Chapter 30

Engaging youth in visualizing sustainable urban plans using geographic information systems coupled with computer visualization

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Abstract

In this chapter, we present results from an out-of-school time STEM (science, technology, engineering and mathematics) education program in the United States in which we engage urban youth in urban planning projects for sites in their neighbourhoods. In the field of urban planning today it is nearly impossible to create any urban plan without the use of GIS technologies. In our work, youth have been using sophisticated GIS modelling technologies to create and evaluate different urban plans for particular areas within their own city. As a part of their projects, youth visit a site to collect basic physical data, talk with residents, and identify the resources that are available to the neighbourhood. With that information in hand, the youth create different site designs using a software package, CommunityViz, and evaluate the economic and ecological impacts of their different designs. In doing this, youth learn about (1) the urban planning process; (2) GIS skills and the role that GIS plays in the urban planning process; and (3) evaluating and comparing the economic and ecological impact of different site designs.

Introduction

Urbanization trends of the past century have increased dramatically worldwide. More than 300 cities boast at least one million inhabitants and 16 ‘megacities’ have populations exceeding 10 million. With increased urbanization, pressure on critical urban natural resources is exacerbated. Resources such as city green space, clean water, air and biodiversity are critical to sustaining ecosystem health and to providing economic, civic and public health benefits for metropolitan area residents (Grimm *et al.* 2000). At the forefront of ensuring that urban ecosystems are sustainable are the young people who live in these communities; however, young people often do not feel empowered to suggest changes nor are they provided many opportunities to engage in developing plans for their

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neighbourhoods or to critically compare and contrast competing urban plan scenarios from sustainability, social justice and environmental justice perspectives (Frank 2006). This lack of empowerment that urban youth feel is most likely derived from the fact that very rarely are they invited into the planning process and, when invited, they do not have the skills to evaluate if the proposed ideas are beneficial to their neighbourhood. The purpose of our work has been to empower youth by supporting them in learning about the process of urban planning, as well as providing them opportunities to use the same urban planning tools as professional planners, namely Geographic Information Systems (GIS) technologies.

Over the past five years, a group of inner-city students in the Boston area have been involved in a College Bound (CB) program at Boston College, a National Science Foundation (NSF)-funded program, and have been charged with solving urban planning issues for a non-profit community development corporation (CDC). The students adopted a parcel of land that has been proposed for development by the city and conducted ground-level scientific research (i.e. determining if the site is contaminated, measuring the surface temperature, noise level, etc.) and evaluated the potential ecological and economic value as a result of developing the parcel of the land. The students additionally conducted a needs-analysis of the neighbourhood and, using that data devised and proposed different urban site designs. In this chapter, we describe the successes and challenges that students experienced during the summer aspect of our program and how leveraging geospatial visualization urban-planning software when coupled with a locally authentic urban planning challenge can enable students to create viable development schemes for unused plots of land in their city.

About the program: why use GIS technology to explore sustainability issues?

GIS technologies have emerged over the last fifteen years as key tools used by environmental scientists, urban planners and ecologists. In fact, GIS technology has become a central technology of urban planners and much of how urban planning is conducted is impossible without the use of GIS technologies. Unfortunately, a disconnection exists between the research conducted by scientists in the field and the manner in which environmental science is taught in a classroom. Few high school students are afforded access to tools regularly used by scientists or pursue authentic inquiries using current scientific data or regional or global information (National Research Council 2006). Recently, there has been a dramatic increase in the computing capacity of these technologies that has created opportunities for youth to manipulate and learn using software tools previously only available to professionals.

Educational and environmental education research related to designing scientific and technological interventions dictates that it is crucial to design projects that engage students in investigating and solving environmental problems that are locally and socially relevant to their lives with the outcome of creating a plan of action to instigate change. As a result, students' plans are often difficult to implement or require lengthy time commitments (Frank 2006) which means that by the time the plan is able to be implemented, if at all, students would have likely graduated high school or moved on to other challenges. With these challenges in mind, we collaborated with Placeways LLC in order to capitalize on their urban planning software tool, CommunityViz (http://placeways.com/communityviz/), which is capable of extrapolating the ecological, economic and social impacts of their site designs in the long term.

CommunityViz is an extension of ESRI's popular ArcGIS software application and provides a large suite of extra functions that combine with ArcGIS to make a more specialized, powerful decision-making platform and set of tools for setting up alternative futures (scenarios) and analysing their effects. Furthermore, the program has tools capable of making interactive three-dimensional (3D) models of real places as they are now and as they could be in future based on specific site designs. Finally, the CommunityViz program is capable of providing a powerful visual interface which is valuable for communicating the urban planning process across the many groups of people who become involved in making decisions about the future of a place. For example, the flexibility and power of CommunityViz allows students to explore a variety of complex research questions such as the impact of green space on how development in the neighbourhood will likely unfold over the next 10 years and how that will impact population growth and the demographics of the neighbourhood. Ultimately, the technology offers an opportunity for students to re-design parcels of land in their neighbourhood and evaluate the impact of their suggested changes on such outcomes as auto emissions, travel time and traffic patterns, air quality, impact of green space on habitat fragmentation, biodiversity and the associated public health profile of the neighbourhood. To help with the visualization and to support describing their designs, students have the ability to export their model in three dimensions for a first-person perspective to evaluate both the structure of the design and its aesthetics. As examples of student work using the CommuityViz software, the following link shows students' vision for the redesign of an urban park in the city of Boston (http://urbanecologyscience.org/parkdesign/flying4.avi). We have also posted an example set of designs that students created for the site that is described in this chapter (http://urbanecologyscience.org/comviz/madison_park_scenario_views.avi).

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Context of study

The students in the program were from low-income areas of the city of Boston, of ethnic minority backgrounds and will likely be first generation college students. The summer institute was an extension of a yearlong program at Boston College. The students were involved in an urban planning project, as well as learning about college and the college application process. During the year, approximately 45 students attended the College Bound program which included bi-monthly Saturday sessions, two three-day spring institutes and a two-week summer institute. Prior to the National Science Foundation (NSF) funded program, students had no prior experience with urban planning. At the start of the program the context of the project was set by project staff along with the introduction of the software. Following this initial introduction, project staff provided the students with the overarching goal of their work, namely to create a redevelopment plan for a large parcel of city land. Student teams visited the sites, collected data and developed land use plans using scientific research software tools such as Microsoft Excel (for organizing physical science data such as air and surface temperature and sound level) and CommunityViz. In this we describe how students engaged in an authentic urban planning process, used sophisticated software, developed visual representations of their data, and what students learned through their urban planning work.

Pedagogical framework

Our program has been jointly informed by Shaffer's theory of pedagogical praxis (2004) and the theory of participatory learning environments as described by Barab and colleagues (Barab *et al.* 2000). Participatory learning environments have five characteristics: (1) they should be designed to engage learners in authentic science; (2) learners should be engaged in the 'making-of-science', and not simply memorizing a set of readymade knowledge; (3) learners should be engaged in participatory science learning activities with others who have less, similar, and more experience and expertise than themselves, supporting the emergence of collaborative group work, and not simply individuals working in isolation (Resnick 1987); (4) learners should not be simply completing the task for some reward (e.g. grades, professional development points), but should be working toward addressing a real-world need that they have identified as important to themselves and to society (Savery and Duffy 1996); and (5) learners should be working in participatory science and should be given the opportunity to participate in a professional community, not simply hearing about the work of other authentic science communities.

The theory of pedagogical praxis suggests that new technologies make it possible for students to participate in meaningful learning activities by serving as a bridge between professional practices and the needs of learners (Shaffer 2004). In other words, new technologies make professional practices, previously only available after years of training, accessible to novices. This is perhaps no more apparent than with the rapid increase in the use of GIS and similar tools to explore the natural world. For example, Google Earth and Google Maps, two of the most well-known geospatial technologies, have enabled not just specialists to overlay data and to evaluate the relationships between objects, locations and other types of data, but has engaged the general public in performing simple geospatial analyses. With the emergence of these new tools, attempts have been made to engage students in becoming urban ecology scientists through the evaluation of the ecological, economic and social benefits of green space for urban residents. To do this, our program has been constructed around the typical practices of professional urban ecologists and informed urban planners. This latter point is critical because, according to the theory of pedagogical praxis, successful learning environments are established when the learning activities are aligned with authentic professional practice (Beckett and Shaffer 2005). Hence, in our work, we have focused on not just having students *do* urban planning projects, but *be* urban planners while using the same technological tools and resources as the professionals.

To assess the impact of the program on student outcomes, a mixed method approach was used, relying primarily upon surveys, student lab reports, student created visualizations and student feedback regarding the learning activities. Research questions have focused on social and environmental justice as a viable approach for student engagement in learning about scientific concepts and sustainability. To that end our guiding questions are:

- What connections do learners make between the GIS computational modelling and their neighbourhoods? How do students use the technologies to learn about sustainable urban plans?
- Given that mathematics is central to understanding the impacts of urban planning, what do students learn about mathematics and how do they make connections between mathematics and urban planning?

We begin by describing the project that served as the basis for our research. Next, we examine the ways in which the data show important transitions in student thinking, both in relation to the understanding of effective urban design, as well as their ability to understand complex mathematical representations of data. We conclude with some thoughts on future involvement of youth in urban planning.

Research context: the students' work

Students were involved in the program for the entire year starting in the Fall, followed by a Spring semester that included two three-day institutes and concluded with a two-week summer program. This amounted to approximately 256 contact hours with the students. During the spring sessions, the students were introduced to CommunityViz and learned how to use it to lay out their development plans for an unused parcel of land. By the first week of the summer program, the students were introduced to various other technologies used to collect physical science data, including air and ground temperature and sound levels. These tools included iPads coupled with Pasco probeware (for Bluetooth-enabled, digital temperature measurements), mercury thermometers and decibel meters (for recording urban noise levels and developing a sound map of their site). The students then visited their local field site (an empty city lot) and collected physical science data twice over the course of two days. The quantitative data were then entered into Microsoft Excel and 3D surface plots were generated for each of the variables. The students analysed the data with the aid of guiding questions and drew conclusions with respect to the sound and temperature profiles across the site.

During the second summer week, the students used CommunityViz, to lay out an urban development design for the empty lot based on what they had learned about the site during their visits and their analyses of the physical science data. Using the software, they were able to assign various kinds of buildings (apartments, townhouses, single- and multi-family homes), surfaces (grass, brick, cobblestone or concrete), businesses and recreation (coffee shops and basketball courts), surface features for aesthetics (benches, light poles and street clocks), and, importantly, various kinds of greenery (a variety of species of trees, potted plants and shrubs). The GIS software tracked students' design decisions in terms of cost, environmental impacts (carbon emissions and water and energy usage) and social impacts (job creation, number of children expected to move into the neighbourhood and growth in the number of neighbourhood residents). At the end of the institute, students compiled their data from the field site visits and their urban development plans and presented their projects to their peers and CDC representatives using Microsoft Power Point and Camtasia video-making software.

Participants and data collection

Approximately forty-five students attended the summer institute; however data were collected from one of three classes comprised of approximately twenty students as we did not have the capacity to videotape every group of students (see Tables 1, 2, and 3 for demographics). Classroom activities were digitally

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Table 1. Gender distribution.

	Frequency	Percentage (%)
Female	38	61.29
Male	24	38.71
Total	62	100

Table 2. Racial/ethnic diversity.

	Frequency	Percentage (%)
Hispanic or Latino	21	33.87
Black/Afro-Caribbean	16	25.81
Black/African American	10	16.13
African American and Afro-Caribbean	4	6.45
Black and Hispanic/Latino	3	4.84
African American and White	3	4.84
Black, White and Asian	2	3.23
Asian/Asian American	2	3.23
White and Hispanic/Latino	1	1.61
Total	62	100

Table 3. Class year.

	Frequency	Percentage (%)
Freshman	16	31.37
Sophomore	12	23.53
Junior	18	35.29
Senior	16	31.37
Total	62	100

recorded and meaningful interactions were transcribed and analysed further during research team meetings.

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Data analysis

A naturalistic, interpretive analytical approach to the qualitative data was undertaken, one in which the 'story' underlying the case of interest, i.e. the informal STEM education program, was identified and communicated to readers (Stake 2000). The 'story' of reoccurring topics, content or issues that evolved over time as a result of student participation in the program was traced throughout the data in order to describe the development of the factors that played significant roles in their change over time.

Digital video data of the program activities were transcribed verbatim and analysed individually by the research team, comprised of one professor and three doctoral students in education. Following initial individual reading of the data, the team collectively identified and discussed the dominant themes and how these changed over time. Research team members alternated between close individual analysis of the data and collective in-depth discussion of emergent findings. Multiple themes were identified; however, we focus here on two themes of interest to readers of this book: (1) growth in the students' abilities to lay out, from a systems perspective, plans for urban development and how students explored the trade-offs between ecological sustainability and economic development; and (2) development in the students' mathematical and analytical skills and how mathematics (particularly graphical interpretation) became a tool to explore the first theme.

Results and discussion

Developing connections between planning, green space and urban youth

Even though sustainable development is often understood as a unifying concept that resolves tensions between social and economic development while also accounting for environmental protection, there are trade-offs to be made, balancing the need for economic development and preservation of the urban ecosystem (Connelly and Richardson 2004). It was these tensions that students had to examine, struggle with, and come to a resolution as a part of their work. In the following we explore how students integrated these ideas into their thinking and how their designs and conversations reflected these trade-offs.

Generally, students who participated in our program were from high poverty areas of the city which filtered their ideas for what should be included as part of the plan for their site. In particular, many youth focused on the economic impacts of their designs and discounted the ecological impact as evidenced by the following comment in response to a presentation by an ecology educator on the value of green space:

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> Seriously, we don't need trees. How can trees help? They sure aren't going to help me. I want to be able to get a job or walk down the street and be safe. Trees aren't going to change nothing. Wont' work. What a waste of time.

After two weeks of work, as well as more of a focus by the project staff on supporting students to examine how a design that values positive ecological impact can also improve the economics of their site, students began to appreciate and recognize the importance of integrating green space while also being sensitive to the real need, from their perspective, for economic development of the site.

For example, in the following excerpt from a student presentation, she notes the importance of green space and explains its role in their design (See Figure 1 for the students' design).

> Our project is Madison Park. That was the site where we went to. That's how it was. With a lot of trash around as you can see. And it was empty. So, we made a design. And we put buildings with a lot of green space to prevent air pollution. And we think that our design is better because you have less buildings and more green space and prevent pollution, which causes many health problems and stuff like that. (Student 1)

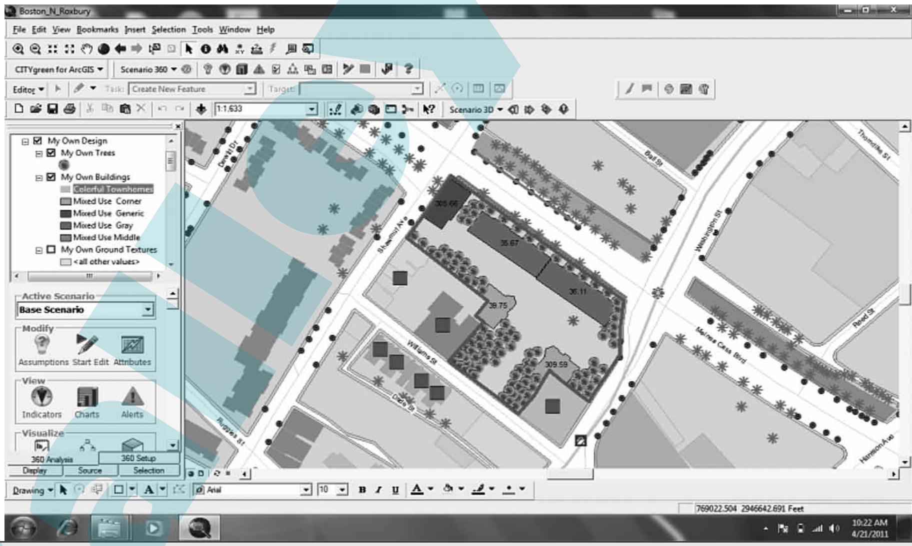

Figure 1. Student created urban plan for a parcel of land as shown in CommunityViz.

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Essentially, through a series of design decisions and arguments regarding the value of different components of their design, students slowly realized that a mixed-use plan provided a good balance between economic and ecological impacts. They acknowledged design measures that would work in concert with the newly created green space, such as decreasing the number of cars within the area and increasing the walkability of the area. The student explained in the following interaction:

> And there is less cars going around, so that means there is less CO_2 going around. One thing we didn't put in our design is parks and benches and stuff like that. We had everything but those. And that's basically it. (Student 1)
>
> Okay, so what is vehicle trips per day? What about that? (Audience Member)
>
> Because our design doesn't have that much houses, and business, there is not a lot of cars coming around so that's why that one is above. Vehicle trips per day. There is not that much cars going around our place. (Student 1)

Following this presentation, another student in the group spoke up about the reasons for their design:

> We were trying to do a balance between both people, commercial floors and green space. So basically what we did was some places are stop and shops and town homes and we left a lot of green space so that we can make maybe a community garden. (Student 2)

Developing a design alone is valuable and being able to evaluate the impact of that design is central to what urban planners do in their practice; however, the students were expected to be able to defend why their design was the most ecologically and economically viable option. To accomplish this, CommunityViz was utilized to create alternate scenarios for the same parcel of land such that the students could compare the impacts of their design with others. Specifically, the students were provided two other potential designs that were created by a professional urban planner. One design focused on residential use, while the other design focused more on commercial development. This approach enabled the students to compare and contrast their designs against other competing ideas to better defend their plans against other students' plans. For example, in the following the student is explaining how their design is different than the other design scenarios (see Figures 2 and 3):

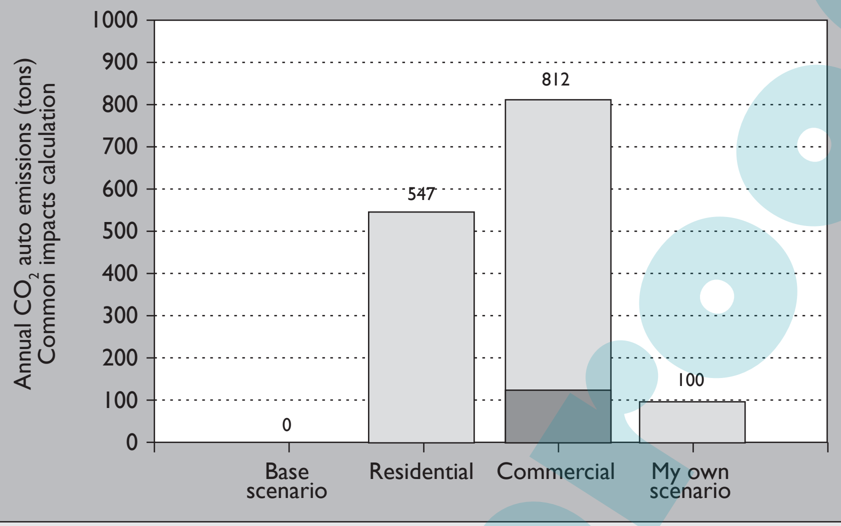

Figure 2. Results of student comparison of CO_2 emissions for four different urban plan scenarios: pedestrian mall (mixed use), a public park, mostly residential, and their own design.

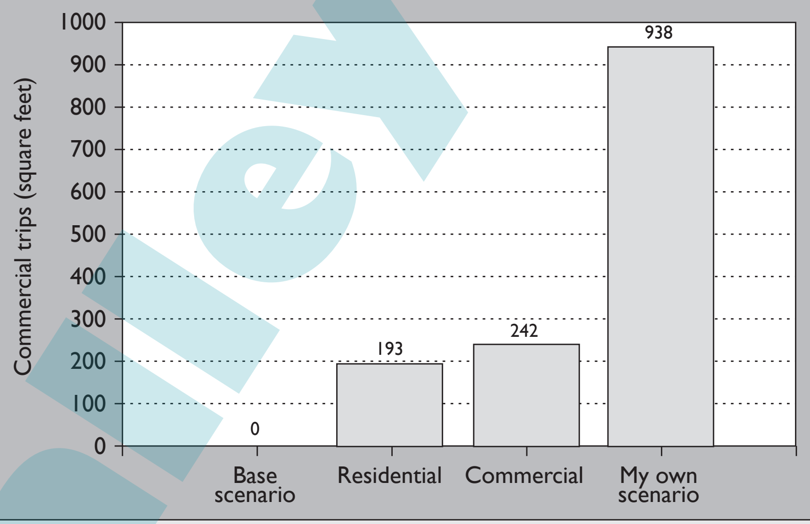

Figure 3. Results of student comparison of vehicle trips per day for four different urban plan scenarios: pedestrian mall (mixed use), a public park, mostly residential, and their own design.

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> Oh, I didn't see that. And how about the graphs, what are the graphs? (Audience)

> Here, total building feet is less than the residential and the mall. And over here, the ground floor, it's more than the residential but it's less than the commercial. And with the building square feet, it's still basically the same thing. So basically we're trying to put less pollution in the air but get more out of it. (Student 2)

In summary, the students were able to investigate sites, design developmental plans and evaluate different scenarios by comparing and contrasting the ecological and economic impacts of the various designs. It is in this process of critical examination of designing for both ecological sustainability and economic development that students are challenged to evaluate their own design ideas and whether their own design is a good fit for their neighbourhood.

Understanding and using mathematics to create urban plans

To successfully argue for a particular design over another, it was necessary for students to use data to support their arguments. A major advantageous aspect of CommunityViz was its ability to generate a wide range of graphs on both economic and ecological impacts of a particular design. As a part of the summer institute, students were challenged to examine an area within their community that was underutilized and to consider development options that may have been stymied by conflicting opinions within their community (i.e. Community Development Corporations, environmentalists, developers, government officials) by using the data that CommunityViz generated. The students were charged with gathering important background information such as community environmental conditions, maps, photographs, and the like. Each of the student groups were then instructed to organize and analyse the data and invited to present their list of problems and ideas individually; however, to properly analyse these data, students had to critically examine mathematical implications of dealing with the cost and physical layout of changing a vacant lot into a beneficial and effective sustainable design.

In this section, two major themes are examined that emerged from students' perspectives while learning how to use the technological tools in exploring different urban plans from a sustainability perspective. The themes are (1) using graphical representations of data within the realm of practical or actual experience, as opposed to the abstract, theoretical or idealized sphere of the classroom (real-world context) to understand the value of an urban plan; and (2) how students used graphical representations to create their interpretations.

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Real world connections

Although graphs are explicitly taught in mathematics classrooms, many subject areas such as science or social studies utilize graphs to represent and interpret 'real life' phenomena. It is this connection between what is learned about graphs in mathematics classrooms and the connection to what is being studied that is rarely made (Dunham and Osborne 1991). When GIS was first introduced to the College Bound students, the curricular focus was to learn how to use a program as complex as the CommunityViz software package. When finished, students had a complete simulation; however, when presenting the material collected, students struggled to understand the connection with the physical site that was being studied and the graphs that they had generated. As a result, the graphs were difficult for the students to read and interpret.

Instructors utilized a 3D surface graph created in Microsoft Excel to demonstrate decibel readings over different areas of one vacant lot studied (Figure 4). The graph was exciting to many of the students because it was a type of graph that neither students nor many instructors had seen before. This factor alone increased the difficulty of accurately interpreting such a graph. The students were charged with collecting data and creating 3D graphs twice across a two-week period. After first attempting to create a graph, many students were unable to make connections between data graphically represented in a 3D image and details of the physical site displayed on an aerial map of the same location, even though there were several

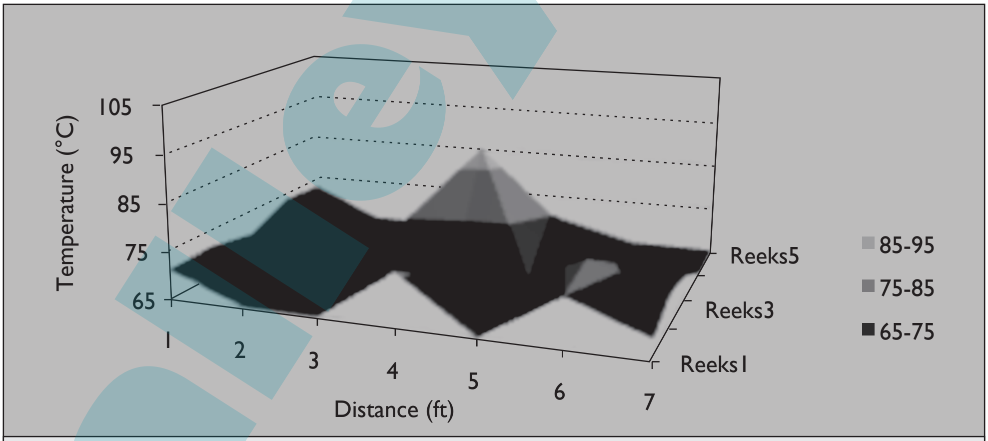

Figure 4. A surface map of sound at a study site. This graph allowed students to determine where trees or other sound damping ecological strategies could be employed.

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markers on the graph to indicate the location of their site. One example of such discrepant thinking is as follows:

> There are points on the graph that are higher and lower.
>
> (Student)

No further explanation was offered, either for the graph on which this occurred or what the description represented in terms of the physical location. A week later, during the second attempt at creating graphs from the same site, and after several discussions on interpreting graphs, the same student gave a very different answer:

> Well, the temperature is higher at the point (60, 20) on the graph and lower at (0, 100). The (60, 20) was near the concrete and (0, 100) was near the trees. (Student)

With much practice of discussing and interpreting graphs, an increase in understanding of the relationship between the site and the graphs students generated was observed.

Utilizing graphical data to communicate urban plan outcomes

In the current National Council for teaching of Mathematics 2000 Principles and Standards for School Mathematics (NCTM 2000), a central learning tenet states: 'Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge' (National Council of Teachers of Mathematics 2000, p. 20). Understanding is the key. The basic goal of education is to prepare students to be life-long learners and to function effectively in the world. In order for this to occur, students must understand the mathematics that they are taught. Based on research pertaining to learning methods (Bransford *et al.* 2000), a learner acquires knowledge by the construction and ability to discuss knowledge to others. This was exemplified by ten-minute presentations developed by students on the last day of the (CB summer institute). Students presented the data that had been collected and analysed. Understanding of the urban planning and data analysis was demonstrated through the use of graphs in conveying data points and a discussion of the proposed sites with others.

When one student was asked what was confusing about these graphs, their response was:

> What is confusing is how the graph is shaped, the 3D part.
>
> (Student)

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After the second time of the intervention, however, the same student exclaimed:

> What might be confusing [for others] is the shape. We can help the audience understand the graphs by using them to explain what's happening in the park. (Student)

When asked about the relationship between the sound and distance variables a student's response was:

> Yes, we see a relationship. The variables are distance (ft.) and decibel. The relationship between both variables is that it depends on where on the graph explains where in the park the different decibels. The closer to the street, the higher decibel rates. (Student)

> Without distance graph you wouldn't know where in the park each sound level is and wouldn't be able to explain it to other people. (Student)

The increased practice with reading and interpreting graphs, led to an understanding of how to explain and present the data effectively.

Perhaps what is of most interest is that we found that with relatively little training, when compared to the training that a professional urban planner would receive, youth are not only able to learn to use GIS tools to help them understand and compare planning alternatives, but are also ready to engage with the planning process. For example, in our work, we partnered with a local community development community corporation that was working to redevelop the same site that students were exploring. In fact, the skills that the youth were developing filled a need in the community development corporation as noted by the project manager at our partner CDC:

> We do not have the capacity to use the sophisticated software that your students can use, so if they could develop the models and use the software to evaluate the ecological and economic impact of the various competing designs that would be of immense help.

Thus, students were learning both the skills necessary to think through an urban plan but were also contributing the improvement of their neighbourhood because they had the developed technical skills necessary to help the CDC prepare a more robust and compelling argument in support of the redevelopment of the site under study. In fact, this engagement in this process helped to focus the youth to consider the various impacts of the different designs that were being proposed and

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to make recommendations based upon their analyses. For example, one student in comparing the sites noted that:

> This site's got more energy cost, but it means more commercial … as long as we are bringing in more jobs, it will help the community.

What is important about the previous comment is that the youth were engaging in the critical thought process of evaluating both the positives and negatives associated with various designs.

Conclusions and suggestions for future research and development

The concept of sustainable development has emerged as a critical feature of most community master urban plans. In fact, it is not uncommon to find the phrase 'sustainable city' in a city's master planning documents; however, if such a sustainable city is to truly come to fruition it is critical that the voices and ideas of urban youth play role in how their own neighbourhoods are designed (Chawla 2002). Yet, as noted by Frank (2006) although youth participation in planning has been rather limited, when youth are engaged in the creation of plans for their community, the results are more positive (Santo *et al.* 2010) with youth learning to question and challenge inequalities and develop attributes that contribute to greater care for their city and environment in the future (Chawla 2002). However, it has been noted that by engaging students in urban planning using GIS technologies, their unique insights regarding the nature of the development at their study site along with their data and CommunityViz models provided additional support for our partner CDC to argue for their design in front of the city planning commission.

As mentioned earlier, young people are rarely consulted or invited into the planning process (Frank 2006). Furthermore, when adolescents *are* invited to participate in community governance and planning, adults tend to set low expectations for the performance of youth and expect them to conform to strictly prescribed parameters that have been set by adults that diminish the value of their insights. As noted by Glaeser (2011), cities place great emphasis and value on attracting young talented individuals to help spark economic growth and innovation; however, if youth have little voice in the design of their neighbourhoods even the best urban plans will be unsustainable over time and likely have very little buy-in from the communities that such designs are trying to help (Santo *et al.* 2010). In our work, we have found that youth, when given appropriate supports can influence how their neighbourhoods should be developed.

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Through the use of urban planning technologies and real-world data collections, students made meaningful connections between the physical sites and the urban plans that were created. This emerged through graphs which created multiple means of representation, provided symbolic representations of real-life situations, and produced visual models to assist with explaining the data collected (Mokros and Tinker 1987). Using the graphs allowed students to articulate and explain the ecological and economic weaknesses of their urban plans. Thus, if society moves toward sustainable designs for our cities, the findings show that urban youth have creative and often very thoughtful ideas regarding how their neighbourhood should be developed. We have found that youth are very interested in balancing economic and ecological impacts of development plans while also being concerned about the aesthetic nature of the designs and if such designs 'fit' within the existing community structures.

Today it is nearly impossible to engage in the urban planning process without knowledge of GIS and how to manipulate data using GIS software. The work in which our students have been engaged as a part of this informal STEM education project has opened up opportunities for them to not only learn how to use GIS technologies but also to learn about the role that such technologies play in the urban planning process. However, most students do not have the opportunity to use GIS software as a part of their K-12 educational experiences. The reasons for this are many, but one of the most important reasons was well articulated in the National Research Council's publication: 'Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum' (National Research Council 2006):

> Geographic information science has significant but as yet unrealized potential in the K-12 curriculum.... In principle, GIS reflects many of the ideals of exploration-driven, discovery-based, student-centred inquiry. Nonetheless, current GIS software is less well equipped for data exploration and hypothesis generation than for data analysis and presenting information. In addition, current GIS is too cumbersome and inaccessible for effective use in K–12 education (p. 8).

In other words, current GIS technologies are not effectively used in the K-12 classroom due to their complexity. Fortunately, there are a number of future research and development questions that have emerged as a result of our work that needs further investigation that we think that if explored can enable all students to have access to this important technology for learning about urban planning. First, what is needed is an easier technological entry point through which youth can engage in the research field of urban planning in meaningful and realistic ways that enable youth to examine the trade-offs and impacts that competing urban plans will have for a neighbourhood, but without removing the complexities of the urban planning process. Our work has not looked in depth at the outcome on student content learning and we have found little existing research that does this. Thus, it would be important to identify the concepts and content knowledge that youth develop as they participate in the process of urban planning. Lastly, as argued by the NRC, current GIS technologies are expert-based, 'industrial strength' technologies that are inviting because of the potential for engaging students in authentic science, yet are difficult to learn and challenging to install and manage in most school computer laboratories. Thus, if we hope to scale the use and implementation of GIS-based urban planning opportunities for youth, we need to develop and test new user-friendly, easily implemented GIS technologies in traditional K-12 settings.

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