One Teacher's Experience with Implementing Geometer's Sketchpad To Promote Student Engagement

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Abstract

This paper is an action research study of one teacher's experience with implementing Geometer's Sketchpad (GSP) in a secondary geometry classroom. Specifically, the study investigated how GSP technology impacted student engagement as the teacher modified textbook lessons to accommodate academic non-achievers. At-risk students were less engaged with GSP than students who were on track to graduate from high school, and least likely to access computers at home. Engagement was defined as active participation by the student in their learning process through affective, behavioral and cognitive domains, which are referred to as the ABCs of student engagement. The class consisted of twenty students of mixed gender and academic backgrounds. Findings indicated that students who used computers for word processing were more engaged with GSP than students who utilize computers primarily as a game console. There were different levels of engagement due to disparities among students; however, throughout the implementation process of GSP software into the geometry curriculum, students were engaged.

Keywords: Computers, engagement, Geometer's Sketchpad

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One Teacher's Experience with Implementing Geometer's Sketchpad

To Promote Student Engagement

Our country is approaching the ten-year anniversary of one of the most intensive national reform in education: the "No Child Left Behind Act of 2001" (NCLB). This Act was signed into law on January 8, 2002 by United States President George W. Bush (Public Law 107 – 110, 2002). The goal of the Act was to close the achievement gap so all students will experience success in the educational system. To measure the gap and determine school status, all federally-funded states were required to develop a set of standards to assess basic skills. The State of Washington developed the Essential Academic Learning Requirements (EALRs). Throughout the United States, K-12 students have struggled to meet the expectation that all students achieve at high levels in mathematics (Haycock, 2001; National Center for Education Statistics, 1999; Mullis, Martin, Gonzalez, & Chrostowski 2004.). Based upon the 2009 National Assessment of Educational Progress (NAEP) in mathematics at grades 4 and 8, NCLB did not have a national impact on improving mathematics achievement (Vanneman, Hamilton, Baldwin, Anderson, & Rahman, 2009).

Washington developed its own examination, the Washington Assessment of Student Learning (WASL). Each spring, all public schools are required to test their students in Reading, Writing, Science, and Mathematics to determine whether their students meet standard. The NCLB Act states that all students need to be 100% proficient by 2013-2014. Schools which consistently fail to make Adequate Yearly Progress (AYP) must implement a restructuring plan or risk: (a) being closed and reopening as a public charter school, (b) replacing staff, (c) turning over school operations to a state education agency, or (d) being contracted out to an outside entity. After more than a decade of using the WASL to assess students in their general knowledge of mathematics, the level of student achievement in Washington remained below minimum standards. On the 2008-2009 tenth grade assessment for mathematics, 45.5% of the state's sophomores met standard (Office of Superintendent of Public Instruction, 2009). The Washington Senate declared an academic emergency and approved Senate Bill 6534 – 2007-08 to revise and strengthen the mathematics learning standards (Senate Bill 6534 - 2007-08).

Schools throughout Washington enroll students in algebra classes as early as their seventh grade year, three years before the mandatory sophomore year test. Other students are not enrolled in geometry until their junior or senior year of high school which is after the testing date. To measure student knowledge from these courses while the information is still fresh in their memories, Washington decided to replace the 10^{th} grade mathematics assessment with an examination in algebra and geometry at the conclusion of the course. In the summer of 2008, the Office of the Superintendent of Public Instruction (OSPI) released the Washington State Learning Standards for Algebra and Geometry (OSPI, 2008). Algebra and geometry students throughout the state would be taking the inaugural End-of-Course Assessment for High School Mathematics (EOC) in the spring of 2011. This assessment, enacted by the Washington State legislature and signed by the governor, would measure the content knowledge of those students enrolled in algebra and geometry classes at the conclusion of their academic year. Meeting a minimum standard on these tests will be a requirement for a Washington high school diploma (RCW 28A.655.066, 2009).

One Washington school that has struggled to improve its mathematics scores is Rhubarb High School[1]. Rhubarb High School is consistently below the Washington average in number sense, communicating understanding, geometry sense, measurement, and making

[1] In this study a pseudonym was used to replace the name of the sampling site.

connections on the mathematics portion of the WASL (OSPI, 2009). In 2009, this suburban high school had 32.4% of its 10th graders meeting the WASL mathematics standards (OSPI, 2009). Failing to meet AYP, Rhubarb High School is examining its teaching practices and curriculum. In hopes to improve geometry achievement, Rhubarb H.S. adopted the *Discovering Geometry* mathematics curriculum which included Geometer's Sketchpad (GSP) as part of its supplemental materials (Key Curriculum Press, 2001). Not only had the school failed to meet AYP in mathematics, most curriculum and content areas at the high school were struggling to pass the Washington State assessment (OSPI, 2009). At the time of this study, Rhubarb High School was in the process of implementing school-wide standards and protocol, which included active student engagement, to promote student learning.

Computer Technology Rationale

Computer technology is part of students' daily life. On the first day of school, students in this study were informally surveyed to discover what resources were available them at home to assist in their geometry class. The majority of the students had access to a computer and to the internet. The students had Facebook accounts, played computer games, and used word processing tools. Most students had cell phones and were fluent at text messaging. Unlike the classrooms of twenty, or even ten years ago, students entered my class with a variety of technological experiences.

Computer technology also has the potential to enhance student learning. There are applets, on-line activities, software programs, and websites that students may reference for additional instruction. Depending on implementation, technology may increase student motivation and engagement, allow for greater task complexity, change student and teacher roles, and promote cooperative relations among students (Means, Olson, & Ruskus, 1997; Solvberg, 2003). Technology has been found to equalize learning opportunities for all students (Solvberg, 2003). The benefits of technology are best seen when its application directly supports the curriculum objectives being assessed. According to Roscheele (2000), technology that promotes higher levels of cognitive complexity increases learning, while software programs that rely on entertaining repetition has the opposite effect.

Geometer's Sketchpad

The computer technology that was utilized for this action research study was Geometer's Sketchpad (GSP). GSP is a dynamic geometry software program which empowers teachers and students to construct and transform geometric objects, or components of objects, to be dragged across a computer screen. GSP provides immediate feedback, motivates students to think mathematically, and engages students (Deturek, 1993; Jackiw, 1995; Ruthven 2008). GSP was chosen as the "most valuable" software title by one in five high school mathematics teachers (Becker, 1999). This dynamic capability allows for students to make conjectures about various geometric properties. Students use GSP as a scientific inquiry tool to observe patterns, discover rules, formulate hypotheses and make conjectures as they construct and manipulate various geometric objects on a computer (Becker, 1999; Enderson, 2001; Hoyles, 2003; Idris, 2009; Ruthvan, 2008). One example of the dynamic capabilities of GSP is examining the angles of a triangle. The student may use GSP's measurement tool to determine the size of each angle of a triangle as well as the sum of all the angles of a triangle. If the student alters the shape of the triangle by dragging one vertex, the GSP program shows the sum of the remaining angles to remain the same as the triangle changes size and shape. As the student transforms the triangle, they might make the following conjecture: though the measurement of the angles of the triangles may vary, the sum of the angles of a triangle is always 180 degrees. Through GSP, students can move from being observers of static triangles to active participants in exploring the interrelationships of the angles of triangles. The use of dynamic geometric software technology enhances the student's educational experience through exploration and examining the meaning of data through computer engagement (Hannafin R, 2001; Idris, 2007; Jiang, 2002; Kozma & Johnson, 1992).

GSP was chosen for this action research study for several reasons. One reason was GSP was purchased by the school district as part of the adopted Key Curriculum Press (KCP) secondary mathematics curriculum, and had not been integrated in the classroom. GSP is a dynamic mathematics visualization software program put out by KCP to supplement its geometry curriculum by promoting student exploration by manipulating, animating, and transforming geometric objects. Providing students with instant feedback, GSP allows students to manipulate a single variable multiple times to test and verify conjectures (Enderson, 2001). A second reason was the use of dynamic geometric software is referenced in the state standards and the common core state standards initiative, as well as recommended by the National Council of Mathematics (NCTM) standards (Common Core State Standards Initiative, 2010; NCTM, 2000; OSPI, 2008). However, the most important rationale for using GSP as part of this study was academic research supports the use of dynamic geometric software in the classroom to promote academic achievement (Idris, 2009). Tat and Fook (2005) stated GSP was an effective visualization tool in their study of Malaysian students. Journal articles and literature readings indicated GSP has the potential to be an effective tool for teaching and that it had a positive impact on student engagement and achievement (Battista, 2002; Hoolebrands, 2007; Kasten & Sinclair, 2008; Phonguttha, Tayraukham, & Nuangchalerm, 2009).

Geometry curriculum at Rhubarb High School consists of the examination of different shapes and their properties. GSP enhances the instruction through visualization, modeling geometric problems, discovering relationships and their properties, and problem solving (KCP, 2001; Weaver, J., 1999). The traditional construction, calculation and visualization tools of geometry showed "marked deficiencies as means of exploring and reconstructing elementary geometry by the student" (Schumann, 2001). Students learn the process of exploration when using GSP by investigating relationships and making conjectures (Hannafin, M. 1997; Sinclair, 2003).

Geometry Standards. The Washington State Standards explicitly recommends using dynamic geometric software as an example of implementing the following standards (OSPI, 2008):

- G.1.B Use inductive reasoning to make conjectures, to test the plausibility of a geometric statement, and to help find a counterexample. (Ex. using dynamic geometry software, decide the plausibility of a conjecture.)
- G.2.C Explain and perform basic compass and straightedge constructions related to parallel and perpendicular lines. (Ex. "Constructions using circles and lines with dynamic geometry software …")

The NCTM *Principles and Standards* "calls for geometry to be learned using concrete models, drawings, and dynamic software. With appropriate activities and tools and with teacher support, students can make and explore conjectures about geometry and reason carefully about geometric ideas" (NCTM, 2001). The Common Core Standards Initiative (2010) states:

> Dynamic geometry environments provide students with experimental and modeling tools that allowed students to investigate geometric phenomena in much the same way as computer algebra systems allowed them to experiment with algebraic phenomena. When making mathematical models, technology is

valuable for varying assumptions, exploring conjectures, and comparing predictions with data (retrieved from www.corestandards.org/the-standards/mathematics/high-school-geometry/congruence).

GSP as a tool for teaching. Similar to a word processing program, GSP is a tool to enhance classroom instruction (Idris, 2009; KCP, 2001). It is a software drawing program that constructs, measures, and transforms geometric objects on a computer screen. GSP may be used in the classroom as a demonstration tool in teacher facilitated instruction or it may be used in a computer lab setting. Having their own computer creates an opportunity for students to independently explore and develop conjectures relating to the various geometric properties. As students manipulate figures on the computer screen, they make conjectures about geometric relationships based upon their observations (Idris, 2009; McGehee, 1998; Weaver, J., 1999). The tools of GSP allow students to make precise measurements so properties of congruency may be identified (KCP, 2001).

The teaching of secondary geometry at this Rhubarb High School utilizes Kolb's (1984) Cycle of Experiential Learning: active experimentation, concrete experience, reflective observation, and abstract conceptualization. Student ability to manipulate the GSP program has a direct effect on student conceptualization and internalization of mathematical properties. Mathematical critical thinking develops when results produced by the software are not as the student anticipated (Ruthven, 2008). Teachers need to create an environment in which students are actively engaged in the learning process (Roscheele, Pea, Hoadley, Gordin, & Means, 2000). Research has suggested using dynamic geometric software may prevent students from becoming "lost" in the process (Jackiw, 1997). GSP allows students to work with figures easier, faster and more accurately, removing obstacles which might distract students from the key points of the lesson (Idris, 2009; Jackiw, 1997; Ruthven, 2008).

GSP and student achievement. The use of GSP with students promotes higher cognitive levels of thinking (Idris, 2009). A student "communicates with the software [GSP] more or less the way one thinks about the geometry" (Deturek, 1993, p. 371). GSP focuses on experiencing a geometric exploration rather than on mastering a particular concept (Deturek, 1993; Idris, 2009; Ruthven, 2008). Other research indicates GSP promotes conceptual understanding (Idris, 2009; Phonguttha et al., 2009), student motivation and engagement (Johnson, 2008; Sinclair, 2006), and student self-efficacy (Isiksal, 2005). Nicolas Balacheff (1996), a researcher of technology-enhanced learning, states that GSP is "used to support more established forms of pedagogical practice, notably student activity directed towards empirical confirmation of standard curricular results, often through guided discovery, as already prevalent in the teaching of geometry in many educational systems." Forythe (2007) and Idris (2009) emphasize that learning geometry is not easy due to visualization of geometric properties. However, with the use of GSP, students are able to connect the concrete with the abstract (Idris, 2009). GSP provides immediate feedback, motivates students to think mathematically, and engages students (Deturek, 1993; Forysthe, 2007; Idris, 2009; Jackiw, 1995; Ruthven 2008).

GSP is a learning tool that provides intrinsic motivation for the student to work in a learner-centered environment (Idris, 2009). Often in my geometry classes I have mentioned to my students that we are not just learning mathematical concepts, but learning a different language like Chinese or Japanese. There is a new vocabulary to pronounce, spell, and use in the proper context, as well as symbols and notation to learn. Noraini Idris (2009) did a quasi-experimental regarding the impact of GSP on student achievement. Using levels of van Hiele thinking, she concluded that with the appropriate "selecting and sequencing of instructional materials, using GSP in the secondary classroom shows potential significant academic achievement" (Idris, 2009, p. 104). GSP's greatest impact on student learning is when the problems are of high cognitive demand. (Hannafin, 2001; Hannafin & Scott, 1998; Knuth & Hartman, 2005; Roschelle, 2000). In a study of seventh and eighth graders, Hannafin and Scott (1998) concluded low achieving students had significant gains on high cognitive questions compared to their classmates when GSP was incorporated as part of their instructional process. By including GSP lessons, the achievement gap between low and high achievers is diminished (Hannafin & Scott, 1998).

There is no computer technology that consistently and reliably improves academic achievement and learning outcomes without receiving instructional support (Hannafin, Truxaw,Vermillion, & Liu, 2008; Nicholas & Ng, 2009; Phonguttha et al., 2009). Hannafin, Truxaw, Vermillion, and Liu (2008) did a study of GSP that used two different instructional methods using dynamic software: (1) an online geometry tutorial, and (2) a workbook requiring students to do GSP activities with references to the online tutorial. The students in first group completed their work in 90 minutes whereas the students using the workbook took 3 hours. The study determined that there was no significant academic achievement difference between the two groups, indicating that it might be the dynamic nature of the program which promotes student success. "Although computer technology was a pervasive and powerful force in society today with many proponents of its educational benefits, it is also expensive and potentially disruptive or misguided in some of its uses and in the end may have only marginal effects" (Roschelle et al., 2007, p. 77).

Previous Study

In the spring of 2010, I had done a short inquiry project as part of my Masters in Education program at The Evergreen State College (TESC). The research question was "Does a dynamic geometric software program increase self-efficacy of high school geometry students?" I utilized GSP with a unit of study on circles and angle relationships in my high school geometry class to determine if the students enjoyed using the software program. I was also interested in determining if students thought GSP was beneficial to their understanding of the geometric concepts that were being presented in class. Having never used GSP in the classroom, I wanted to know whether or not I should consider incorporating the program into future course syllabi.

Having read literature regarding gender, computers and self-efficacy, I wondered if there existed gender inequity regarding computer technology. According to Isikasal (2005), boys were more willing to solve activities with computers than girls. Additionally, boys were more confident than girls when using computers. This was supported by additional research stating male students had more interest in computers than female students (Gist, 1989). When faced with computer difficulties in the classroom, boys preferred the "trial and error" method and would more often opt to "figure it out" themselves rather than asking the teacher questions (Isikasal, 2005). I was concerned that using GSP in the classroom might favor boys over girls. I needed know if there were inequities and how to best address these potential classroom disparities when using computers.

The methodology for the spring inquiry project was that of a case study. Students utilized the school computer lab twice a week for three weeks to work on lessons involving GSP. Due to my inexperience with the program, I consulted with the district's secondary mathematics specialist, an experienced GSP teacher. He led the class for the first two days in the computer lab. Not only did I receive the benefit of his expertise, the students had the benefit of two teachers in the computer to lab to use as resources. The GSP lessons were part of the supplemental materials package of the district adopted curriculum, *Discovering Geometry* (KCP, 2004). At the end of each daily lesson, there was a teacher-guided discussion summarizing the results of student conjectures. At the conclusion of this unit on circles and angle relationships, the students were given a survey[2] regarding their experience using GSP.

None of my students were familiar with GSP prior to this unit of study. The student survey, regarding their classroom experience using GSP, was used to determine the impact of GSP on student self-efficacy. The survey focused on students' prior knowledge regarding computer technology, as well as their attitudes towards geometry and GSP. Despite the boys' enjoyment of computer games and their confidence with computer skills, they thought that GSP was a "waste of time." One high achieving boy stated, "For me, waste of time. Took longer to get the things down than needed if you were using paper and pencil….not my way to learn, but might be for others." The girls indicated that GSP helped them with visualizing, but served no other purpose. One low achieving girl stated "I thought it was nice visual and hands on program, but I felt that most things were already gone over [in class]." Despite the student comments and the survey results indicating GSP was a "waste of time," 90% of the students surveyed stated that GSP should be continued in the classroom.

Upon reflection, I determined that additional research needed to be done regarding GSP and its effectiveness in the geometry classroom. One conclusion I came to from this previous study was, despite being considered a "waste of time," my students seemed to be engaged with the lesson. This was confirmed by the district math specialist who was in the computer lab with me during the first two GSP instructional days. The analysis of the previous study suggested additional investigations should be examined regarding *engagement* in terms of student learning and the classroom utilization of GSP.

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[2] The class survey was a modified form on Dr. Martha Tapia's "Attitudes Towards Mathematics Inventory" (ATMI) (Tapia, 2004).

Multi-Dimensional Construct of Student Engagement

Student engagement in complex mathematical tasks is a main component of teaching and learning (NCTM, 2000). Meaningful learning takes place when students are engaged in their own learning: students attempt classroom assignments, they ask relevant questions, and utilize their resources (Smith, 2005). They take pride not simply in earning the formal indicators of success (grades), but in understanding the material and incorporating or internalizing it in their lives (Newmann, 1992). Student engagement also refers to a "student's willingness, need, desire and compulsion to participate in, and be successful in, the learning process promoting higher level thinking for enduring understanding" (Bomia, 1997).

Engagement and Learning. "To teach is to engage students in learning; thus teaching consists of getting students involved in the active construction of knowledge" (Christensen, 1991, p. xiii). Engaging students maximizes their achievement when learning conceptually complex and content-dense material (Bondy & Ross, 2008; Phonguttha et al., 2009; Smith, 2005). "If students are disengaged, the quality of the lessons will be irrelevant and misbehavior will reveal students' underlying resistance" (Bondy & Ross, 2008, p. 54). Today's students, who are accustomed to fast-paced, compelling, and rewarding video games, often find school slow, boring, and antiquated (Papert, 1994, p. 5). To engage these students, and ensure they utilize their class time actively exploring, analyzing, and communicating their findings, teachers need to develop worthwhile tasks that acknowledge the realities of the computer environment (Sinclair, 2003). Student engagement includes the interactions within the learning environment between the student and the learning materials (Sinclair, 2003). Factors affecting a student's motivation and engagement to learn include: interest in the subject matter, perception of its usefulness, general desire to achieve, and self-efficacy (Hannafin, Burruss, & Little, 2001; Johnson, 2008; Sinclair, 2003). Students who are not engaged in their own learning are unlikely to succeed. Imagine a student sitting at a computer. The student is typing on the keys so that the triangle on the screen changes color from red to blue and blue to red. You observe this pattern for two minutes. Is this student engaged? Does the definition of engagement change due to the perception of the person at the computer, the administrator who walked into the classroom, or the teacher who has a particular learning objective planned the day's lesson? I believe there are multiple levels of engagement occurring. This action research project will be focusing on three particular constructs of engagement: affective, behavioral, and cognitive, which I have referred to as the *ABCs of engagement* (Connell, 1990; Finn, 1989, 1993).

Affective Engagement. Affective, or emotional, engagement is the motivator for the student to participate in a task (Hannafin et al., 2001; House, 2006; Kong, Wong, & Lam, 2003). It may be either intrinsic or extrinsic. Is he finding this activity rewarding so that he would like to continue? Does it hold her interest? A student who is "zoned in" to an activity is able to block out the environment around them; they are intent in the processing of the task. Would he do this task if it wasn't required? Is she doing this task because it is required? Grades provide extrinsic motivation for many students to participate in the task. The opposite of emotional engagement is disaffection. "Disaffected children are passive, do not try hard, and give up easily in the face of challenges….they can be withdrawn from learning opportunities or even rebellious towards teachers and classmates" (Skinner, 1993, 572). Emotional engagement often reflects student self-efficacy based upon previous experience: "I have always done well in this subject," "I struggle with math," or "When will I ever use this?" Finally, emotional engagement may also be impacted by the student's relationship, or perceived relationship, with the teacher: "she always calls me," "she had my brother in class," or "my friends told me about this teacher." Self-efficacy, expectation, interest, involvement, perceived control, and autonomy were found to be related to affective engagement (Ainley, 1993; Guthrie & Wigfield, 1997; Hannafin et al., 2001; House, 2006; Miserandino, 1996; Skinner & Belmont, 1993; Kong et al., 2003; Phonguttha et al., 2009).

Behavioral Engagement. Behavioral engagement is the “on-task” behavior (Connell, 1990; Finn, 1989). Early educational studies treated engagement as “time-on-task” (Chapman, 2003). Being on-task is often correlated with classroom management in that the student is doing class work and following the rules. The student is not disrupting the learning environment. Students wandering around the classroom are not engaged, nor are students who are sitting motionless. To be behaviorally engaged, the student must be demonstrating effort. Behavioral engagement addresses student learning styles: visual, auditory, and kinesthetic (Felder, 2005; Sprenger, 2004). The lack of student behavioral engagement in their learning is an indicator of a potential at-risk student (Birch & Ladd, 1997). For the purpose of this study, behavioral engagement was defined as a student who was working at a computer (visual and kinesthetic), completing a worksheet (visual and kinesthetic) or discussing the task with another member of the class without a teacher-initiated prompt (auditory).

Cognitive Engagement. Cognitive engagement may be defined as “student learning.” Newmann (1992) states students make a psychological investment in learning as indicated by: (1) the level of questions students ask, (2) the work produced, or (3) time needed to complete the task. Cognitive engagement involves brain activity (Kuhn, 2006; Roschelle, Tatar, Chaudhury, Dimitriadis, Patton, & DiGiano, 2007). Students are cognitively engaged when there is an intrinsic desire to persist at a task. Cognitively engaged time is the most important influence on academic achievement (Marks, 2000; Slavin, 2003). In my study, cognitive engagement was defined as student self-regulated learning as determined by: (1) student-talk, (2) student perception of the task, and (3) the amount of time the students spent accessing GSP.

Engagement, Technology, and Implementation of GSP

Technology provides opportunity for student engagement. “When students are placed in the relatively passive role of receiving information from lectures and texts (the *transmission* model of learning), they often fail to develop sufficient understanding to apply what they have learned to situations outside their texts and classrooms” (Bransford, 1999). Teacher beliefs about technology and its implementation are paramount to its success in the classroom (Battista, 2002; Beswick, 2007). “Curricular frameworks now expect students to take active roles in solving problems, communicating effectively, analyzing information, and designing solutions-skills that go far beyond the mere recitation of correct responses” (Roscheele et al., 2000).

The integration of technology as part of teacher instruction is an on-going process (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005; Means & Olson, 1994). In a study by Dwyer, Ringstaff, and Sandholtz (1991), teachers proceed through stages of integrating technology with their classroom instruction. The first stage is familiarization of the hardware or software. At this first level of implementing technology, teachers find it challenging to anticipate problems that may occur with the technology, or in the classroom as a result of the software (Dwyer, Ringstaff, & Sandholtz, 1991). The next stages are the adoption, adaptation, and appropriation which incorporate technology into existing curriculum. As the teacher progresses through each of these stages of technology implementation, he or she becomes more familiar with the software or hardware. And as a result, the teacher begins to modify lessons in anticipation of student difficulties with the technology. The final stage is the reflection stage where the teacher adjusted their teaching practices and perceptions of technology (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005; Means & Olson, 1994). This implementation process may take three to five years (Juersivich, Garofalo, & Fraser, 2009).

The implementation of GSP in my classroom process merges the Dwyer, Ringstaff and Sandholtz (1991) study with Lewinian Experiential Learning Model (Kolb, 1984). Although I do not consider myself fluent with GSP, I am familiar with the dynamic software program. I am currently in the adaptation stage of the Dwyer, Ringstaff, and Sandholtz model (1991). As I adapt my curriculum and my teaching, I continually make observations and reflections, form generalizations about my teaching style and how it impacts student engagement, and then test my hypotheses in additional classroom and computer lab settings (Kolb, 1984). This cycle will repeat as I continually inform my teaching practice.

Action Research Study

My goal as a teacher is to provide a learning environment where students are actively participating in their learning process. Research findings indicate GSP increased student achievement as measured by pre and posttest scores (Forsythe, 2007; Hannafin et al. 2008; Idris, 2009). Hannafin & et al. (2008) stated that there was no data with regards to the amount of time which the students were engaged during their study. Affective, behavioral, and cognitive engagement are critical to student academic success (Connell, 1990; House, 2006). The purpose of this study was to determine the impact that GSP has as an instructional tool on student engagement. Is GSP a viable tool to engage students to foster learning, or do I need make modifications to its implementation? Does the student's prior experience with computer animation influence the role of GSP in the classroom? Are there gender inequities with regards to using computers in the classroom? These concerns led to my research question: “How does student predisposition towards technology impact the effectiveness of dynamic geometric software with regards to student engagement?”

It is the nature of action research to be used in a real, rather than contrived, setting (Pedretti, 1996). This holistic study will reflect the realities of teaching in a secondary geometry classroom utilizing GSP as an instructional tool. The study is meant to inform a teacher about incorporating an instructional tool which might result in a high level of student engagement and improved academic achievement.

Chapter 2: Methods and Analysis

Setting

I conducted a single case study using my geometry class at Rhubarb High School. My high school is one of four public high schools in the Rhubarb School District of Washington. The school district is a mixed suburban and rural community covering 215 square miles making it is one of the larger districts in Washington (District website, ret. July 2010). The district has grown by about 5000 students in the last ten years partly as a result of bordering a military base. Rhubarb High School serves approximately 1100 students in grades 10-12. Twenty-eight percent of the student body is eligible for free-and-reduced lunch indicating a low socioeconomic community (District site, ret. July 2010). Approximately 30% of the students are ethnic minorities (OSPI, 2009).

The No Child Left Behind Act of 2001 (NCLB) established requirements for the standards and assessment systems of states. Each school within the state is required to have met the standards for Adequate Yearly Progress (AYP). Rhubarb High School has continually failed to meet AYP standards and is classified as a school that "needs improvement." As part of its restructuring plan to meet AYP standards, Rhubarb High School is participating in the Southern Regional Education Board's (SREB) *High Schools That Work* (HSTW) program. HSTW target low-achieving schools by providing strategies to improve student learning. Rhubarb High School is one of the 1,200 sites in 30 states and the District of Columbia that utilize the HSTW framework.

HSTW is "the nation's largest school improvement initiative for high school leaders and teachers" (SREB, 2002, ret. September 2010). HSTW strategies are utilized to help urban high schools raise student achievement and graduation rates. One objective is to have students participate in rigorous academic and technical studies where they will complete quality assignments and meet higher expectations. The mathematics goal of HSTW corresponds to NAEP's proficient level of performance. Students are expected to understand geometric concepts, apply geometric ideas and explain their geometric reasoning in various problem-solving situations. The goal for teachers is not only to know their subject matter, but engage students in their own learning (Bottoms, 2003). Utilizing GSP in the classroom serves the dual role of incorporating technology in the curriculum and student engagement.

Rhubarb High School is on the 6-period day schedule. Students take six classes that meet the criteria for high school graduation (i.e. math, language arts, music,) plus an advisory class. All classes, except advisory, meet daily for 55 minutes. My geometry class meets in a portable classroom with an LCD projector, a document camera, an overhead, and one computer. The geometry class uses the textbook, *Discovering Geometry* (Serra, 2003). Each student has his or her own copy checked out to them through the school library. Also, the student edition of the textbook may be found online at the Key Curriculum Press (KCP) website.

The class had access to the computer lab in the main building which is laid out with three rows of eight computers facing the front of the room. Occasionally, students from other teachers' classes come and work independently on the computers in the back of the room while classes are in session. My class visited the computer lab once a week for 5 weeks. In the lab, each student had the opportunity to personally interact with the GSP program by creating constructions, doing investigations, and making conjectures. While the students were engaged with GSP, my role was that of investigator and facilitator. I examined the implementation of GSP in the lesson. Should each student have their individual computer, or should students be paired? What were the student frustrations? How could I prepare my students ahead of time for the computer lab? I used questioning strategies that focused the students' thinking about mathematical relations when using the computer software. Meanwhile, I took field notes as reference for modifying future lessons regarding the implementation of GSP in my curriculum.

When the class was not in the computer lab, GSP was used as a demonstration tool in the classroom for whole class instruction due to the availability of one computer. Mr. Euclid introduced GSP to the students in the computer lab. Thereafter, prior to visiting the computer lab, I addressed student concerns about their previous computer lab experience, positively reinforced student successes using GSP, and provided additional lesson information to the student based up student exit slips, observations from field notes, the *Discovering Geometry* instructional materials. The intent of the *Discovering Geometry* curriculum was to encourage student exploration and the determination of geometric conjectures. Though I modeled some constructions in the classroom, I had the students follow written instructions in the computer lab. My intent was to determine how the students would interpret the directions; and if a student was absent from class, would they be able to work independently with GSP? When the students returned to the classroom after being in the computer lab, I addressed additional student concerns about GSP. Additionally, I reviewed the student findings by having students demonstrate or explain the steps they followed to determine various conjectures to the rest of the class. Clarifying questions were asked to determine student understanding of the geometric concepts being investigated in the computer lab. I addressed student misconceptions, reinforced newly discovered geometric concepts, and provided a review of the lesson for those students who were absent or struggled in the computer lab.

Participants

The students in this study were pre-determined through random, electronic selection as part of the school registration process. There are nine sections of geometry offered at

Rhubarb High School throughout the school day. The purpose of programming the computer to schedule students into geometry classes is to equalize class size and provide an equitable distribution of students for each teacher with regards to grade, gender, and academic level. The intent of using a computer-generated class roster is to have a random sample of the student body enrolled in geometry and removing bias from the study. However, there was the potential that classroom enrollment would be impacted by student demand for other courses offered during the same class period. I had one student transfer out of the class the first week of school due to a JROTC class conflict. Students who receive credit for working a job were required to be enrolled in the work-based learning class that was offered the same period. Similarly, orchestra, drama, and the student leadership classes conflicted with my geometry class. It is undetermined if there were other factors that influenced my final class enrollment.

Twenty students in my geometry class participated in this action research study. The class was of mixed ethnicity with 70% White, 15% African-American/Black, 15% Asian, Hispanic or Asian/Hispanic-mixed as determined by the federal requirements based on the U.S. Department of Education Federal Register (OSPI, 2010). This classroom data was in alignment with the school data: 67.8% White, 10% Black, 9.3% Hispanic, 8.5% Asian, and 12.1% other (OSPI, 2009). There were 11 girls and 9 boys, consistent with the overall school enrollment (OSPI, 2009). The class comprised 13 sophomores (7 female/6 male), 4 juniors (3 female/1 male) and 3 seniors (1 female/2 male). In the three previous years, the percentage of sophomores enrolled in my geometry class was 80%, 94%, and 89% compared to my current 65%. The 13 sophomores were considered to be at grade level in mathematics. One sophomore was also in my math intervention class that focused on remedial mathematics skills. Thirty-five percent of the class was upper classmen compared to an average 11% from the past 3 years. The juniors and seniors were considered to be below grade level in mathematics. These students are classified as “at-risk” of failing to graduate from high school. All the juniors had previously taken geometry and were repeating the course. Two of the seniors enrolled in my geometry class will not be graduating this school year. One student had a 504 Plan on file for academic accommodation (Rehabilitation Act of 1973[3]). Seventy-one percent of the upperclassmen had not passed a full year of algebra and *moved on* in the mathematics sequence. One third of the class was below a 2.0 cumulative grade point average (GPA) based on a 4.0 scale. Only 15% of the students had passed the mathematics portion or “met standard” of the eighth grade WASL. The 8th grade WASL scores were predictors of future performance (http://www.erdc.wa.gov/indicators/pdf/04_8th_grade_wasl.pdf, ret. July 2010). Approximately 50% of the state student population was considered “proficient” in mathematics (Table 1). Of the seventeen students in my class that did not meet standard; seven students had received a score of *1* which indicated that they were “below basic” and required mathematics intervention.

[3] Section 504 of the Rehabilitation Act of 1973 is a law that states "no qualified individual with a disability in the United States shall be excluded from, denied the benefits of, or be subjected to discrimination under" any program or activity receiving federal funding, including a right to full participation and access to a free appropriate public education for all children regardless of the nature or degree of disability (U.S. Department of Education, 34 C.F.R. §104).

Table 1 WASL Comparison Table

2008 8th grade WASL						
WASL Level	Washington State	Rhubarb S.D.	2010 – 2011 Geometry Class			
			Grade 10	Grade 11	Grade 12	Total
4	21.3%	4.3%	0%	0%	0%	0%
3	30.2%	30.3%	16%	0%	0%	16%
2	23.2%	36.9%	42%	11%	0%	53%
1	23.7%	27.8%	11%	5%	16%	32%
N/A	1.3%	0.7%				

Note. A comparison of participants WASL scores with those in the district and around the state. From Washington State, OSPI; Class Roster. The percentages do not add to 100% due to rounding of the figures.

Students who are at-risk are in danger of dropping out of the educational system (Batsche, 1985; Jerald, 2007; McCann & Austin, 1988). According to McCann and Austin, students who are at-risk of not meeting educational standards tend to have behaviors that interfere with the learning of other students, often require disciplinary action, and often have family characteristics that place them at risk (1988, pp. 1-2). At-risk students have poor self-efficacy, do not like mathematics, and see no purpose for mathematics (Jerald, 2007). They are academically low achievers (Batsche, 1985; Jerald, 2007; McCann & Austin, 1988). As a teacher of at-risk students, I may need to employ additional interventions to engage all students in their learning process. This may include differentiating instruction, providing additional instruction of basic skills, and promoting student self-esteem by offering additional positive reinforcement. Addressing the needs of my at-risk students is important because academic performance and school engagement matter equally, and that they are often, but not always, intertwined (Jerald, 2007).

Instructional Implementation of GSP

I have been employed with the Rhubarb School District for 27 years, of which the past 20 years were at Rhubarb High School. I have taught geometry to students in grades 8-12 at both the junior and senior high level for the majority of those years. Throughout my teaching career, I have used a variety of textbooks and instructional strategies. I am in my fourth year of using the district-adopted *Discovering Geometry* textbook with my classes (KCP, 2007). With regards to educational technology, I have a variety of experience. I have taught BASIC computing programming, utilized a graphing calculator in the classroom, lectured using PowerPoint and worked with word processing software. My formal classroom preparation with GSP was limited to attendance at a half-day district-sponsored workshop when Rhubarb School District adopted *Discovering Geometry*. I had taught a geometry unit on circles with GSP as part of a college course during the spring prior to this action research study. Not having much experience with GSP hindered my ability to *troubleshoot* and to anticipate student difficulties. Recognizing my limitations with GSP, I participated in an online webinar that provided GSP instruction, "GSP Webinar: Jumpstart Your Geometry Class w/ Dynamic Geometric Constructions" (KCP, 2010). I also sought the input of others who utilized GSP in the classroom for consultation and reflection regarding lessons. The district secondary mathematics specialist was available for questions and guidance. Yet, despite having purchased GSP as part of the *Discovering Geometry* textbook adoption three years ago, I discovered that none of the geometry teachers in Rhubarb School District were using GSP in their classes.

Instructional resources for GSP were varied throughout this study. The *Discovering Geometry* textbook adoption included as set of computer worksheets that were available for classroom use with GSP (Appendix A). These worksheets were utilized in the computer lab as part of this study. Each worksheet was designed to coordinate with a particular section of the textbook. The textbook publisher provided a website that specialized in GSP use in the classroom that included inquiry-based math lessons with dynamic activities and demonstrations (KCP, 2007). I also utilized an online website that had pre-made GSP constructions which offered student explorations (Roberts, F., & Roberts, D., ret. Nov. 2010).

The method of instruction was dependent upon access to the computer lab. Most instruction occurred in the classroom. At these times, the unit objectives were supported through teacher facilitation of classroom activities, textbook investigations, and traditional paper-and-pencil practice problems. I used GSP as an instructional tool in the classroom to review topics that were addressed in the computer lab, and as a visual aid to clarify geometric concepts. When the class met in the computer lab, the students were encouraged to work independently or collaboratively with another student doing GSP inquiry lessons. These lessons were followed by class discussion. Due to limited access to the computer lab, the GSP lessons did not coincide with the classroom study. This meant that when students were studying a particular lesson in the classroom, their computer lab experience with GSP was either a premature introduction or a review of classroom objectives rather than a coordinated sequencing of instructional activity.

GSP in the classroom as teacher-directed instruction. GSP in a teacher facilitated classroom was utilized through both teacher-guided and student-guided discovery. I reviewed the GSP lesson from the previous day. A teacher-guided inquiry method was used to direct students to a predetermined result while at the same time preventing students from forming geometric misconceptions or becoming frustrated with the program (Hannifin, 2001; Ruthven, 2008). I manipulated dynamic figures that were designed in ways that students were able to make conjectures about a *rule* which would apply to the situation. One example was creating four angles by constructing two lines that intersect to form an “X”. As I moved the lines of X, the students would make hypotheses about the relationship of the four angles. The other method of utilizing GSP in the classroom was for the students to interact with the lesson and to make conjectures about a geometric property. An example is when students were given instructions on how to create a pair of lines and a transversal. The students completed the accompanying worksheet and answered questions which required them to manipulate the GSP construction (Appendix B). As the students progressed through the lesson, they discussed with their classmates’ insights and mathematical concepts that resulted from using GSP. This sharing of information reinforced their own knowledge as well as providing them with mathematical confidence (Heid, 2007, 185; NCTM, 2009).

GSP in the computer lab as student-led inquiry. The geometry class utilized the school’s computer lab for structured GSP use. Each student was able to have their own computer, and there was a computer for teacher use which was connected to an LCD projector which allowed for whole class instruction and guidance. None of the students had previous experience of utilizing computers in the lab during their math classes. During the first two computer lab meetings, there were two teachers in the room with the students. Myself, and the Rhubarb School District’s secondary math specialist, Mr. Euclid.

I had invited Mr. Euclid to assist with the class for several reasons. One reason was my limited familiarity with the GSP software. Due to my lack of experience with the GSP program, I was interested in seeing how another educator would implement the program in terms of instruction and classroom management. I recalled my experience as teacher-learner when attending a GSP workshop and having a lack of presenters to assist the class. I was frustrated to find that my triangle would not cooperate; I fell behind the rest of the class in the activity. My teaching partner for the workshop tried helping me and ended up becoming confused and frustrated as well due to his lack of experience with the program. Thus, having two instructors to assist students with their initial introduction to GSP was another reason that I had invited Mr. Euclid to the classroom. Mr. Euclid introduced the students to the GSP through a PowerPoint presentation on the history of geometric designs and patterns. Then, as he discussed the GSP tools, I was available to circulate among the classroom to assist students. Having multiple instructors available to help students identify, analyze, and correct their mistakes made the lesson flow and prevented students from being distracted. Most importantly, Mr. Euclid was available to support students in questioning unexpected results with their initial encounter with GSP (Ruthven, 2008).

The introductory GSP lesson provided an opportunity for students to explore GSP. Mr. Euclid clarified student instructions to the computer by emphasizing that it was not just a drawing, but a construction based on mathematical rules. Students used commands to color, move, or animate objects and *played* with their creations. According to Sinclair (2003), “GSP tasks should involve at least one of the following: (1) focus student attention on details in the sketch, (2) to encourage students to explain their thinking about the relationships they observed, (3) help students move through an investigation by prompting them to examine the evidence in the onscreen model, to check hypotheses, or to consider other possibilities, or (4) help students develop a proof. As part of the introduction to GSP, the students had an opportunity to explore and create a design. Then, the students were given a worksheet of designs which they were to duplicate. These worksheets were from the supplemental curriculum materials (KCP, 2007). Students created duplicate designs at their own pace in order to promote engagement and transfer of knowledge (Hannafin et al., 2001; Idris, 2009). Students were encouraged to work together and exchange ideas. Mr. Euclid and I had discussed in advance that the lesson may be revised due to particular needs of the students as determined by their pre-test, exit slip, or questions which arose through the natural classroom process. At the conclusion of the time in computer lab, there was whole class discussion to clarify the results of the student investigations. This was a time to clarify any erroneous mathematical conceptions that resulted from the investigations. At the conclusion of the class, students reflected upon their learning either by journal writing or completing an "exit slip." A similar format was used with each subsequent visit to the computer lab.

Data Sources

The study utilized a mixed-methods design involving simultaneous use of both quantitative and qualitative methods. During the research process, the qualitative data was instrumental in clarifying, interpreting, and describing the quantitative results. For example, the qualitative data of the students in the class and the quantified data of student surveys assisted in the determination of students who were interviewed.

There was a triangulation of methodology to protect the validity of the study (Mertens, 2009). Multiple data sources were used to eliminate bias, provide richer data, and serve as a means of interpreting complementary findings (Mertens, 2009; Seliger & Shohamy 1989). Data was collected from student surveys, observations, interviews, pre-test/post-test scores, and other relevant documents. Having multiple methods that reached the same conclusion protected the reliability of the methods and the validity of the research findings (Mertens, 2009; Seliger & Shohamy 1989). Also, if there were inconclusive or conflicting results, then new research questions could be identified.

Student information page. At the beginning of the school year, each student provided me with information about themselves (Appendix C). The information collected included their legal name and their preferred name to use in the classroom. Students were asked about internet access because our textbook and other instructional resources are available online, plus an online tutoring service was provided by the local public library. Additionally, students were asked the following questions:

- In math class, do you prefer to work with other students or by yourself? Why?
- Do you consider yourself good at math? Explain.
- Tell about the time that you felt most successful as a student.
- What is one thing that I (the teacher) could do to help you succeed in this class?

The student responses provide insights to attitudes regarding mathematics as well as study habits (House, 2006).

Pre-test and post-test. Prior to beginning the geometry unit, the students were given a pre-test to determine their knowledge of geometry. This was important for two reasons. First, due to the various mathematics backgrounds of the students (applied algebra, algebra and geometry – there were two students repeating the course), I needed to be able to assess their current knowledge. Second, the pre-test would provide a benchmark to measure student academic growth. At the conclusion of the unit, the students were given a post test on the material which included questions that were similar to the pretest.

Video Analysis. As the students used GSP in the computer lab, I recorded the students' level of engagement by video-taping the class as they worked through the lesson. My intent was to code for all the ABC's of engagement. By transcribing student conversations, affective and cognitive engagement was evaluated through the use of word choice and level of questioning. Student comments included: "How do I make a line?", "Is it okay if my lines are not parallel?", "I like making my lines move." or "What do we do next?" Behavioral engagement was coded based upon observing task behaviors of students. Off-task behaviors include those behaviors which were not directly related to the activity set by me. These behaviors included: wandering around the classroom, text-messaging, putting heads down on desks, etc. On-task behaviors would include: working on the computer, answering questions from the student lab handouts, and collaborating with classmates.

Student daily log. Throughout the geometry unit of study, and as a matter of classroom routine, students filled out a "Student Daily Log." This was a quarter sheet of paper on which students answered the classroom warm-up (a short question or problem that was on the board as students enter the classroom), wrote down the daily learning objective and provided feedback to the teacher regarding student understanding of concept or skill which was being presented in class (Appendix D). The students turned these papers in to me at the conclusion of each class as an exit slip. These slips were used as a classroom *thermometer* in order to adjust my lesson plans and determine if additional review or clarification was necessary. These daily logs brought additional insights regarding student thinking about the lesson and the objectives being addressed that day. The exit slips were relevant because they relied on the short-term memory of the student and were more succinct by focusing on only that day's lesson rather than an end of the unit survey.

Survey. At the conclusion of the unit, the students were given a survey about their experience with GSP. Students were asked questions about their perception of geometry and GSP (Appendix E). Using a 5-point Likert scale, the student responses were quantified by having the students give a rating of one to five for a given statement. The questions were randomized so that a response of *5* did not always reflect agreement. Responses were analyzed by gender, prior computer knowledge, and mathematics achievement as determined by being academically on-track or at-risk. One of the senior boys, I considered to be my "outlier" student due to the fact that he either left all surveys blank or marked the same neutral response throughout the form. The survey was used to determine if a students' attitude or self-efficacy influenced their level of engagement when utilizing GSP technology.

Student Interviews. The rationale of student interviews was to elicit students' ideas about GSP, gain insight regarding student understanding of mathematical ideas, and to inquire about their learning experiences in mathematics. Based upon survey responses, two students were asked to be interviewed. Student #1 had a positive self-efficacy and attitude with regards to geometry and GSP. According to the student information survey, he stated that he was "pretty good [at math] because I know what I'm doing most of the time." Student #2 found geometry confusing and did not have much confidence in her ability to do geometry or use GSP. Another criterion for selection was student perception of computer games. Student #1 liked to play computer games. Student #2 thought that computer games were a waste of time and did not enjoy playing computer games. I inquired about their understanding of the geometric concepts as well as their thoughts regarding GSP. I asked students questions about the two methods.

- How do you use computers at school? At home? ….at school?
- Describe the process of doing a geometric construction using Geometers' Sketchpad.
- What is your opinion about Geometers' Sketchpad?
- Which did you prefer: (a) making your own construction, or (b) having the construction pre-made?

Meeting with each student individually, I had the student redo one of the lessons which was done in class using GSP. I then had the student repeat the lesson using a pre-made construction (see Figure 2.1). In the first lesson, the student had to construct the parallel lines and transversal; as well as utilize the angle measurement tool of GSP. Whereas in the second lesson, not only is the angle measurement given; the angle selected angle is shaded. In both lessons, the student has the possibility to determine the relationship between the corresponding angles.

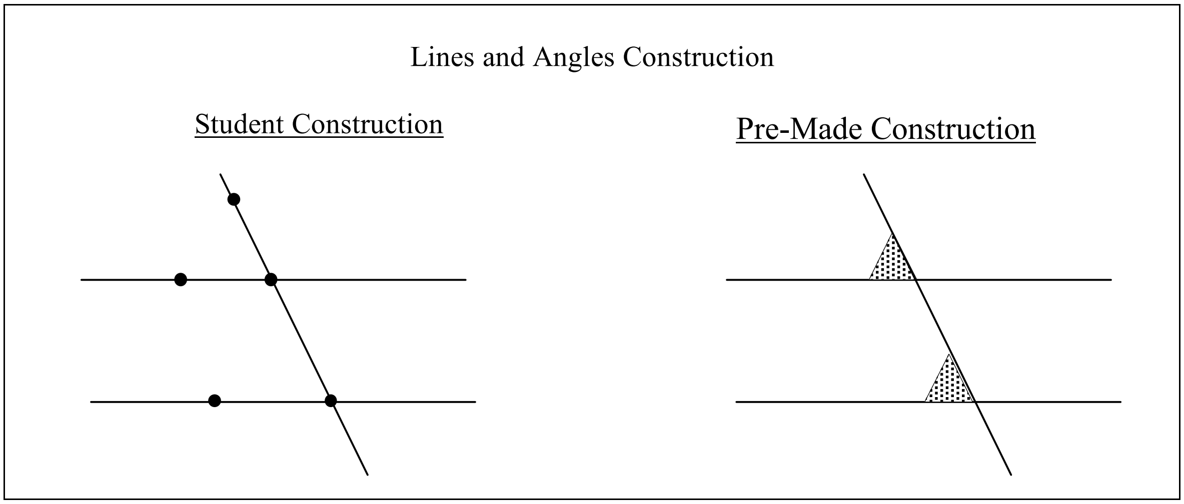


Figure 2.1. Angles are indentified by points in student construction of lines cut by a transversal. In pre-made constructions, angles are identified by either points or shaded regions.

These individual student interviews were video-taped and coded by the levels of cognitive complexity or knowledge descriptors for mathematics (Petit & Hess, 2006; Webb, 2002). The first level of cognitive complexity was recall and recognition of previous learned concepts: Was the student able to locate the appropriate tool on the GSP toolbar? The second level was application or skill: Did the student remember the process for doing the construction? The third level was that of strategic thinking: Was the student able to make appropriate conjectures? And the fourth level was the student's ability to extend their thinking: When provided with a variation of the task which required an alternate approach or multiple steps, was the student able to determine a viable solution?

Teacher reflection. Each time GSP was used in the classroom or in the computer lab, I wrote notes about my experience. The notes would not only include comments regarding student engagement, but how I felt about the implementation of GSP in the curriculum. I recognized that the success of lesson is dependent upon a combination of the quality of the resources and the teacher preparation for the lesson. Since the computer lab experience was a student discovery experience, I had the opportunity to rotate around the room and listen to student conversations, observe activity on the computer screen, and to answer individual questions. I was able to record some field notes to use as reference when I reflected upon that day's GSP experience. I supplemented these observations by videotaping the class as my classroom duties as a teacher often interfered with accurate record keeping.

The district secondary mathematics specialist, Mr. Euclid, wrote additional teacher reflections (Appendix F). Mr. Euclid facilitated the first two sessions with GSP in the computer lab. During the first session, Mr. Euclid introduced the students to GSP through an exploratory activity on creating circle designs. In the second session, Mr. Euclid presented the first lesson that correlated with our unit of study, "Lines and Angles." Having the input of another educator added validity to my reflections regarding the level of student engagement when utilizing GSP.

Analysis

Student engagement. This action research study focused on student engagement while utilizing GSP. Data analysis determined if students with prior computer experience had a predisposition to be more engaged in learning geometry with GSP. Surveys were developed to determine students' prior computer experience as well as their attitudes toward learning with computer technology. Survey data was studied for gender inequities and whether at-risk students were at a disadvantage when using computer technology. Using data from several sources, and to preserve the integrity of the results, student engagement was examined affectively, behaviorally, and cognitively. Due to the breadth of each of these three aspects of student engagement, this action research focused on "active participation" by the student in their learning process (see Figure 2.2).

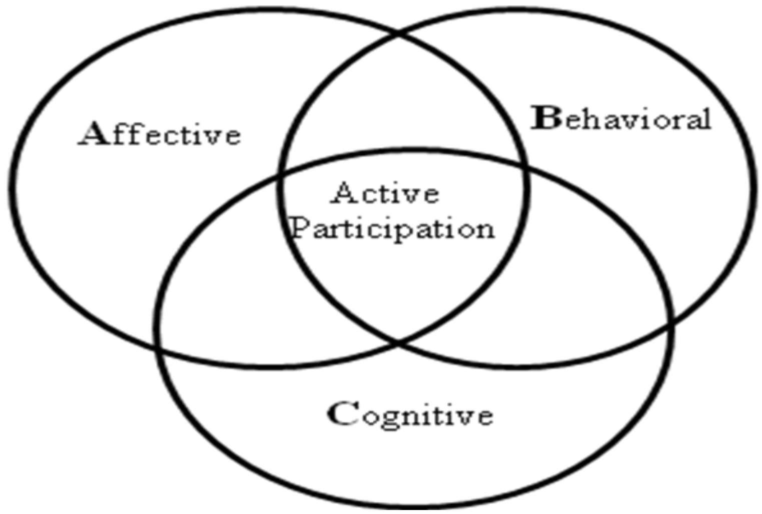


Figure 2.2 The ABC's of Student Engagement

Affective engagement. Affective engagement is the intrinsic motivator for active student participation (Hannafin et al., 2001; House, 2006; Pierce, 2006). Student attitudes towards geometry, computers and GSP were examined in terms of perceived self-efficacy and their affective processes. Data was collected from the student inventory given at the beginning of the school year, surveys, and questionnaires. The student inventory provided insight to the students' lives: who lives at their home, their activities and interests, and their future goals (Appendix C). The students were asked what grade they expected from this class and how they viewed themselves doing mathematics. This student self-efficacy has been found to positively correlate with student engagement and achievement (House, 2006, Phonguttha et al., 2009; Schunk & Zimmerman, 1994).

Using questionnaires and surveys are considered to be the research standard for measuring affective engagement (Chapman, 2003; Fennema & Sherman, 1976). The student surveys measured student attitudes regarding geometry and GSP. The student responses were summarized quantitatively on a 3 point scale: (1) did not like, (2) no opinion, and (3) liked.

Using student prior computer knowledge, gender, and academic success as control variables, I examined affective engagement to determine whether or not there might be inequities in my implementation of GSP. For example, my informal study in the spring of 2010 indicated that boys who liked computer gaming did not like GSP. Also, I was looking for an instructional tool that would motivate the at-risk students to be more successful in the classroom.

Behavioral engagement. Behavioral engagement included "effort, persistence, concentration, attention, asking questions, and contributing to class discussions" (Fredricks, Blumenfeld, and Paris, 2004, p. 62). Students behaviorally engaged may be viewed as students following accepted classroom “norms” or as students being actively involved in the learning process. I chose to study the latter rather than making a determination of what was or was not appropriate classroom behavior. I focused on students being actively engaged with the GSP. Through the use of video tapes, student engagement was coded for visual and kinesthetic task behaviors. Student engagement was tallied in one minute intervals for 30 minutes.

My first determination of students being behaviorally engaged was recording what the students were looking at in a particular moment of time (Appendix G). Were the students looking at their computer or that of another student? A student may have been talking to the student, listening to a response, or just looking at the student. It was not determined if the exchange between the two students was related to the task or not. Also noted was whether the students were looking at their worksheets. Cognitive task behaviors, of reading and internalizing the information on the worksheet, were not recorded; only the behavior of students looking at the worksheets at a particular moment in time was marked. Information about students was recorded as to whether or not they were looking at a source of information, such as a white board or the teacher. If students were looking in other locations, they were usually considered to be “off-task.” This included students looking into their bag, at a student who was not sitting next to them, their clothing, getting out their seat, sharpening a pencil, etc.

Another source of data for behavioral engagement was the placement of the students’ hands, particularly their dominant hand (Appendix H). Again, the student’s intent was not determined; the only question addressed was “what was the student touching?” I was looking for indicators of students being physically engaged in the active participation of their learning. Was the student holding the worksheet that consisted of instructions for the task as well as questions which needed answering? Was the student holding a pen or pencil? Or was the student’s hand resting on the computer mouse? It was not recorded whether the student was actually moving the mouse because this data was a *snapshot* in time. A student, who pointed to a monitor, whether it was their assigned computer or another computer, was tallied as “computer usage.” This also included students adjusting their computer or moving the computer cords. I noted when a student’s hand was raised. If the student’s hand was not in one of these positions, then the student may not have been physically active in their learning process. A student rubbing their face, having their arms crossed, or having their hands on the table may be cognitively engaged with their learning process, but were not scored as being behaviorally engaged. Any behavior that did not involve contact with the computer, a writing utensil, or paper was listed as “other” with the only exception being a student with their hand raised.

In summary when I examined behavioral engagement, I recorded only visual and kinesthetic engagement by the student. Auditory learning was not examined due to limitations of my technology. Only those activities which involved the dominant hand of the student and what the student was observing were coded. I recognize that identical behaviors may be considered being engaged or off-task depending upon the context and the level of demand being placed upon the student. The two observations were combined to quantify the data as either behaviorally engaged or off-task (see Figure 2.3).

Behavioral Engagement Correlation Chart

<table>
<tr><th>Visual Engagement</th><th>Kinesthetic Engagement</th><th>Defined</th><th>Rationale</th></tr>
<tr><td rowspan="2">The computer</td><td>Computer interaction
Worksheet
Writing utensil
Raised hand</td><td>Engaged</td><td rowspan="4">Visual engagement seemed to be a more defining factor than kinesthetic because many students would let their hand rest upon the mouse or hold a pencil while being either looking at the computer, the worksheet or elsewhere.</td></tr>
<tr><td>Other (K)</td><td>Off-task</td></tr>
<tr><td rowspan="2">Worksheet</td><td>Computer interaction
Worksheet
Writing utensil
Raised hand</td><td>Engaged</td></tr>
<tr><td>Other (K)</td><td>Off-task</td></tr>
<tr><td rowspan="3">The teacher board/screen</td><td>Computer interaction
Worksheet</td><td>Engaged</td><td>The teacher was usually working with these students, either individually or in a small group.</td></tr>
<tr><td>Writing utensil</td><td>Undetermined</td><td rowspan="2">Some students would sit for as long as five minutes with their hand up or holding a pencil, waiting for the teacher to finish helping another student.</td></tr>
<tr><td>Raised hand
Other (K)</td><td>Off-task</td></tr>
<tr><td rowspan="3">A classmate</td><td>Computer interaction
Worksheet</td><td>Engaged</td><td>Student discussion may have not been related to the GSP task.</td></tr>
<tr><td>Writing utensil
Raised hand</td><td>Undetermined</td><td rowspan="2">This determination was based on video analysis which seemed to indicate that if the student was not looking at the computer or worksheet, there seemed to be dialogue unrelated to the lesson.</td></tr>
<tr><td>Other</td><td>Off-task</td></tr>
<tr><td>Other (V)</td><td>Other (K)</td><td>Off-task</td><td>The students were not being involved with the lesson or using GSP.</td></tr>
</table>

Figure 2.3 Correlates the kinesthetic behavior, and the visual behavior of the student to determine whether or not the student was behaviorally engaged. Auditory behaviors were not recorded.

Cognitive engagement. A student's investment in their own learning indicates cognitive engagement. It is "their beliefs about the importance of academics and good grades, degree of studying and homework completion, capacity to confront challenge, and willingness to go beyond the minimum requirements" (Sciarra, 2008, p. 219). To promote cognitive engagement in my classroom, I create packets for each unit of study. Incorporated within these packets are pages for students to practice terminology (word searches, crossword puzzles, journal writing), write notes and record the results of investigations and group tasks, and work on textbook problems. My personal experience has shown that by eliminating distracters, such as having a student copy a diagram from the book, students are able to concentrate on the geometric concept. They remain focused to continue the task at hand and thus cognitively engaged (Forsythe, 2007). The packets have a page for additional resources including the availability of after school tutoring, online tutorials, and supplemental lesson activities. The packets serve as an instructional management tool. The students stay organize (fewer papers are lost), I no longer have to squint at a student assignment trying to decipher whether I'm looking at problem 4 or 9, and parents are able to track their student's progress. It is my intent to incorporate GSP lessons, and resources, as part of these packets to enhance student understanding of geometry concepts. As I implemented GSP in my classroom, I recorded questions students asked, and difficulties they encountered. I made determinations about scaffolding student learning whether it was having students create a glossary, write down procedures, or reflect about their GSP experience. One purpose of this study was to determine barriers for student success and engagement when incorporating GSP technology in my curriculum.

My first indication of cognitive engagement of students using GSP was the computer screen. What was on the computer monitor? (1) The GSP program, (2) something other than GSP, or (3) the computer was turned off? I recognize having the GSP program running does not mean that the student has to be cognitively engaged; but it does represent the initial student interest and a willingness to investigate the GSP task. Student motivation is a contributor to student cognitive engagement (Forsythe, 2007; Hannafin et al., 2001; Idris, 2009; Johnson, 2008).

A second measure of cognitive engagement used in this study was the comments and the questions which were being asked by the students of each other and of the instructor. Were the questions relevant to GSP and geometry? Field notes and the classroom video tape provided a random sampling of student-talk which was divided into two categories: student-to-student and student-to-teacher. Because I was seeking information on how I would like to incorporate GSP into future classes and what additional scaffolding might be required, I created subdivisions of student-talk: (1) mechanics of GSP, (2) terminology, (3) clarification of instructions, (4) geometry concepts, and (5) other (Appendix I).

Additionally, I examined cognitive engagement by the feedback I received from two student surveys. The first survey was given at the end of a class lesson. Using a 5-point Likert scale, students rated the lesson in terms of difficulty and their perception of their own understanding by indicating if they would do well if a quiz was given on the topic. Also, students were asked to indicate three things that they had learned from the lesson because students who see relevancy in the task or activity tend to be more engaged (Newmann, 1992; Splitter, 2009). Since this was a free-response question, the students' replies represented a level of their own complex thinking. The second survey was given at of the conclusion of this action research study (Appendix J). Students were asked about questions regarding their confidence with GSP (see Figure 2.4), and their experience with GSP compared to doing class work alone (see Figure 2.5). The results of these surveys were used as a student reflection tool about their learning and their experience with GSP.

Student Confidence Survey		
I could complete the activity using GSP….		
if there was no one around to tell me what to do as I go.	YES	NO
if I had only the GSP manual for reference.	YES	NO
if I had seen someone else using it before trying it myself	YES	NO
if I could ask someone else for help if I got stuck.	YES	NO
if I had someone demonstrate the activity first.	YES	NO
if I had used a similar geometry software program	YES	NO

Figure 2.4 Survey of student self-efficacy regarding GSP.

Student Self Analysis of GSP and Class Work	GSP	Class work
I believe that this activity will help me in college.	Y N	Y N
I learned more about the topic as the result of the activity.	Y N	Y N
This activity helps me in my geometry class.	Y N	Y N
I tend to do more than what is required.	Y N	Y N
I like to explore other options.	Y N	Y N
I did the task and then was "done."	Y N	Y N
I found it easy to use.	Y N	Y N

Figure 2.5 Survey given to students about their beliefs regarding the value of GSP and class work.

Another indicator of cognitive engagement was academic achievement (Idris, 2009; Phonguttha, Tayraukham, and Nuangchalerm, 2009). One measure of student knowledge was the use of a pre and posttest for the unit. An improvement in score would indicate learning occurred. However, due to a multitude of instructional activities that occur in the classroom throughout the study, I cannot isolate the effectiveness of GSP with regards to student academic growth. GSP may be a contributor to academic success by providing visual recollection for the students (Idris, 2009). Another measure of student knowledge was having students answer questions on a worksheet that correlated with the lesson. These worksheets were created by the textbook publisher as a supplement for GSP. Throughout the study, the worksheets were modified to incorporate student renditions of their constructions on the computer, and to focus student attention on particular terminology and concepts. These adaptations were the result of student frustrations that I encountered in the computer lab, and by the responses I heard from students when checking for understanding at the conclusion of the class period.

A final measure of cognitive engagement was interviewing two students while they worked on a mathematical task which utilized dynamic capabilities of GSP. The first task was a repeat of a lesson which was done in class where the students had to construct parallel lines and find the measures of angles created. The second task had a pre-made construction. In both tasks, the students were asked to determine the angle relationship of a pair of corresponding angles. Four levels of cognitive complexity were applied to student comments made during the taped individual interviews as they worked on the tasks. Utilizing the depth of knowledge levels for mathematics descriptors, student remarks and questions were recorded as (1) recall, (2) skill, (3) strategic thinking, or (4) extended thinking (Petit & Hess, 2006).

By examining student motivation, confidence, academic achievement, the level of student-talk, and student self-analysis of their own thinking; the student's cognitive engagement was determined. Though it is possible to compare pre and posttest scores or count the number of times a student use particular term or phrase to quantify the data, I did not feel that this would be representative of a student's cognitive engagement due to other instructional methods such as the inconsistencies of coding words and the practicality of recording all the student conversations in my classroom. For the purposes of my study, cognitive engagement was considered to be a qualitative measure rather than quantitative.

Conclusions

The research evolved as students proceeded through the geometry unit. Lessons were modified accordingly, utilizing the information from the exit slips as indicators of student understanding, classroom work and the level of student engagement using GSP. The level of engagement fluctuated as students progressed through the GSP worksheets. Many students had not experienced technology as an exploratory tool to further their understanding of mathematical concepts. Students who used computers for math often played games involving "trial and error" manipulation until they entered the correct number into a box. None of my students had used a graphing calculator to explore mathematical ideas like the slope of a line, thus, the concept of technological exploration was new to the participants. This lack of previous technological exploration may have hindered student ability to extend a lesson or recognize the possibility of exploring other options.

GSP is not a unique tool in a geometry classroom. It has existed for over two decades. At a time when most students played "Oregon Trail" on the computer, GSP was being developed (Jackiw, 1995). Although GSP has been updated, the quality of computer games and their capabilities have grown exponentially (Colwell, Grady, and Rhaiti, 1995). Ten years ago most students did not have the same access to computers that they do today. The experiences which students have regarding technology are varied. I am unsure whether a student's predisposition toward technology is a mitigating factor between those students who experience success in school and those students who are at-risk.

This study is not about the educational value of GSP. Research states incorporating GSP in the classroom promotes academic achievement (Idris, 2009; Phonguttha, Tayraukham, and Nuangchalerm, 2009). The purpose of this study is for me to examine how to effectively implement GSP into my curriculum so that students are engaged in the learning process affectively, behaviorally, and cognitively. It is an opportunity for me to become acquainted with an educational resource and to reflect upon my teaching practices.

Limitations

There were several limitations to this study. Variables of this study to consider included me (as the instructor and the researcher), the students, and the methodology of data collection. Since the nature of action research takes place in a real, rather than contrived, setting, one limitation was my dual role of being both researcher and teacher (Creswell, 1998; Nolan, 2007). My experience of having taught geometry for over two decades without GSP may unintentionally affect my analysis, and subsequently my evaluation of research outcomes. My interpretation of observations, video transcripts and exit slips may have been unconsciously influenced by my relationship and on-going classroom experience with my students. I confirmed the validity of my findings with Mr. Euclid and other mathematics educators who reviewed my research. Another limitation was my lack of familiarity with the GSP software. I relied on the prepared GSP worksheets which correlated with the textbook. Researcher or experimenter effects may challenge the external validity of the study (Sliger & Shohamy, 1989). Due to the scheduling of the computer lab, student access to the computer lab did not necessarily coincide with the corresponding classroom lesson.

Another variable to consider was the students. The students' prior experience with technology and computers was self-assessed. Student responses to the Likert Scale were variable. Knowing the topic of my research study, students might respond favorably to the survey questions thinking that they were *helping* me to a particular conclusion. The limited number of students (20) from whom data was gathered affected the interpretation of the results. I had one student whose responses, or should I say non-responses, may have impacted the interpretation of the data. Also, because this study took place over the course of several weeks, student attendance was a factor data analysis. Students who missed the first day of using GSP in the computer lab needed additional instruction and did not necessarily complete that day's activity. One threat to the internal validity of this action research study was sample size (20). The number of students who attended class varied throughout the study due to a death in the family, a home situation, an illness, and other circumstances. If a student was absent for an extended period of time, academic achievement or underachievement may not be the result of interacting with GSP. Sliger and Shohamy (1989) state: "Findings can be said to be internally invalid because they may have been affected by factors other than those thought to have caused them, or because the interpretation of the data by the researcher is not clearly supportable" (p. 95).

The last variable to consider was the methodology. I was the co-leader for the geometry professional learning community (PLC) for Rhubarb School District which had purchased GSP and wanted to see GSP being implemented in the classroom. Being a researcher-participant creates a potential bias in my data gathering, analysis, and reflections. Also, the students may not have responded honestly to surveys and questionnaires. The first time the class visited the computer lab, I had Mr. Euclid introduce the lesson which may have influenced their views regarding my knowledge and instruction of GSP. Another consideration is that this study was completed in less than two months. Having a limited amount of time for the research study, may hide potential trends or indicate a pattern that is fallacious. Another factor is that this study covered only one particular unit of study in geometry. This unit of geometry was early in the academic year, and students were still learning the fundamentals of naming lines, and angles. Students might have reacted differently in a different unit of study, and if they had a larger repertoire of skills.

Chapter 3: Research Findings

The District and the School

Four years ago, Rhubarb School District adopted *Discovering Geometry* (KCP, 2007). The Discovery series included the dynamic software program, GSP. There were less than a handful of teachers who incorporated GSP into the classroom. Many teachers didn't, myself included, because we were so overwhelmed with learning the new curriculum that there wasn't time to invest in learning something that may or may not be successful in the classroom. Now, I am familiar with the geometry curriculum, I have worked out textbook investigations with my class, and I have analyzed my students' test scores with those of other geometry students around the state for strengths and deficiencies. I feel I am better prepared to modify my instruction to incorporate GSP in my classroom.

This action research study was an opportunity for me to analyze GSP as a means of engaging students and as a visualization tool. Rhubarb School District had adopted a school improvement program for its secondary schools called HSTW (Appendix K). According to HSTW, one of its ten "Key Practices" which impact student achievement was having "students actively engaged: engage students in academic and career/technical classrooms in rigorous and challenging proficient-level assignments using research-based instructional strategies and technologies" (SREB, 1995). As my research study played out, there were on-going modifications to my instruction as I analyzed data, sought input from my students, and reflected upon my field notes.

Taking place at Rhubarb High School, the study started two weeks into the academic school year with an introduction by the district secondary math specialist, Mr. Euclid. This was an exploratory class session which introduced the students to GSP and its tools in the computer lab. Thereafter, the class met in the computer lab weekly for a unit of study on lines and angles. The class used the supplemental worksheets which accompanied the textbook as their primary resource (Appendix A). When the students were not in the computer lab, they were in the classroom doing investigations from the textbook, learning the terminology of geometry, and reviewing algebra skills. In addition to reviewing computer lab explorations, GSP was used as supplementary instructional tool in the classroom by providing students with another perspective on a concept being studied.

Research Participants

This action research study involved students in my geometry class. The class was at the end of the school day when students are traditionally at their lowest productivity and lower level of academic achievement (Biggers, 1980; Zager and Bowers, 1983). The number of students in the class varied throughout the study due to schedule changes, the fact that the high school has a itinerant population to the nearby military base, and a couple of students ran away from home. For the purpose of data analysis, my class consisted of the 20 students who turned in permission slips although the number of students enrolled in my class fluctuated throughout the duration of the study. Due to circumstances, not all twenty students participated in all components of this action research study regarding the impact of GSP on student engagement.

My class consisted of seven at-risk students as defined by being in the 11th or 12th grade and not on-track to graduate from high school. The two boys were severely credit deficient and would not be graduating with their class. One boy, whom I will call Steven[4], stated, "I have only 4 credits. There is no need for me to be here. I can't graduate." His mother informed me that she had given approval for her son not to participate in the class, or even attend class, because having two math classes were unnecessary since he would still

[4] In this study, participant names were replaced with pseudonyms.

have to take a math course the following school year. When this boy filled out his survey, he gave an identical reply to every question. Steven's survey, video-taped data, and test scores were compiled with the rest of the class, despite the possibility that his responses may not be an honest reflection of his attitude, behaviors, or learning. The remaining five at-risk students were motivated by the fact that they could still graduate as seniors if they passed this math course and the state's mathematics assessment at the end of the school year.

The thirteen sophomores were varied in their academic histories, in their personal histories, and in their classroom behaviors. These student characteristics, I believe, might have had an impact on student engagement in terms of behavioral, attitudinal, and academic. Academically, 6 of the thirteen students had passed algebra with either an A or a B. Of the remaining seven students, five had taken Algebra, and two had passed Applied Algebra. Belle, who was in foster care, was the only geometry student who was also enrolled in my Math Lab course (a mathematics intervention course meant for students who were concurrently enrolled in algebra and had been assessed to needing additional instruction).

Examining Student Engagement

Student engagement is considered to be multi-dimensional. My action research study looked at the ABC's of engagement: affective, behavioral, and cognitive. Due to the broadness of these aspects of student engagement, this action research focused on "active participation" by the student in their learning process (see Figure 2.2). Students were given surveys to determine if those students with prior experience with computer technology had a higher level of active engagement using the GSP (Appendix L).

Affective Engagement. One component of student affective engagement was self-efficacy (House, 2006). Self-efficacy is the student's belief in him or herself about being successful. On the first day of class, students filled out a student inventory (Appendix C).

Students were asked to respond to the following question: “Tell me about the time you felt the most successful as a student.” Replies included: “When I get A’s.” “Last year I passed all my classes.” “Probably elementary school because I got really good grades and was even asked to take a test for smart classes every Friday.” “When I received my 4.0 GPA for all three years of Jr. High.” “When I had an A+ in math.” Student responses indicated there was a correlation between student’s perception of him or herself as a learner and their grades. Affective engagement needs to account for student’s thoughts, feelings and actions (House, 2006). It is their self-confidence and motivator for initiating a task. To provide on-going monitoring and interpreting of students’ affective engagement, several data resources were employed: surveys, reflective questions, and exit slips.

After the first day of the unit on lines and angles, the students were asked to write a few sentences about their views of GSP (see Appendix M). This was the class’s second day in the computer lab; the first day was an exploratory lesson on the workings of GSP. Some of the comments were a general interpretation of GSP: “So far geometry sketch pad is going very well. It is pretty easy to understand. I would like to know more about geometry sketchpad.” “I think that it is going good.” Other comments provided insights to student understanding. “I think I am doing ok. It’s pretty fun but some things are confusing like conjectures.” “Need to know more about the vocab, and to find out about angles.” And there were a few comments about the technology itself, indicating technical difficulties or ways to improve the program. “I’m confident about figuring out the measurements of the angles. One thing I need to work on is remembering how to label points.” “There should be more toolbars tools so that way you don’t have to go looking for stuff.” The student’s comments provided me with my first look at GSP in terms of student attitudinal engagement. The majority of the students stated GSP was “fun”, “easy”, or “going fine” indicating a positive reaction. The one student, who stated who using GSP was “hard,” was the same student who inquired about the purpose of GSP. “I want to know what to do with this.” Cognitively, several students expressed concern about their limited geometrical vocabulary.

Further student insight was gained by having students respond to the question “What was the best thing about today’s class? and “What was the one thing that they didn’t like about today’s class?” Rose stated, "The most frustrating thing about this class is that it is difficult to work with this site. I want to learn how to work use it more so that it'll all be easier for me to do what the worksheet asks. I did, however, learn how to use lines and make them and such. I just would want to understand and how to use and do this website more."

After our last day in the computer lab for this unit, students were given a questionnaire. This was a measure of student efficacy to the tasks which were associated with the GSP lesson. Using a 5-point Likert scale, students rated their self-confidence using GSP (see Table 2).

Table 2

Student Self-Confidence and Gender Comparison

I could complete the activity using GSP if….	Girls (n = 6) %	Boys (n = 7) %	Class Total (n = 13) %
No one was around	33%	71%	54%
Never used GSP	33%	71%	54%
Had manual for reference	100%	71%	85%
Seen someone else use GSP	33%	57%	46%
Ask for someone for help	100%	100%	100%
Someone got me started	83%	71%	77%
Seen a demo	67%	86%	77%
Used a similar program	33%	57%	46%

The boys seemed to have a greater sense of self-efficacy about their abilities to use the GSP program than the girls. 71% of the boys stated that they could complete the GSP activity without ever having used the program or having someone around to assist, compared to 33% of the girls. The student response indicates that the students would have more self-confidence if they had someone get them started on the GSP activity, and then let them work independently without being told what to do. As a teacher, I like the fact that my students want to use me as a resource rather than play "follow the leader" on an assignment. In the computer lab, I handed out the GSP worksheets which correlated with the textbook. I reviewed the basic techniques for creating lines, circles, and segments; measuring angles, and labeling points. I gave minimal directions to the class about the task, since I was promoting the publisher's "self-discovery" process. With each subsequent visit to the computer lab, I modified the prepared task worksheets based upon the questions, frustrations, and misinformation that I heard and saw during the investigation.

Table 3

Student Self-Confidence and Grade-Level Comparison

I could complete the activity using GSP if….	On-track (n = 9)	At-risk (n = 4)	Class Total (n = 13)
	%	%	%
No one was around	56%	50%	54%
Never used GSP	56%	50%	54%
Had manual for reference	67%	50%	85%
Seen someone else use GSP	56%	25%	46%
Ask for someone for help	100%	100%	100%
Someone got me started	89%	50%	77%
Seen a demo	78%	75%	77%
Used a similar program	33%	75%	46%

When examining student self-confidence during the activity, the on-track students were more inclined to complete the activity if they had seen someone else use GSP, then the at-risk student. And the reverse was true if they had seen a similar program. The other interesting statistic, not seen in Table 3, is the students who previously indicated the highest enthusiasm for playing computer games had the least self-confidence on completing this activity (Appendix N). My sense is students were looking for direction on "how to play" the game. An analogous situation is when a child gets a box of Legos for their birthday and aren't sure how to begin constructing with the Legos. The child's previous experience with Legos is that they come as part of a particular kit with a particular set of directions. Another possibility is that the students categorized GSP as a computer game for learning. In Ke's (2008) study of computer gaming for math, four themes emerged: (1) computer games for learning are considered "work" and gaming is "play" (Rieber, 1996), (2) students do not reflect on their experience, (3) peer communication is unrelated to the learning, and (4) students rely on the teacher or paper and pencil rather than online tools if there is difficulty. Overall, the students felt self-confident that they would be able to complete the GSP activity if there was someone to get them started on the task and was available to ask for help as they encountered difficulties. However, if the GSP task was more cumbersome than another method, the student would utilize the alternative method, as was seen when students were asked to determine the measure of an angle supplementary to a previously determined angle measure (see Figure 3.1).

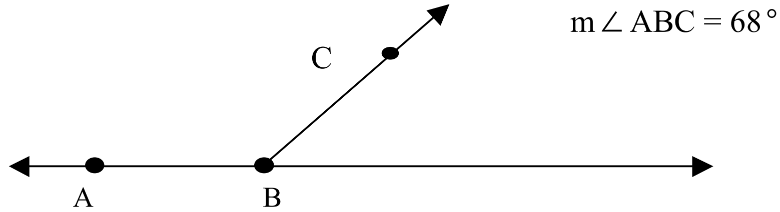


Figure 3.1. Enhanced duplication of sample GSP screen. Angle ABC was determined to be 68 degrees. The students would use paper and pencil to solve for its supplement rather than utilize GSP.

Behavioral Engagement. Student physical behavior was examined to determine if they were actively engaged with the lesson. I video-taped my geometry class in the computer lab while they were doing a GSP lesson to determine a geometric conjecture. Thirty minutes of continuous class time was evaluated for "on-task" behaviors which indicated that students were engaged with the lesson. I coded for what the students were doing with their hands and where the student was looking. The combination of these two behaviors was the mediating factor of student engagement during the lesson (Appendix O). Student discussion was not considered part of behavioral engagement, but rather cognitive engagement. The tapes were only coded for student physical behaviors. On-task participation behaviors included both facial and kinesthetic characteristics (see Table 4).

Table 4 Characteristics of Behavioral Engagement

Where was the student looking?	What was the doing with their hands?
• The assigned GSP worksheet which correlated with the textbook.	• The student was holding or touching the worksheet.
• The computer which had GSP on the screen.	• The student was operating a computer mouse or pointing to something on the computer screen.
• Looking at the student next to them exchanging ideas pertinent to GSP.	• Holding a writing utensil to write down conjectures and answer questions.
• Seeking answers from the teacher, or looking at the board in from of the classroom with additional notes.	• The hand was raised to get the attention of the teacher to ask a relevant question.
• The student was focused elsewhere; including: a student across the room, looking through personal belongs, had their head down on their desk, turned around in their seat, and other possibilities not included above.	• The student may have been holding a purse, someone's hand, or just sitting with their arms crossed.

Data for behavioral engagement was coded for thirty minutes on two consecutive days (see Figure 3.2). The on-track students were engaged throughout both days. The at-risk students were initially engaged for the first fifteen minutes and then their level of engagement significantly decreased on the first day. This decline in student engagement was not due to the fact that they were done with the task. The lack of engagement, from my observation of the video, was due to one student disrupting his friends. According to my field notes for the first day, the students were struggling with the construction process of GSP. The students were mislabeling angles, and lines that looked to be intersecting were not attached. The time between visits to the lab did not promote student retention of procedural skills. On the second day, the class worked together to re-create the construction from the previous day. We reviewed the basics about the tool bar. Students were partnered to check each other's work. Students that were successful with their constructions were recognized for their work, and had the opportunity to present to the class their hints and strategies. Once all the students had completed the basic construction of two parallel lines cut by a transversal, we reviewed the measuring tools of GSP. Then the students used the dynamic capabilities of GSP to complete the task. Throughout this entire process of my guiding students to completing their construction, and the students sharing their insights, the class was behaviorally engaged. My conclusions were GSP did promote continuous behavioral engagement.

Student Behavioral Engagement: Before and After Lesson Modification

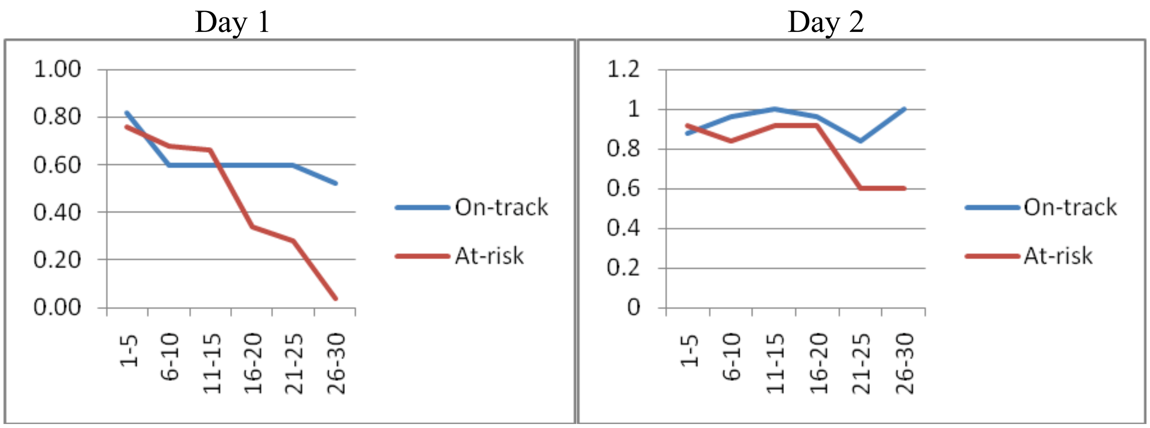


Figure 3.2 Graphs represent the percent of time students were behaviorally engaged in 5 minute increments.

Cognitive Engagement. When examining pre-test and post-test scores, there was academic improvement from the first test to the second test (see Table 5). However, this may be due to other factors: (a) geometric investigations found in the textbook, (b) homework assignments, (c) class notes, or (d) direct instruction by the teacher. As stated previously, cognitive engagement is student self-regulated learning as determined by: (1) student-talk, (2) student perception of the task, and (3) the amount of time the students spent accessing GSP. According to my field notes, student surveys, and the video tape of students using GSP, the students were determined to be cognitively engaged.

Table 5

Geometry: Angles and Lines Unit Test

Question	Pre-Test	Post-Test	% Change
1.	57.14%	71.43%	125%
2.	7.14%	71.43%	1000%

Note: Class average for correct response on similar pre and posttest questions. See Appendix P for questions.

Instructional Implementation of GSP Field Notes Reflections

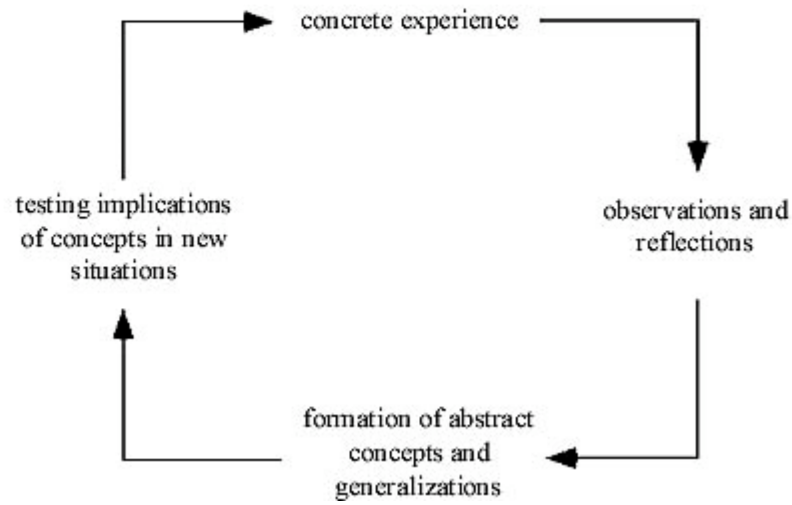


Figure 3.3. Lewinian Experiential Learning Model. (adapted from Kolb, 1984, p. 21)

The implementation of the GSP software program into my geometry curriculum was an inquiry-based activity where I examined the effectiveness of the program as it related to student engagement. Using my previous experiences of teaching geometry, I asked questions of my students about their learning of GSP, monitored and recorded student behaviors, formed conclusions, and modified instruction based upon my observations to facilitate student engagement. The lesson procedure was a continuous cycle of reflecting, identifying problems and issues to investigate, implementing new ideas, and observing the plan (Appendix Q). Each week in the computer lab brought a new level of technology implementation: *entry, adoption, adaptation, appropriation,* and *invention* (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005; Means & Olson, 1994).

Week 1. I appreciated having a second instructor in the computer lab. Having two instructors decreased student *wait time* for technical assistance, provided feedback to the student, and promoted student inquiry. As expected as part of the *entry* level of technology implementation, I frequently found that I did not anticipate many of the concerns by students

(Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005). The students seemed comfortable with using computer technology as determined by the minimal questions about having to turn on the computer or how to login to their individual student accounts. I was able to help students who were unable to access the computer themselves while Mr. Euclid introduced GSP to the class using a Powerpoint presentation. While the class worked on an exploratory activity using GSP (Appendix R), Mr. Euclid and I addressed student concerns, asked questions about their GSP construction, and affirmed student progress. By giving students frequent, *positive feedback*, we supported students' beliefs that they can do well which is a motivator for student engagement (Deci, Ryan, & Koestner, 1999; Deci, Vallerand, Pelletier, & Ryan, 1991; Logan, Medford, & Hughes, 2011; Martens, de Brabander, Rozendaal, Boekaerts, & van der Leeden, 2010; Pintrich, 2003; Weaver, M., 2006). With the support of two teachers, the students were engaged throughout the lesson (see Figure 3.4).

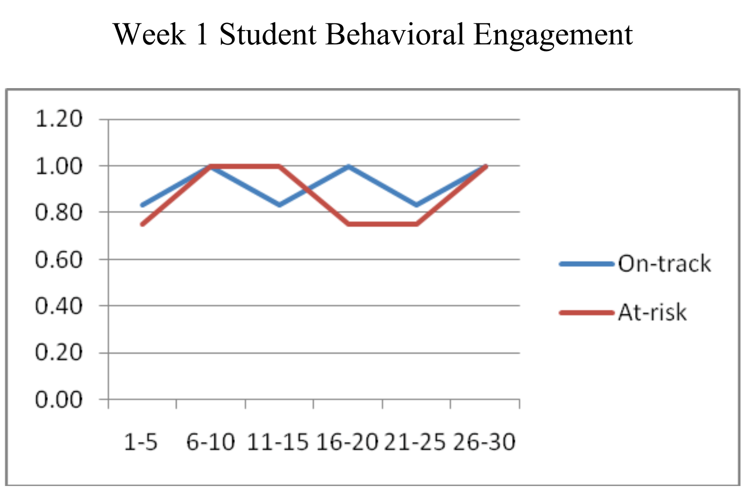


Figure 3.4. Behavioral engagement was determined through video tape analysis of student visual and kinesthetic behaviors: (1) what was the student looking at? and (2) what was the student doing?

Week 2. This was the first week that the students used GSP to determine a conjecture in the lines and angles unit. Reflecting upon the class's previous visit to the computer lab, I felt that I was at the *entry* level of technology implementation. To provide additional instructional support, Mr. Euclid returned to the computer lab. Throughout this time, we were able to informally assessed students progress as they followed the instructions on a worksheet which supplemented the geometry textbook. I heard students asking questions of one another about the technical procedures of GSP: How did you label the point? Where is the measurement tool? This was significant because not only were the students working collaboratively, it was early in the school year, and many students did not know each other. "What does *conjecture* mean?" was the most frequently asked question by the students. The worksheet instructions had asked the students to make *conjectures* about their GSP work. A few students looked up the word in their math glossary, though most students asked the instructors. At this time, I recognized the computer lab had some physical limitations about being used for classroom instruction. There was no place to write and define the word *conjecture* for future student reference. The one small white board in the classroom was saved with information for other classes. There was no available wall space to put up new words and their definitions. Difficulties with technical procedures and new terminology were anticipated concerns with the implementation of GSP. Students recognized these obstacles, found solutions, and continued to be engaged with the task.

My concern with the implementation of GSP was students making incorrect or incomplete conjectures. In this lesson, the students had to measure angle ABC and compare its measurement to angle EBD (see Figure 3.5). Several students misidentified angle ABC as either angle CAB or angle ACB resulting in faulty conclusions. Although the class reviewed conjectures and came to consensus about properties of two intersecting lines, I believe that the feedback about the angle measurement needed to be more immediate. Having pre-constructed drawings, of intersecting lines with angles marked and the students utilizing only the dynamic capabilities of the GSP, is one solution. Another solution is to incorporate the GSP software into the classroom lesson by having students having students draw two intersecting lines on a sheet of patty paper[5]. Then, using a protractor, the student measures the angles and makes a conjecture about the vertical angles. Folding the patty paper, students may verify their conjecture. And finally, the class would use GSP to demonstrate that this conjecture may be extended to all vertical angles.

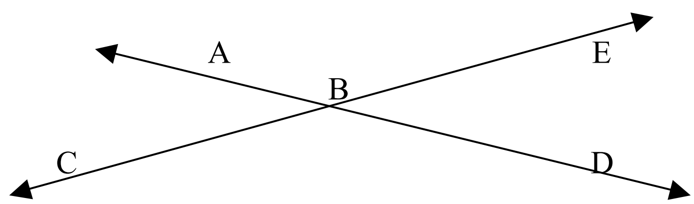


Figure 3.5 Measuring Vertical Angles.

Week 3. I began to feel confident in my use, and my ability to teach, GSP technology having listened to Mr. Euclid's responses to student inquiries, and working out the GSP lesson with minimal difficulties. I was by myself in the computer lab this week. Due to students needing additional scaffolding of the task, I re-wrote the original worksheet provided by the publisher. The modified worksheet reflected terminology being used in the classroom, clarified instructions, and provided increased space for student responses. I felt that I was moving towards the *adoption* level of technology implementation (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005). At the adoption level, teachers begin to anticipate student difficulties and develop strategies for solving (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser,

[5] Patty paper is squares of translucent paper that is used to separate hamburger patties. Students may write on and fold the paper to identify geometric properties and congruencies.

2009; Foo, Ho, & Hedberg, 2005). Many students seemed to be working and asking each other questions about the task. I noticed students seemed to be working in clusters. The students seemed to gravitate to certain students (nature of human behavior). I also sensed students seemed to lose *focus* on the task when I approached. Instead of asking their *partner* or someone near them questions, students would ask me questions. In one example, Chloe was in the process of asking Steven questions, then in mid-question turned to me and restated the question starting with, "Mrs. Wilson…". Steven listened-in, but was basically given the cold shoulder by Chloe. My response was to refer to the question back to Steven and bring him back into the exchange with Chloe. The students were unconsciously determining a hierarchy of authority with regards to either GSP or the study of geometry.

The task of identifying angle relationships given two lines cut by a transversal was meant to be a one-day lesson; however, this task became a two-day lesson. I did not anticipate the amount of time it would take the students to construct parallel lines, and then create a transversal passing through the parallel lines and label the eight resulting angles. Throughout the lesson, I found myself giving clarification regarding the construction of parallel lines. Most students, when given a line, drew by *eye-balling* a second line through a point not on the original line. This resulted in angle measures with no discernable pattern other than "vertical angles are congruent" and "adjacent angles are supplementary" which was a reinforcement of a previous class. I expected students to identify the relationships between corresponding angles, alternate interior angles, and alternate exterior angles. Fortunately, this was easily corrected by eliminating the free-drawn line and using the "construct tool" to create a second parallel line. I added the words *sketch*, *draw,* and *construct* to the vocabulary list. At this point in the curriculum, the students had not done formal constructions with straight edge and compass which is when I traditionally have introduced the terms: sketch, draw, and construct.

Students worked on the task until the end of class. Their sense of anxiety increased as they realized that they wouldn't be done with the task before class ended. This pressure to finish was relieved when they heard that the class would be in the computer lab the following day. I was fortunate to be able to schedule the lab for the next school day, though typically the computer has to be scheduled a couple of weeks in advance due to the demand for the computers by teachers of other classes.

Week 4. I reviewed with the students various features of GSP. Initially, I wanted students to create parallel lines by using only the *draw* tools of the GSP so that they grasp the idea that *through a point not on a given line, there exists one and only one parallel to the given line.*[6] However recognizing the limitation of time, and convenience of the construct window, I demonstrated both constructions on a screen in front of the room while the students followed along at their computers. I also reviewed terminology pertinent to the lesson: corresponding angles, alternate interior angles, alternate exterior angles, and transversal. Most of the students had discerned their meanings based upon their prior experience with the words. And I began to informally extend the lesson by posing questions for the students to explore when they were completed with the task.

I felt less overwhelmed. There were fewer technical and vocabulary questions. I found moving about the computer lab difficult. The room was arranged like the tines of a fork. I walked between the tines until I arrived at a dead end, and then I turned around re-tracing my steps. Having the review session at the beginning of class assisted those students

[6] Euclid's Parallel Postulate is the fifth axiom in a set of books known as *Euclid's Elements* which provides the foundation of the study of Euclidean geometry.

who were absent the previous class. Not having access to GSP outside of the computer lab created internal conflicts for some students: Do I help a classmate who has been absent? Or do I finish the task? I did not see any student extended the lesson, which I needed to address for future classes. As I reviewed the lesson, and planned for the following week, I realized that I was using GSP as a strategic teaching tool which was the next level of technology implementation: *adaptation* (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005).

Week 5. The students were comfortable with the computer lab routine. Technical difficulties involving signing on to student accounts, and accessing GSP on the computer were non-existent. However, I was unable to use the demonstration computer that projected to the front of the classroom due to a reconfiguration of the cords by the teacher using the computer lab earlier in the day. The students were particularly glad to be in the computer lab because it was raining outside, which meant they did not have to venture into the weather to reach my classroom. Students were still struggling with the construction component of GSP as confirmed by Rose's statement:

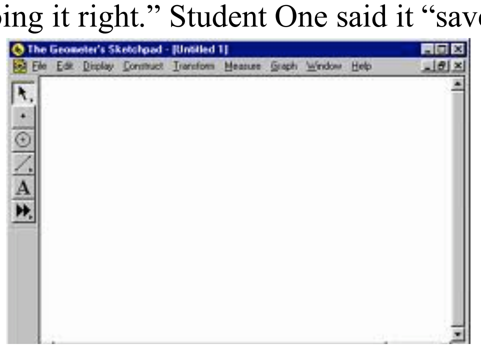
> "The most frustrating thing about this class is that it is difficult to work with this site. I want to learn how to work use it more so that it'll all be easier for me to do what the worksheet asks. I did, however, learn how to use lines and make them and such. I just would want to understand and how to use and do this website more."

All the students were on-task though I was not positive if it was because they were conscientious students, familiar with the lesson material, or for some other undetermined consideration.

Week 6. Due a power outage, there was no school today. This was the week that I was planning to have students extend their knowledge about parallel lines, transversals, and angle relationships to other situations; similar shapes, parallelograms, and work with more than two parallel lines. I was unable to re-schedule for the computer lab for another three weeks. At which time, my class would be using the computer lab for a different geometry unit. Regarding levels of technology implementation, I was at the threshold of *appropriation* (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005). *Appropriation* is the sense of confidence to explore how GSP may be used other than what is provided by the instructional materials.

Student Interviews

The student interviews were used to compare student engagement using GSP and an online version with similar investigations, but not creating the construction by the student. Both students agreed that it was less frustrating and easier to make conjectures using the pre-made construction. This concurs with the research that GSP was more manageable when the students have prepared figures and measurements rather than constructing the figures for themselves because of the complexities of the software (Ruthven, 2008). When Student Two had created her construction using GSP, the parallel lines were not connected to the transversal. As a result, the she was unable to manipulate the angles and to discern that corresponding angles are congruent (see Figure 3.6). Student Two stated having the shading on corresponding angles of the pre-made version focused her attention on just the angles and she could “see it”. She also “liked it better to have the shape put together” so she knew that she was “doing it right.” Student One said it “saves time from having to put it together yourself.”



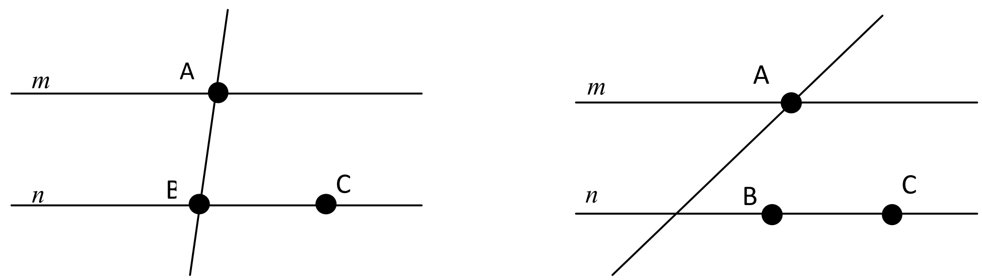


Figure 3.6 Enhanced duplication of student work when line m is connected to the transversal and line n is not connected to the transversal. Dragging the transversal does not change the measurement of angle ABC. Visually, the angle formed by the transversal and line n is altered as the transversal is moved on the computer screen.

"What is your opinion of GSP?" I asked both students. Student One said it was "okay." When I asked him to elaborate, it took him a minute before admitting that doing the worksheets was "boring"; but he liked "playing" with the program. He stated he really did not learn anything which he had not learned in class. Student One stated he liked making the designs we did in class the first day especially watching figures move. Student Two stated that GSP was "fun." I asked her to explain, "fun." She just repeated, "I don't know. It was just fun." Thinking my questioning was making her uncomfortable because she started looking around the room, I did not press her further.

The two students were very different with regards to their computer background. Student One has a computer at home. He plays some games on the computer like "Spider Solitaire" but not the animation games. His parents monitor the computer and it is meant for school work. Student Two said there is a computer at home; but she does not "go on it much." She states she likes to play the game where you make cakes, match the shape and put frosting on it before times runs out.

Conclusions

Conclusions drawn from the study determined that students' prior experiences with technology influenced their level of engagement and academic achievement. One possible relationship is that the computer skills used for word processing is similar to the skills required in using GSP. Both word processing and GSP use *pull-down* windows, and require knowledge of its *tools*. According to the video analysis, the girls with word processing experience were more engaged with GSP than those students who did not work with word processing software on a regular basis. Based upon my student interviews, familiarity with computer does impact student success in school. Whether or not, a student likes to play computer video games or uses word processing is not as important as computer fluency.

Computer Knowledge. Technology brings to the educational experience: engagement, exploration, real-world simulation, and skill building opportunities (Kozma and Johnson, 1992). The students were familiar with computer software technology, and most had a computer available to them at home (see Appendix S). One student, who did not have access to a computer at home, had marked "neutral" on all responses of the survey indicating that his responses might be considered unreliable. Slightly more than half of the students used computers for word processing or other purposes such as Facebook or reading the news.

None of the students had used GSP prior to this course, nor had they seen it used in any manner by another student or teacher. Of the seventeen students who completed surveys, regarding their computer usage (see Figure 3.7 and Figure 3.8), 76% had access to a computer at home. All the students had familiarity with the computer, whether it was word processing (47%), playing computer video games (41%), or accessing the internet for research, news, or Facebook (88%).

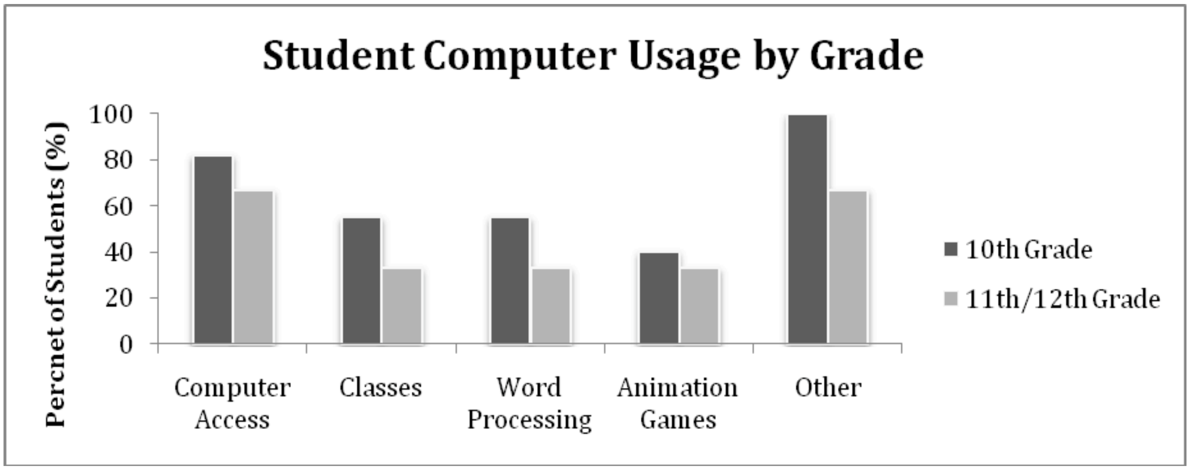


Figure 3.7 Compares 10th grade students use their time on the computer to 11th and 12th grade students.

Computers and Academic Achievement. Tenth grade students enrolled in geometry at Rhubarb High School are considered to be average academic achievers because they were not accelerated in mathematics in the junior high school. The eleventh and twelfth grade geometry students are considered to be at-risk for earning their high school diploma because they are below grade level mathematically. Part of the rationale for incorporating GSP into the geometry curriculum was research stating GSP has the potential to increase academic achievement (Connell, 1990. Idris, 2009; Phonguttha, Tayraukham, & Nuangchalerm, 2009). Due to both eleventh and twelfth grade participants being at-risk and the relatively small sample size of participants, compared to the tenth graders, I combined the older students into one group for analysis. According to Figure 3.8, my at-risk students have an additional disadvantage of not having the same prior knowledge and experiences with computers as my students who are at grade level.

Students who were at grade level mathematically were more engaged than those students who were below grade level despite their prior experience with computers. The level of engagement using GSP correlated with academic aptitude of geometric concepts. An increase in a student's score on the post test might indicate that the student had benefited from the use of GSP if it were not for other variables including: quizzes, class assignments, textbook investigations, and individual study skills. Those students who demonstrated higher levels of engagement using GSP showed a greater increase on their post-test score compared to their pre-test scores, but to other classroom factors. According to Figure 3.7, my at-risk students have an additional disadvantage of not having the same prior knowledge and experiences as my students who are at grade level. An indicator of socioeconomic status (SES) is having a computer at home (Warschaue, Knobel, Stone, 2004). As indicated by Figure 3.7, students that were at-risk in my class had less computer access. Therefore, the at-risk student did not have the same potential opportunity to learn, and practice, various computer skills.

Computers and Gender. The survey question, "I use computers as part of my classes," may have been interpreted differently than I had intended. I was asking if teachers were requiring students to use word processing tools, access information online, and utilize educational software programs. The data showed boys used computers twice as often in class as girls (see Figure 3.8). This data also indicates that gender may be a factor when implementing technology into classroom curriculum, or there may be other considerations such as student schedules. A student's class schedule may require more, or less, technology than another student's schedule. For example, some Rhubarb High School course electives tend to enroll a particular gender. Class rosters indicate boys chose Power Sports (a machine tools class, which uses technology) as an elective whereas more girls were enrolled in Child Development that uses less technology (Rhubarb H.S., ret. January, 2011). Another factor was misinterpreting the statement "I use computers as part of my classes" as "I use class time to do work on computers." I think this latter explanation was more feasible because sophomore boys (80%) used the computers in the classroom almost three times as often as sophomore girls (33%) and their class schedules are the most similar compared to other grade levels due to minimal elective options (Appendix S). Also, boys had less computer access at home than girls. Boys may have taken advantage of opportunities to use computers during class time, whereas the girls would be able to supplement their class time by finishing assignments or doing research as home.

The boys may be using computers in their classes, but the girls are using the computer more for word processing. Approximately 60% of the girls used the computer for word processing compared to less than 40% of the boys; again, this might be the result of having access to a computer at home. These numbers were reversed when playing video animation games on the computer. The survey did not specify how often or where students played animation games. So, the availability of computer did not influence the response as it did with regards to “word processing” and “other.”

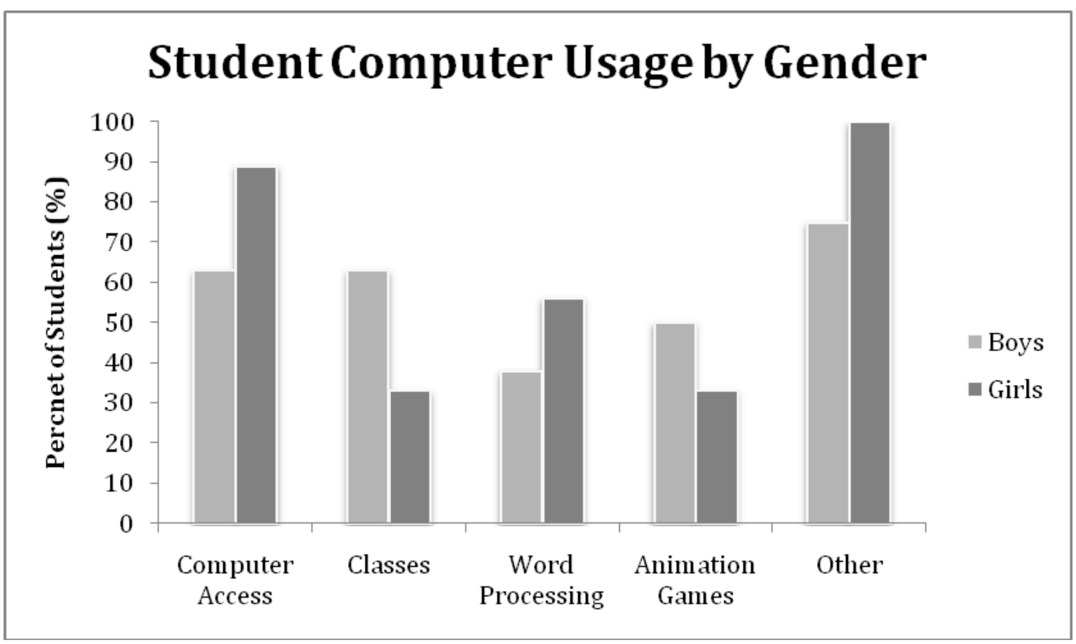


Figure 3.8 Representation of the percentage of male/female students who have access to a computer and use computers for classes, word processing, animation games, and other online activities.

To summarize, my findings indicated that the students enjoyed using GSP to explore various properties of geometry. Furthermore, the students were engaged throughout the lesson, unless there complications with creating the figure. The students were not always able to complete the construction. If the student completed the figure, there were often errors that lead to a student misconception about a geometry concept, or an incomplete conjecture. During the student interviews, the students expressed that they would rather give a constructed geometric figure, and then utilize the dynamic capabilities of the software to explore and hypothesize about various geometric properties.

With regards to GSP implementation, the findings were mixed. Utilizing GSP in the class room as a demonstration tool was successful because many students were able to visualize geometric concepts that were being explained. However, the use of GSP was limited in my class room due to lack of other technology. There was only one computer available to use. Although there was an LCD projector that enabled the entire class to see the screen, the students were unable to readily interact with the GSP software. In the computer lab each student was assigned their own computer, so the students were able to interact with the GSP software. Although the students enjoyed their time in the computer lab, as the instructor, I felt that additional scaffolding was necessary for the students to complete the task. Also, I was concerned that most of the time spent by students during the class was creating the figure rather than exploring the properties of geometry. And finally, because the visits to the lab occurred weekly, the students had difficulty retaining the process to complete a GSP skill such as creating two intersecting lines. Overall, I liked the potential of GSP software in my class room as a learning tool for visualization, and to promote student engagement.

Chapter 4: Conclusion

We live in a technological age of computers which has been developing rapidly over my 28 years of teaching. When I first started teaching, the Apple II computer was starting to infiltrate the school systems. The computer was named Time magazine's "Man of the Year". I taught computer literacy classes where my students learned about the history of the computer, practiced key boarding skills, learned BASIC computer language, and used "Turtle Logo" as an introduction to geometry. The internet consisted of a modem connected to a local college computer which required a telephone connection. My classroom had chalk boards and no overhead. Worksheets were printed off on a ditto machine, graphing calculators were still a thing of the future, and my first computer cost a month's paycheck.

Today, my students walk around with cell phones which are far superior to the communication devices that were used on the television show *Star Trek*. Most students have computers at home which are used for communication, research, games, and word processing. The students in my classes have access to programmable calculators; and computers are an integral part of education. Computer technology in the educational system is changing rapidly. More mathematical instructional programs are available online, plus YouTube[7] and math sites such as mathteacher.com have "real" people performing basic mathematics instruction. (http://www.mathtv.com/ or http://www.khanacademy.org/). Many school districts, including Rhubarb School District, offer online courses for students.

Rhubarb High School is struggling to meet the state's proficiency standards in mathematics. Rhubarb High School implemented the HSTW program whose tenants encouraged teachers to raise academic standards by engaging students in their educational process through research-based instructional strategies and technologies. Rhubarb school

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[7] YouTube is an online video sharing website.

district had adopted the KCP curriculum materials for *Discovery Geometry* four years ago as a means of incorporating problem solving and student inquiry into the geometry curriculum. GSP was included as part of the adoption package, but was not used in the classroom setting either as a demonstration tool, or as an investigative tool for student learning in a computer lab setting. According to KCP (2001), GSP is an effective instructional tool for today's diverse student body. Researchers of the University of California report that mathematics teachers find GSP to be "the most valuable tool" for students (Becker, 1999). The National Council for Teachers of Mathematics' Standards explicitly recommends the use of dynamic geometry in the K-12 mathematics curriculum (NCTM, 2000). Research states using GSP in the classroom promotes student engagement and academic achievement by utilizing the dynamic capabilities of the program (Deturek, 2003; Hannafin, 2001; Hannafin & Scott, 1998; Hollerand, 2007; Idris, 2009; Knuth & Hartman, 2005; Roscheele, 2000).

My action research study was to investigate how to improve student engagement through the implementation of GSP into my instruction of the school's geometry curriculum. According to Lappan and Briars (1995, p. 138),"There is no decision that teachers make that has a greater impact on students' opportunities to learn and on their perceptions about what mathematics is than the selection or creation of the tasks with which the teacher engages students in studying mathematics." In what ways do teacher actions during the setup and implementation phases impact the cognitive demands of mathematical tasks? Recognizing student attitude and previous mathematics achievement is a possible motivator of student engagement. I examined student experience with computer technologies, student attitudes, and my at-risk student population when analyzing my data for GSP implementation in my geometry class.

Relating Findings of the Research Study to Findings in Literature.

Academic research has found that GSP has had positive impact on student achievement (Battista, 2002; Connell, 1990; Hannafin, 2001; Hannafin & Scott, 1998; Hollebrands, 2007; Idris, 2009; Knuth & Hartman, 2005; Roschelle, 2000), conceptual understanding (Frekering, 1994), motivation and engagement (Deturek, 1993; Jackiw, 1995; Johnson, 2008; Means, Olson, & Ruskus, 1997; Ruthven 2008; Sinclair, 2006; Solvberg, 2003). In each of these studies, the methodology included pre- and post- tests or surveys with little description of what is occurring in the classroom, other than using GSP, between the two data assessments. In my classroom, multiple instructional strategies are applied: textbook investigations, patty paper explorations, and the use of geometric tools (protractors, rulers, and compasses), informal assessments, paper-and-pencil exercises, and collaborative tasks. Part of my role as a teacher is to provide a balance of instructional activities which engages my students: affectively, behaviorally, and cognitively.

This study was different from previous research for several reasons. One reason was that I identified, and analyzed, three facets of engagement: affective, behavioral, and cognitive (Newmann, 1992). Another reason is that technology inequities were determined to exist in the classroom as a result of students' prior computer experiences. And a third reason was that this research recognized the at-risk student population as potentially requiring differentiated instruction in order to be actively engaged in the learning process. This action research study was part of the entry, adoption, adaption, and appropriation stages of incorporating technology into the curriculum (Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005; Means & Olson, 1994).

Throughout the study, the affective component of student engagement correlated with the research. GSP is a dynamic mathematics visualization software program put out by KCP to supplement its geometry curriculum to promote student exploration by dragging, animating, and transforming geometric objects. GSP provided immediate feedback, motivated students to think mathematically, and engaged students (Jackiw, 1995; Ruthven 2008). The students were attracted to the computer. They liked to "play" with the animation features of GSP.

The behavioral component of student engagement was task related: (1) "What was the student observing? (2) "What was the student doing?" Initially the students exhibited on-task behaviors. As the students encountered difficulty or became frustrated, there were different reactions. Some students would try alternative solutions or redo the task. Many students would seek assistance from another student or from an instructional authority such as the teacher or book. Other students would sit and "play" with the computer. These students were physically engaged; but were not cognitively engaged. The students who had experience with word-processing were the most likely to persist working on the GSP lesson when they encountered difficulty indicating that there might be a correlation between the two tasks. At-risk students were the least likely to remain engaged. And the at-risk students had the least computer background whether it was word processing, gaming, or social networking.

The third component of engagement was student learning, or cognitive engagement. The students reported that GSP helped them "see" the concept of pairs of angles would remain congruent as other characteristics of the diagram were modified. The two students who were interviewed concurred that having pre-made sketches not only reduced their anxiety about the "correctness" of their sketch; but they found that it was easier to identify relationships between angles. Removing the task of creating the construction, improved cognitive engagement was also seen graphically (see Figure 3.2). My field notes indicated that there were fewer misconceptions and frustrations due to mislabeling of the constructions. The results of my study supported research that GSP was a valuable visualization tool (Idris, 2009; KCP, 2001; Tat & Fook, 2005; Weaver, J., 1999).

As a teacher, I found implementing GSP into my instruction was frustrating. Research did not address how a teacher would incorporate GSP into their instruction. My concerns included: the computer lab facility, the merging of classroom lessons with the GSP lessons, and maintaining student engagement. The computer lab facility was not meant for instruction. It was difficult for me to move about the room to assist students. There were no boards for students to reference if directions had been revised, words defined, or examples presented. The instructor’s computer was not always properly connected to the LCD projector due to other classes using the room. Having limited, and uncertain access, to technology hindered my ability to maximize my use of GSP as a demonstration tool. Being in the computer lab, meant GSP lessons did not always coordinate with the classroom lesson because of the necessity of signing up for the lab a couple of weeks in advance or missing a lab time due to a power outage. There were times when my students stated, “We’ve already seen this in class”.

My study was early in the academic year, when students were familiarizing themselves with geometry terminology and basic foundations of point, line and plane. Many students were still learning how to use three letters to name an angle which hindered their ability to correctly identify properties of corresponding angles when given two parallel lines cut by a transversal. I found that the worksheets associated with the *Discovering Geometry* curriculum were frustrating for the students, and often led to student misconceptions about basic geometry properties. Many students were not able to make correct conjectures using the dynamic nature of the program due to faulty constructions. My research showed that after approximately 20 minutes into the task, many students were no longer engaged with the task due to technological difficulties. However, throughout the class period, students stayed near their computer and occasionally "playing" with GSP as if waiting for additional instruction. If the study was later in the academic year, the students would know the "alphabet" of geometry. Having students that were familiar with GSP would encourage the creation of higher level cognitive demand tasks.

Implications of Findings and their Relevance to Future Educational Practices.

As a teacher, I am constantly reflecting upon my classroom practices and how they impact student achievement and engagement. Did the time for the students to learn and solve problems using GSP in the computer lab justify the time spent away from the classroom? I think my students would have been better served by using laptops in the classroom rather than using the computer lab since many of the investigations did not require the full class period. Also, at the beginning of the academic year, I would recommend not having the students create the constructions. However, I would utilize pre-made constructions and have students determine conjectures through the dynamic capabilities of the software. By introducing a dynamic software program into my geometry curriculum, I affirmed my hypotheses that students will be engaged affectively, behaviorally, and cognitively. Also, because GSP does promote engagement with students who are at-risk, I need to examine various methods of differentiated instruction that incorporates GSP. And in order to promote continued student engagement, I would encourage students to extend the task by modeling appropriate *play* activities.

Since I began my research, KCP is offering Sketchpad Link to educators. Sketchpad Link is an online subscription that makes GSP more accessible for classroom instruction. Sketchpad Link is "aligned to leading math textbooks and state standards, Sketchpad LessonLink offers pre-built sketches, teaching notes, student worksheets, and tips on using Sketchpad to provide teachers with all the resources they need in one place" (Embury, Blohm, & Associates, Inc., 2009). My recommendation for future studies is to examine Sketchpad LessonLink for student engagement and academic achievement as it pertains to teacher instruction. And more importantly, make recommendations on the implementation of GSP in the classroom and computer labs so teachers will be less overwhelmed with new technologies.

Questions for Future Action Research

Computer technology is moving at a faster rate than the research is being developed and analyzed. Is going to the computer lab an out-dated classroom activity? Would having a class set of computer laptops be a better utilization of time? Students could use laptops in the same manner as they use their calculator, as a convenient tool to enhance learning. As schools look at alternative school days, would having a combination of classroom experience and online GSP activities be a viable option for future geometry classes? "Sketchpad and other software were never intended to replace such important hands-on activities, but can be used in different ways to enhance and extend children's learning experiences" (de Villiers, 2007, 49).

Closing Comments.

I appreciated the opportunity to explore the use of GSP with my geometry class. As my district's PLC geometry co-leader, I was able to present the GSP software to my colleagues near the end of my action research study. It was at this meeting that one of the other geometry teachers brought up the idea of using GSP with interactive whiteboards. I have never seen an interactive whiteboard used in the classroom. Moreover, I am intrigued by the potentiality of utilizing the dynamic capabilities of GSP with interactive whiteboard technology. I believe that technology supports student-centered learning environments, and that there is value to incorporating GSP into my curriculum. GSP promotes student engagement, helps with student visualization of geometric concepts, and provides opportunities for student exploration of testing, and verifying, conjectures. GSP is a scientific inquiry tool that supplements instruction, in lieu of replacing the lesson. And similar to a calculator, the tool needs to be available for instruction, rather than have the instruction support the tool. As the result of this research, I am able to advocate for the use of GSP in the classroom; as well as make recommendations to make the school's computer lab more accommodating as an instructional facility.

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APPENDIX A

Discovering Geometry
An Investigative Approach

Discovering Geometry with The Geometer's Sketchpad®

DISCOVERING MATHEMATICS™

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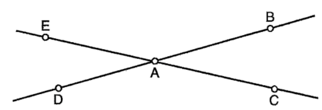
Lesson 2.5 • Angle Relationships

When two lines intersect, they form four angles whose vertices are the point of intersection. In this activity, you'll investigate relationships between pairs of these angles.

Investigation: Pairs of Angles

Sketch



Steps 1 and 2

Step 1 In a new sketch, construct $\overleftrightarrow{AB}$ and $\overleftrightarrow{AC}$. Start the second line at A to make sure it is a control point of both lines.

Step 2 Construct point D on $\overleftrightarrow{AB}$ so that A is between D and B. Also construct E on $\overleftrightarrow{AC}$ so that A is between E and C.

Step 3 Measure the four angles: $\angle BAC$, $\angle CAD$, $\angle DAE$, and $\angle EAB$. (Remember that to measure an angle you need to select three points on the angle, using the vertex as the middle point.)

Investigate

1. Drag points B and C. Record anything you notice about the relationships among the angles.
2. In your sketch, $\angle BAC$ and $\angle CAD$ are a **linear pair** because the outside sides of the angles form a line.
   a. Find all the other linear pairs in your sketch.
   b. Write a conjecture about the relationship between angles in a linear pair (Linear Pair Conjecture). Choose **Calculate** from the Measure menu to test your conjecture.
3. When are the angles in a linear pair equal?
4. In your sketch, $\angle BAC$ and $\angle DAE$ are a pair of **vertical angles.** This name is related to the fact that the angles share the same vertex. $\angle CAD$ and $\angle EAB$ are another pair of vertical angles. Make a conjecture about the measures of vertical angles (Vertical Angles Conjecture).

EXPLORE MORE

1. Two intersecting lines form four angles. If you know the measure of one of the angles, you can find the measures of the other three. Suppose you have three lines intersecting in a single point to form six angles.
   a. How many angle measures do you need to know in order to find the other angle measures?
   b. When are all six angles congruent?
2. Suppose you have four lines intersecting in a single point to form eight angles. Answer Question 1 for this case.
3. Now generalize your results from Questions 1 and 2. Suppose you have n lines intersecting to form $2n$ angles. Answer Question 1 for this case.

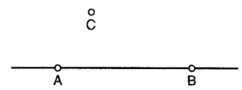
Lesson 2.6 • Special Angles on Parallel Lines

In this investigation, you'll discover relationships among the angles formed when you intersect parallel lines with a third line called a **transversal.**

Investigation 1: Which Angles Are Congruent?

Sketch

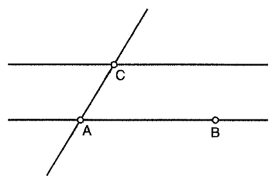
Step 1 In a new sketch, construct $\overleftrightarrow{AB}$ and point *C*, not on $\overleftrightarrow{AB}$.



Step 1

Step 2 Construct a line parallel to $\overleftrightarrow{AB}$ through point *C*.

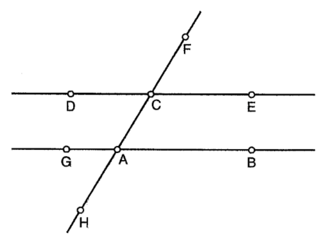
Step 3 Construct $\overleftrightarrow{AC}$. Drag points *C* and *A* to make sure you attached the three lines correctly.



Steps 2 and 3

Step 4 Construct points *D, E, F, G,* and *H* as shown.

Step 5 Measure the eight angles in your figure. (Remember that to measure angles you need to select three points on the angle, making sure the middle point is always the vertex.)



Step 4

Investigate

1. When two parallel lines are cut by a transversal, the pairs of angles formed have specific names and properties. Drag point *A* or *B* and determine which angles stay congruent. Also drag the transversal $\overleftrightarrow{AC}$. Describe how many of the eight angles you measured appear to be always congruent.

2. Angles *FCE* and *CAB* are a pair of **corresponding angles.**

a. List all the pairs of corresponding angles in your construction.

b. Write a conjecture describing what you observe about corresponding angles (CA Conjecture).

3. Angles *ECA* and *CAG* are a pair of **alternate interior angles.**

a. List all the pairs of alternate interior angles in your construction.

b. Write a conjecture describing what you observe about alternate interior angles (AIA Conjecture).

(continued)

Lesson 2.6 • Special Angles on Parallel Lines (continued)

4. Angles *FCE* and *HAG* are a pair of **alternate exterior angles.**
   a. List all the pairs of alternate exterior angles in your construction.
   b. Write a conjecture describing what you observe about alternate exterior angles (AEA Conjecture).
5. Combine the three conjectures you made in Questions 2–4 into a single conjecture about parallel lines that are cut by a transversal (Parallel Lines Conjecture).
6. Suppose, in a similar sketch, all you knew was that the angle pairs described above had the properties you observed. Would you be sure that the original pair of lines were parallel? Try to answer this question first without using the computer.

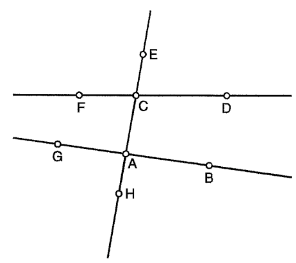
Investigation 2: Is the Converse True?

Sketch

Step 1 Draw two lines that are not quite parallel. Intersect both lines with a transversal.

Step 2 Measure all eight angles formed by the three lines. Add points if you need them.

Step 3 Move the lines until the pairs of angles match the conjectures you made in the previous investigation.

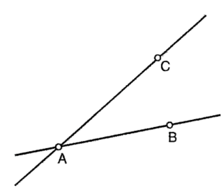


Investigate

1. Lines with equal slopes are parallel. To check if your lines are parallel, measure their slopes. Write a new conjecture summarizing your conclusions (Converse of the Parallel Lines Conjecture).

EXPLORE MORE

1. Angles *ECA* and *BAC* in Step 4 in Investigation 1 are sometimes called **consecutive interior angles.** In a new sketch, find all pairs of consecutive interior angles and make a conjecture describing their relationship.
2. Angles *FCD* and *HAG* in that same figure are sometimes called **consecutive exterior angles.** Find pairs of consecutive exterior angles in the figure and make a conjecture describing their relationship.
3. You can use the Converse of the Parallel Lines Conjecture to construct parallel lines. Construct a pair of intersecting lines $\overleftrightarrow{AB}$ and $\overleftrightarrow{AC}$ as shown. Select, in order, points *C*, *A*, and *B*, and choose **Mark Angle** from the Transform menu. Double-click point *C* to mark it as a center for rotation. You figure out the rest. Explain why this works.

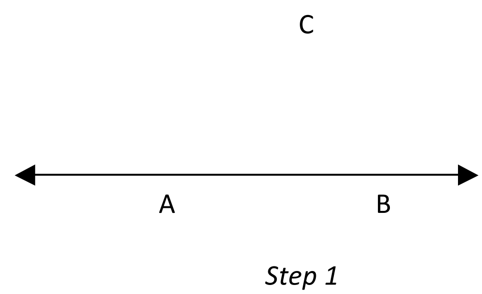
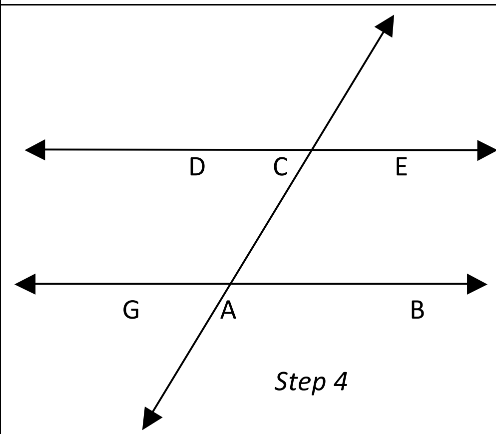


APPENDIX B

Lesson 2.6 Special Angles on Parallel Lines *(Modified)*

Objective: Discovering relationships among the angles formed when parallel lines are intersected with a third line called a transversal.

INVESTIGATION 1: Which Angles are Congruent?

<table>
<tr><th colspan="3">SKETCH</th></tr>
<tr><td>Step 1</td><td>In a new sketch, construct line AB and point C, not on line AB.</td><td rowspan="3">
</td></tr>
<tr><td>Step 2</td><td>Construct a line parallel to line AB through point C.</td></tr>
<tr><td>Step 3</td><td>Construct line AC.
Line AC is called a
____
Drag points A and C to confirm that you attached the three lines correctly.</td></tr>
<tr><td>Step 4</td><td>Construct points D, E, F, G, and H as shown.</td><td rowspan="2">
</td></tr>
<tr><td>Step 5</td><td>Measure the eight angles in your figure. Use the diagram on the right to record your measurements. (Remember that to measure angles you need to select three points on the angle, making sure that the middle point is always the vertex.)</td></tr>
</table>

DEFINITIONS Define in words or by diagram each of the following:		
PARALLEL	TRANSVERSAL	CONJECTURE

Which other words have you encountered that are new or unfamiliar to you?

<table>
<tr><th colspan="3">INVESTIGATION 1 (Continued)</th></tr>
<tr><td>Step 1</td><td>• When two parallel lines are cut by a transversal, the pairs of angles formed have specific NAMES and PROPERTIES.
• Using your sketch, drag point A or B and determine which angles stay congruent.
• Drag the transversal, line AC.</td><td>Describe how many of the eight angles you measured appear to ALWAYS be congruent.</td></tr>
<tr><td rowspan="3">Step 2</td><td>• Angles FCE and CAB are a pair of CORRESPONDING angles.

• Make a sketch below, marking the corresponding angles with identical tick marks.</td><td>List all the pairs of corresponding angles in your construction.

How many pairs of corresponding angles did you come up with?

Check with your partner to confirm your answer.</td></tr>
<tr><td colspan="2">Make a conjecture describing the relationship about corresponding angles.

If two parallel lines are cut by a transversal,
then the corresponding angles are ______________________________</td></tr>
<tr><td colspan="2">Make a conjecture describing the relationship about alternate interior angles.

If two parallel lines are cut by a transversal,
then the alternate interior angles are ____________________________</td></tr>
<tr><td rowspan="2">Step 3</td><td>• Angles ECA and CAG are a pair of ALTERNATE INTERIOR angles.
• Make a sketch below, marking the alternate interior angles with identical tick marks.</td><td>List all the pairs of alternate interior angles in your construction.

How many pairs of alternate interior angles did you come up with?

Check with your partner to confirm your answer.</td></tr>
<tr><td colspan="2">Make a conjecture describing the relationship about alternate interior angles.

If two parallel lines are cut by a transversal,

then the alternate interior angles are _______________________________</td></tr>
</table>

<table>
<tr><td rowspan="2">Step 4</td><td>• Angles FCE and HAG are a pair of ALTERNATE EXTERIOR angles.
• Make a sketch below, marking the alternate exterior angles with identical tick marks.</td><td>List all the pairs of alternate exterior angles in your construction.

How many pairs of alternate exterior angles did you come up with?

Check with your partner to confirm your answer.</td></tr>
<tr><td colspan="2">Make a conjecture describing the relationship about alternate exterior angles.

If two parallel lines are cut by a transversal,
then the alternate exterior angles are ______________________________</td></tr>
<tr><td>Step 5</td><td colspan="2">Combine the three conjectures you made in steps 2-4 into a single conjecture about parallel lines that are cut by a transversal.

It two _____________________ lines are cut by a transversal,
Then every pair of ___________________________________ angles,
___________________________________ angles,
and ___________________________________ angles,
are ______________________________.</td></tr>
<tr><td>Step 6</td><td colspan="2">EXTENSION

What happens if you have three lines cut by a transversal?

Make a sketch below, and mark congruent angles.</td></tr>
</table>

Note: Lesson is teacher modified version of Lesson 2.6 (KCP, 2001).

APPENDIX C

STUDENT INVENTORY

____

Last Name First Name Preferred Name

Birthdate: __________ Grade: 10 11 12 Junior High School: ________________

Parent/Guardian Information				
Name	Best Phone #	Best Time to call	Additional Information	Other phone #s (email)

Who else lives at home? (Name and Relationship) Is there another language spoken at home?

Do you have access to the internet? YES NO

Do you have access to a graphing calculator? YES NO

Do you ride a bus to school? YES NO

What grade do you expect from this class? A B C F

Do you work better [A] alone [B] with a partner [C] in a group

Are you comfortable asking questions in class when you are having difficulty understanding? YES NO

When do you usually do your homework (time of day) and where are you usually when you do it (bedroom, kitchen, school, on the bus, etc.)?

What activities are you involved with (or hope to do) in and out of school?
This may also include jobs, church activities, family obligations, etc.

What are your future goals? What are you planning to do after high school? What do you anticipate that your life will look like in 10 years from now?

Student Inventory *(continued)*

In math class, do you prefer to work with other students or by yourself?
Explain.

Do you consider yourself good at math? Explain.

Tell me about the time you felt the most successful as a student.

What is one thing that I could do to help you succeed in this class?

APPENDIX D

Student Daily Log

Student Daily Log

Name: Date:

Objective:

Warm-Up (write the problem, show the work, label answer):

The one thing that I would like Mrs. Wilson to know is……

EXIT

My level of understanding of today's math is:

1	2	3	4	5
Clueless	Weak	Ok	Good	Excellent
I need to study or focus more (attend tutoring sessions, see teacher)	I need to ask questions, re-do the problems that were done in class.	I have most of the concepts; just need a little more practice.	I get it!	I am prepared to take quiz on the today's lesson.

1. What is 1 thing you learned today?

2. What is 1 thing you want to know more about?

3. What is 1 question you still have?

Note: Quarter slips of paper (front/back) that students turned in at the end of each class period to provide feedback to the teacher.

APPENDIX E

STUDENT PERCEPTIONS REGARDING GEOMETER'S SKETCHPAD

Geometers' Sketchpad (GSP) in the Computer Lab

Using the scale below, mark each of the following statements:

[A] Strongly Disagree [B] Disagree [C] Neutral [D] Agree [E] Strongly Agree

A B C D E 1. I was comfortable Geometers' Sketchpad.

A B C D E 2. Geometers' Sketchpad helped me visualize objects.

A B C D E 3. There are many technical difficulties when I use Geometers' Sketchpad.

A B C D E 4. I like learning about geometry using Geometers' Sketchpad.

A B C D E 5. I avoid doing the Geometers' Sketchpad activities.

A B C D E 6. I would like to work more with geometers' sketchpad.

A B C D E 7. I thought Geometers' Sketchpad was a waste of time.

A B C D E 8. I was always confused when using Geometers' Sketchpad.

A B C D E 9. I think that using Geometers' Sketchpad helps my grade.

A B C D E 10. I would like the class to continue going to the computer lab, and using Geometers' Sketchpad.

A B C D E 11. Learning to use GSP was easy for me

A B C D E 12. I find it easy to get the GSP program to do what I want to do

On the back of this survey, please write additional comments about Geometers' Sketchpad.

APPENDIX F

Reflecting on GSP lessons at RHS by Mr. Euclid

[Week 1] Lesson Objective or Purpose:

Explore the use of GSP
Review of Geometry concepts: Radius, Diameter, Circumference, Intersection
Become Familiar with Menu of GSP to use as a tool for learning
GSP operates on the Definitions and Postulates of Geometry.
Work in a cooperative manner

I felt there was more initial interest in the activity this year, compared to last year, with the PowerPoint about cathedral windows and the comparison of the Cathedral to the Seattle Space needle. The activity seemed to have an anchor. The students seemed to catch on quickly during the basic introduction to using the menus and tools. Allowing some free exploration time after the introduction is a smart move. I announced an amount of free exploration time, and that we would need students' attention after that to start the next activity.

That next activity, Daisy Wheels, required the students to follow instructions and to address questions about their work. I did not do the follow up, so I am not sure about the overall impact. During questioning about Radius, Diameter, etc., some students were able to respond with justification. Students were discussing and sharing strategies to solve image issues such as true intersections which connect the dimensions of figures. Most students were able to follow the instructions. Eventually I think we had 100% engagement.

I think having two teachers present made the lesson format possible. In the regular classroom I might have done a demo on using menus and tool as preparation for the lab session.

[Week 2] Lesson Objective or Purpose:
Explore the use of GSP
Geometry concepts: Vertical Angles, Vertical angles conjecture, Linear Pair Conjecture
Become Familiar with Menu of GSP to use as a tool for learning
GSP operates on the Definitions and Postulates of Geometry.
Work in a cooperative manner

Evidence of Success:
Able to follow the written instructions
Develop conjectures, Test, and Justify
Can express that GSP operates on the Definitions and Postulates of Geometry.

The lesson required greater focus on concepts of geometry. Maybe some vocabulary was not developed yet. The lesson seemed to take more effort to get the students moving on the work. Again there was good math discussion between student neighbors as they worked through the task. This lab should have had more closure and that would have been a plan for the next day. I think students will adapt to using GSP as a "serious" learning tool that can be fun to use, rather than just a fun diversion.

APPENDIX G

Visual Engagement

What are the students observing?	Implication	Alternative Implications
The computer	• The student was working at a computer or collaborating with a classmate.	• The student was not using GSP on the computer.
Worksheet	• The student was focused on the accomplishing the task by reading the worksheet or writing on the worksheet.	• The student was looking at the paper; but not focusing on the task.
The teacher, the white board in front of the classroom, or the overhead screen.	• The student was seeking additional instruction or clarification.	• The student was seeing if the teacher was occupied elsewhere.
A classmate	• The student was collaborating with a classmate related to GSP.	• The student was visiting with another student unrelated to GSP.
Other (V)	• The student was looking at a calculator or other math resources.	• The student was looking at the clock.

APPENDIX H

Kinesthetic Engagement

What was the student doing?	Implication	Alternative Implications
Computer Interaction Student's hand was placed upon a computer mouse, or the student was pointing to a computer screen.	• The student was working at a computer or collaborating with a classmate.	• The student was not using GSP on the computer.
Worksheet Student's hand was either holding or resting on the worksheet associated with the lesson. This also included students using paper or math textbook resources.	• The student was focused on the accomplishing the task.	• The student was just holding a sheet of paper. The paper might be used for an activity unrelated to GSP. • Making paper airplanes would fit this description.
The student was holding a writing utensil.	• The student was working on the worksheet associated with the lesson.	• The student was poking other students with a writing utensil. • The student was writing unrelated to the lesson.
Raised hand.	• The student was seeking additional instruction or clarification related to the task.	• Signaling another student across the classroom. • Asking for a hall pass.
Other (K)	• The student using a calculator. • A student was sitting with his or her arms crossed; or their hands resting on their face/head.	• The student was holding hands with another student. • The student was out of their seat. • Holding a cell phone.

APPENDIX I

STUDENT TALK

Lesson: Date:
Objective: Source: Field Notes Video

Student Talk Codes:
1 Mechanics of GSP
2 Terminologies
3 Instruction Clarifications
(T – teacher, W – worksheet)
4 Geometry Concepts, Properties, Conjectures
5 Other

Student	Comment	Student Talk
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5
		1 2 3 4 5

Comment Code: (S) comment made to another student, (T) comment made to teacher, (X) comment made to self

APPENDIX J

Lesson 2.6 Questionnaire

1. Three things that I learned in class today are:
   a.
   b.
   c.

2. Did I find today's class interesting?

1	2	3	4	5
Not Interesting		Okay		Very Interesting

3. If I had a quiz on what I learned in class today, how well would I do?

1	2	3	4	5
My quiz would be blank	I would get most of the problems wrong	I would get some problems wrong	Make minor errors	Extremely Well

4. I thought today's worksheet lesson using GSP was…

1	2	3	4	5
Easy		Okay		Difficult

5. I would rate today's lesson in class as…

1	2	3	4	5
I hated it!		Okay		I enjoyed it!

6. I prefer learning concepts using GSP? YES NO

7. One thing I liked about today's class…..

8. One thing I did not like about today's class is…

APPENDIX K

High Schools That Work (HSTW)

Key Practices --- High Schools That Work

1. High expectations: Motivate more students to meet high expectations by integrating high expectations into classroom practices and giving students frequent feedback.
2. Program of study: Require each student to complete an upgraded academic core and a concentration.
3. Academic studies: Teach more students the essential concepts of the college-preparatory curriculum by encouraging them to apply academic content and skills to real-world problems and projects.
4. Career/technical studies: Provide more students access to intellectually challenging career/technical studies in high-demand fields that emphasize the higher-level mathematics, science, literacy and problem-solving skills needed in the workplace and in further education.
5. Work-based learning: Enable students and their parents to choose from programs that integrate challenging high school studies and work-based learning and are planned by educators, employers and students.
6. Teachers working together: Provide teams of teachers from several disciplines the time and support to work together to help students succeed in challenging academic and career/technical studies. Integrate reading, writing and speaking as strategies for learning into all parts of the curriculum and integrate mathematics into science and career/technical classrooms.
7. Students actively engaged: Engage students in academic and career/technical classrooms in rigorous and challenging proficient-level assignments using research-based instructional strategies and technology.
8. Guidance: Involve students and their parents in a guidance and advisement system that develops positive relationships and ensures completion of an accelerated program of study with an academic or career/technical concentration. Provide each student with the same mentor throughout high school to assist with setting goals, selecting courses, reviewing the student's progress and suggesting appropriate interventions as necessary.
9. Extra help: Provide a structure system of extra help to assist students in completing accelerated programs of study with high-level academic and technical content.
10. Culture of continuous improvement: Use student assessment and program evaluation data to continuously improve school culture, organization, management, curriculum and instruction to advance student learning.

Presentation: Taking the Key Practices to the Next Level, Bethel High School, Friday, August 27, 2010
Heather Boggs Sass, PhD 6155 Maxton Place, Worthington, Ohio 43085 614-847-5832
Heather.sass@sreb.org

APPENDIX L

STUDENT SURVEY QUESTIONS REGARDING COMPUTER BACKGROUND

Using the scale below, mark each of the following statements:

[A] Strongly Disagree [B] Disagree [C] Neutral [D] Agree [E] Strongly Agree

A B C D E 1. I use computers as part of my classes.

A B C D E 2. I use a computer as a word processing tool.

A B C D E 3. I like to play animation games on the computer.

A B C D E 4. I use a computer for things other than word processing or games.

A B C D E 5. I have access to a computer at home.

.

APPENDIX M

Computer Lab Day 4 Exit Question and Sample Responses

GSP Experience	No 1	No Opinion 3	Yes 5	M	SD
1. Was the class interesting?	1	5	2	3.2	1.1
2. If I was to take a quiz, I would pass.	3	3	2	2.75	1.6
3. The worksheet lesson was difficult.	4	3	1	2.25	1.4
4. Liked learning using GSP	3	2	3	3.0	1.7

Note: To retain validity of the data, all class data was used rather than subcategories due to minimal data response. Scores were reported using a Likert 1-5 Scale.

Free Response Question	%
1. What was the best thing about today's class?	
Constructing angles	38%
I actually learned.	13%
Being on the computer.	38%
It is important to pay attention.	13%
2. What I didn't like about the class was…	
Exploration II	25%
Interpreting questions	50%
Nothing, I like it all	25%

APPENDIX N

Day 2 Exit Question and Sample Responses

After the second visit to the computer lab, the students were asked to describe their experience with GSP. Despite some technical difficulties, the responses below indicate that students were engaged in the lesson.

Abigail: *"The geometry sketch pad is going ok. I'm having a difficult time trying to use the computer. I want to learn how to use it more."*

Adam: *"This is going pretty good. need to know more about vocab. and to find out about angles and what the buttons mean."*

Caleb: "*So far geometry sketch pad is going very well so far. It is pretty easy to understand. I would like to know more about sketch pad."*

Chloe: "*This is hard. I want to know what to do with this*."

Danica: "*everything is going fine don't really want to know anything more"*

Ethan: *""Gemetry sketchpad is going fine. Its pretty easy. I have no problems with it. I don't really have anything I want to know more about."*

Girl: *"Geometry sketch pad is going good. I like using it. It makes geometry easier for me cause I get a visual."*

Kelly: *"everything is going good. Ive learned a lot circles segments"*

Madison: *"The Geometry sketch pad is going good for me. I'm confident about figuring out the measurements of the angles. One thing I need to work on is remembering to label the points."*

Ryan: "Its going well the only thing I am having trouble is that when you calculate things you have to click it individually instead of having both clicked."

Unknown #1: "*Geometry sketch is going good and bad, because i can do most of the lessons but i tend to get stuck or mess up a lot, and i would like to know more about constructing points."*

Unknown #2: *"In the geometry sketchpad I get it-maybe it takes a little time but I get it. I cant get how to change the lines! I want to know what the point is!"*

Trent: *"I think it is going good. There should be more toolbar tools that way you don't have to go looking for stuff."*

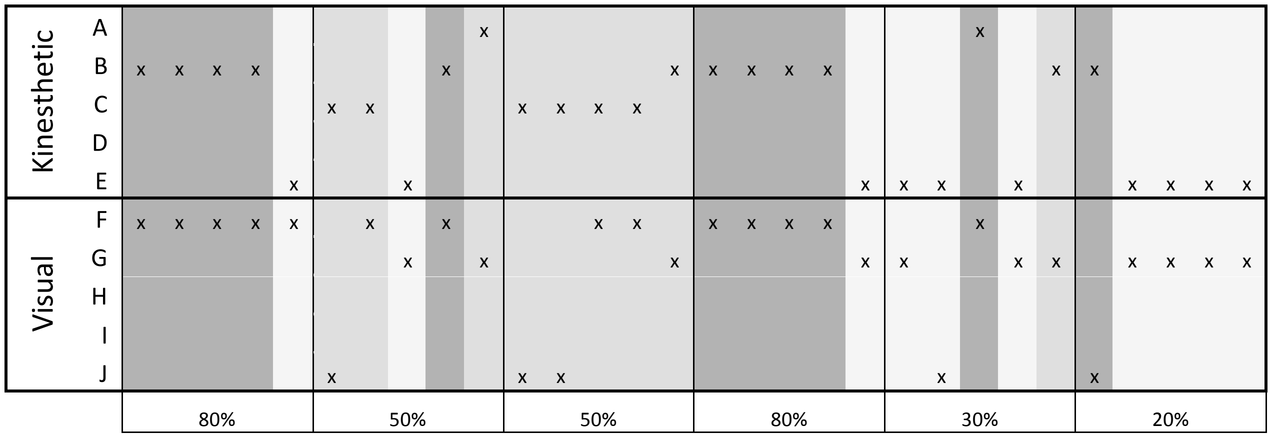
Zoe: *"I think I am doing ok. It's pretty fun but some things are confusing like conjectures."*

Note: The student responses were copied as the students had written them down on paper. Several students did not write their name down on the paper; these students are recorded as *unknown*. Pseudonyms have been used for students' names.

APPENDIX O

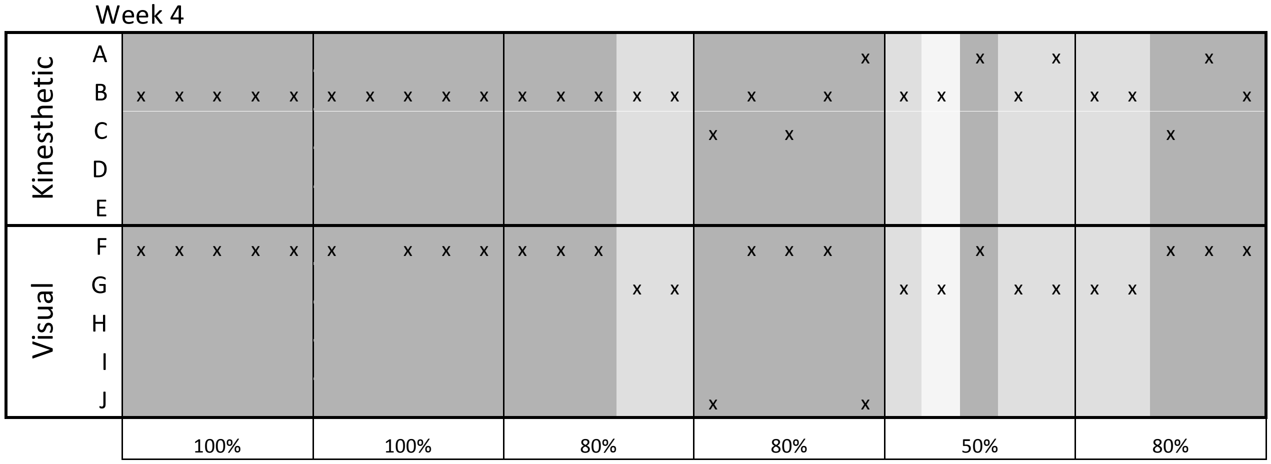
Behavioral Engagement Coding: Sample Student

Week 3



Percentage of time student was engaged in 5 minute intervals.*

Week 4



Percentage of time student was engaged in 5 minute intervals.*

Behaviorally Engaged | Engagement Undetermined | Not Engaged

*Percentages were calculated by giving a score of: 2 points - Behaviorally Engaged, 1 point - Engagement . Undetermined, and 0 points - Not Engaged. Engagement percentage was calculated for each 5 minute interval by dividing the points acquire by the points possible (10).

Kinesthetic

A Student was holding worksheet.
B Student was using computer.
C Student was holding a pen or pencil.

Visual

F Student was looking at computer.
G Student was looking at another student.
H Student was looking elsewhere.

D Student had hand up to ask a question.
E Other
I Student was looking at teacher.
J Student was looking at worksheet.

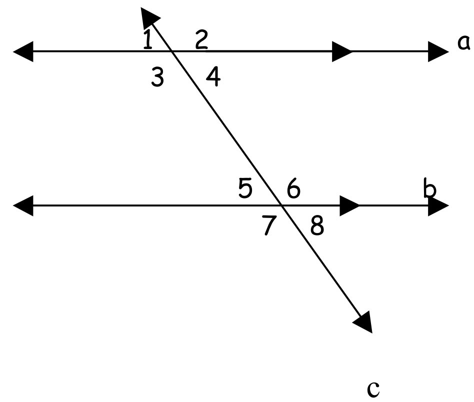
APPENDIX P

Pre and Post Test Sample Questions

PRE-TEST

Use the diagram at rig

1. If m∠2 = 50°, then m∠7 = ______

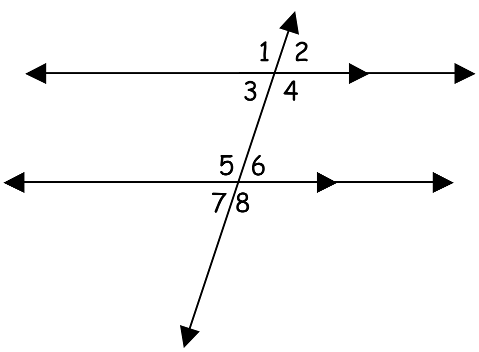


2. If m∠2 = 90°, then line b and c are?

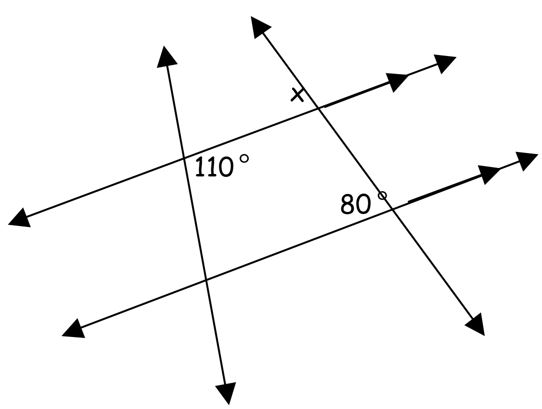
3. ∠1 and ∠5 are known as ________________________________ angles.

POST-TEST

1. Using the diagram at right,
State the relationship between angles 1 and 5:



2. Solve for x.



APPENDIX Q

Applying Lewinian Experiential Learning Model to GSP Lesson Implementation[8]

CONCRETE EXPERIENCE	REFLECTION Lesson Implementation		PLAN of action *(implemented the next week)*
WEEK	Positive	Concerns	
1 Introduction Level of Implementation *Entry* level- teachers frequently found that they were unable to anticipate problems in their classrooms.	2 teachers available: • address student concerns • relieved frustrations Students were able to work independently on lesson Students sought advice from one another.	2 teachers not always a possibility Lack of space on worksheet for student response	Invite Mr. Euclid to week 2 Rewrite student worksheet
	Interacting with student increased name familiarity	Early in school year, did not know all student names	Continue working with individual students
	(A) Affectively Engaged • Excited animating constructions (B) Behaviorally Engaged • Students were on-task. (C) Cognitively Engaged as exhibited by • student talk • student collaboration about the task and GSP • questions asked of instructors	Absent students.	Assign absent student a study buddy.

[8] Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005; Means & Olson, 1994

<table>
<tr><th>CONCRETE EXPERIENCE</th><th colspan="2">REFLECTION
Lesson Implementation</th><th rowspan="2">PLAN of action
(implemented the next week)</th></tr>
<tr><th>WEEK</th><th>Positive</th><th>Concerns</th></tr>
<tr><td rowspan="4">2

Lesson
2.5
Lines & Angles

Level of Implementation

Entry level- teachers frequently found that they were unable to anticipate problems in their classrooms.</td><td rowspan="4">2 teachers available:
1) address student concerns
2) relieve frustrations

(A) Affectively Engaged
• Excited about returning to the computer lab.

(B) Behaviorally Engaged
• Students were on-task.

(C) Cognitively Engaged as exhibited by
• student talk
• student collaboration about the task and GSP
• student looking up terminology in glossary
questions asked of instructors</td><td>2 teachers not always a possibility</td><td>Request a student teacher assistant (peer tutor) to assist students with technical difficulties. Encourage students to ask one another questions.</td></tr>
<tr><td rowspan="3">Affectively & behaviorally engaged until encountered new terminology:
conjecture

Lack of board space to create a word wall.

The concepts of the lesson had previously been discussed in class.</td><td>Create word wall.
Discuss bringing in white board for student use.
Highlight words for future computer lab sessions; introduce terminology prior to lesson activity.</td></tr>
<tr><td>Have students create a GSP notebook with lesson notes, student conjectures, and glossary.</td></tr>
<tr><td>Review lesson objectives and new ideas/terminology at the end of class.
“Math Congress”

Alignment of curriculum and computer lab needs to correlate either by (1) adjusting lesson plans or bringing GSP into the classroom as part of a whole class lesson or (2) individual laptops.</td></tr>
<tr><td>3
Lesson 2.6 A

Level of Implementation

Adoption level- teachers delivered teacher-centered lessons but also began to anticipate problems and develop strategies for solving them.</td><td>(A) Affectively Engaged
• Excited about returning to the computer lab.

(B) Behaviorally Engaged
• Students were on-task until they encountered difficulties approximately 20 minutes into task

(C) Cognitively Engaged as exhibited by
• student talk
• student collaboration about the task and GSP
• task related questions asked of instructor</td><td>Only 1 instructor, many students had questions, concerns, or needed positive reinforcement.

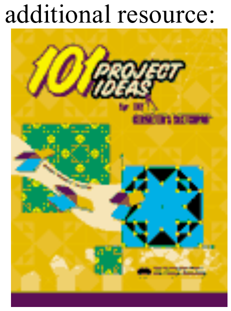
When students had questions, they would raise their hand and not continue with the task.

Students struggled with the words “alternate” and “consecutive”.</td><td>Need to encourage students to answer each other questions.

Implement red/green cups as a means of students indicating that they had questions without having to keep their hand raised so that they may examine alternative solutions on computer.

Revise lesson plan modeling the construction with the class. Will also as a review for students that were absent.</td></tr>
</table>

CONCRETE EXPERIENCE	**REFLECTION**		**PLAN of action** ***(implemented the next week)***
	Lesson Implementation		
WEEK	Positive	Concerns	
4 Lesson 2.6A Revisited Level of Implementation *Adaptation level* - teachers started using technology to their advantage and began to embrace pupil-centered orientations	(A) Affectively Engaged • Exit slips indicated that the students enjoyed using the dynamic capabilities rather than the construction capabilities. (B) Behaviorally Engaged • Students were on-task. (C) Cognitively Engaged as exhibited by • student talk • student collaboration about the task and GSP • questions asked of instructor	Going through the construction process with the students, provided GSP lesson review and additional scaffolding for the task. Students need to be challenged more about their conjectures and provided opportunities to see the purpose of the conjecture in the "real world".	Modify task to promote higher levels of cognitive demand and/or student exploration by posing additional questions.
5 Lesson 2.6B Level of Implementation *Appropriation* teachers' personal attitudes to technology changed to confident expert and willing learner.	(A) Affectively Engaged • Excited about returning to the computer lab. (B) Behaviorally Engaged • Students were on-task. (C) Cognitively Engaged as exhibited by • student talk • student collaboration about the task and GSP • questions asked of instructor		
6 Lesson Extension Level of Implementation *Invention* teachers were disposed to view learning as an active, creative and social process.	(A) Affectively Engaged • Excited about returning to the computer lab as indicated by comments in the class the day before.	Power Outage…No School • Unable to schedule computer lab for another 2 weeks.	Decided to use the lesson extension as part of student interviews. Task/Activity checks Journal entries Exit slips Discussion Participation Projects
CONCRETE	**REFLECTION**		**PLAN of action**

EXPERIENCE	Lesson Implementation		***(implemented the next week)***
WEEK	Positive	Concerns	
Summary Computer Lab	(A) Affectively Engaged • Excited being in computer lab. • Exit slips (B) Behaviorally Engaged • Students were on-task until their GSP constructions were not moving like those of their neighbors (though there were several attempts to make corrections) (C) Cognitively Engaged as exhibited by • student talk • student collaboration about the task and GSP • responses to questions asked of teacher • questions being asked to the instructor Utilization of dynamic capabilities of GSP promotes visualization skills.	Need reference manual for students - GSP construction difficulties. Identify potential pitfalls for students whether it is vocabulary, direction clarification, or misconceptions of lesson objectives. Need a means for students to self-assess their understanding. Difficulty maneuvering in the computer lab to access all students. Need white boards to clarify instructions, vocabulary, and student questions. Need white board to post daily objective and task (particularly as a student reference for students who arrive late to class). Suggest interactive white board for students to model an activity using GSP as part of a whole class discussion. Have a class set of lap tops available for use when unable to access computer lab. Unable to collect student work due to printer limitations.	Recommend students creating a reference manual (may be a separate notebook or a section of a binder) for GSP instructions and notes. Have student journal about their GSP experience, by explaining their procedure for constructing…. Have additional video of demonstration activities. Provide opportunities for additional GSP practice by having software program installed on library computers. Have students created an animation project and present to class that incorporates a variety of geometric concepts/properties. Utilize the book as additional resource:  *101 Project Ideas for The Geometer's Sketchpad* (KCP, 2001). Investigate possibility of online classroom folder….might be time-consuming.

Dwyer, Ringstaff, & Sandholtz, 1991; Juersivich, Garofalo, & Fraser, 2009; Foo, Ho, & Hedberg, 2005; Means & Olson, 1994.

APPENDIX R

Notes: Geometer's Sketchpad lesson in the *Discovering Geometry* Teacher's kit (KCP, 2001).

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APPENDIX S

Computers and GSP Perception Survey Results (Gender)

Enjoys Using the Computer and Student Perception of Geometer's Sketchpad

GSP Experience	Girls n= 9	Boys n= 8	Total n= 15
1. Comfortable using GSP	56%	50%	53%
2. GSP helped with visualization	33%	67%	47%
3. Had technical difficulties	22%	17%	20%
4. Liked learning using GSP	33%	60%	47%
5. Avoided doing GSP activities	22%	0%	13%
6. GSP was a waste of time	0%	0%	0%
7. GSP activities helps grade	33%	17%	27%
8. Liked to continue working with GSP	44%	50%	47%
9. Likes instruction with GSP	11%	50%	27%
10. Pays more attention with GSP	22%	67%	40%

Note: Some percentages do not add to 100% due a neutral option on the survey.

APPENDIX T

Field Notes Summary
Regarding GSP Implementation

	Liked	Frustrating	Further Exploration
GSP	• Dynamic capabilities of program • Students were engaged • Helped students with visualization	• Lack of construction reference material • Constructions • Lack of inquiry materials • Lack of teacher implementation materials • Students were only able to access during lab time-no opportunity for additional practice on own	• Sketchpad LessonLink • Dynamic software availability online • Having constructions premade (at least initially) so that students may focus on the dynamic attributes of the software
Lesson Implementation	• 2 teachers	• Worksheet lessons led to student errors, and misconceptions • Additional scaffolding needed	• Having students create a glossary • Modify lesson instructions
Computer Lab	• Students had individual computers • Teacher computer with projection screen	• Not meant for teaching: no boards, wall space • Difficult to maneuver among computers • Lessons did not always correlate to scheduled computer lab time • Power outage… unexpected loss of computer lab time	• Interactive white board • White board • Bulletin board • Use computer lab for projects rather than lesson investigations
Classroom	• Able to teach to the moment	• 1 class computer that served multiple purposes: attendance, grade checks	• Interactive white boards • Laptops in the classroom • Lesson investigations