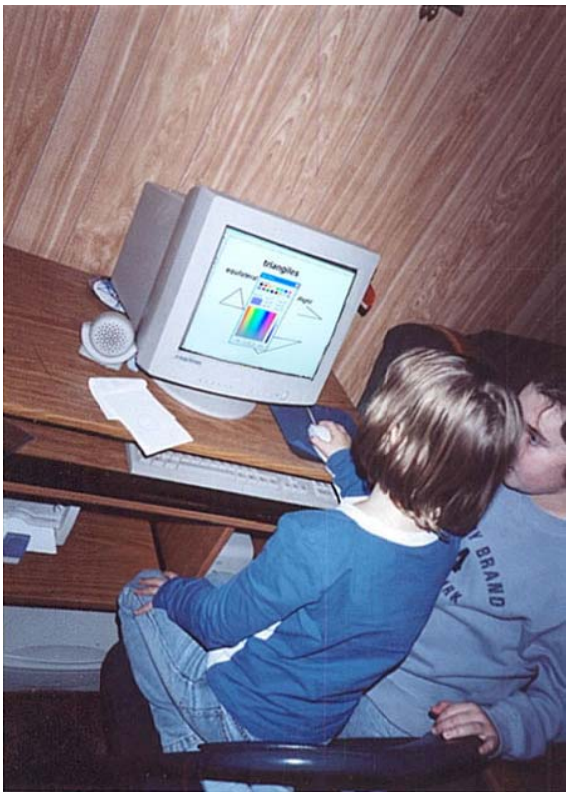

Figure 3. Students A & B experimenting with colors

APPENDIX C: WEBSITES RELATED TO GEOMETER'S SKETCHPAD ACTIVITIES

Carol A. Marinas	http://mcs-cmarinas.barry.edu/net/gsp/index.htm
Key Curriculum Press	http://www.keypress.com/sketchpad/ http://www.keycollege.com/tinkerplots/ http://www.keycollege.com/sketchpad/general_resources/classroom_activities/index.php http://www.keypress.com/sketchpad/general_resources/user_groups/nctm_2004/index.php
GSP Tutorial	http://members.aol.com/markwestbr/GSPtutorial/home.html
Lesson Plans Using *GSP*	http://www.math.byu.edu/~lfrancis/readings302/GSP/GSPLessonPl.html
Math Forum	http://mathforum.org/dynamic/classroom.html http://mathforum.org/sketchpad/sketchpad.html http://mathforum.org/dynamic/sketchpad.weblinks.html http://mathforum.org/sketchpad/littleones
The National Library of Virtual Manipulatives for Interactive Mathematics	http://matti.usu.edu/nlvm/nav/vlibrary.html
Triangle Circles	http://faculty.evansville.edu/ck6/tcenters/index.html
Virtual Institute	http://www.ettc.net/techfellow/sketch.htm
Primary School	http://www.primaryschool.com.au/mathematics-lessonsresults.php?strand=Space%20and%20Geometry&unit=2D&grade=56
Geometer's Sketchpad Resources	http://www.hpedsb.on.ca/sg/quinte/gsp_02.htm

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