

# The Impact of a Professional Development Program on Urban Teachers' Lesson Planning Using Urban Geologic Sites

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**Abstract:** This study presents how a professional development program (PD) of K-12 teachers affects participants' use of the earth system approach and their perceptions of using the urban environment for their science teaching and lesson unit development. This study utilized mixed methods to collect and analyze the data. Eleven urban teachers' pre-post lessons (45 lessons) were analyzed quantitatively using a lesson plan analysis tool, modified by the author, and their lesson reflections were analyzed qualitatively. The findings of this study show that the PD program influences the teachers to choose more topics and content knowledge based on the earth system approach and to assess the topics and content knowledge with more appropriate methods. Specifically, the teachers use more urban environmental factors/topics in their post lesson to teach the environmental topics of urban area. However, according to the statistical analysis of pre-and post-lesson plan scores, the accuracy of the earth system knowledge that participants used in their lessons did not change significantly ( $p < 0.05$ ) (Table 4), which means that the PD program did not affect the improvement of the teacher's content knowledge in earth system science. Implications of this study are discussed

**Keywords:** Earth system science education, urban science teaching, professional development, place based education

## Introduction

Under the increasing pressure of public concerns about environmental issues such as global warming and destruction of ecosystems, earth science knowledge has become essential for a scientifically literate citizenry. Unfortunately, at a time of an urgent need for teaching earth science and earth systems interactions, the number of science teachers with a college major in a disciplinary area in or related to earth science is declining relative to other science disciplines. Only 72% of high school earth science teachers and 20% of middle school earth science teachers certified to teach earth science have a major or minor (Blank et al., 2003). At many elementary schools, earth science is even taught by teachers who have a non- science major or skipped by teachers with poor background knowledge in the earth sciences. This situation is even worse at urban elementary and middle schools that have been struggled with the

shortage of qualified science teachers. According to Jacob (2007), "urban schools were much more likely to have vacancies in critical areas such as math and science" (p. 134). Moreover urban school districts fill the vacancy of science teachers by hiring a substitute or less fully qualified teacher than suburban schools (Jacob, 2007).

Current policies at national and state levels in United States have addressed the need for improving the earth science teaching at both elementary and secondary level through professional development programs and recent national and state level funding efforts are directed toward professional development for high-need districts. However, there are still very few teacher professional development programs directed at improving urban teachers' earth science teaching. Moreover, the existing programs have not provided enough data to show the impact of the program on teacher participants' learning and practice of teaching earth science in urban classrooms (Guskey, 2002). A recent analysis report about the evaluation of professional development programs for science and math shows that many programs do not cover as many of the designed objectives as were outlined and

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intended in the program (Blank et al., 2008). Given this situation, a case study of an exemplary ongoing professional development program would be helpful to suggest a direction for earth science professional development programs for urban school teachers. The professional development program, entitled "Earth System Science for K-12 Teachers (ESST)", was designed to provide professional development for urban science teachers' understanding of earth and environmental science content knowledge relevant to the urban geological environment and is entering its 7<sup>th</sup> year of funding under No Child Left Behind funds. This paper presents an evaluation of the program using a formative evaluation study (Fitzpatrick et al., 2004) to find the program's impact on teacher participants' practice of incorporating earth science content into their planning. The specific study question is "In what way, is the ESST program contributing to the teacher participants' practice of using earth system science in urban environment as an element of their lesson planning?"

## Theoretical framework: Teaching Earth System Science using Urban Environment

### Earth System Science

During last couple of decades, earth science has been re-conceptualized as an interdisciplinary discipline called, Earth System Science (ESS). The concept of earth matter and earth system processes such as water, rock, and carbon cycle and how these processes are related to human society are the major ideas of ESS. The approach to teach about these main ideas is called Earth System Education (ESE). Moreover, given the reality of the acceleration of environmental change and subsequent issues about the global economy and policies, teaching earth as a system has become essential for improving students' scientific literacy (Earth Science Literacy Initiative, 2009). The associated necessity of education for ESS has been reflected in the numerous system oriented education projects, the US national science standards (e.g.,

Global Learning and Observation to Benefit the Environment (GLOBE), Earth System Science Education for the 21st Century (ESSE21)). Therefore, earth science teachers need a sound foundation in these major ideas to choose and develop sound earth science lessons (Lee, 2010; Loucks-Horsley and Matsumoto, 1999).

However, the study of K-12 teachers' understandings of earth system has not been studied enough to show how teachers understand earth system or what earth science concepts they need to understand earth as a system. Most of the research on teachers' understanding of earth science has been repeatedly investigated small, isolated concepts such as causes of day and night, seasons (e.g. Atwood and Atwood, 1996; Schoon and Boone, 1998), moon phases (e.g. Trundle et al., 2002; Suzuki, 2003), and plate tectonics (e.g. Libarkin and Anderson, 2005; King, 2000). While, there is research that shows that teachers have little awareness of the earth as a system and do not connect these phenomena with the concept of earth system interactions (Summers et al., 2000). Yet, not a single study examined teachers' understanding of the concept of "systems" in general earth science context or as it is applied to the earth system in particular.

Understanding earth as an integrated system requires not only correct conceptions about earth science but also a holistic view to see how systems and systems' elements interact with other parts of our planet. Due to the complexity of the earth system, it is very difficult to address all the detailed ideas needed to fully explain the Earth system using the idea of dynamics, feedbacks, time scales, and interconnectedness. Researchers in the disciplines of earth science and earth science education have used various approaches to identify important earth system concepts (e.g. Johnson et al., 1997). The concepts that are repeatedly mentioned in the literature were, Earth physical structure, System interactions including matter cycle (water cycle, carbon cycle, etc.), Scale of time and space, Energy sources, and Human activity. Our framework uses these five concepts to select and organize earth system knowledge for the ESST program.

### Using urban geology and environment

The second purpose of the professional development program was to improve teachers' understandings of urban geologic sites. Many science educators argue the importance of helping urban students to connect their community environment to school science (Burke, 2007; Fusco, 2001; Hammond, 2001). Recently, "place based education", or teaching and learning at a particular place has been spotlighted as a useful approach to connect students' lives or community to school science (Yu et al., 2007). By using urban geologic sites and natural environments, teachers can make earth science lesson meaningful to their students and can promote their further science learning outside of school (Shin, 2001). Davies (2006) also showed that by using urban environment, teachers can easily engage urban students in science and improve their science achievement (Davies, 2006).

While there has been argument about the importance of the teachers' knowledge of local environments to connect students' lives to school science, most teachers lack an understanding of urban natural environments and geologic sites as teaching resources (Cochran et al., 1993). To improve teachers' understandings of urban geology and environment, we adopt the place based education approach. Place based approach in teaching science is especially useful to engage people who are not familiar in a place in learning about scientific knowledge connected to a certain place (Smith, 2002). It is also important in terms of changing peoples' perceptions of a place as a useful learning resource (Smith, 2002). Further, a place-based education approach can help teachers develop contextualized lessons for the particular urban context where their students can make sense of natural phenomena (Glasson et al., 2006). Based on this perspective, most of the program instruction happened on field trips to local urban geologic environments to help teachers connect their understandings of earth system with real geologic site in the urban area as well as improve their understandings of urban geologic and natural environments. In the ESST project, urban geologic environment included, water

resource such as rivers, lake, creeks and ponds as well as geologic site such as parks, flood plain, and rock strata along the rivers.

## Methodology

Since this study employed a formative evaluation study (Fitzpatrick, 2004), the researcher observed the program to understand its content and structure as well as to collect data throughout the summer program and the following academic year. The researcher and the program's principle investigator worked closely to evaluate the impact of the program on teacher learning and practice.

### Program description

Since 2004, a two year community college and a graduate school of education in a major metropolitan area of the Midwest have been engaged in a professional development program titled, Earth System Science for K-12 Teachers, or ESST. This program has been funded for 7 years (until 2011) by the Department of Education in the state through Improving Teacher Quality Program (ITQP) and by additional funding from the state Pollution Control Agency. The data for this study is based on the 2007 July program. The main purpose of the program is to increase teachers' general earth science and environmental content knowledge using earth systems perspective through exposing teacher participants to urban geological and natural environments in the cities.

To improve teacher's general earth science and environmental knowledge, the curriculum included an introductory overview of earth and environmental science and advanced topics such as water resource and quality, global warming, climate change, and natural disasters, building up an earth system approach. In particular, the program focused on using examples from geological sites such as rock structures near a water fall, parks, lakes, and rivers in the local urban area to support teacher knowledge of urban geology and environments. The 2007 July class (from July 10<sup>th</sup>

**Table 1.** Topics and activities addressed in the program

Topics	Activities	**
Building ESS knowledge and skills	Weather map reading, analysis of current conditions, cloud observations; fronts, storms, mid-latitude cyclone, tornadoes, hurricanes, and urban climatological risk: extreme heat waves	L, Ds
	Night sky observations in urban area	F, Dm
	Stream and Lake Monitoring Program presentation	
	Topographic map reading exercise and land form analysis of the urban area	L, Ds
Field investigation	Visiting a wildlife refuge and identification of wildlife, grasses, shrub, and tree near rivers	F, Ds
	Field trips to river and river valleys in the cities	F, E
	Visiting two lake in the cities for limnology and water quality	F, E
	Species management in rivers and parks	F, Ds
	Visiting a regional park in the city for fossil hunting and identification of rocks and minerals, fossils found in road side using field microscopes and hand lenses	F, Ds
	Soil assessment field activities: Soil resource, erosion, running water	F, E
Earth science teaching strategy	Discussion of method and tool for collecting student data about their everyday lives in urban area.	Dm, Ds
	Developing teaching strategy using urban geologic environments	L, Ds, F
	Make a list of materials and equipment that will support units	
	Developing methods of assessing student's everyday life shaped by urban place they live	

\*\*Instructional methods: Field trip (F), Experiment (E), Demonstration (Dm), Lecture (L), Discussion (Ds), Assessment (A)

2007 to July 20<sup>th</sup> 2007) curriculum specifically focused on water resources in the earth system. This class involved shore line and on- the-water investigations on three lakes and three rivers in the urban metro and outlying regional areas. Most of the program's activities were designed as out-door field investigate and scientific inquiry by using urban natural environment. Table 1 describes the topic and activities.

Each day, following brief classroom presentations, teacher participants traveled to field sites in the metro area where they examined water quality, rocks, geologic structures, and completed data collection and analysis of atmospheric, hydrologic, biome and soil characteristics in these locations. In addition, the instructors tried to connect earth science knowledge and urban sites. They helped the teachers to understand how to use urban site as a teaching resource and how to consider urban student's accessibility to the sites.

### Participants

The participants of the program were recruited through an advertisement flyer and visits to schools in

the cities. A total of twenty seven teachers from urban and suburban schools around the cities were participated in the program. However, the data for this study was based on eleven teachers who were teaching highest need urban schools. While two thirds of the teachers have more than five years of teaching experiences, they had a wide range of experience level (one to thirty years). They were also diverse with respect to their prior science background, having taken from none to more than fifteen post-secondary science courses prior to enrolling in the program.

### Data collection

The evidence of the participants' learning about the urban geological environment and ESS was determined by comparing participating teachers' lesson plans before the program with lesson plans at the following academic year and the teachers' short reflection of their teaching. Total 45 lessons were collected that were developed by the eleven urban teachers. Instead of observing all participants' classrooms, lesson plan analysis provides information about a larger unit of teaching (Jacobs et al., 2008). To get a complete view of all teachers' learning and

their practice, all participants developed two earth science teaching units (including at least three earth science lessons). The teachers could choose any topic in earth science and environmental science such as water cycle, climate change, and rock cycle and rock formations, representing some lesson they had used in their prior earth science instruction. They developed the second earth science lesson after the program during the following academic year. In addition, teacher participants wrote reflections on their lessons based on their implementation experiences.

### Data analysis

The teachers' lesson plans were analyzed by a modified lesson plan analysis tool based on the Science Lesson Plan Analysis Instrument (SLPAI), developed by Jacobs et al., (2008). I adapted the two main categories as the main structure of the lesson plan analysis but changed the subcategories based on the understandings of earth systems education and place based education (Table 2). Using the lesson plan analysis tool, I examined the improvement of the teachers' lessons as an evidence of the impact of the program. Specifically, the two categories of the analysis tool were for examining the accuracy of the lessons regarding earth system approach and urban resources; the first category is *Alignment with Endorsed Practices (AEP)* including three subcategories and the second category is *Lesson Design and Implementation using an Earth System Perspective (ESP)* including seven subcategories.

In the first category of AEP, I looked at the lesson's overall alignment with three most fundamental guides for earth science lessons: Alignment with standards; Use of urban resources such as geologic and natural environments and; Earth system and environmental literacy, respectively, for lesson objects, strategies, and overall purposes. For guideline standards, I used the state earth and space science standards because the state standards are one of the most fundamental and overall guide lines for the teachers in the state. The second sub-category, Use of urban geologic and natural environments, is a hallmark of the ESST

project to provide active and field based learning experiences to make Earth Science engaging for inner city learners. In this category, I evaluated how much teachers' lesson topics covered important urban environments, such as three main rivers in the cities, numerous lakes in the urban area, and potable water usage, as elements of every student's daily life. If teachers used rivers and lakes or water activities that can easily connect urban water resource to students' everyday lives, their lesson got higher scores on this category. The lessons' alignment with earth system literacy is also an important component of this category and evaluated by recently published document about earth system literacy (Earth System Literacy Initiative, 2009).

In assessing the teachers lesson design and implementation using an Earth System Perspective (ESP), I looked at 5 subcategories including; Goal Orientation of ESP, ESP Content Accuracy, Content Presentation Using ESP, Meaningful Application Using ESP, and Assessment Using ESP. In the subcategory of Goal Orientation of ESP, I examined that how the lesson's purpose reflected the earth system or concepts, specifically interconnections between earth systems and human impacts on it. In the subcategory of ESP Content Accuracy, I looked at the accuracy of teacher's understandings of earth system processes such as matter cycles, and how the processes link parts of the earth system together. For example, if the teacher used water cycles as a topic and addressed how the water cycle relates to climate change in terms of changing solar energy input and how human affect the cycle with content knowledge accuracy, the teacher received high scores. In the subcategory of Content presentation using ESP, I looked at how the teachers presented their ESS knowledge using different presentation method such as using concept maps, flow-charts or diagrams or used real data or simulations to address ESS concepts. In the subcategory of Meaningful application, I looked at connections between ESS knowledge and environmental problems related to human actives such as water quality. In the sub-category of Assessment, I looked at

**Table 2.** Analysis instrument for earth systems lesson plans for urban learners

Main category	Sub category
Alignment with endorsed practices (AEP)	Alignment with state standard Alignment with earth systems and environmental literacy Use of urban geologic and environmental resources
Lesson design and implementation using earth system perspective (ESP)	Goal orientation of ESP Content accuracy Content presentation using ESP Meaningful application of ESP Assessment using ESP

what extent the teachers used the ESS content for assessment and how and what assessment methods were used to assess students' understandings of earth system knowledge such as constructed concept maps, as one example.

For each item, teachers' lesson plans could be rated as Exemplary (3 points), Developed (2 point), Needs Improvement (1 point), or Not Addressed (0 point). I calculated each teacher's pre and post lesson plan scores by averaging score of their lessons because the numbers of each teacher's lessons were varied from 3 to 9 lessons at both pre and post lesson plans. As a group, peer examination was used to ensure the validity of our analysis. Quantified scores of the teachers' earth science lessons were compared based on each sub-scale and total scores of the whole items.

The reliability of the analysis was examined using independent double-scoring of 100% of the lesson plans (N=45) by two other researchers in addition to the author. The average inter-rater agreement in this test was 87%. The scores from three examiners' 4-scale rating were averaged and described as descriptive data result tables at the result section. The teachers' reflections of their lesson implementation were analyzed separately using qualitative analysis method. Qualitative analysis proceeded with initial descriptive codes being assigned to the teachers' lesson reflections. Related codes were then grouped according to the same subcategory used for the lesson plan analysis. The coding was conducted independently by two researchers, including the author. The inter-rater reliability in this coding was 86%. The interpretation of the classroom observation descriptions were also cross-examined with the instructor.

## Result

*"In what way, is the ESST program contributing to the teacher participants' practice of teaching earth science?"*

This analysis captured the evidence of the change of teachers' interests and views in learning earth science through earth system approach and using urban geology by comparing their pre and post lesson units.

Table 3 presents a paired T-test result based on teacher's pre and post lesson assessment in Alignment with Endorsed Practices (AEP). There were no significant differences between pre and post lessons in the sub category of Alignment with Earth science state standards. However, the lesson score for the sub category of Use of urban resource and Alignment with earth science and environmental literacy were gained significantly ( $p < 0.05$ ). As the teachers described in their lesson reflections, they wanted to use more natural and environmental urban resource for improving their students' awareness about the importance of the natural environments surrounding them. Especially one teacher was using outdoor activity at the school yard for water quality lesson and another teacher used field trip to the lake near the school for water quality testing lesson. Nine of them are not doing field trips, nor using urban geology or environment as main context of their earth science teaching. This may be because of time requirement to plan outdoor activities, budgets for field trips, difficulty of setting up all other things such as (class schedules with other classes), or less support from the school principal. But more importantly, this may be because they did not know enough about the urban geology or environment for

**Table 3.** A t-test result of pre-post lesson scores in alignment with endorsed practices (N=11)

Alignment with endorsed practices (AEP)	Pre-lesson		Post lesson		P values
	Mean	SD	Mean	SD	
Alignment with state standard	2.64	0.67	3.00	0.00	0.104
Use of urban resources	0.64	1.21	1.55	1.04	0.043
Alignment with earth science and environmental literacy	1.09	1.22	2.73	0.65	0.005
AEP Average	1.45	0.73	2.42	0.88	0.026

\*p< .05

their own specific teaching topic. For example, one teacher said in the teaching reflection that “using urban geologic resource and environment was quite new for them to adapt immediately in their science teaching”. They might think that they need to learn more about the urban geology or environment to use in their earth science teaching or merely hesitate to use urban resource for the their teaching because it is new to them.

Compared to their pre-lesson plans, teacher participants’ post lesson plans showed greater foundation in the relationship between people and the Earth systems and alignment with earth and environmental science literacy, especially the interactions between human and living environment. The teachers tried to connect environment or even earth science to human activities and how the human society affects to the earth environment. This also reflects, in part, a program focus on current rates of global change, resources consumption, and subsequent impacts to Earth’s environment and field activities for atmosphere, water, soils, land cover and ecosystems.

Table 4 presents a paired T-test result based on teacher’s pre and post lesson assessment in Design and Implementation using Earth Systems Perspective

(ESP). There were no significant differences between pre and post lessons in the category of Content accuracy. This means that there were no significant differences between pre and post lessons in terms of earth system science content accuracy. However, there were significant differences between pre and post lessons in the sub-category including Goal orientation of ESP, Content presentation using ESP, Meaningful application using ESP, Post-assessment using ESP (p<0.05). First, in the subcategory of Goal Orientation of ESP, on average, teacher’s post lesson score were improved significantly. It means that the post lesson reflected more earth system approaches or concepts especially for addressing interconnections between earth sub-systems and between earth system and human activity. Second, the post lessons were also significantly improved in the subcategory of Content presentation using ESP. It means that the teachers were using more appropriate teaching strategies or method to present earth system concepts such as concept maps, flow-charts or diagrams, or using real data or simulations to address ESS concepts. There were also significant improvements in the teachers’ lesson plans in the subcategory of Meaningful application. It means that the post lesson presented

**Table 4.** A t-test result of pre-post lesson scores in lesson design and implementation using earth systems perspective (ESP) (N=11)

Lesson design and implementation using ESP	Pre lessons		Post lessons		P values
	Mean	SD	Mean	SD	
Goal orientation of ESP	1.36	0.92	2.36	0.92	0.026
Content accuracy	2.45	0.69	2.64	0.67	0.553
Content presentation using ESP	1.00	0.77	2.09	0.83	0.003
Meaningful application using ESP	0.91	0.83	2.73	0.65	0.000
Post-assessment using ESP	1.09	1.14	2.36	0.81	0.008
ESP Average	1.09	0.53	2.36	0.71	0.000

\*p< .05

more concepts that represented environmental issues and possible solutions about environmental problems related to human activities such as global warming. Finally, in the sub-category of Post assessment, there were significant improvements in the post lessons compared to the pre lessons. The post lessons presented more concrete methods for assessing students' earth system knowledge and were more coherent with lesson content and topics compared to the pre lesson plans.

## Conclusion and Implication

It is critical that urban teachers learn how to connect earth science content to all contexts of the inner city urban environment, including the geologic environment contexts of their students' experience. The program used a variety of teaching methods to help the teachers to improve their understandings of scientific knowledge or urban environment and investigation skills in the outside field context.

As the result shows, the ESST program positively affects the teacher participant's practice of teaching earth science in terms of lesson planning. The program affect the participant teachers to choose more topics and content knowledge based on earth system approach and present and assess the topics and content knowledge using more appropriate methods. Especially, the teachers use more urban environments for their post lesson for teaching topics more environmentally founded in the urban area. The teachers also used more hands-on activities because they thought hands-on activities were more relevant to their students to understand complex earth and environmental science concepts. This result also supports the findings from other research about the impact using place as important context for learning and improving awareness of natural environments (Fusco, 2001; Gay, 2000).

Teachers' pre and post lesson analysis result shows that overall, the main category of Alignment with endorsed practices was less improved than the main category of Lesson Design and Implementation Using an Earth System Perspective (ESP). Particularly, there

were no significant differences between pre and post lesson plans in terms of alignment with state standard and content accuracy of earth system concepts. This result may due to both the short period of the professional development program and the need to focus on more piecemeal content subjects under the standards for grades K-6, and the fact that understanding Earth Systems appears only indirectly for grades 7-8 and not explicitly until the standards for 9-12 grades. Thus for a class with a predominance of K-6 grade teachers, an Earth System Perspective will be less evidenced in lesson plans.

Overall, the teacher participant become more interested in learning about urban geology and water resources as a result of the field experience in the program and as a result became more interested in teaching earth science concepts using urban geologic and environmental resource. More importantly, I could understand urban teachers' perceptions related to the concerns about science teaching using urban environments. In reflecting on their views of earth science teaching, in particular, the teachers were addressing the difficulty of doing field investigations. I found that if urban teachers have more confidence about teaching earth science concepts and hand-on and field based activities, they are more likely to use local urban geology and environmental resources near to where their students live. This is important to make their science teaching more relevant to their student's everyday lives. As Bank et al. (2008) found, most of the professional development program for urban science teachers has not focused on how to improve urban science teachers' skill to make science teaching more relevant to their urban students but on teaching content knowledge. Researchers have suggested the need of improvement of professional development program by considering teacher learning as a situated cognition (e.g. Borko, 2004; Penuel et al., 2007). Urban teachers' knowledge of students' everyday life context and culture may be more important than learning science content knowledge for more culturally relevant teaching (Gay, 2000). This program shows a direction of how to incorporate the needs of urban



teachers' pedagogical skill and their content knowledge by using urban environment as an important context for teaching earth science.

I believe, the instructional approaches in the program using urban environment were most effective in helping many of K-5 teachers who have little experience in teaching earth science. Breaking the big idea of Earth System down to their students' level is always a big commitment for the teachers, especially due to their lack of content knowledge, resources and guidelines to reorganize and represent the earth system knowledge at an appropriate level. The earth system approach used in the program helped the teachers to understand big ideas of earth system and the field investigation reinforced their understanding. The information collected from this study could be used to reformulate the program and give some feedback to stakeholders including state Department of Education, as well as scholars and program developers who are interested in developing professional development program for urban teachers.

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