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Remote Sensing as a Tool for Phenomenon-Based Teaching and Learning at the Elementary School Level: A Case Study for the Urban Heat Island Effect

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Abstract: Satellite remote sensing has been largely adopted in all kinds of environmental applications as it has proved to be an excellent tool for research and decision-making purposes. It has also been recognized as an important educational tool in the past years. However, it has been insufficiently incorporated in school practice, especially at the elementary level. This article describes the use of remote sensing as a tool to present science topics in the elementary classroom. A phenomenon-based approach was adopted to introduce the Urban Heat Island Effect (UHI) to eighty-one second and third-grade students. The students' experiences in their learning environment were collected with the use of a questionnaire developed for that purpose. The pedagogical approach encouraged the students' critical thinking and individual observations to try to explain the phenomenon working with the other students and the adults in the classroom. The phenomenon-based approach, along with the powerful visualizations of the remotely sensed data kept the students motivated and active. Seventy-one percent of the students reported that this was an engaging activity, and seventy-eight percent said that they would like to participate in similar activities in the future. The rest of the responses were neutral. None of the students were previously familiar with remote sensing or the UHI. This experience showed that it is critical to have adequate and appropriate resources readily available, as well as efficient facilitation in order to tackle this pedagogical approach. The activity was organized for Earth Observation Day (EOD), 2016, in the framework of a West Virginia View funded project. EOD is a STEM (Science, Technology, Engineering, and Mathematics) educational outreach event that occurs yearly and during which scientists, all of whom are experts in remote sensing and related geospatial technologies, are available to support teachers in their respective states.

Keywords: Remote sensing, urban heat island, phenomenon-based learning, STEM.

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Introduction

In the past decade, there has been evidence that the application of geospatial technologies can be a powerful tool for the enhancement of teaching and learning. It has been found to promote interest in science in a range of thematic areas. Since the National Research Council published a report about spatial thinking in the K-12 Curriculum' (National Research Council, 2006), several educators and education researchers have explored ways to incorporate spatial tools and spatial thinking into classrooms. At the various levels of the education system from early childhood to higher education (e.g., Verdine et al., 2017; Newcombe, 2016; Utterly & Cohen 2012).

The geospatial technology field has been rapidly evolving, providing many opportunities in a wide range of disciplines and occupations. This growth is both exciting and challenging. Data and tools for geospatial processing and analysis are essential for the monitoring and management of natural resources at all scales, from local to global. Reports emerging from several research bodies address the need for K-12 schools to teach spatial thinking skills that are facilitated and strengthened using geospatial technologies (Adaktylou et al., 2018). Of the geospatial technologies, satellite remote sensing has been so broadly adopted in all kinds of environmental applications due to its cost-effectiveness, multiple options of temporal orbiting and spatial resolution and the large area of coverage. Given this, there is a significant

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demand for people trained in remote sensing in private companies in the public sector and academic institutions of higher learning.

Surveys and statistical analyses have demonstrated that both domestic and foreign institutions of higher education have added remote sensing class curricula. This fact suggests that these institutions consider that a remote sensing general education curriculum plays an important role in improving the geographic literacy of contemporary college students (Wang et al., 2014). The use of satellite imagery is now propagated for or even included in K-12 school curricula and the national educational standards for geography. Remote sensing data are characterized - in addition to their high clarity and timeliness - by having great educational potential. This potential has been insufficiently used in school practice. Working with remote sensing data in schools is often limited to analog applications, for instance, to improve map reading skills (Naumann et al., 2009).

Visualization of spatial relations and changes in an area can help students understand the impacts of a phenomenon on the environment, society, and the economy. More broadly, spatial relationships and their comprehension allow students to understand various civic issues, including social, environmental, political, and economic ones, at local to global scales (Bednarz & Bednarz, 2015). An international comparative study (Siegmund, 2011), showed that the use of satellite imagery induces high motivation and interest by the learners. In this study, younger students especially, were highly motivated and interested although their specialist knowledge about satellite imagery was generally lower when compared with older participants. Factors like image coloring, complexity, and ambiguity, as well as general difficulties in image understanding (Gerber & Reuschenbach, 2005) often prevent inexperienced users from interpreting satellite imagery successfully. For that reason, Beckel and Winter (1989) point to the importance of a gradual image analysis following instruction and the provision of additional information, e.g., describing image content.

It should be recognized that there have been many important initiatives aiming at creating geospatial technology-related materials that educators can bring in the classroom. Some of these programs are: AMERICAVIEW, My NASA Data, SATELLITES (Students and Teachers Exploring Local Landscapes to Interpret the Earth from Space-part of the GLOBE (Global Learning and Observations to Benefit the Environment) Program at: globe.gov) (Hedley et al., 2008, Adaktylou et al., 2018), the MultiSpec software platform (developed by David Landgrebe and Larry Biehl at Purdue University), GLOKAL change (Jahn et al., 2011) and the OMEGA project at the University of Alberta, Canada (Kirman, 2011). All these groups have designed and created high-quality materials for the acquaintance of students with geospatial technologies. At the respective websites, they provide resources that can be used for inquiry and project-based learning instruction.

"GLOKAL Change", is a web-based learning platform developed at the University of Education Heidelberg, Germany. It highlights four topics of environmental changes in terms of sustainable development. It consists of interactive learning modules, for students aged 10 to 16 years. The goal is to learn to evaluate economic, ecological and social impacts of recent environmental changes occurring in different geographic areas worldwide and in Germany. Information is provided by remote sensing and other resources.

The GLOBE Program has created a worldwide community of students, teachers, scientists, and citizen scientists that use its resources and are working together, for more than twenty years now, collecting data and trying to understand the environment at local, regional and global scales. In this work, as explain in detail in the methodology section, I have used the Surface Temperature Measurement Protocol that has been developed for SATELLITES and the GLOBE Program. The SATELLITES program was developed to introduce basic concepts of Earth System Science and Physical Geography to in-service teachers and K-12 students, through the presentation and application of geospatial technologies (Hedley et al. 2008). Elementary, middle and secondary level educators attend a one-week summer institute, where they receive training in Earth system science content, spatial thinking concepts, and geospatial technologies. Then, in the following fall, teachers engage their students in inquiry-based research projects using the content and technologies applied during an organized field campaign. The SATELLITES campaign, now called 'Urban Heat Island Effect-Surface Temperature Field Campaign', aims to discover how the land cover of the ground affects its surface temperature. Students can set up research studies at their schools, such as looking at the difference between paved and unpaved areas, such as a parking lot and a grassy area.

With a plethora of high-quality resources available, the question becomes how to use them effectively in the classroom, to make events occurring in the world, that students should know about, exciting and relevant for them.

A 2000 study showed that forty percent to sixty percent of high school students (the results were generally consistent across grade levels) were "chronically disengaged." The sample included 3,669 students representing 143 social studies and mathematics classrooms in a nationally selected sample of 24 elementary, middle, and high schools (Marks, 2000). Another study found that eighty-one percent of those who dropped out of school thought that "opportunities for real-world learning" would have helped them stay in school (Bridgeland et al., 2006). More recently, in 2009, yet another study with ninth graders, found that the more relevant science was to students, the higher was their interest in science. Also, the greater were their expectations for success in science classes. Also, the better they did in class, as measured by second-quarter grades (Hulleman & Harackiewicz, 2009).

With the central ideology of incorporating real-life events into school concepts, phenomenon-based learning has lately received extensive media coverage and publicity (Sahlberg, 2015; Symeonidis & Schwarz, 2016). This new vision originated from the learners' curiosity, self-motivation, autonomy, and individual observations to seek for and explain the holistic, real-world phenomena around them (Kivelo, 2015; Silander, 2015). By investigating real-life problems from various angles and trying different strategies to solve them, students become familiar with real-world situations that can be complicated (Bobrowsky, Korhonen & Kohtamaki, 2014; Moilanen, 2015). Collaborative work is an essential element of the process. Phenomenon-based learning starts from the shared observation of holistic, genuine, real-world events in the learning community (Silander, 2015). The phenomena are studied as complete entities, in their real context, crossing the boundaries between multiple subjects. The phenomenon-based approach also refers to a reorganization of teaching. In that context, learning can take place in problem-solving-approach where learners are continuously encouraged to actively participate in finding information, asking questions, working with peers or groups. They practice discussion and negotiation skills, reach conclusions, obtain results, and reflect their own experiences for the entire learning process (Kivelo, 2015).

Phenomenon-based learning became more known from a recent (2016) education movement in Finland's educational system. This reform required asking that students take one module each year with the phenomenon-based learning approach. The purpose was to better prepare students for real-life. Finland is consistently at the top of the rankings of the world's education systems. Moreover, this, with just one standardized exam at the end of 12th grade. The Educational Community has often discussed the excellent performance of the Finnish students with the least test anxiety and the most life satisfaction in PISA tests. Still ensuring the high rates of students' academic achievements, with mean reading, mathematics and science considerably above OECD (Organization for Economic Cooperation and Development) average (OECD, 2015).

Phenomenon-based learning has a theoretical framework that has common elements with problem-based learning, project-based learning, and inquiry-based learning. There is a key difference, however. Phenomenon-based learning must have a global context and a multidisciplinary and interdisciplinary approach. So, a topic must be a real-world issue or "phenomenon," and learners need to apply different perspectives in order to study it. For example, to understand a question about the Urban Heat Island, some knowledge from different subjects such as physics, mathematics, geography, history, and social science will be needed. Teachers facilitate their students to study phenomena as complete entities in their real contexts. Kirsti Lonka, a professor of educational psychology at Helsinki University, gave an interview to the BBC saying: "When it comes to real life, our brain is not sliced into disciplines ... we are thinking in a very holistic way. So, when you think about the problems in the world – global crises, migration, the economy, the post-truth era – we really haven't given our children the tools to deal with this inter-cultural world." (Spiller, 2017).

Resources and support need to be available in order to use this pedagogical approach. There is a vast array of applications, services, products, and tools created to serve a multitude of functions in education. Digital tools in the classroom in specific, have been considered as an essential asset to learning (Buckenmeyer, 2010). According to the U.S. Department of Education (n.d.), technology in the classroom ushers in a new wave of teaching and learning that can enhance productivity, accelerate learning, increase student engagement and motivation, as well as build 21st-century skills. Finding the appropriate tools or materials that teachers can draw upon to engage the students and support meeting the learning goals and objectives of the class can be an intensive task. Sometimes teachers feel that not being familiar with the tool they might lose control in their classroom, or that they may be less connected to students.

The present study proposes to use remote sensing products as a tool to introduce the Urban Heat Island (UHI) effect to elementary school students, with a phenomenon-based approach. The purpose was to have students get to the UHI effect themselves, from different points of view, posing their questions and being facilitated to gain new understandings. Eighty-one students of two Morgantown West Virginia elementary schools were affected. LANDSAT 8 images and related products were used to build the phenomenon-based approach. The urban heat island effect was chosen as it has been attracting increasing attention among the global scientific community and the general public, especially of the ones living in cities. Global population rise and continuous growth of the global economy have caused an increasing consumption of resources. At the same time, there are spatial needs for different land-use types like living space, industry, services, and infrastructure, that have altered the area of natural ecosystems. The unavoidable reshaping of natural landscapes has led to profound interventions in the natural environment. Resulting changes are the cause of the UHI phenomenon, that is, urban areas usually being quite warmer than their rural surroundings.

Heat islands can affect communities by increasing summertime peak energy demand, air conditioning use, air pollution, and greenhouse gas emissions, heat related illness and mortality, and impaired water quality (Environmental Protection Agency [EPA], n. d., Golden, 2004, Reid et al., 2009). Emergency managers, regional organizations, national governments, and adaptation professionals across the world are working to prepare local climate adaptation plans. These plans include strategies to mitigate UHIs in a future world with stronger heatwaves. It will be necessary, in a warmer world, to plan for the fact that crowded cities need to maintain (and increase) vegetation to create shade and cool the surrounding air by evapotranspiration. Cities need to ensure cooling breezes flow through, scouring out heat

and air pollution. Cities need to have places for at-risk people to go when their dwellings become too hot to bear during heat waves. Also, cities need to ensure that new buildings are well-insulated against added heat. Planning for uncertainty and many moving parts in cities is a challenging task (Filho et al., 2017; Staley, 2015).

Satellite imagery has been used as a dependable tool to assist in urban planning related to UHI mitigation. The Landsat program has been available since the beginning of the seventies, which allows for a time series analysis to get a deep insight into the spatiotemporal development of a geographic area. LANDSAT imagery has a low spatial resolution (30 m × 30 m per pixel), but still provides good detail of information on a geographic area. Spatial analysis at a very satisfactory scale allows for spatial structures and changes to be identified. Furthermore, satellite imagery displays the earth's structures in its natural appearance in contrast to maps, since no artificial entries or modifications in the representation have been carried out (Gerber & Reuschenbach 2005, Siegmund & Menz 2005). Observing and interpreting an image can provide much information on the geographic area that it represents. Moreover, LANDSAT data is freely available, provided by USGS, and can be accessed online with user-friendly tools, such as Earth Explorer or Glovis.

All the above being said, the questions of interest for this study were: i. how effective remote sensing can be as an instruction tool for elementary school students? and ii. can the learning process be facilitated using a relatively new pedagogical approach, that is Phenomenon -based learning?

The goals of the study were: i. to introduce remote sensing and its applications to the Morgantown elementary schools' students ii) to discuss the UHI effect, its causes, consequences and mitigation opportunities iii) to provide a holistic perspective of the UHI so as to have students understand how complex environmental issues are. The instruction materials that were used were remote sensing -derived products, while the pedagogical approach that was adopted was phenomenon-based teaching and learning.

Methodology

The activity was organized for Earth Observation Day in the fall of 2016. It took place in the framework of the project: "Introducing thermal and surface radiating properties to K-12 students through the use of Landsat derived products". West Virginia View funded the project for 2016-2017, and the author was the Principal Investigator. Earth Observation Day (EOD) is a STEM (Science, Technology, Engineering, and Mathematics) educational outreach event of AmericaView and its partners. Governments and numerous organizations, all over the world, are investing in STEM education, recognizing that students involved can gain knowledge and skills that help them understand information, and collect and evaluate evidence in order to make decisions. In the US, the Department of Education published its first STEM education Strategic Plan in 1998, asking for action in a nationwide collaboration with learners, families, educators, communities, and employers, to promote STEM education (US Department of Education, n.d.).

AmericaView is a nationwide, university-based and state- implemented partnership of remote sensing scientists who support the use of LANDSAT and other public domain remotely sensed data. This happens through applied remote sensing research, K-12 and University STEM education, workforce professional development, and technology transfer. In 2016, EOD was celebrated officially on Tuesday, 11 October. The goal of this project was to introduce to students, their teachers, and the broader community remote sensing as an exciting and powerful educational tool. The theme/phenomenon selected for the activity was the Urban Heat Island effect.

Activity design

Eighty-one students (second and third graders) in Suncrest Elementary and North Elementary classes participated in this STEM initiative. Before visiting the schools, the author met with their teachers, one from each school, in after school hours, to explain the event and the approach. The aim was to make sure that the activity was aligned with the goals of their classes and to explain how the teaching process was going to evolve. The author shared a lesson plan that she had prepared (see Appendix) and provided some useful-remote sensing basics- links for them to use. The teachers and the author maintained close communication to make sure everything was clear, and there were no areas of concern or any unanswered questions. The author visited the two elementary schools (on Friday 21 October and on Tuesday 25 October), to introduce the activity to the teachers and to interact with the students and talk about the UHI after they had completed the related field activity. The times of the sessions were: 8.30 am – 10.00 am for the Suncrest Elementary and 1 pm – 2.30 pm for North Elementary. At both schools, there was one more teacher in the classroom during the activity, acting as an observer / assistant. This was a first-time event for both schools and interest has been expressed to have it repeated.

Implementation

The urban heat island phenomenon was not predefined but stayed rather vague at the beginning. Satellites and satellite remote sensing were introduced, and images of Morgantown were shared. The students identified the area. Where the river is, where their school is, where there are green spaces and where the city is built-up, where the houses of their families are. Soon, the UHI was brought up by the students themselves. They observed the surface temperature map -

that the author had created from LANDSAT 8 imagery- and compared it to the satellite images and the map of the city that were also available (Figure 1).

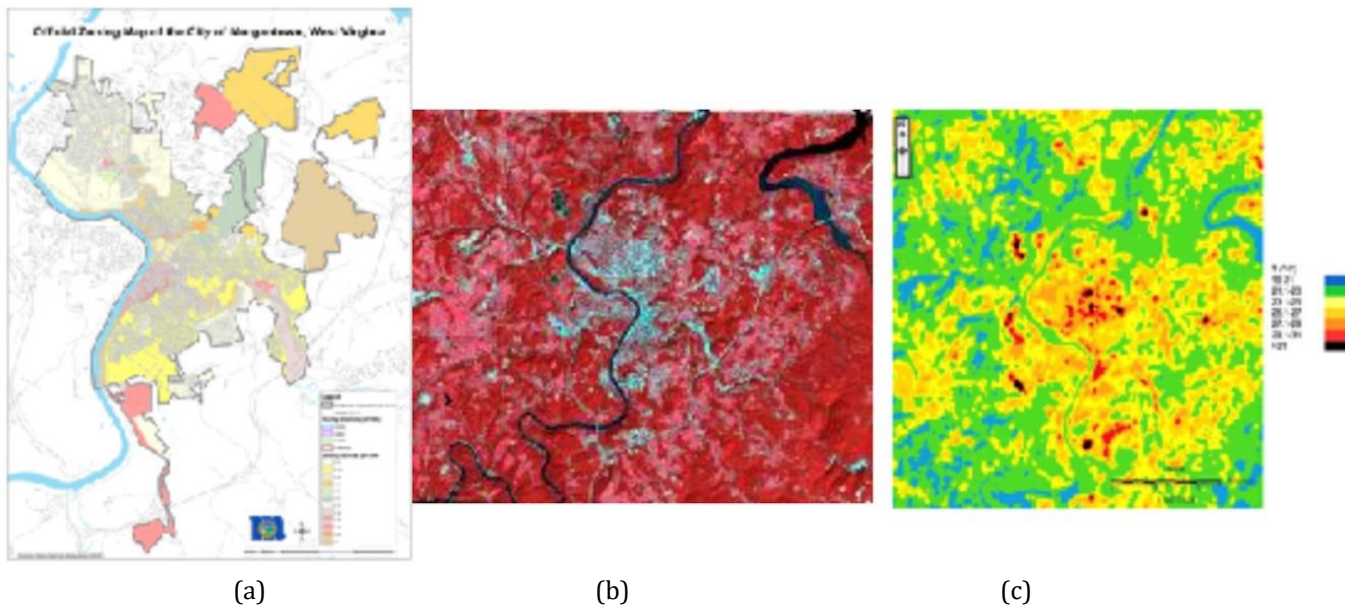


Figure 1. (a) Map of the city of Morgantown, (b) Landsat 8 image of Morgantown and (c) Land Surface Temperature map derived based on Landsat 8 data (There was a combined use of the maps, so that students would be able to identify areas)

There was a discussion about the different colors on the Land Surface Temperature map and the students associated the presence of natural surfaces with lower temperatures in the city. They noticed that the areas outside the city were quite cooler. Even though they did not know the terminology, they posed their questions, which led to the definition of the phenomenon and the related discussion. What was observed was that built-up areas are hotter than nearby rural areas that have natural surfaces. And that within the city, there are 'hot-spots', areas that are quite hotter than the rest of the city. Other examples, such as the ones presented in Figure 2, were shown to the students to support the spoken word and solidify what they had learned with visual clues.

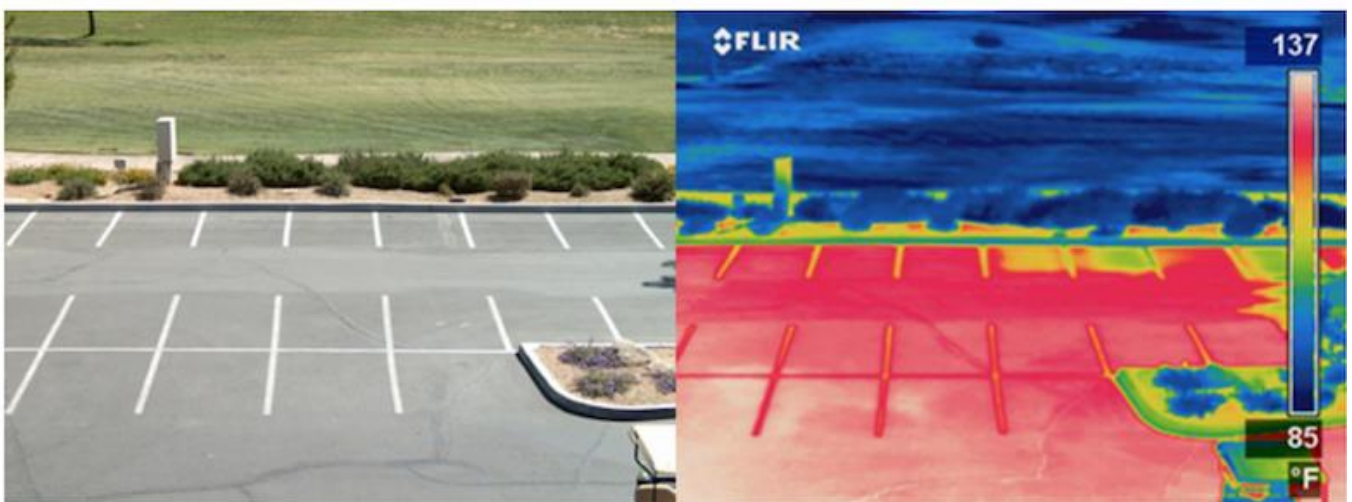


Figure 2. Visible (left) and thermal infrared (right) Images of a parking lot in Rio Verde, Arizona Source: Larry Scofield-APCA).

Students did their fieldwork, following the UHI effect discussion. They used infrared thermometers (that had been provided to the teachers, along with respective instructions to use and a related demonstration, Figure 3) to measure the temperatures of different types of surfaces. The students had their written instructions along with the verbal instructions from their teachers (see Appendix). The Protocol followed for the fieldwork was the one used for the SATELLITES campaign of the GLOBE Program. The author had created a modified version of the related data sheet, as the original one had sections for cloud and snow cover, that the students were not going to use for the specific activity

(to be noted that there was no snow and there were clear skies). There was also no need to record the individual coordinates within their site for this study. Moreover, the author added some information and pictures on the data sheet to make sure the students would remember some basic points when taking the measurements (for example that they needed to look for homogenous, large and exposed areas). The North Elementary School students explored the different temperatures they could measure in their gardens. These gardens have been put together and maintained with the guidance of WVU Professor Dr. Jim Rye. They also took measurements in the surrounding artificial surfaces in their schools. Likewise, the Suncrest students explored the broader area at their school.



Figure 3. The students used infrared thermometers (IRTs) that are temperature sensing devices using electromagnetic radiation to make non-contact surface temperature readings.

This outdoor activity, with students having their specific tasks, facilitated their learning, and guided them to become mindful of their learning as their feedback showed. Students at Suncrest Elementary worked on team projects using their measurements. They went beyond the initial instructions and compared shaded with no shaded surfaces of the same type. The teaching and learning progression for this class is shown in Figure 4. Students observed the materials provided, tried to identify patterns and connect them to the data that they had collected.

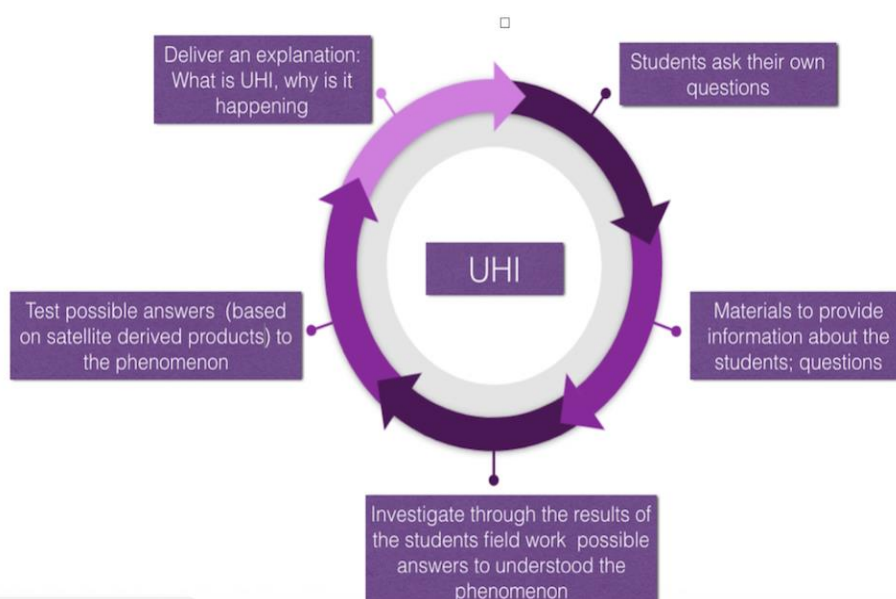


Figure 4. The teaching and learning progression of the phenomenon-based approach that was used to introduce the UHI using remote sensing images and products.

The students asked questions, related to everyday life experiences and reached a point of comprehension. They could understand what the satellite image was presenting, even if they did not know the technical details involved. They perceived the thermal comfort in their school, in their neighborhood and why it matters. They had questions about the UHI at other places of the world. Several images from other cities around the world were explored. There was a discussion about surface temperature data provided by other students on the GLOBE website. The Morgantown Elementary students were able to see that their peers are involved in the same kind of activities and reach similar conclusions. They understood the extent and complexity of the issue and the importance of action.

The Suncrest Elementary students worked on team projects and had their work presented in posters on the wall when I visited the school. Their work demonstrated how they had grasped the concept of UHI and how they had understood how to implement the GLOBE protocol for the retrieval of surface temperatures (Figure 5).



Figure 5. The posters that the students created to present their fieldwork.

Students collaborated in small groups, talked about the concept of temperature and different temperatures measured for different surfaces. They explained how they created the graphs and talked about the challenges they had in some cases. We discussed these challenges and talked about the appropriate way to represent measurements, thinking of what they represent and using averages to make comparisons (for example between shaded and exposed areas of the same type). Students spoke of temperature range based on their measurements, and they drew their study sites. While interpreting the graphs, they used the concept of equivalence as well as the strategy of comparing as they noted the relationships between the different temperatures. They also talked about other students having measurements that were like their own for the same kinds of surfaces. We talked about the thermal properties of different materials. How different material types reflect, absorb, and emit electro- magnetic radiation in different ways. They thought of examples, based on their personal experiences, things they had learned at school or heard from their parents. Another important thing that is worth bringing up was that while discussing, the students saw that their comments and the solutions they suggested were respected by each other.

Data collection

Students at both schools took a survey after the end of the activity. The survey questions were read and explained to them thoroughly, so that there would be no confusion or misunderstandings. The survey was put together by the author for the specific activity and the purpose was to collect the students' thoughts about i. remote sensing, ii. the data collection activity they were involved in and iii. what they learned about the UHI with the pedagogical approach that was adopted. Having a set of questions that are tailored to the specifics of the activity helps get a clear idea of the affected participants' views and perceptions. The survey was quite brief, so as not to overwhelm the students. It consisted of 14 questions that are presented in Table 1. Most of the questions were a Likert scale type and the options for responses were strongly agree, agree, neutral, disagree, strongly disagree. There were only two open-ended questions.

Table 1. The survey questions that were read and explained to the students before asking them to provide their feedback

Q.1. The activity was engaging.

Q.2. The activity made me think that it is important to know about science in my everyday life.

Q.3. The activity helped me better understand my local environment.

Q.4. The hands-on component (taking measurements with the Infrared Thermometers) was very important in helping me understand the topic of the activity.

Q.5. Please write down new words or concepts you learned participating in this activity.

Q.6. Which parts of the activity did you enjoy more?

Q.7. The activity was appropriate for my age and skills.

Q.8. I knew remote sensing before I participated in this activity.

Q.9. The satellites images and maps based on satellite data helped me understand what urban heat island is.

Q.10. I had heard of the urban heat island before participating in this activity.

Q.11. The surface temperature activity helped me understand what I learned in the classroom about the UHI.

Q.12. The activity I participated in helped me clarify some concepts I have learned in my science class.

Q.13. I would like to learn more about remote sensing and its applications.

Q.14. I would like to participate in hands-on activities like this again.

West Virginia View asks that the participants in any activity that is supported by the Organization provide some testimonials, describing the value added to their settings. The two Morgantown Elementary School teachers provided their feedback to the author. The teachers' testimonials are presented in the 'Results' section.

Results

The teachers received this activity with enthusiasm. They felt that the author provided them with good quality classroom resources that enhanced their knowledge and increased their confidence to teach science more effectively. They thought they had an opportunity to access and use authentic scientific tools and practices. This is very important, especially for urban students whose school science experiences often lack resources. They came to value the potential benefits of a different pedagogical approach for its impact on students' motivation and identity development. They also appreciated the holistic perspective of this pedagogy. Teachers provided the following thoughts in their testimonials:

'...Your UHI presentation was a wonderful connection to our temperature math/science activity and the real skills and applications that professionals use to provide very real and important services to us. The slides were very vivid and interactive. I hope to use your ideas, and this resource even more efficiently as I become more trained and used to the program. Our school's STEAM emphasis is ideally reflected in this activity. The math classes used the thermometers to complete a project that reflected several important tools and skills such as collecting data, making a line graph, noting important variables, measuring and mapping area in a scale drawing, using a directional compass, finding coordinates, and working as a team to collaborate for a presentation of the data.'

And: 'I really enjoyed doing this activity with my students! They were excited to go outside and take measurements of the temperatures of different surfaces with the infrared thermometers. I completed this activity with third grade academically gifted students. Many of the science concepts were new to the students, but they were very interested in learning about the content... Having Nektaria as a class speaker was a wonderful experience that was very beneficial for the students. They were thrilled to hear about research and science from an actual scientist'.

Both teachers stated that the phenomenon-based approach proved to be very effective for their students, keeping them active and engaged. It had them think about what is happening in their local environment and helped develop a sense of place. One of the teachers mentioned that the students were still trying to identify potential 'hot spots' in the city when driving with their parents, many days after the event.

All the answers that the students provided are presented in Table 2. The responses collected for question 5 ('Please write down new words or concepts you learned participating in this activity') reflected that students learned the scientific terms used to describe the UHI (for example 'hot-spots'), its causes (for example overpopulation and urbanization) and its mitigation (for example different construction materials and more green spaces). The students also learned about 'remote sensing' and how useful it is in our effort to monitor the environment and the UHI effect in specific. The increase in students' science vocabulary was quite remarkable, especially given that they had no previous knowledge on this topic. They built science content and practice of mind and developed their scientific literacy.

The responses for question 6 ('Which parts of the activity did you enjoy more') indicated that the students enjoyed acting as real scientists. That is, learning how to use the instruments, going out to take measurements, exploring their data and drawing conclusions from it. They also stated that they liked learning about remote sensing from a real scientist. And talking about their work in class.

Table 2. The answers provided by the students at the two elementary schools

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Q.1	50	21	10		
Q.2	61	14	6		
Q.3	70	8	3		
Q.4	59	14	8		
Q.5					
Q.6					
Q.7	44	27	10		
Q.8				8	73
Q.9	66	10	5		
Q1.0				6	75
Q.11	63	7	11		
Q.12	20	48	13		
Q.13	65	11	5		
Q.14	70	8	3		

Students were fascinated by the remote sensing related material. They found them very useful and perceived them as enablers for their understanding. They said that they would like to learn more about this technique and its possibilities (Figure 6a). The hands-on component of the activity was very appealing to the students. They loved going out, taking measurements and then using these measurements to prepare their posters and discuss them. This is something that they would like to do more frequently. Students had the opportunity to interact, to analyze and assess their data, and share their learning experience in the classroom (Figure 6b). They learned about the UHI; they added to their science vocabulary and were able to use the right words to describe what the effect is. They were involved in the learning process, so the phenomenon-based approach proved to be a very successful framework to build their knowledge. The strong inquiry-based component that it encompasses made the process engaging. Students asked questions that led to the definition of the phenomenon/problem. They were able to associate what they were seeing and listening to with their everyday life experiences. Being in different places of the city or being in various areas of their schools' and their surroundings. The phenomenon-based approach made the UHI concepts relevant to the students. They were also able to realize how complex this global environmental issue is. That information from multiple disciplines and action from multiple stakeholders is required to understand it and to deal with it. The activity helped the students develop a better sense of place (Figure 6c). Moreover, very importantly, this activity made students think that science is relevant to everyday life and made them want to learn more about it (Figure 6d).

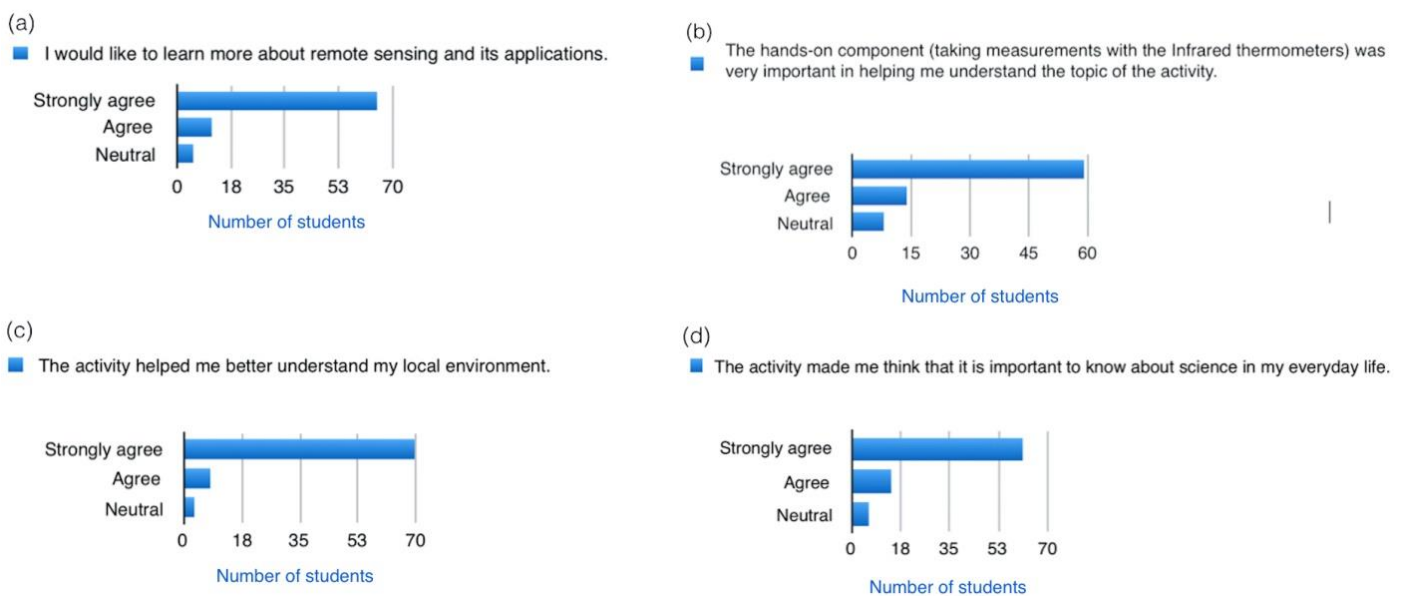


Figure 6. Students' responses for: (a) the use of remote sensing resources, (b) the hands-on component of the activity, (c) the development of a better sense of place and (d) the relevance of the activity.

Feeling that science is relevant is a very important factor to cultivate and retain students' interest for science.

Discussion

In this study, the author used remote sensing products as materials for elementary school students' instruction on the Urban Heat Island, adopting a phenomenon - based teaching and learning approach.

Remote sensing is a widely used tool for innumerable environmental applications. In the last decades there has been an explosion of face to face and online courses that introduce the technique's principles and applications. However, it has not yet been consistently incorporated in K-12 education, let alone in younger students' curricula. The introduction of remote sensing to second and third graders was exciting and at the same time challenging experience. Students that participated in this study's activity were not at all familiar with remote sensing. Satellite remote sensing and its products was a didactically helpful practice to call students' attention to a phenomenon of the present. It inspired them to want to learn more about it and its mitigation. However, one needs to be cautious in providing the information that is developmentally appropriate for students and not get in length in technical details that may be fascinating but are beyond the learning abilities of the students. Teachers and students in the two schools recognized the value and relevance of integrating remote sensing in their classrooms. The teachers expressed a keen interest in repeating the activity in their classrooms and in incorporating geospatial technologies to a higher degree in their science instruction.

The UHI effect was selected as a topic of discussion in the classroom. An in -depth knowledge of the phenomenon is required to: i. be able to simplify it, without limiting the science involved and ii. to be able to capture its complexity and its significance for many different aspects of our lives.

Research in science education indicates that students are looking for opportunities for real-world learning. Studies show that the relevant science was to students, the higher is was their interest in science and the greater are their expectations for their own success in science classes. The phenomenon- based approach is a recent pedagogy that has its origins in a 2016 education reform in Finland's education system. It has its basis on learning that has more context to real life issues and the better prepares students for that. The existing literature review shows that it is a very promising practice, especially in our times, with all the social and environmental challenges that require a multitude of skills and knowledge for young people to advance. In this study, phenomenon-based teaching and learning worked well in the classroom. The study revealed that students, despite their young age, were able to learn, make connections across subjects and note the relevance of what was discussed to real life. They communicated well among them and with the adults, they worked together in teams, thought critically and expressed their thinking in the survey. A very important finding of the analysis was that they enjoyed the process and they learned.

The student work, based on their own measurements, the survey feedback and the teachers' testimonials provided the opportunity for a rounded analysis in the effort to assess the activity. This work is different from relevant studies in that: I. remote sensing does not often reach the elementary school classroom as a main instruction tool, ii. the students were not only actively involved in field studies, like young scientists, but also determined the flow of the UHI discussion with their questions and thoughts, as suggested in the phenomenon-based pedagogy, and iii. the students had a chance to reflect on what they did and provide valuable information regarding their attitudes and the knowledge they gained.

Conclusions

Although the inclusion of geospatial technologies and remote sensing in specific, in K-12 education has increased in the last decade, its potential has yet to be more widely explored. This applies especially to younger students that are rarely exposed to these practices. Given the advantages that remote sensing offers for a multitude of disciplines, it is critical to escape from the current situation where only a few teachers use satellite images and products to talk about science topics, let alone dedicated software to analyze remote sensing data. Developing skills based on geospatial technologies can add to a teacher's toolkit in terms of having a variety of ways to engage students with important information about nearly any science topic.

Educators are looking for ways to provide their students with information, technology, and media literacy, that will allow them to become good communicators and collaborators and to become flexible and creative critical thinkers. Creativity, problem-solving, teamwork, and critical thinking are skills that cannot be easily developed by sitting in the classroom, listening to the teacher or by reading and watching videos. These skills can be developed from active engagement and from doing, both of which are key elements in phenomenon-based learning. Students have an essential role in identifying gaps in their knowledge that they want to fill.

This study discussed the use of remote sensing as a tool to introduce the UHI effect in a phenomenon-based approach to elementary school students. The analysis of the data indicated that there were important benefits for the students and teachers involved. The teachers were prompted to new ways of thinking about their science instruction in order to engage them to be curious, involved, and motivated to learn more about science. The set of tools used included conventional and interactive maps and remote sensing imagery and their products. The students learned about the UHI and were able to think about the complexity of environmental issues. They were able to think not only about the present, but in terms of the future and terms of sustainability. Their questions brought up the ecological, social, and

economic dimensions of the UHI issue, drawing from their experiences, the materials they were provided within the classroom, and the discussions that took place.

This work is a contribution to the efforts that are taking place in all education settings to attract and motivate students to science and to build knowledge in science for the future citizens of the world. There are students to reach, and maybe especially those for whom traditional teaching methods have been less effective. An important piece of the study was that the participants' (teachers and students) voice was captured, reflecting the effect the activity had on them. There are excellent databases on several websites describing the tools that are developed and available for use, but the perception of the end-users is often missing. The opinions of the ones who form and inform a tool may be very different from the opinions of the ones who use the same tool.

The author is planning to collect more data from different groups of students for other phenomena that are of interest to students and their communities, as standing issues, for example climate issues, or emerging situations such as occurring natural hazards. Another goal related to this study is to cultivate the systemic participation of the students of the two Morgantown elementary school, as well as those of other schools in the State, in the recurring GLOBE, Urban Heat Island Campaign.

Limitations and Suggestions

Phenomenon-based learning is characterized by a lack of very formal structure. So, one should be careful not to miss the focus, especially when dealing with very young students that can be easily distracted. A framework that will help guide the students through this process must still exist. The topic that is chosen should have a global context and relevant to real life issues or events. The students should be able to perceive these connections easily from their everyday life. Developing in inquiry question to start the discussion is very useful. Like for example: 'what do we see here', or 'why do you think this is happening?'

The facilitation of the learning process should be following a plan for the skills and knowledge that the students are expected to gain. The knowledge and skills acquired should be assessed in a way that does not overwhelm the students. Also, as the presentation of topics is holistic, a broad range of materials and resources should be available, to keep the students engaged and interested. Time availability is important, as this approach involves looking at a topic from very different perspectives, from very different subjects. Also, an open structure of time is necessary so that the students can engage in the discussion. So, one class period will probably not be enough to follow this approach. The time period required will depend on the topic selected to study.

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Appendix A:

Surface Temperature Data Sheet

Study Site : _____

Observer name/s: _____ Date: Year ____ Month ____ Day ____ Local Time (hour:min): _____

Clear skies: Yes No (provide details on the next page).

Find your test site. Make sure that the area is:

- I. As large a possible. For example at least 15 m X 15 m. Ask your teacher. Homogeneous - we are looking for grass covered surfaces and asphalt surfaces in this case.
- II. The surfaces are exposed, that is do not measure in shaded areas.

Go to about the middle of that area and take 9 measurements for the surface temperature. You will calculate the average temperature for each one of your test sites.

15 m x 15 m



Type of surface (select one) Grass Asphalt Bare soil Concrete	
Surface temperature (C)	
1	
2	
3	
4	
5	
6	
7	
8	
9	

Appendix B:

2016-2017
Mrs. Boback10/10/2016 - 10/14/2016
Class View

	<p>Use Math: Digital Thermometers to find an average of temperatures in an area: measure temperature</p> <p>Standards</p> <p>M.K-12.MP.5 Use appropriate tools strategically.</p> <p>M.K-12.MP.6 Attend to precision.</p> <p>M.K-12.MP.8 Look for and express regularity in repeated reasoning.</p> <p>M.K-12.MP.4 Model with mathematics.</p> <p>M.4.MD.2 Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.</p> <p>M.4.MD.3 Apply the area and perimeter formulas for rectangles in real world and mathematical problems. For example, find the width of a rectangular room given the area of the flooring and the length, by viewing the area formula as a multiplication equation with an unknown factor.</p> <p>M.4.NBT.5 Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers, using strategies based on place value and the properties of operations. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.</p> <p>Students will</p> <ul style="list-style-type: none"> • name the instruments used to measure perimeter and temperature • measure perimeter and temperature with correct instruments • record the information length/width and temperature measurements in a chart
<p>Tuesday 10/11/2016</p>	<p>Lesson / Instruction</p> <p>Access Schema</p> <ul style="list-style-type: none"> • What measurements do we take using rulers and thermometers? • How do we measure perimeter and area? • What tools would be best for measuring a large area? <p>Explain the task</p> <ul style="list-style-type: none"> • Use digital thermometer to take temperatures of ten specific places within the assigned areas • Record temperatures in the chart • Model how to use the thermometer • Model where to record it on the chart <p>Do</p> <ul style="list-style-type: none"> • Students will use the digital thermometer to take temperatures of specific places • Students will record their measurements on a chart • Students will record the temperature of the same spot using a regular thermometer • Students will record the measurement <p>Think</p> <ul style="list-style-type: none"> • What was the same? • What varied? • Why may have the difference occurred? <p>Write</p> <ul style="list-style-type: none"> • describe thought process <p>Differentiation / Accommodations</p> <ul style="list-style-type: none"> • students will be in teams that will help them use the tools and to make the map with partners who can help <p>Homework / Evidence of Learning</p> <ul style="list-style-type: none"> • Measure your outdoor space and record it on a map diagram <p>Instructional Strategies</p>

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2016-2017
Mrs. Boback10/10/2016 - 10/14/2016
Class View

	<p>3 Labeled Diagram</p> <p>3 Cooperative Learning</p> <p>8.3 Foster collaboration and communication</p> <p>Materials / Resources / Technology</p> <ul style="list-style-type: none"> • graph paper • colored pencils • meter sticks • measuring tapes
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