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Eagle Vision : new directions in K-12 GIS

Cody Wiley

Cody J. Wiley
Candidate

Geography
Department

This thesis is approved, and it is acceptable in quality and form for publication on microfilm:

Approved by the Thesis Committee:

, Chairperson

Accepted:

Dean, Graduate School

Eagle Vision: New Directions in K – 12 GIS

BY

CODY J. WILEY

A.S., Engineering Technology, New Mexico State University, 1991
B.A., Philosophy, New Mexico State University, 1991

THESIS

Submitted in Partial Fulfillment of the
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ABSTRACT

Eagle Vision is an NSF-funded three-year project that instructs High School teachers working in tribal schools in GIS and GIT, and in GIS-based curriculum design. Integration of GIS into the secondary level classroom has faced many barriers, and despite extensive efforts on the part of Eagle Vision to circumvent these hurdles, many of them appeared. Furthermore, an additional problem regarding spatial literacy became apparent. Overall, however, the program was successful in increasing use of GIS and GIT, and provided crucial information that will help improve teacher professional training in the area of GIS.

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CHAPTER ONE: INTRODUCTION

The call to incorporate Information Technologies (IT), including Geographic Information Systems (GIS) or the somewhat broader Geographic Information Technologies (GIT), into K-12 education in a meaningful way is growing, driven primarily by the explosive growth in applications. The rapidly increasing workforce needs of businesses require more students prepared for GIT careers. GIT is an increasingly important component of a variety of careers in the public and private sectors, including but not limited to the environmental and natural sciences, and urban and regional planning. Government agencies also see the need to maintain competitiveness in the Science, Technology, Engineering and Math (STEM) disciplines for which they provide research funding. In science, GIT is diffusing into disciplines ranging from Anthropology to Zoology, as researchers use technology to gather data, track wildlife, analyze patterns, model systems and more. In short, many groups in these sectors, from government agencies to private corporations are increasing their use of GIT for management of public and business resources.

Incorporating GIT into the classroom will prepare the students for these careers as they learn the technology. The integration of GIS into public education is also seen as an aid to the larger movement towards a hands-on method of scientific education known as problem-based learning (PBL) or inquiry-based science (IBS). Theoretically, the students would not only learn the technology, but also scientific methodology, critical thinking skills and other valuable skills for an information age.

Despite a national level awareness of the institutional importance of GIT and the increasing relevance of GIT to vocational pathways, multiple barriers to implementation in the secondary educational system result in very low use of GIT in mid- and high-school level classrooms. These barriers have been well documented by a growing body of literature, particularly those related to the steep learning curve of GIS. Yet other barriers, in particular the low levels of spatial literacy which hamper use of GIS – and which can lead to accidental misuse of GIS as well – have been insufficiently addressed given the push to implement this technology.

Until recently, with the publication of the National Research Council (NRC) report, “Learning to Think Spatially” (NRC 2006) there has been little discussion of the justifications underlying the implementation of complex, professional level GIS in the classroom. How best to do this remains to be further researched. Additionally, the use of the PBL system is not well supported. Finally, in the rush to remove the documented barriers, an almost entirely hidden barrier, the lack of spatial literacy required to use the GIT appropriately, may go unnoticed.

One program with the goal of learning how to better integrate IT into the K-12 system is the National Science Foundation (NSF) funded Information Technology Experiences for Students and Teachers (ITEST) program. ITEST provides three years of funding to pilot projects that explore novel methods of creating student-centered, community-based IT learning environments in the secondary schools and during after-school hours. Each ITEST project is categorized as either Youth-based (serving only secondary-age youth) or Comprehensive (providing professional development for teachers in addition to the youth component). ITEST currently has four funded cohorts of 72 projects. Included in these ITEST cohorts are approximately 20 groups that use GIT in their projects to various degrees. Some of these are primarily based on GIS.

One such project is Eagle Vision (EV), a comprehensive Cohort Two ITEST program that works with teachers and students in tribal high schools. This program aims to pole-vault the teacher participants over the learning curve high bar, while circumventing some of the other barriers that occur with GIS implementation. Furthermore, it aims to provide basic spatial literacy to the educators, so that they will be prepared to use the software at an appropriate level and in a sound manner.

Designed to keep the same teacher cohort for the entire three-year period, EV lead the teachers from classes in traditional basic GIS to the preferred PBL-GIS and some data analysis. An unexpected challenge and opportunity came when the program had to bring in new teachers the second year to join returning teachers, due to recruitment difficulties and attrition. New teachers were given an online course to catch-up with the returning teachers, and so were able to successfully join in the PBL environment.

This lead to two basic problems to be explored in this research: whether EV will circumvent barriers, allowing teachers to fully implement GIS and whether Web-based instruction can accelerate the process of getting teachers past the learning / teaching about GIS stage to the using / teaching with GIS stage.

The two problems lead to three hypotheses in the context of the EV program. First, that EV will circumvent barriers, allowing teachers to fully implement GIS in their curriculum. Second, that the new teachers who used the online course will have equivalent skills and efficacy as the returning teachers who had a primarily traditional style GIS course the first year. Third, that both groups would be at equal levels of GIS implementation in their classrooms.

The following chapters review previous research into the benefits of and barriers to GIS in secondary education, and draw attention to the need for spatial literacy in GIS use. The Eagle Vision project is discussed in detail. Findings to date on this program will be explored, and future plans will be extrapolated.

CHAPTER TWO: RESEARCH IN GIS AND K-12 EDUCATION

A GIS is an integrated software system for the handling of geospatial information (NRC 2006). It is usually considered as a computer based tool for mapping, spatial database manipulation and decision support or analysis. It is also a tool for the "acquisition, editing, storage, transformation, analysis, visualization" or any other task that can be done with geospatial information (NRC 2006). As such, it is often divided into four components: the software used for mapping and data analysis, the hardware (computer) which runs the software, the infrastructure (including data sources and standards) and the user (Chang 2004).

GIS is increasingly becoming a media, "focused on the communication of geographical information" in digital form (Sui and Goodchild 2001). Media are a means of communication, and the end product of GIS is not the software or the database itself, but rather the ability to create ways to communicate the information. Geographical information is also becoming embedded in society, similar to other media. Examples include Web-based map information, Global Positioning Systems (GPS) enabled cell phones, and a growing number of other uses.

A GIS is also part of the Geospatial Technology (GT) sub-domain of Geographic Information Science and Technology (GIS&T), which includes two other sub-domains, Geographic Information Science (GISc) and GIS&T Applications. The GT sub-domain also includes data gathering technologies such as remote sensing, data storage and manipulation including GIS, data analysis and display software, and GPS (DiBiase, DeMers et al. 2006).

The GPS is a GIT consisting of a system of satellites and support systems from which users with a receiver can gather locational and navigational data. These technologies are often interrelated. For example, with a handheld GPS unit, geographic coordinates can be taken and then be imported into a GIS.

GIT is becoming increasingly important to our modern economy. Skills in GIT are necessary in a variety of careers, and have great potential as educational tools. Thus, interest in integration of GIS in K1-12 education is high. The drive to place GIS in the classroom is partly due to the explosive growth of the Applications sub-domain. Research has shown a variety of educational benefits, but along with these, non-trivial barriers to GIS implementation also exist.

Benefits of and Barriers to GIS in K-12 Education

GIT can be incorporated in a wide variety of educational curricula. These include not only STEM subjects, but also humanities and other subjects that are not normally associated with IT. Research has shown a number of benefits of including well-designed GIS programs in pre-college education. These include, but are not limited to, an improvement in student attitudes and motivation, increased focus, and development of higher-level thinking skills (West 2003). Middle-school students in a GIS-PBL environment had improvements in science self-efficacy and technology, and demonstrated a modest improvement in "integrated science process skills, especially data analysis (geographic and mathematical) activities" (Baker and White 2003). Given a set of lessons, students "demonstrated a better ability to synthesize, identify, and describe reasons for human and physical patterns" (Kerski 2003) than those using traditional methods. It also "fostered higher-order analytical and synthetic thinking, and increased students' knowledge of absolute and relative locations of places across the globe" (Kerski 2003).

Importantly, GIS also helps a range of students, including those who may not do as well in traditional settings. It provides a means to stimulate visual learners and to reach nontraditional learners. GIS also helps below-average and average students more than above-average students (Kerski 2003), giving them an opportunity to catch up. Students with "identified special needs" showed improvement in science attitudes and self-efficacy (Baker and White 2003). Also, gender is usually not a factor in performance (Kerski 2003), although male students have been shown to have an improved attitude towards technology and science, and science self-efficacy, while female students did not change on these two measures (Baker and White 2003).

Reasons that educators use GIS are similar. Teachers believe GIS improves teaching and learning environments. Specifics include that GIS "enhances problem solving, enables spatial data analysis, supports interdisciplinary connections, and is enjoyable to students" (Audet and Paris 1997). Many decide to use GIS because "they want their students to understand data, the relationships among data, and to be able to perform spatial analysis with those data" (Kerski 2003). Other often-mentioned reasons include having a specific task that GIS can accomplish, the visual capabilities of GIS, and developing job skills (Kerski 2003). Perceived benefits included the team learning environment and opportunities to partner with the community (Kerski 2003).

Because of the benefits, efforts have been made to include GIS in the K-12 classroom. Nonetheless, research shows that implementation is low. Based on a survey of teachers who bought ESRI ArcView, Idrisi or MapInfo GIS, Kerski (2003) found few secondary schools have GIS (less than five percent) and of that sample, only about half are actually using it, and only 20% of teachers who use GIS use it in more than one lesson plan in more than one class. Additionally, educators using the ArcView software used GIS in more courses and more ways than the IDRISI or MapInfo users. Kerski speculates that this is due to the training and support provided by ESRI, the maker of the ArcGIS software packages, including ArcView.

The range of GIS use is very wide: "those who are using GIS do so in a wide variety of settings, in different degrees, and in many ways, from preparing maps to be used as tests and on overhead projectors, to incorporating it into fieldwork and with global positioning systems" (Kerski 2003). These uses are legitimate, but the mere use of GIS does not imply automatic arrival of the benefits that accrue from GIS integration.

The key to the list of benefits is that they come as part of a *well-designed* GIS lesson plan. This is usually proposed in terms of problem-based learning, inquiry-based science, community-based projects, or student-centered learning, which will be discussed later. As GIS use can range from the low end (e.g. the use for overheads mentioned above, or use for point & click drills) to full integration (e.g. teacher uses the GIS as part of a student-centered, problem-based community project, or inquiry-based science project), only a small percentage of the already low numbers of teacher-users are maximizing the potential for GIS in the classroom, or meeting the goals of those who call for GIT integration.

Kerski's (2003) survey did not indicate a static scenario, however. Given a choice to decrease, maintain, or increase their use of GIS in the upcoming year, nearly three quarters (71.9%, n = 327) of the teachers indicated they would increase their use, and only a small percentage (4.3%) chose to decrease, leaving nearly a quarter (24.7%) who planned to at least maintain their current use. Teachers are very positive about the use of GIS in their teaching, and many are willing to invest the time to make it a success (Kerski 2003).

Who are the teachers using GIS? Veteran science teachers, especially chemistry teachers, who use it most often for water quality studies, comprise the largest single group. In general, many of the respondents are veterans who have been in the field for 20 years or more. Interestingly, science teachers who used GIS outnumbered geography teachers by approximately two to one. Most K-12 educators were introduced to GIS through in-service training opportunities (Kerski 2003). While they have some form of outside training, many are also largely self-taught, and consider their technical and professional development as on-going, as shown in another survey of 95 users of IDRISI and ArcGIS software (Audet and Paris 1997).

In general, adoption of GIS in the classroom remains in the early stage – thus placing teacher-users as innovators on Roger's (Rogers 2004) scale of adoption and diffusion of innovation. The "solitary GIS missionary" stereotype (Audet and Paris 1997) is still the situation in most schools. However, teachers feel positive about the benefits of GIS to their teaching (Kerski 2003), and believe it to be a worthwhile effort (Audet and Paris 1997).

Regardless, integration remains low. In large part, the low integration, and even lower full integration, is due to numerous and significant barriers to implementation. Research is mainly unanimous in naming items on the laundry list of problems. Here they are grouped into four main subdivisions: time, personnel, institutional, and project-related. These are not mutually exclusive categories; there is significant overlap and interaction between them.

First is the issue of time and training related to both the learning curve and the need to create complex, open ended lessons. Lack of time for training (Audet and Paris 1997; Gatrell 2001), is a significant hurdle. The time requirement to achieve a basic level of competence usually is the equivalent of a one-semester course at the community college or university level. Many teachers use their own time for training, and even when training time is available, there is a dearth of education-oriented GIT training (Kerski 2003). Training programs mostly address technology; there seems to be little if any on PBL or the underlying spatial principles of GIS.

Once a degree of competence is gained it must be maintained. For a teacher who is already busy with other duties, a period of time away from the GIS will very likely result in forgetting of materials already learned. Even professionals who routinely use GIS forget aspects of they don't use regularly. The "forgetting curve" (D. McTaggart, personal communication) of intermittent GIS use is an additional complication to integrating GIS in K-12 education.

There are other time hurdles as well. Once trained, the teacher must work on lesson and data creation and maintenance (Kerski 2003), developing assessments, and other tasks. Lesson creation, in the PBL format, requires searching out a problem to work on, laying groundwork, and ensuring resources are available among other tasks. This groundwork is necessary to provide the students with a challenging, but not insurmountable, task. And just as there is a lack of education-oriented GIS training, there is also a paucity of assessment tools for GIS and spatial literacy.

The second set of barriers consists of personnel (educator) issues of a psychological and philosophical nature that provide the foundation for teacher comfort and willingness to use GIS in a problem-based context. This grouping covers a range of educational, philosophical and psychological issues, including psychological comfort with technology, lack of spatial training or awareness, and philosophies of teaching.

Personal characteristics include comfort levels in multiple areas. First of these is "cyberphobia" or computer anxiety, which leads to avoidance of technology altogether, or if it is used, a cut and dried "Drill & Practice" approach (Gatrell 2001). Use of GIS presupposes a level of basic and specific (e.g. computer file management and database skills) technology skills, and involves use of complex software (Kerski 2003). The complexity of GIS exacerbates the discomfort and thus reliance on drill and proactive strategies (Gatrell 2001).

Technological comfort level isn't the only issue however; interpersonal comfort zones also play a role. A primary example is the comfort the teacher has in allowing students freedom to explore in class (Kerski 2003). Personal teaching philosophy is also a factor. These philosophies include (or preclude) use of the inquiry-based instruction model which facilitates integration, and student-centered learning/ classrooms.

In summary, teachers who are more comfortable with technology, who have the ability to let go of a degree of control, and who are already practiced in PBL models, are more likely to be comfortable with GIS as an instructional tool. Other characteristics of teachers using GIS are activity levels (as indicated by conference attendance) and adaptability (Kerski 2003).

There are also a variety of institutional factors relating to the support system in a broad sense, including financial, systemic, and personnel including other teachers, technical staff and administration. One problem is the cost of software and hardware (Kerski 2003), however, the relative importance of hardware/software problems is less than that of most other issues. Systemically, the traditional school-day structure is not amenable to providing long blocks of time that would allow project based GIS implementation (Kerski 2003).

Technical (IT) or administrative support (or both) can be lacking, and at times the administration or IT staff actively resist implementation. School politics (Kerski 2003) can kill a GIS project. On the other hand, having other teachers to work with on GIS projects is related to success. Indeed, the total number of teachers at a school using GIS was the most important variable affecting implementation (Kerski 2003).

Finally, even if all the preceding pieces are in place, project availability and related issues such as logistics and student safety can present difficulties. Is there an appropriate project available (Kerski 2003)? If so, what are the data-gathering needs in relation to the project? If field data is required, is it located in an environment that is physically safe for students? If the answer is a yes, then school buses must be chartered, permissions signed, and so on, before data can be gathered. These logistics may very well limit data gathering to a single day, unless the project is located in the immediate vicinity of the school. Even if field data is unnecessary, data needs remain. Is there free data for that project, online or at a local government agency?

As mentioned, there can be interaction and overlap between all the obstacles. They can be interrelated both within each subdivision and between the main categories.

Within a category, for example, the more training a teacher needs, the more training time they will also need. As an example of interaction between two categories, lack of technology skills relate to psychological comfort.

While there are benefits and barriers that have been well addressed, there are some questions that remain unanswered in the literature, such as how best to use GIS, no small question. This means some cautions should be reserved in the use of GIS. However, the problem-based learning or PBL-GIS method stands out as a promising means of integrating GIS into schools in a relevant, real-world learning environment.

Problem-Based Learning

There are essentially two methods of teaching and learning. The first is the familiar and traditional method, in which general theory and specific applications are kept separate, with theory (possibly) being applied to problems later on – sometimes months or years later. The second is a means of teaching in which learning takes place in the context of solving real-world problems, so that the relevance of the knowledge is immediately accessible. This method is commonly known as Problem-Based Learning or PBL, although it is also known by other terminologies, such as Inquiry-Based Science. "PBL is fundamentally different from traditional pedagogic techniques, because it fails to draw a distinction between theory and praxis, between true and applied knowledge" (Drennon 2005). PBL can be used in many disciplines including both STEM disciplines and the humanities; furthermore it allows the students to apply skills and concepts from a variety of disciplines regardless of the primary focus.

The PBL method is well suited for GIS and visa versa; in this case it is sometimes known as PBL-GIS. PBL is "a highly effective method of exploring and thinking about the world with GIS (rather than simply learning how to manipulate the software)" (Audet and Ludwig 2000). Instead of following rote lesson plans, the students work on projects based on a "carefully chosen and complex problem" (Audet and Ludwig 2000). In other words, students are learning with GIS rather than about GIS (which is the most common case today) (Audet and Ludwig 2000), although students certainly learn technical skills.

PBL-GIS can be used with almost any question that has a spatial context. However, this returns us to the above-mentioned problem of spatial literacy. For educators who are themselves spatially illiterate, it is more difficult to see the potential in those problems for which PBL-GIS is most powerful. This means GIS will often be taught in the learning-about rather than the learning-with manner. Additionally, pre-existing curricula, such as "Mapping Our World" (Malone, Palmer et al. 2005), which do not relate to these local issues and thus to students lives, will likely be used.

PBL can be used in a range of modes from structured to independent, depending on the needs of the students and the comfort level of the teacher. Aside from issues of spatial literacy, teachers do not necessarily have a foundation in PBL style teaching, which creates yet another barrier to PBL-GIS, that of learning the PBL method of teaching. In addition to learning the method, this returns to the issue of teacher characteristics such as need for control versus comfort with open-ended processes.

Even if a teacher is already using PBL or GIS or both, there remains an elephant in the corner: the lack of spatial literacy on the part of teachers. This is a critical topic that has been mentioned in the literature, but often only as a small note in a sea of noise on other barriers. Only recently, with the publication of the NRC report, has this major stumbling block truly been addressed.

The Stealth Barrier: Spatial Literacy

One major barrier to GIS implementation that was not discussed above was the lack of spatial literacy. Spatial thinking is a distinctive form of thinking and requires knowledge and ability in three elements: space, representation, and reasoning. Literacy is a normative statement that indicates what people should know and be able to do based on their knowledge (NRC 2006). The NRC committee tasked with investigating GIS in the K-12 curriculum found that “spatial thinking is not being taught systematically to K-12 students at present,” and that spatial thinking is “not just undersupported, but underappreciated, undervalued and therefore underinstructed”. It is “locked in a curious educational twilight zone: extensively relied on across the K-12 curriculum but not explicitly and systematically instructed in any part of the curriculum”. Furthermore, it lacks content standards and dedicated assessments (NRC 2006).

So, it is unsurprising that the research on GIS implementation also shows that “one of the chief constraints on GIS learning is not hardware or software, but the spatial perspective of teachers and students” (Kerski 2003). Likewise, in their introduction to the issue of *Journal of Geography* devoted to GIS in Education research, the editors recognize a “common thread” running through several articles: “a recognition of the need to help students better analyze the maps they produce – the need for explicit instruction in spatial analysis to promote student understanding of the meaning of the data that has been mapped” (Baker and Bednarz 2003).

Teacher preparation methods and certification requirements lead to generalist teachers who lack substantial coursework in geography. “Although no studies have quantified this, it is apparent that many educators with the responsibility for teaching geography do not have an understanding of the spatial perspective that is key to geography." Thus, "many teachers have limited *pedagogical content knowledge,*" or a knowledge of how best to teach a subject (Bednarz and Schee 2006). This lack of geographic and spatial skills also applies to science teachers, another group that frequently implements GIS. Geography and science teachers "may be under-prepared to conduct the spatial analysis, let alone teach others" to do this (Bednarz 2004). If that is the status of teachers responsible for geography and science, then the case for educators in other subject areas who also use GIS is likely to be more critical.

Despite the need for spatially literate educators, "it appears few teachers are aware of the growing importance of maps or mapping science or are excited about spatial thinking and reasoning, problem solving, or even teaching with and about maps" (Bednarz 2004). In regards to maps, a gateway to spatial skill and literacy, this may not entirely be the responsibility of the teachers. For one, the teacher may not have been taught with maps and would therefore be unfamiliar with the techniques. Few texts or other materials teach educators strategies for teaching with maps. Furthermore, map-skills components of educational materials are often "dry, skill-oriented, and not well connected to the real world," with a focus on teaching about maps, and ignoring teaching with maps (Bednarz 2004).

If the teachers do not have spatial literacy, how can they teach students? In the case study quoted at the opening of this section, "most students lacked this spatial perspective" (Kerski 2003). After a nine day PBL earth science unit, neither students in the paper-based nor students in the GIS-based lessons appeared "to be sufficiently capable of creating generalizations across a series of data points, engaging in basic pattern seeking, describing trends in data, or other exploratory activities" (Baker and White 2003).

These researchers concluded that "teachers and students exhibited difficulty in terms of considering data spatially" and that "this apparent inability to utilize data geographically seems to be a critical issue for the future use of digital mapping technologies in the science classroom" (Baker and White 2003). They suggest that if students had spatial analysis and pattern seeking lessons prior to the unit, significant differences may have been realized between GIS and non-GIS using students, primarily due to the speed of GIS, which frees up time to explore and manipulate data.

To remedy the situation, they base their recommendation for GIS implementation on a pedagogical framework that includes not only content area, but also data analysis and spatial reasoning. They also recommend using materials for students and teachers that include spatial reasoning activities as basic scaffolding for advanced analytical learning (Baker and White 2003).

Likewise, another research project, based on a wayfinding problem, showed that differences in past experience with maps and other spatial activities on the part of students lead to differing levels of difficulty in understanding and solving spatial problems with maps. This researcher also concluded that "direct instruction and experience with maps would begin in elementary school, thus giving students the opportunity to begin problem solving with GIS at a relatively advanced level in middle school" (Wigglesworth 2003).

GIS is "not just a technology, but also a method" and these "methods, more than the tools, make GIS difficult to implement" (Kerski 2003). Laying the foundations for spatial literacy – for teachers as well as students – is clearly a critical component of GIS implementation. Doing so would also help with other problems, such as teaching about GIS rather than with GIS, or the inability to think of GIS as other than a digital atlas.

Originally tasked with two questions on the current role of GIS in the curriculum and future development of age appropriate GIS and curricula, the NRC committee quickly realized that there was a more fundamental issue that had to be addressed first: the role of spatial thinking. This led to two additional questions about the very nature and character of spatial thinking, and how to foster the capacity to think spatially in the educational system (NRC 2006).

So teachers learning to implement GIT in their classrooms not only have the steep learning curve associated with gaining GIS skills (and using them in the PBL context), but they must also learn spatial thinking methods. This double learning curve of GIS and Spatial Thinking provides a formidable hurdle.

The Eagle Vision (EV) project was designed to reduce barriers as much as possible. EV was created to provide teachers with the technical skills of GIS and spatial thinking skills. It was also designed to encourage teachers to make the most of the power of GIT by using it in the PBL methodology. GIS-PBL allows the teacher to involve the student in relevant real-world problem solving.

CHAPTER THREE: EAGLE VISION

Eagle Vision (EV) is training high school teachers from Bureau of Indian Affairs (BIA) and other tribal schools in the use of GIS and GPS, spatial thinking, and in curriculum design for Problem-based Learning (PBL)-GIS. Teachers were recruited from several schools located throughout the country. As some teachers were based at boarding schools, the students represented a broader national reach of tribes than the locations of the schools alone would indicate.

The three-year program was designed to train the same cohort of 20 teachers over the project period. Instruction occurred during annual two-week summer workshops held in mid-July. The first two institute workshops were located at the Center for Educational Technology in Indian America (CETIA) at Laguna Pueblo, NM, and the final workshop was held at The University of New Mexico (UNM) Department of Geography.

Teachers were provided free, educator-oriented GIT training. In addition to the GIS and GPS training, spatial thinking and analysis, and culturally relevant curriculum design help were provided. Teachers were aided in identifying relevant, community-based, PBL projects with spatial components, and in building a lesson plan on these themes.

During the academic year following each summer institute, teachers were expected to integrate their summer plans into their curriculum. An Eagle Vision graduate student was available throughout the year to provide technical and lesson planning assistance, via phone and email. An annual two-day workshop was also held in March to give teachers a chance to share their progress and difficulties, and to get face-to-face assistance from staff.

Year One focused on GPS and introductory level GIS and related principles such as projections, and thus was similar to a traditional college-style curriculum, although assistance was given in curriculum design. Year Two, however, primarily used locally-focused PBL-based GIS lessons, modeling of the type of inquiry-centered education that the program was designed to help educators achieve. Year Three followed up Year Two by incorporating more spatial analysis, requiring the teachers to more fully design their curriculum and to work with their student attendees using these curricula.

In addition to the teacher institute, each year a team of up to four students from each school were selected to participate in a one-week summer student institute, where they received a concentrated orientation to the GIT field. Over the three-year grant period, 120 students were to participate in the summer institutes. The first two summers student institutes were held separately from the teacher institute; the final year however, allowed integration of the student program into the second week of the teacher workshop, so that teachers could test their curriculum immediately.

Addressing the Barriers

The original EV design incorporated some unique features in an attempt to overcome most of the barriers discussed in the previous chapter. These were broadly categorized as time, personnel, institutional, and project.

The EV staff recognized that a one- or two-week workshop would not be sufficient time to impart all the skills that the teachers required, especially as they would be given both an introduction to GIS and to PBL-GIS. Thus, the same cohort of teachers was recruited for an entire three years. This was a significant time commitment on the part of the participants. However, in addition to gaining GIS skills and experience with

PBL-GIS, each year of participation was worth 3 graduate-level semester hours, which helped meet teachers' professional development requirements. Also during the workshops, time and assistance were provided for lesson planning, and the technical support provided during the academic year was expected to help reduce the time educators spent dealing with troubleshooting GIS software difficulties.

To address personnel issues, interested teachers were prescreened during the recruitment phase to help ensure they had sufficient basic computer skills. In most cases, more than one teacher per school was signed on to provide a support system. This follows up the research showing greater implementation at schools with more GIS users. Spatial concepts were woven throughout the project lessons and the curriculum design process, to assist teachers with the issue of spatial literacy.

To avoid the systematic barriers such as lack of financial support, schools whose teachers were attending EV agreed to share costs. EV provided ArcView software (ESRI), and three Garmin GPS units per school. The schools were to provide computers capable of supporting the software, and technical assistance (software installation). Most schools were expected to meet these criteria with classroom or lab computers that already existed. It was assumed that lack of administrative and technical support would not be a problem, having achieved agreement on the part of the schools to support the EV project.

To address the issue of project and data availability, EV project staff worked with the educators during the summer institute to identify and create a relevant project. Again, the year-round support of the program was available to help find useful and useable data, should the teacher be unable to locate any. Furthermore, the design of the second year allowed EV staff to model the implementation of a suitable project, including such aspects as logistics.

Of course, not every single issue could be addressed; items such as school class time structure were beyond the scope of the project. However, it was expected that enough of the procedures had been addressed to significantly reduce barriers for classroom use of GIS.

Eagle Vision: Year One

Year One (2005 –2006) began in March with a two-day workshop providing an introduction to the program and to each other. The first summer institute, held over two weeks in July 2005, provided 16 GIS lesson modules, and four map, compass and GPS modules, of approximately 1½ hours apiece, for an average of four modules a day. Also included were a speaker on native geographies, and curriculum design discussion and planning time.

The map, compass and GPS modules began with a module on map basics. The second module introduced the use of topographic maps with card compasses. The teacher-students then went into a field where points had been preset, and had to navigate between individually assigned starting point and other points. A sufficient number of points were set up such that the participants couldn't follow each other. Then they received a GPS module with an accompanying field experience – the same set of points were reused, but everyone had to take a different starting point/set so they didn't just retrace their tracks from the morning. Also, everyone had to navigate to a point within a courtyard, to illustrate the lesson that just because you had an arrow pointing your way didn't mean you could abandon all thought.

The next GPS and map exercise took them to several waypoints that had been set along Route 66 between the Pueblo of Laguna and McCarty's, NM. These were at historic points and included questions to be answered about the point, such as in this example: "A. I overlook the valley. What is my name? What is the dominant natural feature 10° from here? N 35 – 03 – 55.2 W 107 – 40 – 37.8". They also took a couple of waypoints and wrote questions for them. The final test of their skill came at lunchtime, when they had to find their way off Route 66 to a local restaurant for lunch, with only a waypoint and to guide them and a topo map to show roads and features.

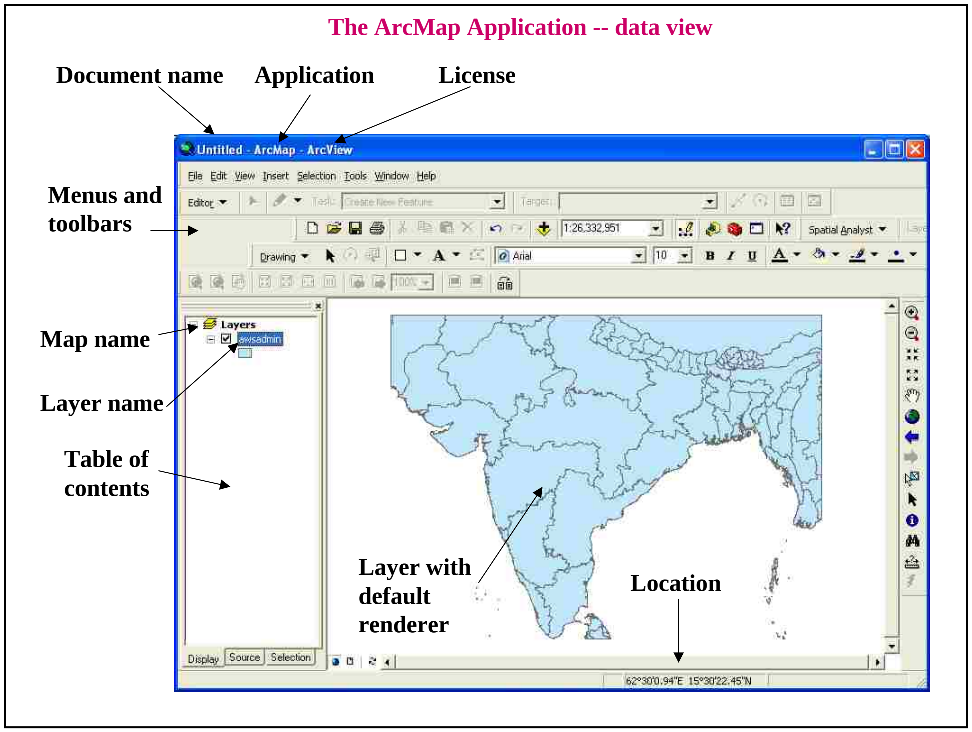
The final GPS module showed them how to download GPS points into a GIS, and hyperlink digital imagery or other documents to a GIS map. For this exercise, they used photos they had taken over their weekend tours, which they downloaded into a pre-existing map of northwest NM (Sittnick 2005) that included roads, counties, Native lands, points of interest and other information. The teachers then took turns presenting their weekend excursions to their peers using the integrated technologies.

The GIS module structure included a traditional classroom style presentation with work-along examples, and in most cases, a short lab that reinforced the subject. The guiding philosophy of the GIS sections, however, was that the teachers would learn to be managers of the technology – that is, they would have an understanding of the concepts, both technological and geographical, as well as the knowledge of how to operate the software. The modules provided an introductory background in GIS, and also self-help tools (search and index exercises). They progressed through standard introductory GIS subjects to the final two modules, which introduced the Model Builder component of ArcView, with the assumption that teachers would want to use this for creation of templates for frequently used processes. Table one below provides a summary of the contents of the GIS modules. Not shown are the map, compass and GPS modules, a guest speaker on native geographies, or the curriculum planning time.

Table 1. ***Eagle Vision Year One Modules and Module Contents.***

Number	Name	General Contents
1	Maps, ArcGIS & ArcGIS License Structure	An Overview of ArcGIS
2	Applications I	ArcCatalog and Icons
3	Applications II - ArcMap	ArcMap workspace, layers, properties
4	Commands and Controls	Custom Toolbars
5	Saving Files and Displays	Saving, .mxd files, pathways
6	Toolbox	General function of tools
7	Vector and Raster Data	Vector and Raster Data Models
8	Extensions	3D and Spatial Analyst
9	Further Ideas About Grid and Raster	Color bands, classification
10	Earth Models and Coordinates	Geoids, Datums, Coordinate Systems
11	Projection	Projections
12	Querying	SQL on Vector Data
13	Select by Location	Querying by relationship, graphic
14	Querying a Raster	Raster Calculator, masking
15	Model Builder I	Reclassification example
16	Model Builder II	Watershed example

Figure 1 is an example page from the one of the early modules.



The ArcMap window usually has several toolbars and menus. As in the case of ArcCatalog you may remove all but the Main Menu.

The terminology should be noted. ArcMap opens with a "document". This is a particular map or collection of maps, and is sometimes also referred to as a "project". The document name shows in the banner. At the start, until you give it a name, it will carry the default name "Untitled". To set the name, click on "file" in the main menu, and use the "save as . ." option. This creates a file with an .mxd extension in a folder or workspace of your choosing.

In the left hand window, referred to as the "table of contents", you will see the default name of the first map (which may be empty until you bring some data into it for display). The name appears as "Layers" until you select a name for it and change it. To set the name, right click on "Layers", click on "properties", and go to the "general" tab.

Within this first map you will see that a single data set has been added. This data set is a "layer", and it will have whatever name it carried in the workspace in which it is located. The name can be reset in the same way as the layers name was reset -- right click, click on "properties", and choose the "general" tab. Changing the name on the map does not change the data set name.

***Figure 1*. Sample page from Module Three (page 1).**

After the two-week workshop, teachers returned home with the expectation that they would begin integrating GIT into their lessons over the 2005 – 2006 school year. In March 2006, the second two-day workshop was held. This provided the participants a chance to present their progress, get face-to-face help, and learn an additional skill. The new lesson allowed teachers to download and incorporate into their GIS aerial photography and Digital Raster Graphic (DRG) topographic maps available from TerraserverUSA. Also, an Eagle Vision FRAPPR map was introduced. FRAPPR is an online mapping based social networking site where people can put their location and place information, chat and otherwise network. The EV community was invited to place themselves and their schools on the FRAPPR site (www.frappr.com/eaglevision/map) and to use it as an additional communication tool.

Entering Year Two: A Challenge Becomes an Opportunity

At the outset of the second year, Eagle Vision was short several teachers and the program director decided to recruit new participants. This posed a new and unexpected difficulty in that the program design assumed one cohort that would progress through the same set of learning experiences at the same times. It also represented a new opportunity however.

New teachers (year two teachers) needed a means to catch up with the original teachers (year one teachers) who were returning to the institute. To do so, the newcomers were provided with three online courses from the ESRI Virtual Campus: "Learning ArcGIS 9" (ESRI 2006a), "Understanding Map Projections and Coordinate Systems" (ESRI 2006b), and "Understanding Geographic Data"(ESRI 2006c). Additionally, a two-day "pre-institute" session was held prior to the main summer institute where they were given the GPS and map lessons of the previous year, and some quick hands-on review with the GIS software using the previous year's data and modules.

Eagle Vision: Year Two

The Eagle Vision plan called for a more sophisticated Year Two (2006 – 2007). In this year, EV lessons were designed to model the type of instruction the teachers would preferably use in the classroom, with GIT used as a tool for community-oriented, problem-based learning. The institute was based on two major GIS-PBL projects and one minor project. Traditional GIS instruction of the sort provided during the first year was limited to introduction of new techniques required as part of the GIS-PBL. This structure was very different from Year One. Additional background in spatial concepts was also incorporated. As in the previous year, curriculum development discussion and planning time were provided, with the addition of assessment rubric creation.

The minor project was structured as an activity that would require multiple data gathering activities over time on the same subject. In this project, teacher teams collected data on state license plates and types of vehicle that came through nearby locations (convenience stops and casinos). Data was collected for a short duration during different times of day and week. Before data collection, teachers first had to select a set of vehicle types to gather data on and make other decisions with minimal guidance from the Eagle Vision staff. Data was analyzed to see the relative amounts of travelers from different states. Teams had to symbolize the data by numbers of vehicles per state, and generate hypothesis about the distributions they saw.

While this exercise required travel by car, it was designed to mimic an activity that could be done within a short walk of a school. This addresses the problem of gathering data without requiring the process of arranging for school buses, having field trip permissions, and similar systematic barriers.

Likewise, the two major projects were specifically structured to take into account restrictions of the school system. Teachers were given a one-day field trip to gather data, as would be the case for them with their students. Prior to the projects they were required to make some decisions about data collection and begin creating background maps and other materials, as if they were their students. After data gathering, they had to coordinate efforts to enter, organize and analyze the data.

As the teachers were from a variety of locations and teach different subjects, one of the EV projects was set in an urban environment and the other in a rural setting. These provided examples of data gathering and analysis in both urban and rural settings, and in social and natural sciences. These two projects are discussed below, and materials can be found in Appendices A and B.

PBL-GIS 1: Urban Albuquerque

The urban project was set in Albuquerque, NM and was based on point data and changes in transportation corridors over time. The teachers were given background material that discussed the history of the major east-west and north-south transport corridors (US 66/I-40 and US 85/I-25, respectively) and on the auto travel industry – hotels, auto repair and gas stations, and eateries that cater to travelers along these routes. (Example material relating to this project is found in Appendix A.) The background material was given to them in the format of a summary of the research their students had already done in preparation for the GIT project.

Before going on the field trip, the teachers built a base map of the Albuquerque area using shapefiles (primarily US Census TIGER files), and Terraserver aerial imagery. They also looked at additional background material, including current and historic transportation maps, historic directory listings and Sanborn maps, which are insurance maps that include information on the type of business at a given location. The materials were from the 1930s, 50s, 70s and current time, as available. Together these materials provided data on where auto-travel businesses were located in the past as well as in the present. The goal of the field trip was to look at the present-day corridors and see how the travel industry had changed over time, especially in relation to realignment of the transport corridors due to the building of the interstate system.

Before they could go out, however, the teachers needed to agree on the type and structure of the data to be gathered. While EV staff could have made those decisions, the teachers needed to understand the types of decisions they would need to make for their students (or have their students make), before going into the field. Otherwise, it would be likely that inconsistent datasets would be gathered. So, while the staff helped guide the decision-making, the teachers had to grapple with the problem themselves and come to an agreed-upon format.

On field trip day, the teachers divided themselves into five groups, and each group was assigned an area, one each to Route 66 east and west of downtown Albuquerque, one to downtown, one to US 85 (north-south), and one to the interstates. Each group went to its section and collected waypoints using GPS and digital photos. They also logged data on the current use and condition of each location.

The teachers had the morning hours for this activity. For lunch, each group was given the address of a restaurant that was relevant to their area, most of which had been in existence for some time. After lunch, they also had a talk from the librarian at the Special Collections branch of the Albuquerque/Bernalillo County Library System about the types of library resources that might be available to them in their home areas, including maps, directory listings and other records. After this, they had time to finish up the fieldwork if necessary.

The next day, the teachers had to download their GPS datasets and photos, and enter the other data into a Microsoft Excel file. This also involved coordination and cooperation to get all the data into one file. To do so required merging the waypoint shapefiles generated by each group's GPS data, and using editing functions to add the Excel data to the waypoint shapefile. Again, EV staff provided assistance but did not do the work for the teachers. Once this data manipulation was complete, the master file was shared over the network and participants were able to work individually with the data if they desired. They could place the waypoints onto their basemap as a shapefile and color code them according to the data attributes, such as current type of business, or condition of building. Figure 2 shows one of the maps created by teachers of the current automobile travel-related businesses. Additional documentation included hyperlinked imagery of the waypoints, such as the photo of an old Route 66 motel now for sale, shown in Figure 3.

Figure 2. **GPS point data taken by teachers along major transport corridors, overlaid on a street shapefile of Albuquerque, NM.**

Figure 3. **A recently closed classic Route 66 Motel, photographed by EV teachers as part of the transportation corridor project.**

Generating a map was not the final step, however. Simple spatial analysis processes were demonstrated using the point data the teachers had collected, to help demonstrate uses of GIS that went beyond mapmaking. The entire project took the major portion of the first week of the institute, and could easily have been extended to include more data analysis had time been available.

PBL-GIS 2: Piñon-Juniper Woodlands

The second week's project was based on areal data and natural sciences and involved a survey of the Piñon-Juniper woodlands in two different sites, one in the Zuni Mountains and the other on a mesa near Mt Taylor. Due to recent drought, the Piñon trees have had low resistance to infestations of the Piñon bark beetle, leading to high rates of Piñon mortality in several areas of New Mexico. The project required an inventory of both Piñon and Juniper trees, including whether they were alive, dead, or cut for firewood. (Sample materials for this project are found in Appendix B.)

As with the urban transport project, teachers were given background information under the premise that their students had already done preliminary research. The teachers then created a basemap, this time using Digital Elevation Model (DEM) raster data. To save time, project staff had already retrieved the entire set of DEMs required for the area and mosaicked them into one DEM that covered the entire location. The teachers did mosaic two DEMs for practice, however. As in the previous week, teachers had to agree on some data gathering basics prior to the outing.

On the day of the field trip, the group met at the local Cibola National Forest Ranger Station, where the district ranger gave a presentation on the local area, the Piñon-Juniper forest, and the bark beetle. Then, teachers divided into two groups one for each of the two sites. They were given only a GPS coordinate pair and a Topo! (Topo! 2001; 2005) map of the study area and had to find their way to their respective sites.

Once at the sites, the each group split into two subgroups. Using their GPS or a compass, they found North. They marked a starting point with the GPS and from there used survey stakes and string to set up 50m x 50m squares, with each of the corners marked with a waypoint. Within the squares, each group decided how best to inventory the trees. They had the option of trying a different method if they did more than one square. A developing thunderstorm cut data gathering short, but all groups completed one or more squares.

Figure 4. **Teacher group gathering data in the Piñon-Juniper woodlands of northeastern New Mexico.**

The teachers also got practice looking at locations as potential projects; at the forest site, they were also to look for other potential natural sciences projects. To finish out the day, teachers were tasked to investigate potential class projects based on Grants, NM, a small town heavily impacted by the boom and bust cycle of uranium mining.

Once again, the day after the field trip required the participants to cooperate and coordinate in downloading and combining data sets. This included the waypoints marking the sample areas and data on tree counts. After the lab was completed, possibilities for analysis and comparison of the two sites was discussed.

Year Two: Wrapping Up

The third March workshop (2007) again provided all participants a chance to report on their progress and to get face-to-face help from the EV staff. Also, customization of projects via programming was introduced. The teachers were not expected to learn programming on top of everything else! Rather this was demonstrated as a possible way the staff can support the teachers, by doing custom applications. Also, they were able to use a pre-scripted application and adapt it to data they had brought to the workshop by following a set of instructions to see this concept in action.

One other item on the agenda for the March 2007 workshop was to give the teachers a survey, in an attempt to gain insight into successes and continuing problems. In addition to seeing if the EV system had overcome barriers, EV staff were interested to confirm whether the new teachers were as comfortable with GIS as the returning teachers, and what impact that had made in their classrooms. If the new teachers were comfortable with the GIS, creating an education professional oriented online course would be a way to speed up the GIS learning process, and teachers could jump right in to a program similar to the second year of EV, which modeled the ideal classroom use of GIS-PBL.

CHAPTER FOUR: SURVEY METHODOLOGY

The EV project was originally set up to have evaluations performed by an independent evaluator each year. These provided data on participant satisfaction, but nothing detailed on GIS learning or implementation. Therefore, in addition to following the teachers' experiences, a survey was created to fill in some of these gaps.

Outside Evaluations

The funding agency, NSF, required annual program evaluations throughout the three-year project period. The educational evaluator who provided the first year evaluation had to resign due to an upcoming conflict of interest. So another evaluator was hired the second year. Both used surveys, and were also to do case studies. However, the surveys were primarily of participant satisfaction with various aspects of the course, and provided little in the way of substantive data on the participants' learning or their implementation of GIS. Case study material has not been made available.

As the outside evaluators' work will not provide sufficient information to evaluate the hypotheses of this thesis, two other types of information are used. The first is a general, overall evaluation of the program based on the informally observations of EV staff. The other is a survey created to partially fill in the gaps in a more formal manner.

General (Informal) Observation

The EV staff was able to assess successes and problems based on a variety of informal information sources. Three major sources included narrative from the teachers, project artifacts, and EV staff evaluation of teacher learning and activity. Narrative sources included in-person discussion with, and e-mails and phone calls from the teachers. Project artifacts consisted of maps and other output. Finally, staff experience with the teachers in the institute allowed evaluation of proficiency levels.

Survey (Formal) Evaluation

The fifteen participants who attended the March 2007 workshop were given a survey to fill out; the full survey is found in Appendix C. Of the fifteen, nine were original (year one) and six were new (year two) teachers. The survey captures some data on the teachers' prior and current GIT skill and confidence, and their implementation of GIT in their own classrooms. There were four sections: a General GIT survey, GPS Skills, GIS Knowledge and Skills, and a section for Additional Comments. Part One included questions about how the teachers used GIT (encompassing GPS and GIS). The rest of the first section, and all of Parts Two and Three, used a rating scale of 1 to 5 representing low and high respectively, and included scales for before and after program participation, and for their ratings of their students' before and after skills.

The qualitative description questions in Part One were designed to find out details of implementation. This included background information about previous GIS experience of the teacher and the semester(s) and subjects for which GIT was used. For those classes that used GIS, the survey required distinctions to be made between use of existing materials, materials that were prepared by the teacher, and what the students did on their own. It also asked whether there were differences between the curriculum plans made at the summer institutes and actual implementation. If there was a difference, it asked whether it was an improvement or not, and the reason for the change, in order to assess barriers. A question about plans for future GIS use was also included. In this section there were also a set of general questions with a 1 to 5 ranking scale.

The three ratings for the GPS skills in Part Two were based on the lessons provided in the summer institutes. The subjects for the ratings questions in Part Three, GIS skills, were also based on institute lessons; however, the content was based on the GIS&T Body of Knowledge (BOK) (DiBiase, DeMers et al. 2006) to ensure a complete coverage of core GIS knowledge in the survey. This structuring provided a total of 23 questions. An additional five were incorporated to repeat a very quick survey that was given to the original EV participants; however, these will not be evaluated at this time, as they essentially duplicate the 23 BOK categories and the two groups were not treated the same in this set of five questions – the original teachers had seen it once before, but the new teachers had not.

An initiative of the University Consortium for Geographic Information Science (UCGIS), the BOK is the first edition of a body of knowledge in the discipline. It was created in part to guide curriculum design and revision, and program evaluation and assessment. It is organized into ten knowledge areas that include 73 units covering 330 topics. Of the 73 units, a subset of common core units were identified by the GIS&T community as providing the basic skills, language and knowledge foundation that would be expected of a graduate of a baccalaureate GIS&T program.

While EV is not aiming to provide the participants a second degree, using the BOK provides a reasonable structure to assess their accomplishments. At least one question was based on the topics covered in the common core units, with a few exceptions. The first exception was Satellite and Shipboard Remote Sensing, which falls in the Geospatial Data knowledge area. This subject was not taught in Eagle Vision due to time constraints. Both topics in the Organizational and Institutional Aspects knowledge area were not heavily addressed during the institutes. Finally, the GIS&T and Society knowledge unit on ethical aspects was left out of the survey. In this case, it was assumed that as educators, the participants had already developed a professional ethic, and relevant topics regarding geospatial data and cultural privacy are discussed as part of the Eagle Vision program in an ongoing manner.

This survey provides qualitative data from the first section, and quantitative data in the form of the teacher's self rankings. However, the quantitative data is used in a primarily descriptive manner, as the sample size is too small for statistical analysis.

Hypotheses

This study proposes three hypotheses, the first of which is based on the original EV program design, and the other two of which apply to the modified program using the online instruction.

1. Eagle Vision will circumvent barriers allowing teachers to fully implement GIS in their curriculum.
2. Second year teachers will equal the first year teachers in GIS skills and efficacy as of the survey time.
3. First and second year teachers will do equally well with GIS implementation after the PBL-based summer institute (that is, new teachers will do as well in their first year as the original group of teachers did in their second year).

Successfully demonstrating the first hypothesis will indicate that the EV method has successfully overcome a sufficient number of the multiple barriers to GIS implementation, and thus provides a model for future teacher professional development.

Even partial success towards the first hypothesis will show what works and what remains to be improved.

Confirming the second and third hypotheses would indicate that Web-based introductory GIS can be a good means of getting teachers up to speed before the classroom experience so that they could spend their time learning how to integrate GIS in their curriculum in a PBL based manner, rather than just learning GIS. That is, providing online preliminary coursework gets the educator up to speed, allowing them to focus on how to integrate GIS into their classroom during the actual summer institute.

For this study, the informal results of EV experience and the qualitative data from the survey will be looked at overall and also compared between the two teacher groups.

CHAPTER FIVE: RESULTS

The following sections will look at EV results to date, including the original evaluations, then the general and survey results. The latter two are intermixed, with survey results supporting general observations.

Previous Evaluations

Outside evaluations where conducted the first and second years of the EV project. The evaluations were meant to determine if the teachers had increased their integration of GIT, use of PBL, the cultural relevance of their curriculum, and general satisfaction with the summer institutes. Related surveys were given to students as well.

Participants were satisfied with the institutes. Unfortunately, the evaluations did not assess GIT use in sufficient detail to determine the level of PBL or GIS implementation – an affirmative answer to a question on use of GIT could mean anything from the respondent took their students out for a Geocaching day with the GPS to designing and implementing a full PBL-GIS project with their students. Nor was the level of understanding of various GIT concepts assessed.

Therefore, the survey discussed in Chapter Four was created to capture some of the missing information on GIT, PBL, and levels of implementation. Additional detail was also captured on barriers to determine what worked and what needs further work.

General and Survey Results: Barriers

One of the major goals of EV was to reduce barriers to GIS implementation. Four classes of barrier were discussed previously, including time, personnel aspects, institutional support and project availability. Participants' levels of GIT implementation varied, reflecting the strengths of and barriers faced by individual educators. Levels of

GIT use included none, introductory (such as geocaching with GPS, or map making with no analysis) to more complex community based projects (such as the relation of well depths and arsenic levels to the location of an arsenic vein in the geological setting).

Despite EV attempts to overcome hurdles discussed in the literature, institutional and time barriers were mentioned by the teachers. Even so, some teachers were able to take intermediate steps (such as GIS use alone) and or use creative means (combining digital technology and manual mapping) to partially overcome the problems. The following sections discuss results of the EV attempt to lower barriers, and the survey results.

Time

Time remains an issue with GIS. The time commitment made initial program recruitment difficult, despite the free benefits (tuition, software, travel); thus, the first year did not meet its full allotment of twenty teachers. However, once in the program, participants took advantage of the credit hours offered towards professional development.

Even so, reducing the commitment significantly should allow more teachers to participate. Therefore, it was a significant advance to see that use of a Web-based introduction allowed year two teachers to fully participate in the PBL-based classes at a level comparable to the returning teachers. This shaved nearly an entire year off their learning process. This new direction requires further development, as the time requirement of the online portion was extremely high. This is not an inherent flaw, however. Rather it reflects the need to change the program unexpectedly and at the 'last minute,' which resulted in the new participants being given the three ESRI online courses before the EV staff had time to review the course content.

It is very likely, based on staff review of these courses, that the new teachers would have been sufficiently up-to-speed if they had only taken the "Learning ArcGIS 9" (ESRI 2006a), which essentially was an equivalent of the GIS modules provided the first year. The other two courses were meant to fill in some of the gaps, but were far more than what was needed for this audience. All three together created a time consuming process for the new teachers, and teacher verbal reports indicated that the ESRI course modules took them longer than the estimated times given on the Website.

Technical and lesson planning support was also provided to help teachers reduce time spent in troubleshooting, data gathering, and other activities. Interestingly, it was not requested nearly as often as expected. Only a few teachers called or e-mailed the graduate assistant. The questions generally involved a basic level of troubleshooting (help in finding a "lost" table of contents) or requests for reminders on basic processes (how to do a procedure). Three queries requested help with finding data, two of which were from the same school.

The lack of calls is probably due in large part to two factors, including slow rates or low levels of implementation and use of pre-existing materials. Firstly, teachers who did not implement GIS would not need technical help. Similarly, teachers who did use GIS, but used it at a less sophisticated level than expected would be more likely to be working within their current skill range. Also, use of pre-existing GIS educational materials – "Mapping Our World" (Malone, Palmer et al. 2005) in particular – decreases the need for outside technical assistance.

Teachers were also given instruction in and an exercise on the use of the ArcView help tools, with the expectation that knowing how to find information for themselves would increase their confidence and efficacy. On the survey, most teachers reported at least moderate proficiency or better, where a score of 1 is very low, 3 is moderate and 5 is very high. A few new teachers indicated a lower score, and it appears that the second year teachers felt less proficient, as shown in the following table, which shows self-ratings of both year one and two teachers as well as all teachers. But it can also be viewed in another way: that the returning teachers feel more proficient since they may have already used this on their own, thereby raising their overall efficacy.

Table 2. *Teacher Help Tool Proficiency.*

Teachers	1	2	3	4	5
Year 1			7		2
Year 2		3	1	2	
All		3	8	2	2

General time availability also remains a problem. A third of the teachers indicated time (outside the institute) as a problem in their survey responses. In the words of one teacher:

> I really thought that we would be involved more quickly with more sophisticated projects. There always seems be some other issue at school that overshadows GIT in education matters. Even though time was allowed and constructively used during the summers, there has always been the chronic shortage of time and focus to really follow through with the intentions. It has always involved a difficult choice of what to sacrifice. Maybe teachers should be single and devote their entire being to education. (not really!)

Personnel

One area that has been a strong success was the partnering of more than one teacher per school. The original program design was to have two to three teachers per school support each other. However, in part due to dropouts and to the accelerated recruitment timetable for the second-year teachers, some participants were the sole representatives of their schools. Of those who worked together, the majority rated their experiences very high (six participants) or high (two participants).

Retention, however, was problematic. Despite pre-screening of teachers, two participants dropped out within the first week due to low computer skill or comfort levels. A couple of other participants were lost, but not from program related reasons (one did not have his contract renewed, another had an injury). This underscores the need to reduce training time. Significantly, another three teachers from one school were lost due to heavy institutional resistance to GIS.

Institutional Problems

Despite pre-screening of the schools, some did not support the teachers in the agreed-upon manner. According to one former EV teacher, her administration refused to allow the IT person into the participants' classrooms for any reason, to keep them from loading the software. Two teachers from this school dropped out before the March 06 meeting due to the extreme politics, the third was persuaded to come to the March workshop, but she felt guilty for using EV money to come and report no progress. This participant also dropped out.

While the most egregious example of institutional non-support, this was unfortunately not the only recalcitrant school. More than one school failed to uphold its end of the bargain in a prompt manner. In three schools (two from the original group, one new school), IT took anywhere from one semester to one year before installing the software. Three more schools either lacked computers (one original, one new) or had insufficient computer memory (one original). Finally, one new teacher reported having neither computers nor on-site technical support at her school. While most of these issues were eventually resolved, they illustrate that the institutional barriers against implementation remain very strong, even in the EV setting were the institution had agreed to support the program and stood to benefit from receipt of free software.

Despite these episodes, most participants reported low levels of institutional resistance to GIT, as shown in the table below. Nine used a rating of 1 (very low), three rated it at 2, and one participant each rated resistance at 3 (moderate), 4 or 5 (very high). This last ranking was from a year two teacher recruited from the same school as the three year one dropouts discussed above, who included their experience in her ranking; however, she gave a ranking of 3 for institutional support, most likely indicating an improvement.

On the other hand, when asked about institutional support of GIT, only one participant each gave low ratings of 1, coming from the second school discussed above (who also indicated low resistance with a ranking of 2). Another rated support at low. A total of five gave moderate ratings of 3, and six participants indicated generally high levels of support.

Table 3. ***Indications of Resistance or Support for GIT.***

	1	2	3	4	5
Institutional Resistance	9	3	1	1	1
Institutional Support	1	1	5	2	5
Cultural Resistance	12	3			
Cultural Support	3	3	4	4	1

As EV focused on tribal schools, the survey also briefly investigated the possibility of parental or cultural resistance to GIT. The invasiveness of GIT, particularly remote sensing, to tribal privacy (eyes in the sky, peering down on tribal lands), was a concern. All participants reported low or very low resistance. Actual support was more varied, as can be seen on the above table. In short, some support was found and no resistance was met, although in some cases there was no real involvement either way.

A small but interesting detail came from the results on support and resistance in relation to teacher-partners' experiences at their respective schools. At three of the schools where pairs of teachers provided each other support, the teachers had different perceptions or experiences in regard to resistance and support of their GIT curricula. These differential experiences are illustrated in the table below, which shows the ratings given by the teacher-partners to cultural resistance and support (CR and CS) and institutional resistance (IR). There were no disagreements on institutional support. All three pairs indicate high levels of cooperation with their partner (WT).

Pair one differed by one rating point on both political and cultural resistance in the low-very low range. The second pair had similar differences on the cultural resistance question. These differences are slight. However, pair two had much different views of institutional resistance, with the first indicating another very low, but the second indicating a moderate resistance. This same pair also had a more diverse view on cultural support, with the person who saw low resistance also indicating high support, while the person giving a slightly higher value for resistance only gave a low for support. Pair three had an extreme divergence on political resistance, with ratings of 1 and 4.

Table 4. ***Differences in Perception.***

	CR	CS	IR	WT
Pair 1	1,2		1,2	5,4
Pair 2	1,2	4,2	1,3	5,5
Pair 3			4,1	5,5

Project

Potential projects were available to all the teachers. The EV staff found, however, that limitations existed in the teachers' conceptualization of the possibilities. At the end of the first summer institute, staff observed that most teachers only conceived of projects that involved static display of information – map-making. Not that this is wrong; rather, it is that most did not see the possibilities for higher-level analysis and the more complex applications of the software in the PBL structure. This was despite staff attempts to guide participants in this direction.

After the second summer, however, staff noted that both the returning and the new teachers were able to conceptualize more sophisticated applications in a more active learning environment. This is a response to the PBL-based instruction that EV modeled for the teachers that year. Teacher comments indicated a much better grasp of how they can use GIS in their class.

In summary, results were mixed but primarily promising. One of the largest remaining barriers is the presence of school resistance, or lack of active support. This was beyond the reach of the EV design to control, in spite of attempts to do so. Other aspects of the program, however, faired well. For example, teachers who had partners in their school did support each other in implementation, and most remained in the program despite the long commitment.

Most importantly, providing teachers hands-on experience in how PBL-GIS can be integrated into their class (second summer) is much more effective help than telling them (first summer). Thus, getting the educators over the steep introductory-level learning curve should be a priority. The unexpected but fortuitous need to recruit additional teachers during the second year and provide them online learning showed that while this approach needs some work, it is a very viable option.

Other Barriers

One issue arose that was not anticipated from the literature review, the presence of strongly disruptive, possibly behavior disordered, students. One educator reported, "in our first year we had a science club class during our required elective period which became the dumping ground for out of control students…. Not much happened that first year. We did do some scavenger hunts and learned how to use GPS units." Less drastic, but along the same lines, another teacher had problems with several students being put in the GIS class "that didn't want the class and that resulted in a few behavioral type issues." Also, a teacher reported a larger class size than they felt was comfortable.

General and Survey Results: GPS and GIS Skills

The survey asked teachers a range of questions relating to the GPS and GIS skills prior to and after EV participation, and they were asked to rate their students skills before and after GIT implementation. Additionally, teachers were queried as to their experience previous to EV. The table below shows that most participants had no previous experience. The specifics of the experience of those who indicated some or extensive experience are further discussed in the following GPS and GIS sections.

Table 5. *GIT Experience.*

Teachers	None	Some GPS	Some GIS	Extensive GIT
Year 1	6		3	
Year 2	4	1		1
All	10	1	3	1

GPS

Teachers were asked about their GPS experience prior to the program and also were given a set of three GPS skills ability rankings. These questions covered navigation, taking waypoints and tracks, and adding GPS data into a GIS. The rating scales provided a "Before" and an "After" for both teachers and their students and ran from very low (1) to very high (5). Both teacher groups had GPS lessons at EV summer institutes as described previously.

Only two teachers indicated prior GPS experience, both from the year two teacher group. While both of these individuals were already comfortable with GPS use, they indicated increased ability levels after EV. In the GPS skills rankings section four additional teachers, three of whom were from the year one group, rated themselves low or moderate (one respondent) rather than very low. This suggests that as many as six teachers may have already had some GPS exposure. The discrepancy may be simple design flaw in the survey; one question asked about both GPS and GIS skills prior to participation. Two separate questions may have been a better way of fully eliciting preliminary GPS skill levels. Finally, two of the low-level users also indicated some knowledge of GPS already existing on the part of their students, at the low level.

Regardless, all teachers reported an increase of one to four points on all GPS skills ratings, where a four-point increase indicated they have moved from very low to very high GPS abilities. The only possible exception to this generality was one teacher who only answered the navigation rating.

Most teachers also indicated increases for their students as well. The main exception was one new teacher who was planning to introduce GPS after the March 2007 workshop. Additionally, one new and one returning teacher indicated no change on adding GPS to GIS, probably due to GIS implementation levels. The same new teacher also indicated no change on the waypoints and tracks question. Two teachers (one old, one new) skipped ratings for their students.

Table 6. *GPS Skills Improvement.*

Teachers	Full	Partial	No Reply	
Year 1	8		1	
Year 2	6			
All	14	0	1	
Students	**Full**	**Partial**	**No Reply**	**Upcoming**
Year 1	7	1	1	
Year 2	3	1	1	1
All	11	1	2	1

GPS lessons included geocaching, mapping, data collection, and other unspecified "activities." Additionally, GPS use showed a progression of sophistication with students first learning how to use the units by geocaching type activities, and then proceeding to mapping and data collection. Those who had not already used the GPS (three of the new teachers) had definite plans to do so.

Very importantly, educators who faced barriers to GIS implementation were still able to integrate GPS. One teacher in particular creatively worked around the institutional barrier to provide lessons to his students:

> Fall 2005/Spring 2006: (due to software not being loaded on computers) Students (in groups of 3-4) created a paper campus map, complete with buildings, sidewalks, lat-long coordinates, legend and a photograph of the building. An aerial campus photo from 1974 was used for the basic map. Using an opaque projector, they drew their map on bulletin board paper about 6' x 6'. These maps were taped to the wall while they worked on creating them. Photographs were taken using a digital camera and printed on a color laser printer, then glued to appropriate locations on the map. Lat-long coordinates were obtained using a GPS unit and then typed on a word processor, printed and glued to the map at the appropriate location.

The GPS was a very successful portion of EV. GPS was easy to learn, and most teachers were or will be able to integrate some type of GPS exercise into their curricula, regardless of barriers of time or institutional resistance.

GIS

Teachers were also given a set of 28 GIS skills ability rankings. These questions were based on lessons given to EV participants through the summer institutes and the online courses, with the UCGIS BOK providing the overall framework for content coverage. The scales all provided a "Before" and an "After" and ran from very low (1) to very high (5). All 28 were asked of the teachers and the first 23 categories also allowed them to rank their students as well. The last five, based on a quick survey from the first institute, are not analyzed in this study for reasons discussed previously.

Ten members of the group had no prior GIS experience. On the other end of the spectrum, one teacher from year two had extensive experience (30 graduate credits in GIS/GPS/RS towards a geotechnology certificate). However, this exposure did not prepare him for how to use it in the classroom; the EV program filled that gap: "Eagle Vision has been extremely valuable for learning how I might incorporate GIT in my high school curriculum."

Three teachers, all from year one, fell in the middle, with some experience in GIS. These experiences consisted of one to two weeks of training in GIS, generally a while ago. Based on their ratings of prior GIS skill, the techniques they learned did not “stick” well – all three ranked their own abilities as “very low” on most GIS questions, although they did remember some individual items. What stood out for these individuals was the potential of GIS: “we saw the potential of GIS in the classroom but had little depth to carry anything out,” and, “I was somewhat [aware] of the nature of GIS, but very little experience. I was familiar enough to know that it was worth pursuing vigorously.”

This section will look at teacher improvement in GIS in an overall fashion. The data fell naturally into four groups, based on the overall patterns of improvement for all categories, and where improvement is counted for an increase of one or more points in their self-rankings. These groupings are none, few, most, or all of the 23 categories. That is, respondents indicated no improvement for themselves or their students in any category, few means improvement in no more than three, most indicates no fewer than 20, and all demonstrates improvement in all areas.

All participants reported an increase of one or more points on most of the 23 GIS skills ratings categories for themselves. Six of the year one teachers (67%) reported an increase in all categories, as compared to one of the seven year two teachers (14%), perhaps due to the longer period of exposure. Of those who showed improvement in most, but not all, categories, no more than three remained unchanged for any one teacher. Slightly more year two teachers rated no change in rankings than year ones, but not many.

The most common categories in which no change was reported, by both old and new teachers, were map algebra (five participants), and point pattern analysis and buffering (three each). These are the most analytic operations on the questionnaire, possibly indicating that weakness in spatial literacy plays a role. Others included queries, resolution, projections and metadata, but with only one respondent indicating lack of change each, these did not show any pattern.

Many teachers reported increases in their students' skills as shown by their rankings on the GIS scales. Two (one from each group) indicated increases in their students' skills in all categories. The majority, seven teachers (six returning, one new), reported improvements in most skill areas. Four teachers (two from each group) ranked their students as improving in only two or three areas. Finally, two of the new teachers had not yet implemented GIS. This result points to an interesting piece of information that will be discussed in the next section.

Discrepancy in Learning and Implementation

The next two tables show improvement of at least one point in the GIS skills of teachers (Table 7) and students as rated by teachers (Table 8). This data was discussed above in general. Here the meaning of these results is further discussed.

As can be seen, all teachers rated themselves as having improved in most or all of the 23 categories queried. Year one teachers did have a higher percentage ranking themselves as improved in all categories than year two (new) teachers. This discrepancy is probably due to longer exposure to the GIS. It does not represent a major difficulty – the teachers with lowest amount of improvement still saw improvement in at least 20 of the 23 areas. Thus, this data seem to indicate that there is no real difference between the two groups in their GIS abilities, a good indication that an online introductory program works well.

Table 7. ***Teacher improvement.***

	None	Few	Most	All
Year 1	0	0	3	6
Year 2	0	0	5	1
Total	0	0	8	7
Year 1 %	0	0	33	67
Year 2 %	0	0	83	17
Total %	0	0	53	47

The students' rankings on the same categories were more widespread, which is not surprising. Those students not yet exposed to GIS cannot be expected to show improvement. However, the difference between year one and year two students is much stronger than the differences between the teacher groups. The majority of year one teachers (seven) rated their students as having improved in most or all categories, whereas only two year two teachers reached this level of improvement, and the majority fell into the none or few categories.

Table 8. ***Student improvement.***

	None	Few	Most	All
Year 1	0	2	6	1
Year 2	2	2	1	1
Total	2	4	7	2
Year 1 %	0	22	67	11
Year 2 %	33	33	17	17
Total %	13	27	47	13

This seems to indicate that that while year two teachers were able to decrease their time learning GIS at the front end, it doesn't necessarily translate into a speedier implementation in the classroom. Thus, lower levels of student improvement for year two teachers relative to year one teachers is reasonable given the time it requires to implement the GIT, especially for those facing barriers.

These results are strongly supported by differences between the two groups. While their GIS skills appear to be roughly equal, their efficacy integration for map making and PBL are unequal. Year one teachers report somewhat higher levels of confidence when responding to the statements “At this point, I know how to integrate GIT in my classroom plans as: A mapmaking tool”, and, as “A tool for PBL”. These results are seen in the accompanying tables. The upper table shows that year one teachers were at least moderately comfortable with mapmaking, and nearly half have ranked themselves as high or very high. The year two teachers, however, were spread almost evenly throughout the entire range. There was somewhat less difference between the two groups in GIT integration for use in PBL, however, the year two group still seems to lag a little bit, as shown in the lower table.

Table 9. *Teacher Efficacy – Mapmaking Integration.*

	1	2	3	4	5
Year 1			5	2	2
Year 2	1	1	2	1	1
All	1	1	7	3	3

Table 10. *Teacher Efficacy – PBL Integration.*

	1	2	3	4	5
Year 1		3	3	1	2
Year 2	2		2	1	1
All	2	3	5	2	3

Additionally, we see lags between mapmaking and PBL integration in some individual teachers of both groups. Implicit in the tables, but not shown, five year one teachers rank themselves equally on map and PBL integration, and four teachers rank themselves one level lower on PBL than on mapmaking. In the year two group, five teachers rated themselves equally in map and PBL integration, and one rated herself lower in PBL than in mapmaking. This is a reflection of the increased complexity of PBL based GIS.

Not surprisingly, student proficiency lags behind the teachers; and so we see some differences between the years one and two student groups. The next two tables are based on teachers' ratings of their students in response to the statements "At this point, my students know how to use GIT to: Make a map" and to "Investigate a problem in their community." In the first case, year one teachers' students are spread throughout the range while year two teachers changes are moderate or lower. In the second, the majority of year one students are rated as high, the rest range from very low to moderate. However, the majority of year two students rate as very low.

Table 11. ***Student Efficacy – GIS Mapping.***

	1	2	3	4	5
Year 1	2	2	1	1	3
Year 2	4	1	1		
All	6	3	2	1	3

Table 12. ***Student Efficacy – GIS Mapping.***

	1	2	3	4	5
Year 1	2	1	1	5	
Year 2	3	2		1	
All	5	3	1	6	

There is a discrepancy between the teacher groups in confidence, and thus also in student levels. One issue is that the same institutional barriers existed for the year two teachers. But this does not appear to be the only issue. It is likely that continued exposure – time to practice, and to digest what has been learned – has increased the confidence of the original cohort, relative to the new group. It appears there is a need to give teachers time to practice and build confidence, even if they do not have institutional barriers. This time might be called the Implementation Lag. Integrating any new and complex skill takes a certain amount of time, and this is most likely exacerbated by lower levels of spatial literacy.

One means of introducing GIS into the class used by some teachers who did not feel confident – or did not have time to finish incorporating their own projects – was to use a pre-made curriculum, Mapping Our World (Malone, Palmer et al. 2005). This is being used as a stand-alone or as an introduction before more complex work.

CHAPTER 6: NEW DIRECTIONS

Eagle Vision results were a mix of expected and successes and remaining barriers. The program shows what works, and provides direction for future efforts in improvements.

The hypothesis of this research was partially proven. The first, based on the original program design, was that EV will circumvent barriers allowing teachers to fully implement GIS in their curriculum, was successful, but not in as direct a path as planned. Institutional barriers were very steep, but eventually overcome. The barrier of teacher time remains problematic, however. Fortunately, this partial success does demonstrate what works and what remains to be improved. Furthermore, the program results point towards a means to deal with the more intractable problems.

The second two hypotheses, which apply to the modified program using the online instruction, were also partially proven. The first of these stated second year teachers will equal the first year teachers in GIS skills and efficacy as of the survey time. While they appear to be equivalent in skill, they do not yet appear to have built the same confidence levels as the original teachers. This is almost certainly a factor of overall time to which the teachers have been exposed to the GIS. If a survey were conducted a year from now, it is likely the new teachers will be indistinguishable from the original.

The final hypothesis was that the first and second year teachers would do equally well with GIS implementation after the PBL-based summer. This was not the case, but it is difficult to say that it was necessarily disproven either. Half of the new teachers faced the same institutional barriers as faced by some in the original group, so it is hard to say what might have happened if they had not faced these barriers. Again, a survey taken a year in the future will most likely paint a different picture.

Additionally, an implementation lag effect is readily apparent. This is partially due to the institutional barriers, and also likely a function of the time it takes to integrate any new and complex skill into a routine. However, implementation (especially at higher levels) is likely exacerbated by lack of spatial literacy. This deficiency makes it difficult to start and especially to progress. Improving teachers' spatial thinking awareness and capabilities would allow them to take simple concepts and readily conceptualize several projects that can be done in their local community. Otherwise, implementation will likely remain stuck at lower levels of sophistication than would do full justice to the intelligence of students and teachers, or to the capacities of GIS.

The overall experience of the program did demonstrate that web based introductory GIS is a good means of getting teachers up to speed before the classroom experience, so that they can spend their time learning how to integrate GIS in their curriculum in a PBL based manner, rather than just learning GIS.

Limitations of the study

There are limitations to this study that should be kept in mind. Firstly, this is an after-the fact survey, taking the place of a true pre & post assessment as should have been done. It also has a reliance on the teacher reportage for their students' abilities, rather than directly assessing the students. And while one of the major barriers discussed is spatial literacy, this survey only evaluated GIS skills and confidence. Finally, this is not the evaluation that might have been done by a trained professional evaluator versed in the requirements of the project.

What Worked

The success of the new teachers sharing the PBL environment with returning teachers indicates the viability of placing introductory GIS material online, and saving the classroom interaction for modeling the processes they will use in their curricula. Use of online materials will provide a significant time-savings up-front. Providing an educator-specific online introduction that includes basic GIS and relevant, related materials, GPS basics, and curriculum information will be even more effective.

Once the online introduction is taken, it is possible to move teachers directly to a hands-on GIT experience in a PBL environment. Providing this type of GIS instruction was also clearly successful in providing educators experience in a model they can utilize in their own classrooms. As can be seen in comparing the materials in Appendices A and B with the traditional introductory curriculum, there is a wide difference in teaching GIS and teaching how to teach with GIS.

Working with partners in the school was successful, as was expected based on previous research. This provides teachers with a support system, and decreases the risks of being the "solitary GIS missionary".

GPS was successful on more than one level. Firstly, it was successfully implemented. However it had additional successes, as a means for teachers to start implementation despite barriers, and as a stepping stone technology. This means that it was implemented by participants even if they felt uncomfortable with the much more complex GIS software.

GIS success was varied, but overall, the participants made tremendous progress despite barriers. The potential is seen in the projects already in existence and those in the works.

What Needs Work – or Just Needs Time!

Implementation results often strongly paralleled the barriers seen in previous research, despite the additional support provided by EV to teachers. In large part, this is related to institutional barriers – a number of the schools were recalcitrant in their duty to load the software or provide computers. As GIT becomes more embedded in society, this problem will decrease, and meanwhile, there are 'short-term' solutions which also will be useful for longer term goals, including fitting GIT into teacher time constraints.

Some of the results may seem like failures, but are not necessarily so; it may be that what is being asked needs to be re-evaluated. In particular, teacher confidence seems to lag behind skill. But building confidence in one's ability to do highly complex tasks takes time - and practice. In addition, learning complex skills is often built up out of smaller, less complex tasks – a procedure that has been largely missing from GIS, due to the all-or-nothing approach to GIS instruction coupled with the complexity of getting to the point where it is possible to do even 'simple' exercises.

This implementation curve is a problem that might be solved in the same manner that will help the teacher barrier issues. This is the stepping stone approach.

The Stepping Stone Approach

A new approach to putting GIT in the hands of teachers is advocated in this section. This method should aid in overcoming barriers of institutional resistance and teacher time, while providing a scaffolding to build teacher confidence. The technology is rapidly developing which will make this approach more feasible. This is the Stepping Stone Approach, which consists of two elements: 1) Technological (GIT) Ability and 2) Spatial Thinking. These two elements will be built up in a deliberate manner.

Element 1: Technological Ability in GIT

The use of GPS in EV provided the clue leading to the stepping-stones method for technology. GPS was a technology that all teachers felt comfortable with, regardless of their overall GIT confidence. Further more it allowed teachers a means of beginning to use GIT in the classroom, even in the absence of school support.

As technologies such as Google Earth (GE) progress, the functionality of these GIT enabled technologies will grow. Yet they are less complex than the traditional GIS desktop program and often free.

How would this work? One example involves GPS and Google Earth Plus (GE+). For $20 per year, an amount any school should be able to afford, one can buy GE+, which allows the user to download GPS data directly into the GE. Students can learn GPS, and how to download it onto GE+ and add layers of roads and other data that is available in GE. For a very low cost, a very small time requirement, and a more familiar and comfortable level of technology, the teacher can introduce students to GPS and a number of GIS concepts such as layers. All this is achieved with the use of a technology that is stimulating and exciting to students – they love zooming in to GE – and that can present locally relevant information.

Even if the school IT staff won't load GE+, if a teacher had a laptop, they could buy it for themselves, and either allow the students to gather around, or if there is a projector, they could project it for the class to see. This provides an increased ability to do an end run around strong institutional resistance.

Another example of how the stepping-stone approach could work is with the use of the growing number of Internet Mapping Services (IMS). Two types of Internet-based mapping are evolving, atlas-style and collaborative webmapping (Baker 2005).

An atlas-style Internet map provides an online map with layers that can be turned on and off, and, at some sites, free data downloads or other information. These IMS allow teachers to introduce GIS concepts, such as layers, in a very easy way. This can be done using information that is locally or nationally relevant to the students and can tie into many types of lesson plans, using information such as state health data or fire data.

The collaborative webmap allows data to be submitted to the website from multiple locations throughout the country or world. The collective data is then accessible to anyone in both mapped and other formats. Bird counts and weather are two subject areas that currently make use of use this technology.

Thus, the stepping stone approach allows teachers to navigate barriers, and also to build their confidence by using less complex, yet increasingly sophisticated technologies, that can be made relevant to their own students. The stepping stone approach also provides a ready made preliminary to use of the full GIS packages. As the new media of GIS grows, the potential of this pathway does as well.

This approach has allies in a sense. For example, in his presentation at the 2007 AAG, the Curriculum Development Manager of the world's leading software firm has identified the ability of internet based GIS tools to improve teaching in conjunction with the traditional GIS. In particular, "teachers seem better able to make the leap using maps to *analyze data* rather than just *look at places* when there is an intermediate technology that introduces them to spatial analysis" (Kerski 2007). Of course, challenges remain, including the need to become spatially literate.

Additionally, the "Thinking Spatially" report specifically recommends redesigns of GIS that are not only educationally functional but also age-appropriate (NRC 2006). The stepping stone approach can be readily adapted to both of those criteria as well.

Element 2: Spatial Thinking

The second element of the Stepping Stone system is to build spatial literacy. This would start teachers off with basics they are familiar with, such as point location, distance and area. From these basics, they would build up concepts such as clustering, scale, proximity, and the effect of changing projections on area and shape. These concepts would be illustrated using real-life examples that would be highly transferable, that is, teachers most anywhere in the country could use the examples with local data. While all exercises could be done in GIS, where appropriate, non-GIS methods could also be demonstrated in keeping with the Technological element of the approach.

For example, creating different projections of a U.S. state can demonstrate changes in area as shown in the attribute table, and shape, which can be seen visually, and also measured using the ruler tool. Or, groupings of points such as restaurants and car dealers can be analyzed for clustering at multiple scales, which demonstrates different patterns of clustering, randomness, and the effects of scale. Both of these examples can be done by teachers regardless of locale, and show them some ways to think about their communities as potential sources of learning.

Obviously, the above examples of technology and literacy lessons need a great deal of development. However, the general principle of breaking these two elements into stepping-stones meets multiple objectives of GIT and spatial thinking implementation at a range of developmental levels.

Recommendations

Based on the results, the following are recommended. First, online, educator oriented introductory GIS/GPS courses should be available. This should be designed in a manner that makes it easy for a teacher to return and find a particular topic if they need to refresh their memory. PBL-based hands on courses should also be available at locations throughout the country, so K-12 educators can experience first hand the type of educational structure that GIS allows. This is a much bigger project, and is probably something that will be done by multiple parties – pre-service education to ESRI workshops for in-service professional development. For those teachers who cannot make these courses, online materials and examples of how to create PBL-GIS should also be available.

For those teachers who are ready to use GIS, one significant time savings would be to make available more readily useable data. This could take the form of ready-made basemaps with a number of standard layers such as land use, vegetation cover, a DEM, and aerial imagery, which can be simply turned on and off as needed. These basemaps would be available in state level formats, and if a teacher needed only a county, there could be a simple macro that comes with the basemap that would allow them to choose the county and clip it. Use of the “Mapping Our World” book (Malone, Palmer et al. 2005) with its prepared lessons and data, even as a stepping stone to other work, indicates the value of ready-to-use materials. This type of prepackaged data would significantly reduce teacher preparation time, and fits in with the stepping stone plan at the next level up from what was discussed above.

Currently, it seems teachers need a long follow up period, of more than one year. This is due to two things. The first is sluggishness on the part of the school to make the software available. Once it is available however, the teacher needs time to build their confidence level, even after they have built their skill level. Based on EV findings, these two items together mean a follow up time of at least 1 ½ to two years (one year to ensure the software is up, another to allow the teacher to get some practice in their skills). If onsite technical support can be provided that travels to the school to load the software and ensure everything is up to speed, then that first year can be dropped. But that presupposes the school will allow administrative privileges to outsiders, an unlikely scenario. There are also remote means of providing technical support by direct manipulation of the remote computer, but this is an even more unlikely possibility. Thus, for now teachers are most likely restricted to phone and email technical support.

There is also a large need for future research, in both GIS enabled education and spatial literacy. The specifics of the necessary research are addressed at length in the "Thinking Spatially" report (NRC 2006), and do not need to be elaborated on here. However, it would be worthwhile to continue to follow the EV teachers, as that may clarify some of the findings of this study. In particular, it would be instructive to have a more clear idea how long a timeframe is required to get teachers fully comfortable with GIS. "What is the implementation curve?" is a question that needs answering. This is related both to the external resistance of schools to GIS and to the teacher's confidence, once the skill set is built.

Finally, all materials should be created in a stepping-stone manner, to build confidence and create ways around other barriers. These steps should integrate spatial thinking on par with the technological skill building. As stepping-stones become available, the implementation lag should shorten, especially for sophisticated projects.

Conclusions

While EV encountered all the barriers discussed in the literature, overall it was successful in moving teachers towards GIT integration. Additionally, the second year change in the program design demonstrated that online learning will get educators through the initial GIS learning stages so that face-to-face learning can focus on how to teach with GIT, rather than on teaching GIS.

Based on the EV experiences, a teacher-oriented online GIT course should be constructed, which includes basics of spatial literacy. Then, pre-service or in-service GIT classes and workshops should focus on PBL-GIS, with spatial literacy woven throughout. Both online and in person learning should follow a stepping stone approach, more representative of most learning, rather than an all or nothing approach as has characterized GIS workshops.

Following these recommendations would also fit in with the recommendations of the NRC report, Learning to Think Spatially (NRC 2006) for GIS and spatial literacy. It would also help move modern classrooms towards the inquiry-based learning method. Eagle Vision has shown a promising new direction in K-12 GIT education.

APPENDICES

APPENDIX A:

URBAN ALBUQUERQUE PBL-GIS

Urban Transport Corridors: Effects of Change Over Time

Your school is in the urban area of Albuquerque, NM. You have decided that it would be useful for your students to understand how major highways influence the economic activities of the corridors through which the highways are built. Additionally, as the major urban corridors change over time, so do the surrounding economic activities. The nature of these businesses changes as the automobile era progresses from its early years to the present.

To understand these geographic, economic and historical lessons, you're going to have your students investigate changes in the East-West (EW) and North-South (NS) transport corridors over most of the last century. Because there are so many things that go on in a city, you have conveniently decided to restrict your project to the automobile travel industry for now – although future projects could certainly be added to this!

The students will study three major aspects of the auto travel industry: places for people to spend the night, restaurants to feed them, and the assorted automobile-related businesses – gas stations, repair garages, dealerships, and various combinations of these. Then of course there are the actual roads. Things weren't always the way they see them today!

They learned that car travel/tourism became very popular in the 1920s. People would get in their cars and travel pre-interstate roads and highways, but they couldn't go as fast as they do today. So, quite a few businesses grew up around feeding them and giving them a place to spend the night that was convenient. Travelers would stop to stay at a new type of hotel, called a tourist court, which were the first motels. They also stopped at gas stations, and their cars would break down so they had to get repairs, as well as gas, tires etc.

Your students discovered that before the interstate system, the main routes that came through Albuquerque were US 85 (NS) and the famous US 66. What's more, these changed as time went by.

When it was first laid out, US 66 used existing roads. These did not necessarily provide the most direct route, however, between Chicago and LA, because they were local roads connecting local towns. Thus, when US 66 came to NM, after coming west from Texas, it went from Santa Rosa northwest to Santa Fe, then south down a portion of 85 through Albuquerque to Los Lunas, and then cut back northwest to Grants, before resuming its northwesterly course. In 1938, US 66 was realigned to go west through Tijeras canyon through Albuquerque and on, saving 90 miles.

Despite the logical explanation of the re-routing, your students did find one, more interesting story. This story has it that Santa Fe was supposed to remain on US 66, and that the alignment was supposed to stay NS in that section. But the governor at the time, Hannett, lost re-election in late 1937, so to spite the Santa Fe politicians, he ordered crews to build the EW section before he left office at the beginning of January 1938. The tale goes that the crews built the road without buying right-of-way, regardless of the elements, and without time off even for Christmas. And while it wasn't finished by January, bad weather kept the new governor from contacting the crews to stop work. By the time he could do anything about it, people were already using the new section – a fait accompli!

So, while you don't know just how true that tale is, it makes a good thought question for your students to consider after they see how highways affect local areas. What might that question be? How might students answer this question (using what skills)? How might some of their scenarios be implemented in a GIS? Hint ideas below!

US 66 was decommissioned with the arrival of the Interstate system… but these roads still exist – Central Avenue being one of them.

US 85 is less well known and less popular than US 66, so your students found less material on it. They have found some basics however. The entire route of 85 ran from the Canadian border near Fortune, ND, to the Mexican border at El Paso, TX, with the NM portion running from north of Raton to Anthony. It ran through Albuquerque, and, as mentioned, a section of 66 was also routed along the Santa Fe – Las Lunas portion of 85 for about 11 years.

US 85 was never officially decommissioned. Parts of it were realigned into the Interstate system. Sections where it deviated became renumbered in the NM state highway system as various NM state routes or business loops, and NM discontinued marking it in the early 90s. The original section of US 85 that ran through Albuquerque is now an arterial known as 4th Street.

Your students then moved on to investigating the Interstate system. They found that its official start was on June 29, 1956, when President Eisenhower signed the Federal-Aid Highway Act of 1956, making it 50 years old this year! (Of course, the interstate system didn't come out of a vacuum – your students learned much about how the US government was interested in nationwide transport systems long before the highway or the car!) The Interstate system, also known as the Dwight D. Eisenhower System of Interstate and Defense Highways or Eisenhower Interstate System, has also been called the Greatest Public Works Project in History.

The new EW route through Albuquerque your students know as I40. Also called the Coronado Interstate, it runs from Barstow CA to Wilmington NC, and in NM from Lupton (AZ state line) to Glenrio (Texas state line). Routed along the old 66, the final portion (Tijeras canyon, east of Albuquerque) was finished by 1980 – your students are amazed that this wasn't so long before they were born! They have also learned that it is a major transcontinental route, so that is why there is so much truck traffic. In town, it ran through areas that were already fairly built up, but typical 70s style interstate-related development did have room to spring up.

Nationally, I25 or the Pan-American freeway, the new NS route, runs from I10 at Las Cruces to I90 in Buffalo, WY. The NM portion runs from Las Cruces to the Colorado border north of Raton – sounding quite familiar, as it was routed along 85. This interstate was also completed by 1980, with the last segment being north of Bernalillo to La Bajada hill. This corridor had less pre-existing development to run through, so on the northern section of town, you see quite a bit of more recent interstate-related development, much of which has been built in recent years.

Recently, the "Big I" or interchange of I40 and I25 had a major rebuild. It was originally designed in 1966 for 40,000 vehicles, but by 2002, was handling 400,000 vehicles per day, and ranked at number 10 in congested interchanges. The rebuilt interchange received an honorable mention for excellence in urban highway design from the US DoT and the Federal Highway Administration in 2002! Among other things, additional frontage roads were added. The new interchange is expected to deliver over 10 billion dollars in savings over the 20-year life of the project.

Despite the benefits of the interstate system in general, and the improvements in NM and Albuquerque in particular, your students have also found that the current interstate system is becoming overloaded. Its 47,000 miles only make up 2.5% of US highways, but carry a quarter of the traffic – about 237 million cars, busses and trucks. In the last quarter century, there has been a 200% increase in traffic, due to strong economy (partially fostered by the interstate system!), but only a 17% increase in capacity. The federal gas tax, which pays for the interstates, is 18.4 cents/gallon, and is unlikely to increase soon. Meanwhile, increased efficiency means less tax is paid.

There is so much truck traffic that the interstates have also been dubbed "the nations' warehouse". Urban congestion in particular is a concern, with urban areas classified as 'seriously congested having grown by about 25% to 41% in the last 5 years. This is also in part due to commuter traffic. Norman Mineta, the current secretary of transportation, has said we are reaching the 'tipping point' of congestion.

So, changes may be yet in store! One thing you plan to do after the field trip is ask your students how the NS and EW transport corridors might look and function in the Albuquerque of the future. What are some questions you might ask to stimulate their thinking, based on what they see on the field trip? Hint ideas below.

Additional information from your students' reports is found further down this paper.

So, your students have put together the following timeline that shows when these realignments happened in the Albuquerque area:

- 1926 - US 66 came down from N from SF thru Albq to LL along 85, then headed W
- 1938 – 66 made EW, 85 remains NS
- Late 60s/early 70s – Interstate system takes over.

Your students already see similarities between then & now – there are motels like Motel 6, and quick eateries – often at gas stations – that all cater to modern-day car travelers along the interstates. But what happened between then and now, besides a bunch of road changes, and how did it affect these businesses?

So you've planned a field trip. Permission slips are signed, chaperones/drivers rounded up. You put together some points for your students to go out and actually see, along with some data. Fortunately, your local Geographer was handy to help you find & compile all this data! You also got materials from the local historical librarian.

You have some addresses of hotels, automobile businesses and restaurants, some old maps, some aerial photography and other materials from different time periods that are within the realignments. You have 1930's, 50's, 70's and now. Your students' job is to go out to these places and see what's there. Is it the original place? If so, how's it doing? If not, is it something similar, or something entirely different – and what? Why?

But before you go, you have to decide what data exactly you want to get, and how to code it in your GPS, so that all the point data can be combined into one file everyone can use when they get into the lab the next day. Then, you split your huge class into groups. Each group will cover a different area, listed below. Some are more walking oriented, and some are more driving oriented.

Each group will go to the addresses listed for its area, take waypoints and use the data dictionary idea, make notes, and take photos (if a camera is available). In addition to the main points they should get an overall feel for their section. They should also drive off their main thoroughfare into at least one residential area and get a feel for that. *Roughly how old is it? Was it more or less affected by changes nearby? What is the overall feel? Take a waypoint & picture here too.*

These area the areas:

1. North-South, along Fourth Street (mostly driving)
2. East-West, West of downtown along Central (mostly driving)
3. East-West, East of downtown along Central (mixed walking & driving)
4. Downtown (walking)
5. Interstate (driving)

Lunch - *restaurants representative of each area/history will be suggested. Addresses are listed on your data sheet.*

1. Red Ball Cafe
2. Route 66 Malt Shop or in Old Town
3. Route 66 Diner or Kelly's Brewpub
4. Lindy's Diner
5.

After lunch, each group may finish any unfinished portion of their zone. Then at (TIME), all groups will meet at the Special Collections Library (ADDRESS).

After that, each group should go visit at least one other group's area. This time, it is not necessary to stop and do all the research – just drive around and get a feel for how it is the same or different.

Before heading back to Grants, any groups that have time remaining can stop by a pre-selected casino. Here they will take additional data for the License Plate Project.

Additional Background on the Transport Corridors

The NS travel corridor has a much longer history than given above. Originally, it was part of the Camino Real de Tierra Adentro, or Royal Road to the Lands of the Interior (Camino Real for short). At about 225 years of age, it is the oldest European highway in the US. One of the most trepiditious sections of the entire US 66 highway existed along this section – La Bajada hill. Blasted and carved by convicts out of a talus slope that drops off La Bajada mesa, this portion of the road was at first more of a switchback trail! The Fred Harvey Company managed to widen it some and eliminate some switchbacks in 1925, as they needed to get their Indian-tour busses through.

Likewise, the East-West transportation has a longer history. Various trails were first established as the nation started moving westward. These early transport corridors included the Old Santa Fe Trail, Jedediah Smith's path across the Mojave Desert to San Bernardino and Beale's Wagon Road across New Mexico and Arizona. The railroads soon followed these routes, with some deviation. These realignments improved the trails in areas, as the rail routes had to follow the lands contours to avoid steep grades. Additionally, the steam engines needed considerable amounts of water, so they had to connect with water sources. Thus, they reinforced the EW corridors by providing new, easier wagon routes, and wagons began following the rail tracks. Many railroad sidings and water stops survived into the highway times.

Originally planned to follow the Old Santa Fe Trail, a lesser-known Gold Rush trail that ran through Oklahoma was used in part, as one of the major planners wanted to bring business to that state. Much, much more information on US 66 can be found online with a Google search on Route 66.

For information on the Interstate system, some places to start are:
http://www.fhwa.dot.gov/interstate/homepage.cfm
http://www.tripnet.org/
http://www.transact.org/

More on all of the transport eras can be found at
http://www.albuquerque300.org/index.aspx?nav=1&level=1&pk=96&fk=&temp=22
In the row titled "Transportation & Communications"

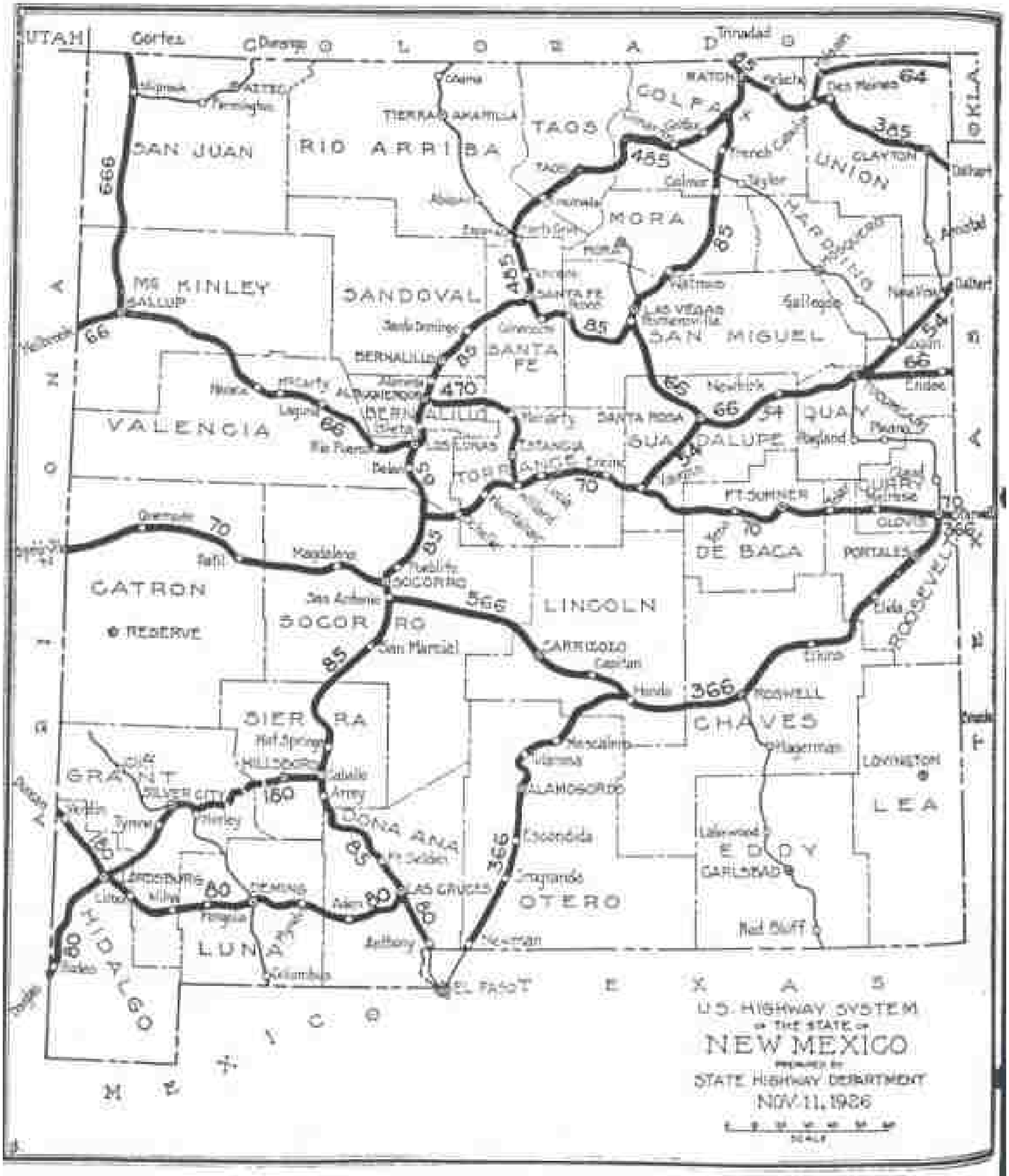
Hint question: How might both Santa Fe and Albuquerque be different today if US 66 had kept its original alignment? Students could answer this particular question many ways: with a writing assignment, math, and so on. IN a GIS, they could draw borders around SF & Abq to show different sizes they think the city might be, or draw in how an interstate using that alignment might go… What other questions can you think of?

Hint question: What might be done to alleviate traffic congestion in Albuquerque? How might the solutions change the current patterns? For example, if mass transit is one answer, there might be less places people get off the transit, but more people getting off there. How would businesses shift and change?

La Bajada hill as part of US 66/85, between Santa Fe & Albuquerque.

United States Highway System

State of New Mexico




UT
Durango
San Juan R.
Navajo Res.
COLORADO
OK
Shiprock
Farmington
Aztec Ruins Nat. Mon.
Bloomfield
Chama
Raton
Capulin Volcano Nat. Mon.
Wheeler Peak
Clayton
Taos
Ghost Ranch
Abiquiu
Espanola
Chimayo
Chaco Culture Nat. Hist. Park
Los Alamos
White Rock
Jemez Nat. Rec. Area
Bandelier Nat. Mon.
Santa Fe
Fort Union Nat. Mon.
Las Vegas
Pecos Nat. Hist. Park
Conchas L.
Canadian R.
Rio Grande
Gallup
Rio Rancho
Bernalillo
Corrales
Zuni Indian Res.
Grants
Petroglyph Nat. Mon.
Albuquerque
Tucumcari
Zuni
El Morro Nat. Mon.
South Valley
Bosque Farms
Acoma Pueblo
Zuni-Cibola Nat. Hist. Park
El Malpais Nat. Mon.
Los Lunas
Belen
Santa Rosa
Salinas Pueblo Missions Nat. Mon.
Clovis
Portales
ARIZONA
Socorro
NEW MEXICO
Pecos R.
Elephant Butte Res.
Lincoln
Roswell
Ruidoso
Gila Cliff Dwellings Nat. Mon.
Truth or Consequences
Lovington
Alamogordo
Artesia
Silver City
White Sands Nat. Mon.
Hobbs
Gila R.
Rio Grande
Lordsburg
Deming
Las Cruces
Carlsbad
Carlsbad Caverns Nat. Park
Anthony
UNITED STATES
MEXICO
EL PASO
CIUDAD JUAREZ
TEXAS
CHIHUAHUA
SON.
New Mexico
0 20 40 60 80
Miles
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APPENDIX B:

PIÑON-JUNIPER PBL-GIS

Mt. Taylor Area Project

You live in an area where there's Piñon-Juniper (PJ) woodland. The last few years have seen a bad drought – and a piñon bark beetle infestation. This is an opportunity for your students to use GPS and GIS in a science investigation of a culturally relevant natural resource. It may also help the local community, the Forest Service rangers, and others make decisions on firewood harvesting, etc., if you can provide them with some data. Hopefully, you'll even be able build on this project with students in future school years, to investigate how things change as well.

Your students have already done background research and learned how humans – Native Americans and Europeans – utilized and altered the piñon ecosystem. Tribal peoples cut wood for raw materials and fuel. They also used fire to clear forested areas for agriculture, moving to new areas as the soil became depleted. The piñon nuts themselves were also a food. In fact, there was a wide trade in piñon nuts throughout the Southwest, which also spread seed into new areas.

The Europeans brought grazing and additional pressures to the ecosystem. Before southwest settlement, the spread of the piñon-juniper woodlands was confined to rocky shallow sites. Fire suppression and heavy grazing, added to favorable climactic conditions and increased seed spread, encouraged the PJ woodlands to invade neighboring grasslands.

Your students have also studied the ecosystem itself, especially in relation to the drought and the bark beetle (Piñon ips). Towards the end of the 20th century, a wet cycle caused extensive growth in the PJ ecosystem, and the trees not only spread but also became unnaturally crowded. Then came the current drought with its dry conditions. High competition for water caused water stress in the PJ woodlands. Stressed trees become more vulnerable to the effects of disturbance.

In piñones, one possible disturbance is infestation by the piñon-bark beetle. The piñon tree uses sap as a defense against infestation, but without sufficient water, the trees cannot generate enough sap to defend themselves. Low defenses can lead to high mortality from infestations.

Reading your students papers, and checking in at the ranger station, you have put together a few more notes on the PJ system, which are at the end of this paper.

You've found two areas for a field trip, where your students will gather data. And of course you've started the planning process. You've got permission slips & rounded up some parents to drive. But before you go, you have a little more planning to do on the data gathering, so that when you get out there, you're ready to go. You don't want to spend field time figuring things out while it gets hot!

Before going, everyone needs to agree on a code system so that all the data can be shared back in the lab. In this case, what might be useful to count? Think about it, then check out the hints below. Once you know what you're counting, come up with a system to record your data.

Your class will split in two groups, with two or more teams per group (each group takes one of the two areas). You have 18 students going. One way is to divide up into 3 groups of 4 and 2 groups of 3.

Then, each set of the two groups of teams needs to decide how to lay out the data sampling survey sections in their area. Each team will do at least one section, more if there is time. Each survey section will be 50m square in size. Should it have an orientation? The teams need to coordinate so that their sections are all contiguous in their area! Using your maps, sketch in the layout of contiguous sections for your area.

Then, each individual team needs to figure out how to actually inventory their section(s) so that everything is counted once, and only once! Hint: there could be more than one way to do this…

The two areas, with GPS coordinates, are:

1. *MESA 35˚ 23.787, -107˚ 40.933 = On top of a mesa and*
2. *HILL 35˚ 11.777, -108˚ 02.070 = In a rolling, hilly area*

You ask your students to consider what might be important in determining what they find within their sections and areas? Hint below.

The morning of the field trip, your first stop will be the Cibola National Forest Ranger Station, where the ranger will give a background talk. (Additional directions will be provided as necessary.)

Once an area is chosen, each team makes a 50m square section using string, according to the group's layout plan, and takes GPS reading at the corners. Then each team inventories their section according to their inventory plan! You'll also have string to help with this. Is it working as well as you thought? Why or why not? If a camera's available, take some photos of each type of data, of the overall area, & anything else that might be useful.

If you have time when you're done, repeat with a second section of 50mx50m. Try a different inventory method if you want.

While you're out, also look around & see what else might be worth investigating – whether in relation to this study or something unrelated. What are the grasses & shrubs like, if any? What is the soil like – does it seem stable, do you see signs of erosion? What human activities might be taking place here? What animals/ signs do you see, if any?

When done with this project, go to Grants, NM. Take a look around town. See what kind of projects you can come up with! There is a history of mining, for example. What things are here students could find – locations of historic interest, resources (hint – museum!), etc? What effect might mining have had on the first nations peoples – good and/or bad? On the land, water and air?

Back in the lab the next day, combine GPS data into one file. Then share it 'round so everyone can add it to their own maps. Then we will explore the data. Some questions – why did we do areas instead of points this time? What might have happened if we tried to GPS every tree? How would you improve this lab? What are some things you can do in your area that might use this type of data gathering & analysis?

We'll finish up with discussion, presentation, & assessments.

Additional Background on the Piñon-Juniper Woodlands

The Piñon-Juniper (PJ) Woodlands cover a large area of the Southwest (17 to 30 million hectares), especially south and central Utah and Nevada, and northern Arizona and New Mexico. This range includes much of the Great Basin, Upper and Lower Colorado and Rio Grande watersheds. In New Mexico alone there are about seven million hectares of PJ forests. The PJ forests have a large range throughout the southwest, with a high degree of heterogeneity in the various parameters and characteristics.

The PJ forest first took shape after the last ice age. Around 11,000-8,000 years ago, the glaciers retreated and mixed conifer forests moved northwards. The PJ forests also moved from the lowlands into higher elevations previously occupied by the conifers. The PJ ecosystem has sustained a variety of species, including humans, providing them with food and shelter.

Both piñon and juniper grow in a semi-arid climate, a water-limited ecosystem. Piñon need more moisture than juniper. The morphology of both species is drought tolerant, with a compact form, which presents minimal plant surface to the elements.

The PJ forest primarily grows at elevations from 1220-2550m. This range is bracketed at the lower level by desert grassland, short grass, chaparral, desert shrub or oak woodlands, where soil moisture becomes insufficient to support the trees. The upper elevation generally intergrades with the lower montane forest of ponderosa or Gambel oak, where cold, wet and windy conditions are too harsh.

Within their habitat range, piñon and juniper grow alone and in mixed stands, with composition depending on temperature, water availability and location. Elevation influences affect stand structure. At lower elevations piñones are shorter and more widely spaced and juniper dominates while at higher elevations, piñon is dominant, growing more densely and taller. Either tree grows best when not in competition with the other.

Juniper acts as a pioneer at many sites, growing under the shelter of shrubs. It then provides shelter for piñon seedlings, as piñon is a settler species rather than a pioneer. The heavy seeds of both species drop near the tree or are dispersed by birds or small mammals. While seedlings grow in the shade of other trees, they become shade intolerant as they grow, with Juniper becoming more so. Their root systems grow quickly, sending out a taproot in deep soil, but lateral roots in shallow soil, where it competes with grasses. Aboveground, both are slow growing, an adaptation to drought, and reach heights of 20-60'. Piñones may be the slowest growing of the pines, but grow faster than Juniper, so they could potentially replace it in many but the driest sites. Intervention of fire, drought and other disturbances may limit this process. A tree can live up to 300 years.

Vegetative ground cover is sparse. Under the canopy, shading, interception, litter and allelopathic (inhibition of growth in one species of plants by chemicals produced by another species) effects keep vegetation to less than ten percent of ground coverage. The intercanopy space, however, is little better. Experiments found approximately 11-12% vegetative cover. This leaves a very high percentage of bare soil, vulnerable to erosion.

Piñon and juniper trees grow in a variety of soils. Common parent materials include basalt, granite, alluvium, sandstone and volcanic rock. The soils tend to be rocky, with textures ranging from stony and gravelly to compacted clay and sandy loams to clay loams. They are well drained and depth generally ranges from shallow to deep (50-150cm). Additionally, they are alkaline and infertile. Soil grades range from Aridisols to Mollisols as elevation increases from lower, drier areas to higher levels. Also included are Alfisols, Entisols, Inceptisols, Vertisols and a few Lithosols.

Evapotranspiration is the dominant mechanism of water loss in this system. Tree uptake of water can reach up to eight meters into intercanopy space, creating competition for water between the trees themselves and between trees and other vegetation. Due to the intermediate closure levels of canopy cover, solar radiation driven soil moisture evaporation is spatially variable, with intercanopy areas having higher evaporation rates, especially in the summer.

Simulated rainfall has been used to measure some hydrologic parameters in the PJ forests. For example, infiltration has been measured, and found to decrease with increasing moisture, as is to be expected. Infiltration also decreases with disturbance of soil. Among other factors, destroying the soil also harms soil microflora, which also decreases infiltration. Biological soil crusts are an important part of hydrological response, and can take decades to recover.

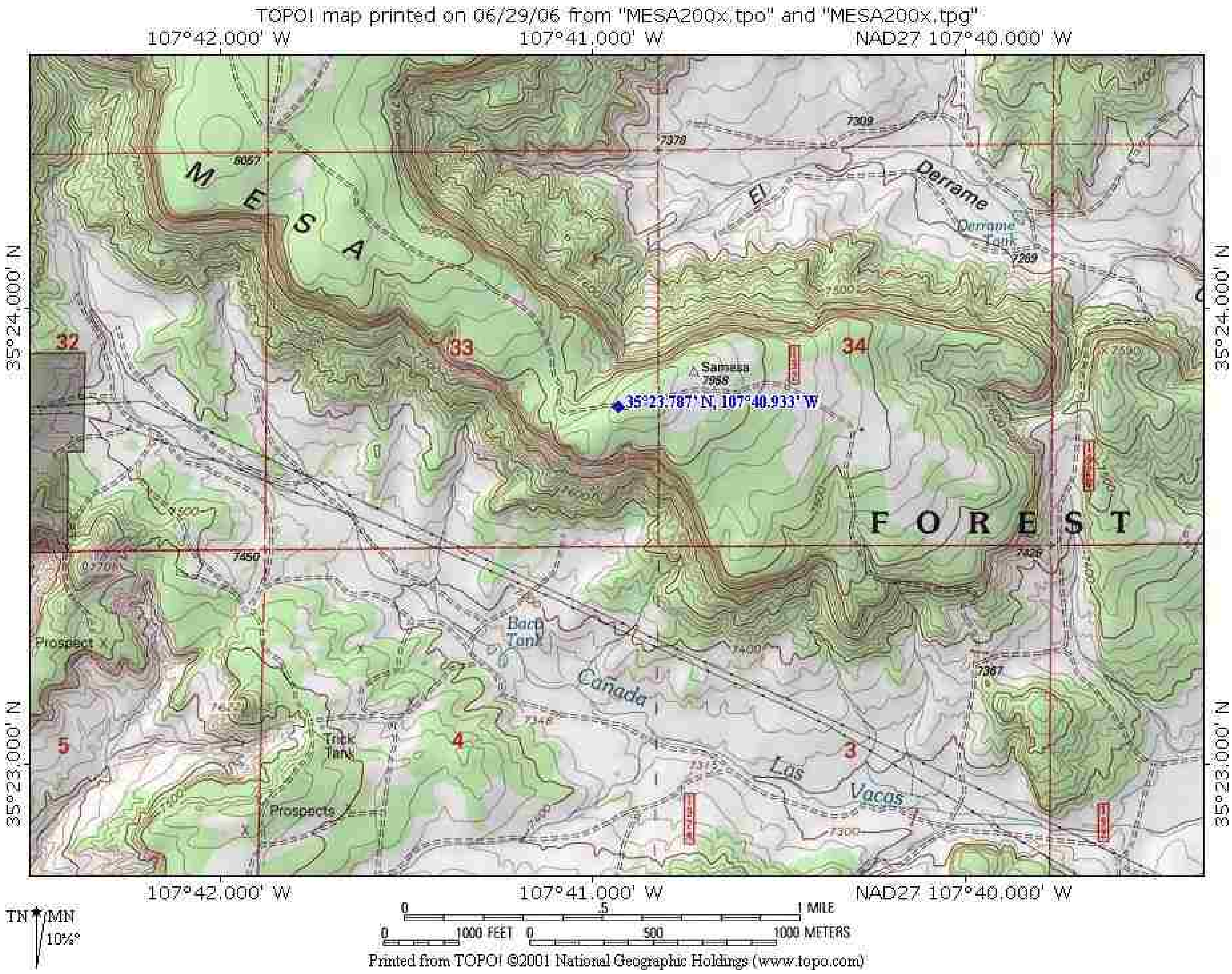
Although sporadic and only a small portion (typically less than 10%) of the water budget, runoff is a fundamental shaping force in semiarid landscapes such as the PJ woodlands. In this system, runoff is generally infiltration-excess overland flow. In overland flow systems, runoff is controlled by infiltration characteristics of the soil. This also means there is a poor correlation between precipitation and runoff, that is, precipitation does not predict runoff in most cases.

Other factors do influence runoff, however. One is the vegetative cover, with bare ground (disturbed or otherwise) having higher runoff than vegetated areas. Vegetation distribution also influences runoff. Stippled or clumped patterns allow more runoff than a more uniformly distributed vegetation pattern. The vegetation may become isolated from a large portion of its water supply as the runoff begins to flow preferentially in a reticular pattern around the clumps. The formation of topographic features such as channels – rills, gullies, etc. – can further concentrate runoff patterns.

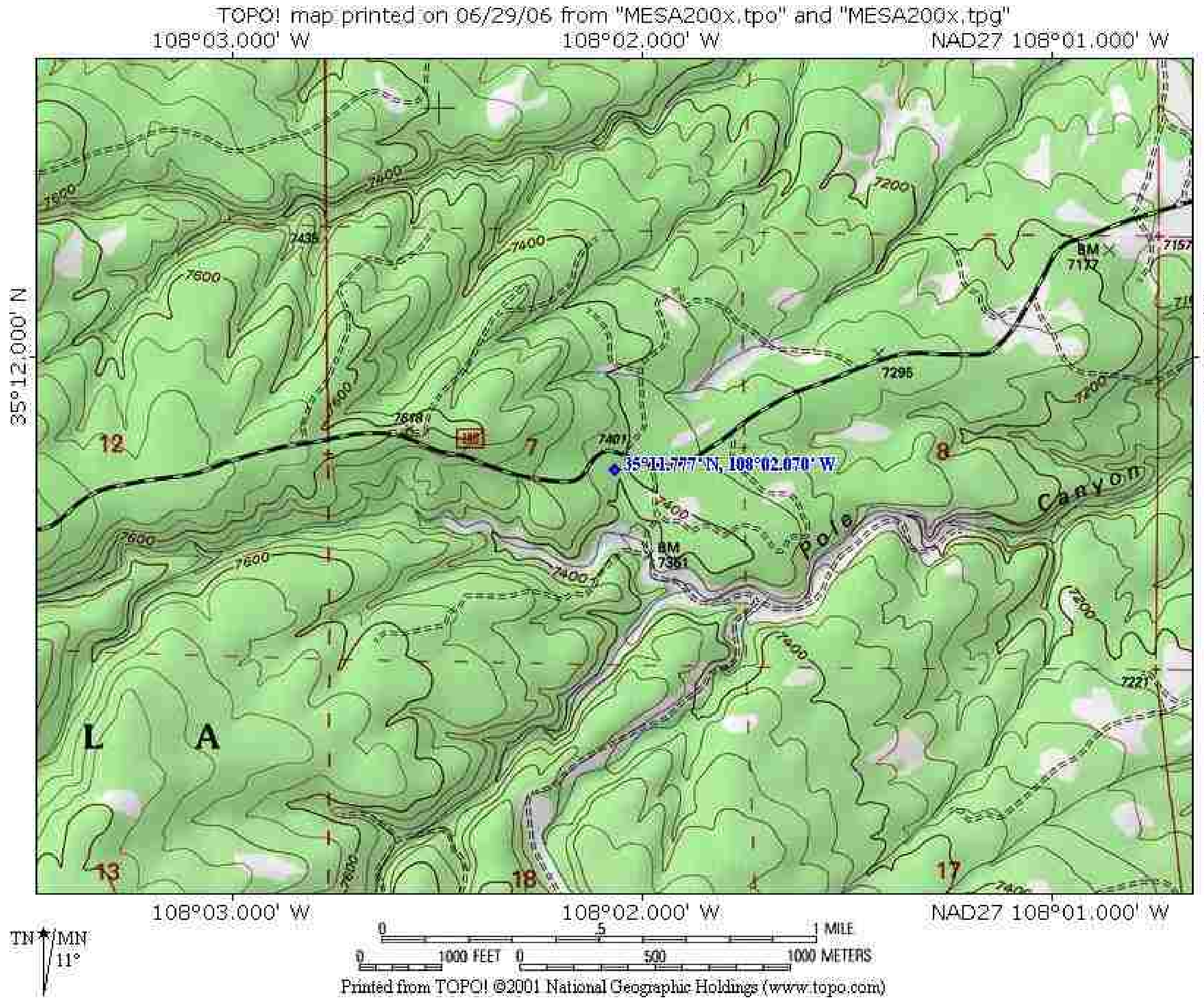
So there are a lot of things to look at in this interesting landscape!

Hint 1. You might count live piñon & juniper trees, dead P&J trees, stumps, other conifer, & other deciduous.

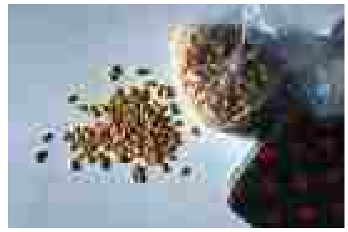
Hint 2. What might affect how much water a tree gets, when it does rain? And what could affect how much water is lost to evapotranspiration? Amount of canopy cover, slope, aspect, vegetation cover (grasses, etc.), soil type -> infiltration vs. runoff, shadiness v. sunniness…



Study Area 1: MESA 35˚ 23.787, -107˚ 40.933



Study Area 2: HILL 35˚ 11.777, -108˚ 02.070



Top – piñon cone & nuts
Middle – healthy but crowded forest
Bottom – bark-beetle infestation

APPENDIX C:

EAGLE VISION SURVEY

Dear Eagle Vision Teachers,

I am investigating and analyzing the first two years of Eagle Vision, in order to help us know what worked, what didn't, and of course how to improve the program to better serve educators. My findings from this survey will also be used in my thesis, and published to help other GIS education programs. No identifying information will be made public, however, and you have the option of filling this out anonymously if you so desire. Ideally, I would prefer to have identifying information at least at school level, to correlate with state-level GIS resources, but it is a higher priority to me that you feel fully comfortable in responding to the survey itself.

This survey is in four parts, each explained below. <u>There are no wrong answers to any part of this survey! It is just as important for us to know and understand when things didn't work as when they did</u> – so if you were unable to use GIT in a particular semester, or your actual use did not meet your planned use, that information is just as valuable as when things went as well or better than expected.

I appreciate the time you take to fill out this survey and give us the benefit of your experience. If you have any questions, please feel free to ask me! Thanks!

Cody

Are you: Year 1 Teacher ___ Year 2 Teacher ___
Your school _________________________________ (optional)
Your name _________________________________ (optional)

Part I: General GIT Survey

The following section is about your use of GIT (GIS, GPS, etc.) and related information. For the first five questions, describe your use of GPS and/or GIS. Provide the subject(s) of the class(es) in which you used them. If you had different plans &/or classes for fall and spring semesters, indicate the semester as appropriate. Include your activities during the current semester. (Year 1 teachers, answer for both year 1 & 2; Year 2 teachers only need to describe the current year, as appropriate.)

1. Describe projects carried out with students using GIT. Include the class name or subject. Distinguish between materials you prepared ahead, and what students did on their own.

2. Briefly describe any materials you created for classroom use using GIT (but did not require your students to use GIT), and indicate in which classes you used these materials.

3. Briefly describe your original plans for using GIT when you left the summer institute, if they were different from above.

4. Briefly indicate whether any differences between your plans and your implementation came out better, worse, or just as well as you envisaged. Also briefly explain why your plan changed, such as supports or barriers you encountered.

5. Briefly describe existing GIS materials you may have used in your class (such as the Blue Book), and what worked and didn't work with those materials.

6. Briefly describe your plans for *future* GIS use.

7. Briefly describe any GIS or GPS experience you had *prior* to joining Eagle Vision

This and the following sections are simple rating scales. Next, rate the following statements on a scale of 1-5, with 1 being very low to 5 being very high.

At this point, my students know how to use GIT to:

Make a map.	1	2	3	4	5
Investigate a problem in their community.	1	2	3	4	5

At this point, I know how to integrate GIT in my classroom plans as:

A mapmaking tool.	1	2	3	4	5
A tool for PBL.	1	2	3	4	5

I can use the GIS help tools to figure out how to do new things.
1 2 3 4 5

I worked with/helped/got help from my teacher-partner (if applicable).
1 2 3 4 5

Was there culturally based resistance to GIS from parents or tribal leadership?
1 2 3 4 5

Was there political resistance to GIS from IT teachers, IT staff or administration?
1 2 3 4 5

Was there support from parents or tribal leadership?
1 2 3 4 5

Was there support from IT teachers, IT staff or administration?
1 2 3 4 5

How was your students' response to GIT as a technology?
1 2 3 4 5

How was your students' response to other subject matter as integrated with GIS?
1 2 3 4 5

Part II: GPS Skills

This section looks at some basic GPS skills. Rate your abilities before and after Eagle Vision, and your students' abilities before and after your use of GPS in the classroom. Use a scale of 1-5, with 1 being very low, to 5 being very high.

	Before	After
I understand navigation with GPS.	1 2 3 4 5	1 2 3 4 5
My students understand navigation with GPS.	1 2 3 4 5	1 2 3 4 5
I can take waypoints and tracks.	1 2 3 4 5	1 2 3 4 5
My students can take waypoints and tracks.	1 2 3 4 5	1 2 3 4 5
I can add GPS data into GIS.	1 2 3 4 5	1 2 3 4 5
My students can add GPS data into GIS.	1 2 3 4 5	1 2 3 4 5

Part III: GIS Knowledge & Skills

This section looks at GIS knowledge and skill in a range of areas. Rate your abilities before and after Eagle Vision, and your students' abilities before and after your use of GIT in the classroom. Use a scale of 1-5, with 1 being very low/completely uncomfortable, to 5 being very high/completely comfortable with using this in the classroom.

	Before	After
I can measure distances and lengths.	1 2 3 4 5	1 2 3 4 5
My students can measure distances and lengths.	1 2 3 4 5	1 2 3 4 5
I can buffer an object.	1 2 3 4 5	1 2 3 4 5
My students can buffer an object.	1 2 3 4 5	1 2 3 4 5
I can use map algebra to generate additional information from raster data.	1 2 3 4 5	1 2 3 4 5
My students can use map algebra to generate additional information from raster data.	1 2 3 4 5	1 2 3 4 5
I can do a point pattern analysis (e.g. ABQ data).	1 2 3 4 5	1 2 3 4 5
My students can do a point pattern analysis.	1 2 3 4 5	1 2 3 4 5
I can find and download data sources.	1 2 3 4 5	1 2 3 4 5
My students can find and download data sources.	1 2 3 4 5	1 2 3 4 5
I can select subsets of data with queries.	1 2 3 4 5	1 2 3 4 5
My students can select subsets of data with queries.	1 2 3 4 5	1 2 3 4 5
I can use symbology and color to meet basic map design standards.	1 2 3 4 5	1 2 3 4 5
My students can use symbology and color to meet basic map design standards.	1 2 3 4 5	1 2 3 4 5
I can edit a database to enter a new data that we collected.	1 2 3 4 5	1 2 3 4 5
My students can edit a database to enter a new data that we collected.	1 2 3 4 5	1 2 3 4 5
I know what a raster is.	1 2 3 4 5	1 2 3 4 5
My students know what a raster is.	1 2 3 4 5	1 2 3 4 5
I understand resolution and scale.	1 2 3 4 5	1 2 3 4 5
My students understand resolution and scale.	1 2 3 4 5	1 2 3 4 5

I understand vector data representations. 1 2 3 4 5 1 2 3 4 5
My students understand vector data representations. 1 2 3 4 5 1 2 3 4 5

I understand the use of spheres, ellipsoids and geoids in modeling the Earth.
1 2 3 4 5 1 2 3 4 5
My students understand the use of spheres, ellipsoids and geoids in modeling the Earth.
1 2 3 4 5 1 2 3 4 5

I know the difference between Geographic Coordinate System and Plane Coordinate System. 1 2 3 4 5 1 2 3 4 5
My students know the difference between Geographic Coordinate System and Plane Coordinate System. 1 2 3 4 5 1 2 3 4 5

I understand datums. 1 2 3 4 5 1 2 3 4 5
My students understand datums. 1 2 3 4 5 1 2 3 4 5

I can project or reproject data. 1 2 3 4 5 1 2 3 4 5
My students can project or reproject data. 1 2 3 4 5 1 2 3 4 5

I understand how different projections are used for preserving properties of area, shape or distance. 1 2 3 4 5 1 2 3 4 5
My students understand how different projections are used for preserving properties of area, shape or distance. 1 2 3 4 5 1 2 3 4 5

I can download and use aerial photos as a backdrop to other data.
1 2 3 4 5 1 2 3 4 5
My students can download and use aerial photos as a backdrop to other data.
1 2 3 4 5 1 2 3 4 5
I know how to use Metadata to assess data usefulness and quality.
1 2 3 4 5 1 2 3 4 5
My students know how to use Metadata to assess data usefulness and quality.
1 2 3 4 5 1 2 3 4 5
I know something about the ArcGIS environment and software (ArcCatalog, license .mxd files)? 1 2 3 4 5 1 2 3 4 5
I know about data models and spatial data in GIS (vector, raster, floating-point grid)?
1 2 3 4 5 1 2 3 4 5
I can do some operations in GIS (clipping, data query, converting a coordinate system)?
1 2 3 4 5 1 2 3 4 5
I know some GIS terminology (coverage, attribute data)?
1 2 3 4 5 1 2 3 4 5
I know how to find and choose data for my projects (internet, unzipping, metadata)?
1 2 3 4 5 1 2 3 4 5

<u>Part IV: Additional Comments</u> Any comments that weren't covered by the above sections or that you would like to expand upon?

REFERENCES

Audet, R. and G. Ludwig (2000). *GIS in Schools*. Redlands, CA, ESRI Press.

Audet, R. H. and J. Paris (1997). "GIS Implementation Model for Schools: Assessing the Critical Concerns." *Journal of Geography 96*: 293-300.

Baker, T. R. (2005). "Internet-Based GIS mapping in support of K-12 education." The *Professional Geographer 57*(1): 44 - 50.

Baker, T. R. and S. W. Bednarz (2003). "Lessons learned from reviewing research in GIS education." *Journal of Geography 102*: 231 - 233.

Baker, T. R. and S. H. White (2003). "The effects of G.I.S. on Students' attitudes, self-efficacy, and achievement in middle school science classrooms." *Journal of Geography 102*: 243 - 254.

Bednarz, S. W. (2004). "Geographic information systems: A tool to support geography and environmental education?" *GeoJournal 60*: 191 - 199.

Bednarz, S. W. and J. v. d. Schee (2006). "Europe and the United States: the implementation of geographic information systems in secondary education in two contexts." *Technology, Pedagogy and Education 15*(2): 191 - 205.

Chang, K.-t. (2004). *Introduction to Geographic Information Systems*. New York, McGraw-Hill.

DiBiase, D., M. DeMers, et al., Eds. (2006). *Geographic Information Science & Technology Body of Knowledge*. Washington, DC, Association of American Geographers.

Drennon, C. (2005). "Teaching Geographic Information Systems in a Problem-Based Learning Environment." *Journal of Geography in Higher Education 29*(3): 385 - 402.

ESRI ArcGIS. Redlands, ESRI.

ESRI (2006a). Learning ArcGIS 9.

ESRI, I. (2006b). Understanding Map Projections and Coordinate Systems.

ESRI, I. (2006c). Understanding Geographic Data.

Gatrell, J. D. (2001). "Structural, Technical, and Definitional Issues: The Case of Geography, "GIS," and K-12 Classrooms in the United States." *Journal of Educational Technology Systems 29*(3): 237-249.

Kerski, J. J. (2003). "The Implementation and Effectiveness of Geographic Information Systems Technology and Methods in Secondary Education." *Journal of Geography 102*: 128-137.

Kerski, J. J. (2007). Internet-based GIS Education Opportunities and Challenges. *AAG 2007 Annual Meeting*. San Francisco, CA.

Malone, L., A. M. Palmer, et al. (2005). *Mapping Our World: GIS Lessons for Educators*. Redlands, CA, ESRI Press.

NRC, C. o. S. f. T. S. (2006). Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum. N. R. C. Committee on Geography, The National Academies Press**:** 313.

Rogers, E. (2004). *Diffusion of Innovations*. Free Press, New York.

Sittnick, P. (2005). Northwest New Mexico.

Sui, D. Z. and M. F. Goodchild (2001). "GIS as media?" *International Journal of Geographic Information Science 15*(5): 387 - 390.

Topo! (2001). New Mexico Seamless USGS Topographic Maps. San Francisco, National Geographic Society.

West, B. A. (2003). "Student Attitudes and the Impact of GIS on Thinking Skills and Motivation." *Journal of Geography 102*: 267-274.

Wigglesworth, J. C. (2003). "What is the best route? Route-finding strategies of middle schools students using GIS." *Journal of Geography 102*: 282 - 291.