

## **AC 2008-1970: USING SIMCITY 4 SOFTWARE AS AN EDUCATIONAL TOOL TO COMPLEMENT MIDDLE SCHOOL SCIENCE AND MATHEMATICS**

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## **Using SimCity 4 Software as an Educational Tool to Complement Middle School Science and Mathematics**

### **Abstract**

SimCity 4 (Electronic Arts/Aspyr) is a popular piece of entertainment software that has great potential for application in an educational context. Although students regard SimCity as a fun and engaging game, it is also a powerful and sophisticated environmental simulator. In this project, students used SimCity to engineer and maintain successful rural, suburban, and urban environments around natural landforms. This project was carried out through an NSF GK-12 Fellowship, pairing graduate students from the Drexel University College of Engineering with partner teachers in urban Philadelphia middle school classrooms.

Through a series of lesson activities using SimCity software, students practiced and developed a number of science and math topics critical in the School District of Philadelphia 6<sup>th</sup> grade curriculum, including landforms, environments, and the use of models to predict outcomes. They applied math skills to better understand scale as a form of ratio, used charts, plots and data tables to evaluate trends, and balanced income with expenditures.

The success of this module's activities was gauged by written and verbal student assessments before and after each of the three activity phases. In these assessments, students were asked to articulate their understanding of various natural landforms and environmental processes, as well as the roles engineers play in the design and construction of towns and cities.

### **Introduction**

SimCity 4 is a piece of entertainment software, developed by Maxis and published by Electronic Arts and Aspyr Media. Since its early development, the SimCity series has garnered attention as an educational tool.<sup>1-4</sup> In the course of this project, students were exposed to a wide variety of educational subject matter encompassing science, mathematics, geography, social studies and civics.

A module composed of three inquiry-based activities was developed around the SimCity software. This long-term project introduced students to the interface and mechanisms of the game, taught them to use terraforming tools to shape their landscapes with familiar and exotic landforms, and allowed them to develop towns and cities in their simulated environments. The students worked in teams to first generate a variety of landforms. Using the software's terraforming and terrain design tools, they created mountain ranges, plains, canyons, river valleys, and other geological features for their land plots. While being introduced to the software and its terrain building tools in the first two activities of the module, the student teams were given civil engineering projects to accomplish. They were asked to evaluate the best location for their projects and to consider the balance of effects the projects would have on society and the environment. In the third activity of the module, students added a human component to their landscapes by constructing and maintaining population centers. Their objective was to design thriving villages, towns, and cities that adapted to and made use of the landforms present, while preserving as much of the natural environment as possible.

This project was undertaken in the course of a National Science Foundation Graduate Teaching Fellowship in K-12 Education (NSF GK-12). In this program, graduate students from the Drexel University College of Engineering were paired with partner teachers (grades 5-8) from the School District of Philadelphia. The schools selected for participation provided an excellent opportunity to bring engineering education to student populations traditionally underrepresented in the discipline. An overarching goal of the program was to increase both the appeal and accessibility of engineering, through science and mathematics, for a broader student community.

This 6<sup>th</sup> grade SimCity project was one of a series of engineering lesson modules implemented by a team of two graduate students working in the 5<sup>th</sup> and 6<sup>th</sup> grade classrooms at Martha Washington Elementary School, in west Philadelphia. These GK-12 modules were designed to generate excitement about Science, Technology, Engineering and Math (STEM) fields. The participating teachers developed new perspectives on innovative ways of teaching science and mathematics. The graduate student teaching fellows, in turn, learned to meet the challenges of a middle school classroom and gleaned valuable insight and teaching experience, particularly as they worked with a student audience much different than their traditional graduate peers. The middle school students were exposed to engineering through inquiry-based interactive learning, with lesson activities that both complemented and enhanced the standard math and science curriculum.

## **Strategies**

The 6<sup>th</sup> grade science core curriculum in the School District of Philadelphia is based on a triad of three major units designed around Pennsylvania educational standards: Landforms, Astronomy and Environments. Each of these units is designed as an inquiry-based science experience, supported by FOSS activity kits (Landforms and Environments) and Holt Science and Technology Short Course materials (Astronomy). Modular lesson plans incorporating SimCity 4 were developed to support the Landforms and Environments units of the 6<sup>th</sup> grade curriculum. By accompanying and enhancing the existing course materials, the SimCity activities were meant to meet one of the stated strategic objectives of the School District of Philadelphia, which calls for “development, design and implementation of a core curriculum that is aligned to state standards.”

Students used the SimCity software in small groups, typically composed of 3 or 4 students sharing a single computer. This team-based strategy was a deliberate choice that was meant to acclimate the students to the collaborative processes of the scientific and technical disciplines, as well as provide students with opportunities to assume various different roles in a team structure. In this way, the SimCity lesson activities were designed to fulfill another strategic objective of the Philadelphia School District – that students be “provided rich education opportunities that will enhance productive citizenship in a democratic society.”

The SimCity module made use of existing computing hardware resources in the school, and introduced the students to the concept of simulation as an important component of engineering. By virtue of the module’s use of gaming technology, students were receptive and eager to more

fully participate. The use of computer simulation also broadened the scope of interactive “manipulatives” used by students to better understand textbook-based materials.

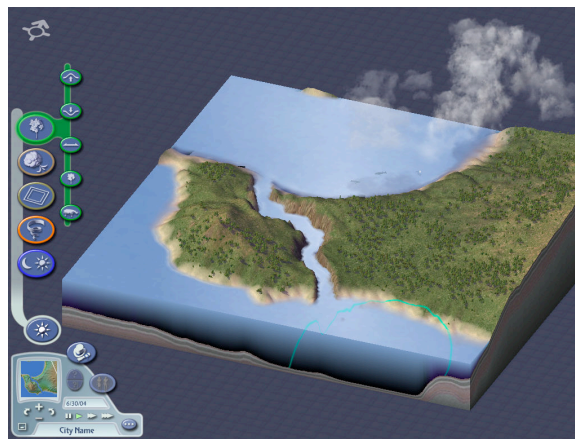
### **Implementation in the curriculum**

Module lesson plans from the Drexel University GK-12 program, including the activities described in this paper, are freely available for download at <http://gk12.coe.drexel.edu/>. The following activity synopses briefly summarize the SimCity activities developed to date. These lesson activities presented students with tasks in the form of design challenges, rather than simply as game play.

#### **Activity 1: Carving Canals**

This activity served as the introduction to SimCity 4. Students familiarized themselves with the software interface and used terraforming tools to manipulate the terrain. Vocabulary introduced in this lesson included isometric perspective, simulation, and terraforming. The activity was preceded by a general discussion of civil engineering, and was tied into math standards involving direction, scale and proportion, and models.

The design goal for this activity was the construction of a canal to connect two bodies of water (Figure 1). Each student team was given the choice of where the canal should be located and what path it should take, and were asked to explain their selection. In this initial lesson, students were allowed to make changes to their landscape without the constraint of limited financial resources. The teams discussed the positive and negative consequences of the canal and its construction, from economic, social and environmental perspectives. As an assignment, each student was tasked with a series of questions requiring individual research on the construction of the Panama Canal.



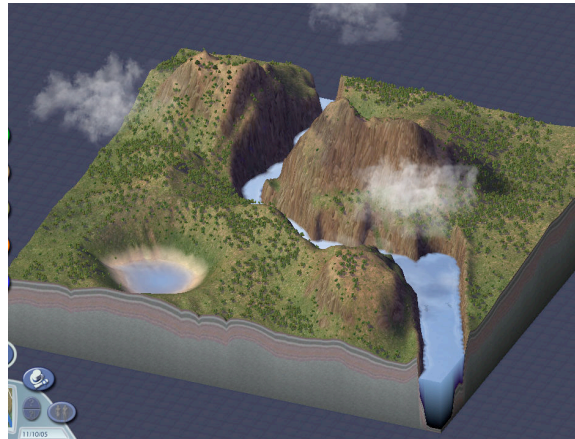
**Figure 1.** In the first activity of the module, student teams were asked to construct a canal to connect two bodies of water.

#### **Activity 2: The Ever-Changing Earth**

In the second activity of the series, students expanded their use of terraforming tools to model a variety of different landform types, including canyons, plateaus, mountains and craters. Each team was tasked with producing a unique landscape, with the sole constraint of producing a terrain on which they could later develop a successful human population center.

While the design goal of the first activity required very basic use of a single elevation-changing tool, this second activity involved using a variety of different tools in combination with one another to produce more sophisticated terrains of varying elevations and grades (Figure 2). It was necessary for students to recognize characteristics of many types of landforms and recreate them in their models.

During this lesson, care was taken to emphasize that the terraforming processes that students were quickly performing within the simulator, such as erosion, occur quite slowly and gradually in nature. The game's "paintbrush" style terrain editing system is perhaps an area of weakness from an instructional standpoint, since it offers little in the way of explanation of how various earth-moving processes occur in reality. This issue highlights the importance of the other activities prescribed by the district curriculum, such as stream table exercises, in which students physically observe erosion and other natural phenomena. The teams were asked to imagine they were the first to explore their landscapes, and to consider the best locations to begin a human settlement. As an assignment, each student researched the Grand Canyon National Park and Crater Lake National Park to learn the history of each park's famous landform structures.



**Figure 2.** More complex terrain was produced in the second activity of the series. Students designed landscapes on which they would subsequently develop towns and cities.

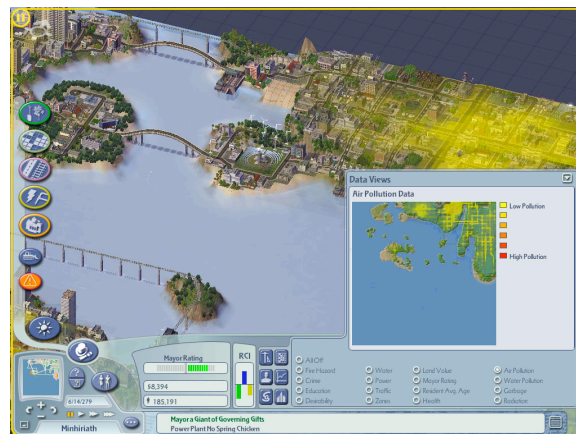
### **Activity 3: Humans and the Environment**

While the first two activities of the SimCity module were each performed in one or two class periods, the third activity was designed as a long-term project that linked the early-year Landforms unit with the late-year Environments unit. Over the course of many class periods, students developed rural villages, small and mid-sized towns, and larger cities on their landscapes. This portion of the module introduced a number of important scientific, technical and civic issues, including waste and pollution management, energy production, transportation infrastructure, and city planning. Additionally, students were required to make use of data in the

form of charts and graphs to evaluate and predict trends, and had to maintain a budget of municipal income and expenditures.

During this phase, students reevaluated many of their preconceived notions about science and engineering, particularly about environmental issues. For example, before beginning the SimCity project, student teams were asked to consider three types of human environments: rural farmlands, small towns and large cities. The teams were to decide which of these environments would likely produce pollution. Prior to beginning the SimCity project, the class unanimously agreed that cities suffer from pollution and that rural areas do not. These perceptions evolved and became increasingly sophisticated as students began designing agricultural villages in SimCity and encountered high levels of water pollution from their farms. They subsequently came to understand that pollution can be encountered in a variety of forms in many different environments, and does not only arise from congested cities and dirty factories.

Students were given the chance to take on different team roles, in rotation: environmental experts tracked pollution and the amount of available green space (Figure 3), city planners directed growth and zoning, budget managers adjusted taxes and approved spending, and human services specialists monitored health and education needs of the population. During this portion of the project, student teams were given a number of specific design challenges, including engineering a transit infrastructure with all roads free of congestion, budgeting for a school, health center, and green space in every neighborhood, maintaining a high tech industry with semiconductor plants, and developing the first city with a subway station used at over 40% capacity.



**Figure 3.** Students learned that pollution could be offset by environmental engineering efforts, including recycling plants, solar and wind energy, incentives for carpooling and public transit, and the planting of more trees.

### Assessment of the effectiveness of the module activities

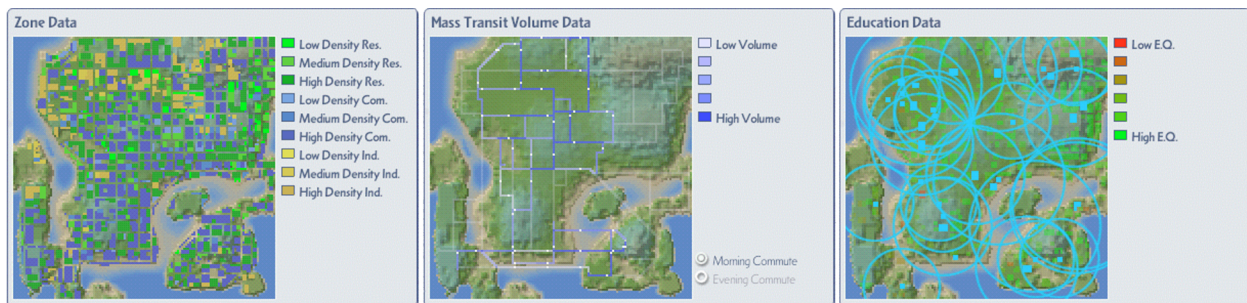
In order to evaluate the effectiveness of the SimCity module in enhancing the existing curriculum, student performance data were gathered in a curriculum-based assessment, with and without the aid of SimCity.



At the conclusion of the Landforms unit, a comprehensive written test was administered to the students. The questions were written by the GK-12 teaching fellows on topics from the Landforms curricular materials. This test was not designed to be an exhaustive survey of the unit, and it was not presumed that unscaled numerical scores could be directly correlated to letter grades (A–F) or benchmark ratings (advanced–below basic). This assessment was simply intended to compare the performance of students who reviewed for the test using SimCity, relative to the performance of students who did not use SimCity in their review.

On the day prior to the assessment, the teaching fellow reviewed unit topics with the students in two separate groups. One group of students (the “control group”) reviewed for the test in the classroom, using their science notebooks and the *Landforms* text from the *FOSS Science Stories* series. The second group of students (the “SimCity group”) used their notebooks and curricular texts, but also had access to the SimCity software. Students participating in this SimCity review group (composed of 6 girls and 6 boys) were selected by the teacher, and represented students of various levels of academic ability.

Each group was given the same 60 min. interval of time for a guided review session. Students were arranged in teams of 3 or 4, and were encouraged to study collaboratively. They were verbally quizzed by the teaching fellow, and were free to ask questions of the fellow and other students in their groups. Both the control group and the SimCity group were free to consult their science notebooks, the *Landforms* text and other curricular materials including photographs and posters. Additionally, the SimCity group was encouraged to make use of the software to practice pertinent skills, such as modeling various landforms, reviewing different types of maps and simulating erosion and other processes. For example, Figure 4 shows several data view overlays displayed on an aerial map of a SimCity land plot, corresponding to types of maps in the Landforms curriculum. The modeled river delta shown in Figure 5 was created by a student in the SimCity group during the review session.



**Figure 4.** Students can selectively monitor many types of data, overlaid on birds-eye-views of their landscapes. The views shown in this figure were used to reinforce recognition of inventory, mobility and thematic maps from the Landforms curriculum.

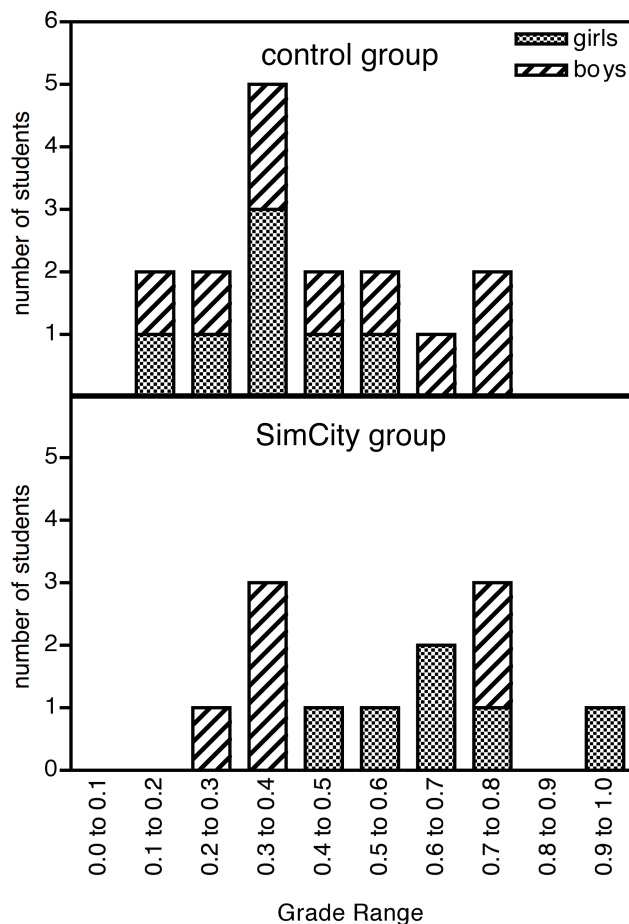




**Figure 5.** Using the software terraforming tools in SimCity, students generated a number of landform types such as this river delta.

The day after the review sessions, the same written assessment was administered to both groups. The test was composed of the following types of questions: identification (14), multiple choice (5), problem solving (2), matching (7), short essay (2) and free response essay/diagram (1). The questions were intended to test a range of different cognitive behaviors, including information recall and comprehension, application, analysis and synthesis.<sup>5</sup> Students were given 45 minutes to complete the test. The average score for control group students who reviewed for the test only with curricular materials was 43%, with a standard deviation 18%. Students in the SimCity group scored an average of 57%, with a standard deviation of 22%. Grade ranges, for both male and female students, are shown in Figure 6.

Of interest is the correlation of gender to the scores of each group. In the curricular review control group (Figure 6 *top*), the scores obtained by female students were clustered in a Gaussian distribution centered at the 30–40% range. There was a similar distribution for male student scores, although boys also managed to score in the 60–70% and 70–80% ranges. In the SimCity review group (Figure 6 *bottom*), female students' scores were significantly improved. Conversely, among the male students, there was a pronounced shift from scores in the 40–50% and 50–60% ranges to the 30–40% range, although the number of highest performing male students in the SimCity group matched that of the control group.



**Figure 6.** The overall assessment scores of students who underwent test review using curricular materials (*top*) is shown for comparison with the scores of students who reviewed using both curricular materials and SimCity (*bottom*).

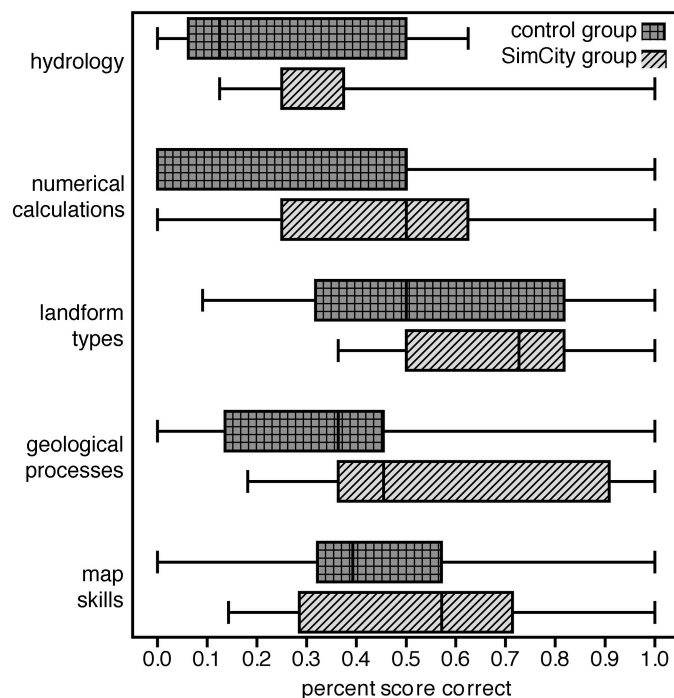
One factor in the differential between female and male scores in the SimCity group may be the cooperative behavior observed among female students while they used the software. Compared with male students, the girls were more often seen assisting one another and sharing in decision-making processes. In the group-oriented computer lab environment, female students were more likely to volunteer responses to questions posed by the teaching fellow, engage in discussion, and ask questions of their own. In the more individual-oriented classroom environment, boys were typically the primary respondents to questions and tended to take a lead in discussions.

The Landforms assessment test covered five general content areas. The SimCity group had higher mean scores than the control group in each subject area: 36% to 25% (hydrology), 48% to 38% (numerical calculations), 68% to 53% (landform types), 58% to 37% (geological processes) and 55% to 43% (map skills). The box-and-whisker diagram (Figure 7) shows the score ranges of both the control group and the SimCity group with respect to each content area. The boxes indicate the 25<sup>th</sup> to 75<sup>th</sup> percentile score range, and the whiskers indicate the lowest and highest individual score in each group. At least one student from both the control group and the SimCity group had a perfect score in each content area, with the exception of the control group in the hydrology section. In 4 of 5 subject areas, the SimCity group had a higher 25<sup>th</sup>

percentile score than the control group and equivalent or higher scores at the 75<sup>th</sup> percentile level.

Among the students in the control group, there was no clear correlation between gender and performance in specific content areas. Boys achieved slightly higher scores than girls in each content category, but the differences were statistically insignificant based on *t*-tests at a 95% confidence interval. Conversely, female students in the SimCity group out-performed male students in all subject areas, and the girls' scores in map skills and numerical calculations were higher than boys' scores by a statistically significant margin.

These statistics are presented as an individual case study of a single classroom, and caution must be exercised in broadly extrapolating from such a limited data set. Nonetheless, the results strongly suggest that the addition of SimCity exercises to the reviewing process led to improved retention and understanding of the assessment material. Further, the data suggest that female students, in particular, benefited from the group-oriented simulation activities.



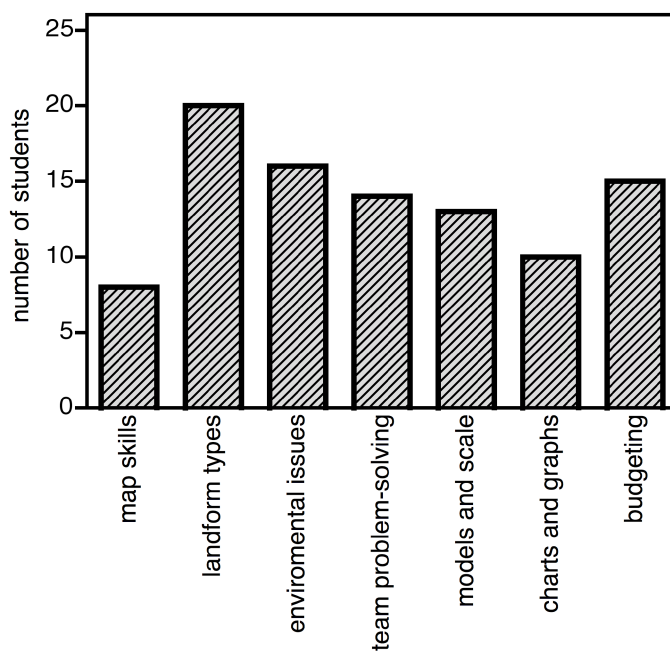
**Figure 7.** Students assessed after reviewing science material with SimCity tended to score higher in particular content areas, compared with peers who were assessed after reviewing with curricular materials only. Boxes extend from the 25<sup>th</sup> to 75<sup>th</sup> percentile ranges, and whisker bars extend from the lowest to the highest individual student score in each group.

### Student attitudes and other impacts

Student response to the SimCity activities was generally quite positive. In casual verbal surveys, girls universally responded that they preferred learning with SimCity rather than with the traditional curricular materials, and had generally positive remarks about working together in teams. While most boys responded in a similar fashion as the girls, a small percentage of male

students preferred the more traditional curricular learning approach instead of the more team-oriented SimCity strategy. Students generally enjoyed the collaborative nature of the module team-based approach, and most felt that they were able to accomplish and learn more as a group than they would have as individuals. However, some students commented that they sometimes were left out of the decision-making process, that they were hindered by arguments and disagreements among the team, and that they would prefer if they were always given the opportunity to choose their own team members.

Students were asked to vote for content areas they felt SimCity had helped them better learn or understand. The results of this survey are presented in Figure 8. The students achieved higher scores than their regional and district peers in mathematics benchmark testing, including content areas addressed by the SimCity lessons such as mathematical reasoning in the context of social science and science, statistics and data analysis, measurement and estimation, and geometry. Finally, this lesson module provided a wealth of opportunities to introduce students to wide array of topics in engineering, particularly as they apply to social, cultural and moral principles. The SimCity activities prompted excellent discussion and engendered an improved awareness of the engineering process, through which math and science are applied to the designed world in which we live.



**Figure 8.** Students volunteered and voted on these topics as areas in which they had been helped by the SimCity module.

## Conclusions

Inclusion of the SimCity module alongside the Philadelphia School District 6<sup>th</sup> grade curriculum gave students an enriched learning experience and aided them in better understanding and appreciating the curricular material presented. SimCity offered many segues into topics of engineering, and engaged students with the use of technology. While it did not supplant the

prescribed curriculum, the module augmented and complemented more traditional science and math lessons to better address Pennsylvania educational standards. With the use of the software, students demonstrated improvements in testing scores, as well as a more receptive attitude toward learning. This project also illustrated that varied instructional strategies may be useful for better engaging both male and female students.

### **Acknowledgments**

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