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Facilitating Scientific Inquiry using CITYgreen and the Problem-Study Framework

Abstract

The *Problem-Study* framework is an approach to learning and lesson design in which the strategies and skills that make science a form of creative, critical, and analytical thinking are made explicit. This framework was used to design and analyze a place-based inquiry approach to learning about the environment with teachers and students using the CITYgreen software, an extension to ArcView 3.x by ESRI. It was found that using the *Problem-Study* framework to guide the design and evaluation of the curriculum as well as assessment of student learning was successful. Teachers learned how to build engaging, real-world projects to teach geography; enhance the students' computer skills; improve math and science knowledge; and to develop an understanding of how ecosystems function. Students' problem-solving skills improved.

Introduction

Research on the use of geospatial technologies (GIS) in schools has shown that teachers and students are able to engage in data visualization and analysis, spatial interpretation, and real-world problem-solving (Alibrandi, 1998; Alibrandi, Thompson, & Hagevik, 2000; Audet & Abegg, 1996; Baker, 2002; Hagevik, 2003; Hart, 1979; J. J. Kerski, 2000; McWillimas & Rooney, 1997). A recent report by the National Research Council, *Learning to Think Spatially* (2006), states that Geographic Information Systems (GIS) has the ability to meet four educational goals: (1) support the inquiry process; (2) be useful in solving problems in a wide range of real-world contexts; (3) facilitate learning across a range of school subjects; and (4) provide a rich, generative, inviting and challenging problem-solving environment (p. 176). Additional research has further documented other important benefits of using GIS such as increased motivation (McWillimas & Rooney, 1997), self-efficacy and attitudes toward technology (Baker, 2002), acquisition of spatial analysis skills (Audet & Abegg, 1996), increased mathematics ability (Coulter, 2003; Coulter & Polman, 2004), and geographic and scientific content knowledge (Alibrandi, 1998; J. J. Kerski, 2003). For more than a decade, educators and researchers have developed curriculum at the same time focusing on teacher professional development. These professional development efforts have engaged large numbers of teachers and provide compelling examples from classrooms of the potential of GIS to enhance teaching and learning. Some of the curricular materials available, educational projects and types of GIS software being used by teachers include:

Table 1. Major GIS Software Products and Curricular Projects

Software Name	Curriculum/ Projects
ArcGIS ArcView (Environmental Systems Research Institute, 1996)	USGS Education Saguaro Project CITYgreen 5.0 Mapping Our School Site (MOSS) Mapping Our Environment Pathfinder Science GLOBE VISIT Casey Trees My Wonderful World Geospatial Education for 4-H Mapping Our World: GIS Lessons for Educators, ArcGIS Desktop Edition USGS Education Earth Exploration Toolbox
*ArcExplorer *ArcVoyager	ArcLessons
MapInfo	GISAS Project
*Google Earth	Google Earth Lessons Google Earth Lessons Blog
*NASA World Wind	World Wind Central
My World GIS	Investigations in Environmental Science
Autodesk	Autodesk DesignKids
*GRASS	Using Digital Tools to Enhance Learning
Idrisi	Secondary Education Project (SEP)
*ImageJ	Earth Exploration Toolbox Ocean Explorers

* Freeware

Teachers and other advocates of using geospatial technologies in schools state that what makes these technologies different and particularly compelling is that students are able to interact with dynamic visual displays of real-world data which provides them with an opportunity to develop fluency in visual representations of data, quantitative data analysis and experience in database techniques (Edelson, Gordin, & Pea, 1999). But despite this enthusiasm, Kerski (2003) found that in a survey of more than 1500 high school teachers who had purchased GIS software, 45% of them had not used GIS and another 15% had no plans of using it. Of those that had used GIS, only 30% had used it in more than one lesson. A report by the GEODE Initiative of Northwestern University (Edelson & Moeller, 2004) identified the significant challenges facing teachers and students in their use of GIS software in the school computing environment. These include; (1) access to appropriate hardware and software, (2) technical and administrative support, and (3) integration of GIS into the curriculum. To address the challenge of integration into the curriculum, challenge number 3, a *Problem-Study* framework (Hagevik, 2003; Swartz, Fischer, & Parks, 1998) has been developed in which CITYgreen (American Forests, 2002), a GIS extension, is being used by teachers and students nationally. The *School*

Environmental Education Program by American Forests (2007) provides professional development, software, curriculum, support, partnerships, and continued technical assistance, which addresses the first two challenges.

Problem-Study framework

The *Problem-Study* framework is an approach to learning and lesson design in which the strategies and skills that make science a form of creative, critical, and analytical thinking are made explicit. It is based on research in: (1) constructivism (Wertsch, 1985) in which change occurs as the students integrate concepts into a conceptual schema and transform the experience into a coherent system (Howe, 1996); (2) critical thinking in which strategies for skillful thinking are made explicit (Swartz & Fischer, 2001); and (3) problem-based learning (Tosteson, Adelstein, & Carver, 1994) in which opportunities are given to investigate realistically complex situations (Sternberg, 2001). The framework is built around three phases (Table 2).

Table 2. Overview of the Problem-Study Framework

Phase	Step	Description	Evidence
Definition	Question	Students generate questions based on present situation.	Creative and critical list of many questions.
	Interest	Students are curious about the present situation and elicit possible solutions.	Purpose, interest and need as well as curiosity about situation. Ideas on possible solutions.
Generation	Instruction	Students find information based on their questions and interests from primary and secondary sources.	Students refine, add to, or change questions or ideas about possible solutions.
	Experiences	Students directly observe, measure, and test possible solutions.	Students begin to relate experiences to problem solutions.
	Consequences	Students model and visualize possible solutions based on consequences and their value.	Students practice and construct relationships based on evidences and their consequences and value.

	Solutions	Students generate the best solutions to the situation.	Students are able to explain how their solutions are based on consequences and value using evidence.
	New ideas	Students explain and interpret their findings.	Students come up with new solutions, new ideas, and future questions based on the knowledge they have constructed.
	Synthesis	Students apply their new ideas.	Students test new ideas directly or indirectly.
Study	Apply	Students analyze their solutions and prioritize their findings based on the consequences and their value.	Students report their analyses and findings based on their new knowledge to their peers.
	Transfer	Students apply their understandings to other contexts.	Students are able to explain why the solutions they chose are the best based on their new understandings and knowledge.
	Reflect	Students reflect upon their thinking and their learning.	Students can describe how they thought about the problem and can describe other ways in which they might use this type of thinking and learning.

Definition

In the first phase students become aware of the circumstances that created the present situation or problem by discussing and understanding any conflicts that exist with their own purposes, interests or needs. For example, a new building is being added to their school campus. But before the situation or problem can be addressed it must be defined. Students may need more information such as where will the building be located and what

will change as a result. If the problem of the new building is defined as how will the building affect the school campus, that may be too broad or as how will the new building affect our athletic fields, then that may be too narrow. It is important that students discuss the problem and define it in a way that is manageable, in other words, in this example something like how will the new building affect the green environment around the school campus. Students then generate questions and possible solutions based on a problem or situation related to their goals, in this case learning what affect humans have on the environment, rather than a means to accomplishing those goals, for instance, saving the athletic fields. Creativity and curiosity are an important part of generating as many well defined questions and solutions as reasonably possible.

Generation

In the second phase, generation, based on additional information students refine their questions and solutions. They may discover that some of their more unusual approaches are unworkable or on the contrary are the most valuable. Students begin to relate to the solutions as they experience observing, measuring, and the testing of their possible solutions. It is in this phase that students assess the possible solutions by carefully considering both the long and short term consequences and weighing how important they might be. Students then generate new solutions based on evidence, consequences, and value. This oftentimes leads to the combining of parts of solutions or to additional questions based on new knowledge they have constructed. Student should test their new ideas either directly or indirectly. For example, they may be able to collect some additional data or make additional observations. Maybe a new source of information could be found that would help them to reach some preliminary new conclusions.

Study

In the third phase, students report their findings to their peers and analyze their solutions based on their purposes and goals. Students transfer their new knowledge to other contexts by adapting it to similar or new situations. This could be done by comparing, role playing “what if” scenarios, creating analogies, or modeling possible new solutions. Students engage in metacognitive reflection as they think about their thinking and learning and describe the processes that they engaged in during the problem-study.

The *Problem-Study* framework provides guidelines for learning, instructional design, and assessment. Based on research, it includes a “learner-centered, knowledge-centered, assessment-centered” environment (Bransford, 1998), the “Learning Cycle” as a way of engaging students in authentic inquiry-based science learning (Abraham, 1998), and Swartz and Fischer’s (1998) problem-based approach to the learning and teaching of science. The following application of the *Problem-Study* framework focuses on a particular type of example, which we call the place-based inquiry approach. In place-based learning, a sense of connection to the land or to communities is developed through environmental project-based learning (Orr, 1992). According to Smith (1999), place-based education programs can be grouped into five types that can be used singly or combined. These include:

- Cultural studies: investigations of local history and culture that is important to the long-term viability of the community.

- Nature studies: unique environmental features of place through projects such as stream monitoring, restoration, and gardening in which there is usually a strong emphasis on science and mathematics.
- Real world problem-solving: an issue is identified and explored in greater depth and work is done within the community to solve the problem.
- Microenterprises: link with economic opportunities in communities through real enterprise partnerships.
- Community regeneration: citizens investigate issues and make recommendations to policy makers.

In the place-based inquiry approach, the same phases of *Problem-Study* are used to define the issue, generate solutions based on evidences, and study and apply these solutions to new understandings but these occur within the community and through community partnerships.

CITYgreen, *Problem-Study* framework, and Place-based inquiry

The *Problem-Study* framework can be used to develop and analyze curricular units. First, the overall goals or objectives of the unit need to be identified. This is usually done by analyzing the overall or general problem or issue that is going to be investigated and then determining the educational goals that best fit the objective. In the place-based inquiry approach, the overall general problem is going to be linked to the community.

CITYgreen, for example, is related to the study of how systems interact and develop together through time, recently known as the biogeoscience (Hedin, Chadwick, Schimel, & Torn, 2002). To do this, people must have knowledge of ecological patterns, systems of causation, and the long-term effects of human actions on those patterns. In addition, these changes often occur across an extensive range of spatial and temporal scales. This is an ideal application of the geospatial sciences.

After selecting the educational goals that best match the overall problem, learning activities need to be designed that will assist the students in defining related problems, which they will directly research, observe, or demonstrate. As a result, new ideas and knowledge will be generated based on evidences. Using GIS students can create multiple representations of their data, their problem solutions, and can use scientific models to investigate their results. For example, CITYgreen involves the use of remotely sensed images, data collection, and modeling to create and analyze current and future problem scenarios. As students explain their solutions based on consequences and value, they will discover new solutions or ideas based on the knowledge they have constructed.

In the study phase, students then apply their new learning through presentation and analysis of the process. As students reflect on what they have learned, they provide arguments and explanations that, in this case, can be used as recommendations to policymakers in their communities.

CITYgreen

CITYgreen, a GIS extension by American Forests (2002), is being used by more than two hundred cities as a powerful application for land-use planning and policymaking.

Remotely sensed images are used to analyze the ecological and economic benefits of trees and vegetation in an area of interest (AOI). CITYgreen uses models to calculate the services performed by trees for reducing stormwater runoff, mitigating air quality, saving summer energy, storing and avoiding carbon, and modeling tree growth.

For example, CITYgreen estimates the annual pollutant removal capacity of trees using removal rates for urban and suburban trees established by the USDA Forest Service. Dollar benefit estimates produced by CITYgreen are based on indirect or “externality” costs associated with a pollutant once it enters the atmosphere, at rates established by the local states’ Public Utilities Commissions. Pollution removal is reported in pounds, on an annual basis. Results include:

- Ozone (O₃) removal and related dollar value
- Sulfur dioxide (SO₂) removal and related dollar value
- Nitrogen dioxide (NO₂) removal and related dollar value
- Removal of particulate matter 10 microns or less (PM₁₀) and related dollar value
- Carbon monoxide (CO) removal and related dollar value
- The sum of individual dollar value calculations for each pollutant

CITYgreen estimates the total carbon storage capacity and the annual carbon sequestration rate of trees, using formulas adapted from USDA Forest Service research. CITYgreen references data from the canopy theme to make its estimates. For individual trees, CITYgreen considers trunk diameter information recorded in the canopy layer theme table. For forest patches and raster datasets, CITYgreen uses overall canopy cover to calculate carbon sequestration values. The program estimates annual sequestration, or the rate at which carbon is removed, and the current storage in existing trees. Both are reported in tons. Carbon results include:

- Age distribution of trees
- Carbon stored by trees (reported in tons)
- Sequestration rate of trees (reported in tons per year)

Using curve numbers for urban and suburban soils developed by the USDA Natural Resources Conservation Service, CITYgreen estimates the stormwater runoff reduction capacity of trees within an Area of Interest. The software employs methods documented in *Technical Release 55: Urban Hydrology for Small Watersheds*, commonly known as “TR-55” to estimate the flow of water over land within the sample/study area boundary. CITYgreen calculates the impact of tree canopy and vegetation on stormwater runoff volume. The dollar benefit is calculated by multiplying the volume of stormwater reduced by trees by a local cost per cubic foot for mitigation (e.g. the cost for building retention ponds, building additional stormwater management facilities, or treating water). Stormwater results include:

- Average 2-year, 24-hour rainfall
- Soil hydrologic group
- TR-55 Curve Number under current conditions and without trees
- Runoff volume under current conditions and without trees (reported in inches)
- Value of stormwater control performed by existing trees (reported in dollars)

The CITYgreen software conducts complex statistical analyses of ecosystem services and creates easy-to-understand maps and reports. Using the *Problem-Study* framework, we developed a middle and high school curriculum unit for earth systems science that combines the use of geospatial data and software with hands-on outdoor activities in which the students observe and measure trees. The unit is an ongoing development effort and the product of many teachers, the American Forests educational support team and curriculum developers. The curriculum has been revised and adapted over a period of five years.

Description of unit and sequence

The overall or “big” idea for the unit is that students will understand how trees provide services to the environment and their communities and ways in which people make decisions everyday that affect trees, the overall environment, and other living things. The unit begins with a discussion about trees and the benefits of trees to the environment. Students are then asked to think about ways their school campus contributes to the health of trees and other living things, including themselves. The big idea of the unit helps create purpose and interest as well as elicit questions that will eventually define the problem, their questions and solutions. As students investigate the big idea, they learn about and question the relationships between trees and their effects on air quality, water quality, temperature, energy consumption, and stormwater runoff.

Understanding these relationships requires an understanding of fundamental science concepts commonly found in national, state, and school system documents. These include conservation of energy, heat, and temperature; human impacts on the environment; water chemistry; components of the air; and ecosystem functioning and health. The curriculum is divided into eight parts which take from one to five 50 minute class periods each to complete.

1. Messing Around. Students use ArcView 3.3, a GIS software, to determine the population change of major US cities between 1990 and 2000. Students then determine which counties in their state show the highest population density. Students consider, “What might be the effects of increased or decreased population density on the environment?” Students then examine an aerial photograph of their region. The students consider their own campus, changes in population, and how it has contributed to the “green” environment in their community. Next, students go outside and observe the environment around their school campus. Based on their observations students generate questions and ideas and offer some possible solutions.
2. Research. Students then research information based on their questions about trees, air quality, water quality, stormwater, carbon, and energy consumption and refine

- their questions based on evidences.
3. Inside procedure: Students begin their small area analysis by creating a site map of their school campus using CITYgreen. After determining the school campus' boundaries, the students "digitize" or draw them on an aerial photograph of their school using the computer. Students digitize other inventory themes such as buildings, impervious surfaces, grasslands, bare earth, shrub cover, water bodies, air conditioners, windows, and other user-created landcover types. The detail of the analysis is discussed by the class and related to the questions being investigated by the students, thereby forming their management plan. Before going into the field to collect data, a site survey and data inventory sheet is prepared and printed.
 4. Outside procedure: Students learn and practice their data collection techniques. Then, using the site survey and data inventory sheet, students break up into groups to collect data about the growing conditions for trees on the site. The data collected on the trees includes height, diameter, species, and health using field guides, tape measurers, and clinometers. Students collect additional information on buildings such as roof albedo, color, air conditioning, insulation "R-value" if available, number of stories and heating system. A group of students can enter data in the field if a lap top computer is available.
 5. Inside procedure: Students update their data by deleting or changing trees or other non-tree features based on their findings using the computer. This is called "ground-truthing". Students make predictions based on their findings before they run the CITYgreen analysis and generate a site report. Students discuss the results and use them to answer their questions. As students discuss their results they write down possible solutions based on consequences and their value to their problem questions. Finally, students determine and explain the best solutions to their questions.
 6. Modeling scenarios: Students will have new ideas as they analyze and discuss their data. To further investigate these questions the students break up into small groups based on common interest in their new ideas, solutions, or questions. CITYgreen can now be used to model and calculate the future benefit of trees using tree growth models and by creating alternate scenarios. For example, students may wonder what would happen if they removed the pond and planted trees there instead or what would be the effect of adding buildings to their school campus. Students predict and test their new ideas, analyzing their solutions using CITYgreen.
 7. Report. Students present their findings to the class and explain why they are making these recommendations based on consequences and value. For example, students asked, "How would the landcover composition change from current conditions if the area of interest included only the area around the school?" Students found that while there were many trees at the edges of the school property, there were few trees around the school itself. Impervious surfaces increased so the volume of stormwater runoff increased and carbon and air pollution benefits decreased. Students decided that it was important to plant more trees around the school campus. The CITYgreen models helped them to create a persuasive argument for tree planting. The students realized that they were

conducting the same analyses as their local governments and participating in solutions in their own communities.

8. Reflect. Students keep science journals or notebooks as they continue to question, predict, revise, experiment, provide evidence, and modify their solutions. At the end of the unit, students draw a line and reflect and write what they have learned and how they learned it. Students reflect on their problem-study and record their thoughts on the process. This is called a metacognition log.

CITYgreen as an example of the *Problem-Study* framework

CITYgreen is an example of place-based inquiry that combines three of the five place-based education program components, according to Smith (1999). Students investigate their environment using mathematics and science to solve real world problems and participate in and make recommendations to policy makers. CITYgreen incorporates all of the steps of the Problem-Study framework as the learner defines, generates, and studies their thinking and learning.

Define: Part 1

During the first phase, the curriculum focuses the student around a “big idea” or overall problem question. In this case the overall question is, “How and what do trees provide for us?” Students then become investigators as they think about, observe, and consider the facts around the overall question. Students use ArcView 3.3 to investigate population in general and hypothesize some of the affects increases or decreases in population might have on the environment using their personal experiences. As students observe their own campus, they will begin to draw relationships between trees and other components of the environment such as water quality, air quality, and temperature. Students brainstorm and generate as many of their own questions and predict possible solutions. Students, who have never thought about trees this way before, become curious about the relationship of trees to the other components of the environment.

Generate: Parts 2 - 6

As students learn about the relationships of trees to the environment and their communities, they continually revisit their questions and possible solutions and refine them. Students experience a combination of hands-on experiences which we call the “outside procedure”, discussions, readings, lectures, and computer-based investigations which we call the “inside procedure” and modeling scenarios. The combination of direct experience and computer-based investigations gives students an opportunity to explore multiple relationships at many different scales. During this phase, experts or other primary sources are often used by schools to help with the data acquisition and problem analysis. Urban foresters, city planners, and GIS specialists oftentimes assist schools, creating an ongoing partnership with the community.

Study: Parts 7 and 8

In the third phase, students create maps of their group-based questions using the CITYgreen models and present their findings to their peers. Students apply their new understandings and ideas through presentations, discussions, and community action through the partnerships they have previously established. Using science notebooks or

journals students write what they have learned and how they learned it. To do this, students are asked to think about their own thinking processes or the steps in *Problem-Study*. First they describe what they did and how. Then they evaluate the process by answering the questions; Was this an effective way to think about this and why or why not? If not, how could you improve this process? Finally students are asked to describe when and how they would use this process again in the future. In this way students are evaluating the process that they just used to construct their new understandings.

Using CITYgreen and the *Problem-Study* framework

An in-depth study was conducted of one middle school teachers and his students (n=33) in which they used CITYgreen to conduct an urban ecological analysis of their school grounds over a 9 week period. The teacher and students were interviewed and the student projects and presentations were analyzed. The students could easily explain how to measure trees and their relationship to the environment. In addition, students could correctly answer questions on how the CITYgreen program worked and what it helped them to accomplish. All of the students completed an analysis using their own problem questions which they formulated based on their school campus CITYgreen project (Table 3).

Table 3. Student CITYgreen Analyses

Problem Question	Conclusion
What would happen if all the Bradford Pear trees at Carrington were replaced with Red Oak and Southern Magnolia trees?	The dominant tree on campus would become a red oak tree, which would improve wildlife benefits but carbon benefits, pollution removal benefits, and energy benefits would remain the same.
What would happen if the impervious surfaces increased by 70% and the trees decreased by 10%?	The carbon storage, pollution removal benefits and stormwater benefits decreased. If you want to make changes to the environment, you should consider the environment first.
How would the trees, carbon benefits, pollution removal benefits, stormwater runoff, and energy savings change if the study area were redrawn to include only the digitized area around the school?	The bare area decreased because we eliminated the bus lot. Stormwater benefits increased as a result. More trees should be planted around the school.
What would happen if 100%, 50%, and 25% of our trees died?	The air would not be as clean with fewer trees. We need to plant the trees we cut down due to building expansion.
What would happen if impervious surfaces increased by 75% and water by 50%?	The stormwater benefits and pollution benefits decreased. We suggest that impervious surfaces be limited at Carrington.
What would Carrington be like without trailers and instead there were trees?	More trees would save Carrington over \$500 per year in carbon and air pollution benefits. A few trees make a big difference.
What would happen if 50% of the trees were cut down or destroyed?	Carbon storage was lower and runoff increased. This would contribute to global warming. There would be less food for wildlife.
What would happen if water increased by 2% and trees decreased by 50%	If water increases then there are fewer trees. There is a decrease in the tree savings and overall energy benefits. The number of species of trees also decreased.

When interviewed, students overall said that they thought using CITYgreen was interesting and very different from what they would normally do in science class. For Example, Tony said, "It is cool and you are going to get to use the computer". Students said that they enjoyed going outside (50%), being on the computer and plotting things (30%), collecting the data (15%), and formulating an individual problem question (5%). Jacinta said, "The GIS part of it was cool and I liked making maps on the computer". Students said that the CITYgreen unit was different from what they normally did in science class because they:

- went outside
- used the computer
- did more mathematics
- worked longer and more in-depth.

Zach summarized the difference by stating, "everybody was doing a different project and there was no book to follow" and Emma said, "It was not just reading out of the book, you actually got to go outside and do it". Their teacher agreed and he felt that the students became more aware of how to collect and analyze data. N.D. said that, "...not only have their computer skills improved but their total awareness of the environment. It was new to them".

Students were able to explain many patterns that they noticed from the projects. Students noticed that they had a lot of Bradford Pears near their school and that they were all approximately the same height. Brittany said, "They do not provide good wildlife benefit. They basically were planted for decoration because they have flowers on them". Students were surprised by how many trees and how many different kinds of trees there were on their campus. During the project, a million dollar school renovation and expansion project was in progress. Students began to think about what the effects would be of the new construction. They realized from CITYgreen that fewer trees would mean decreased pollution benefits and fewer places for animals to live. They also realized the importance of larger trees and replacing trees that had been eliminated as the result of the construction. Carl said, "The more trees and the less buildings the more benefits you have. The more trees the less runoff there was".

At the conclusion of the CITYgreen unit, all students interviewed reported that they could more easily ask problem questions and explained possible ways of solving them. Using Problem-Study, the students were able to identify and explain how they would solve future problems. Understanding how to solve problems will help students develop process skills, which they can transfer to other situations.

Reflections on the *Problem-Study* framework

The students learned about the environment and how to use it to analyze data using CITYgreen. CITYgreen allows for "what if" questions associated with models that can show change over time (McGarigal & Romme, 2003). Audet and Abegg (1996) found that a gradual passage through several identifiable intermediate stages of procedural knowledge was important when using GIS to solve problems. The CITYgreen unit using

the *Problem-Study* framework is an example of a classroom application that addresses how to identify stages as students proceed from a lower level to a higher level of abstraction. The findings of this study also indicate that students benefit from an interactive and exploratory environment. Students enjoyed the balance between "inside work" and "outside work". This helped to motivate the data entry and students understood the connection between the environmental data they were collecting and its representation on the computer. If they had questions about their data, they could go outside and double check their findings. The teacher guides the students through the process using the three phases of definition, generation and study. As the students proceed through the process, the teacher can assess the students' proficiency at each of the three phases. In this case, during the definition stage, the students created lists of ideas and discussed the possible solutions using graphic organizers provided by the teacher. During the generate phase, the students used primary and secondary sources to answer their own questions and collected and visualized data. Their projects assessed their understanding of the relationship between trees and the environment. During the final phase, study, the students applied their solutions to consider how this might affect their school. They wrote reflections and discussed possible actions that they might consider. Therefore, the *Problem-Study* framework, guides instruction and evaluation as students' learn content.

Selected examples of using CITYgreen in the classroom

CITYgreen has been an excellent resource for some as an introduction to GIS and lessons in environmental science, social studies, math, and geography. Lyn Malone who had taught in public schools for 32 years as a social studies teacher recognized the advantages of using GIS in the classroom. In 2000, she and a colleague launched Project One, Two, Tree in response to a Rhode Island initiative that required every town to include an urban forestry component in its comprehensive plan. Malone thought it would be a great community service for the students to create a tree database that the town could expand. They piloted the project in their town of Barrington, where 80 students learned about urban forestry and used CITYgreen to create an inventory their middle school's 217 trees, analyze the range of species, and document their condition. During the next year, Malone trained middle and high school teachers from ten towns to conduct similar classes.

Drew Swierczek, is in his first year of teaching at McKinley Technology High School in Washington DC. McKinley is a newly reopened inner city school focused on providing technology skills applicable to an array of careers. Swierczek, who was charged with developing Community as Laboratory, an elective that uses CITYgreen software to teach students GIS and the environmental benefits of urban trees.

Swierczek had never heard of GIS prior to joining McKinley. Subsequently, he used the CITYgreen manual to teach himself the basics of GIS. He then incorporated the CITYgreen lesson plans and created an atmosphere where both he and the students learned from each other as they learned more about CITYgreen. After learning GIS and CITYgreen, the freshmen and sophomores conducted a tree inventory of their schoolyard and ran alternative scenarios for various planting schemes. Swierczek plans next year to

move out of the schoolyard to adjoining neighborhoods to inventory trees. He also envisions teaching a social studies course using GIS applications to analyze how a city park divides the city economically.

The success stories mentioned are just two in a list that is growing rapidly. In the four years that the CITYgreen workshops have been conducted, there has been a very positive reaction from students, teachers, and school administrators. CITYgreen is helping teachers and administrators bring technology into the classroom to educate students not only in core academic subjects but also in the importance of conservation in their communities. The program supports mission of growing a healthier world with trees through school and student participation by many states in the country such as Texas, North Carolina, Rhode Island, Missouri, Florida, and Georgia.

Conclusion

Students benefit from an interactive and exploratory environment. It is essential that curricula are designed in a way in which students can learn not only content but process at the same time. The *Problem-Study* framework provides guidelines for learning, instructional design, and assessment. Based on research, it includes a “learner-centered, knowledge-centered, assessment-centered” environment for learning. When incorporating technologies such as GIS into the classroom, it is essential that gradual passage through several identifiable intermediate stages of knowledge be identified. The *Problem-Study* framework identifies these stages and offers suggestions for assessment of learning, design of the instruction, and evaluation of the curriculum. Using GIS allows a new dimension to learning as students are able to easily explore, analyze, and predict solutions to multiple problems. It can enhance student learning when approached in a manner that supports good instruction. The *Problem-Study* framework has the potential to offer such support in the classroom.

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