Effects of Science and Engineering Practices on
Science Achievement and Attitudes of Diverse Students including ELLs

Hanna Kim

Northeastern Illinois University
Abstract

This study examines diverse elementary students including English Language Learners (ELLs)’ science achievements and attitude changes following inquiry-based activity experiences. Thirty seventh-grade students explored the harmful and helpful effects of ultraviolet (UV) rays on the human environment using scientific methods to define problems, develop models, plan and carry out investigations, analyze/interpret data, use mathematics and computational thinking, construct explanations (for science) and designing solutions (for engineering), engage in evidence-based arguments, and evaluate/communicate obtained information. These processes are known as inquiry-oriented approaches (NRC, 2000) and have been deepened and redefined as a set of eight science and engineering practices in the Next Generation of Science Standards (NRC, 2012). Individuals designed their own experiments by choosing different materials to test for the best protector of UV light. The Science exploration sheet (SES), which measured the scientific achievement, showed that 92% of students answered their own questions using their individual scientific models. However, pre- and post-attitude surveys revealed that there was no significant change in students’ attitudes about science/scientists following the inquiry intervention (p< .05). Particularly participating teachers’ views of inquiry teaching experiences to their ELLs were discussed.

*Keywords*: NGSS, English Language Learners, Diverse Learners, Inquiry, Science and Engineering Practices, Science Achievement
Effects of Science and Engineering Practices on Science Achievement and Attitudes of Diverse Students including ELLs

The conceptual framework for Next Generation Science Standards (NGSS) articulates a broad set of expectations for all students including ELLs in science. The overarching goal of the K-12 science education framework is that by the end of twelfth grade, all students will have an appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information that relates to their everyday lives; are able to continue to learn about science outside of school; and have the skills to enter careers of their choice in science, mathematics, engineering, and technology fields (NRC, 2012). This framework is designed for a set of eight science and engineering practices and focuses on core ideas in four disciplinary areas (physical sciences, life sciences, earth and space sciences, and engineering), and crosscutting concepts that are designed so students can continually build on their scientific knowledge and abilities applying the practices needed to engage in successful/effective science inquiry and modeling (ARC 2013). The meaning of inquiry-based science is thus deepened by this set of science and engineering practices. The practices are a clear representation of what scientists do as they engage in the scientific inquiry process (Quinn, Lee, & Valdés, 2013).

A review of the research published from 1995-2004 (Schroeder, Scott, Tolson, Huang, Hsuan, & Lee, 2007) determined what science teaching strategies have been effective in improving student achievement in science. The study looked specifically at eight categories of teaching strategies: Questioning, manipulation, enhanced material, assessment, inquiry, enhanced context, instructional technology, and collaborative learning. The results revealed that each strategy is not separate from the others; they are all interconnected directly or indirectly.
Overall, inquiry-based learning strategies, using collaborative learning with heterogeneous groupings was most effective for all students including ELLs.

Existing research on inquiry-based instruction can highlight its strengths as a starting point for personal construction of meaning and lead to higher achievement for all students (Frome, Alfeld, Eccles, & Barber, 2006; NRC, 2000; Quigley, Marshall, Deaton & Cook, 2011). These studies give science educators a clearer understanding of the importance of inquiry-based instruction based on students’ science-related interest, confidence in science, persistence in continuing to study science, and science achievement. Science inquiry using an interdisciplinary approach has been more emphasized in the NGSS, but elementary teachers often struggle with how actually to design and implement inquiry instruction (Banchi & Bell, 2008; Padilla, 2010; Rommel & Ronald, 2012). For many, just understanding what “inquiry” means can be difficult. Science inquiry among diverse learners, including English language learners, is getting more attention than before since the number of ELL students keeps increasing (Lee, & Buxton, 2013; Ricketts, 2011, Trina & Walker, 2010) and educators must be better prepared to accommodate them and their unique educational needs (NRC, 2012).

Teachers need to know how to integrate English language learners into this new way of teaching science (Nabors & Edwards, 2012; Ortega, Luft, & Wong, 2013). Cuevas, Deaktor, and Lee (2005) examined the impact of scientific inquiry-based instructional intervention on third and fourth graders to narrow the gaps in students’ abilities across diverse languages and cultures. This study showed that all students benefited from this specific inquiry intervention. Students’ abilities to ask appropriate questions increased. Additionally, students were better able to plan procedures for investigation, record the results, and draw conclusions, regardless of their grade, achievement, gender, ethnicity, culture, home language, or English proficiency.
Lee & Buxton (2013) found effective science teachers emphasize hands-on, inquiry-based activities for all learners including ELLs because in using hands on activities, the students can see the teacher model an experiment. They also mentioned that various graphic organizers/visual aids that back up what teachers are teaching not only can reinforce for regular students but essential for ELLs.

These studies thus provided evidence that inquiry-based experiences may indeed be beneficial to diverse students’ science achievements and attitudes regardless of their grade level or English proficiency. In this study, we investigate how inquiry-based teaching which was embedded in a set of eight science and engineering practices affects seventh grade students including ELLs’ science achievements (Table 1) and their attitudes toward science. The Green Earth program used a guided-open inquiry approach and created small- to medium-sized inquiry projects.

**Purpose of the Study**

The objective of this study focused on how an inquiry-based approach using the science and engineering practices (Table 1) can motivate diverse seventh grade students’ interest about science and improve their science understanding/science achievements in selected core concepts (Energy: harmful and helpful solar energy; Cause and Effect: UV light/ozone and human health; System: solar/earth System). Participating teachers’ views of inquiry teaching experiences to their diverse learners, including ELLs were collected. The research questions were the following:

1) What are the effects of inquiry practices on student scientific achievement based on understanding the relationship between UV light and human health?

2) What are student attitudes toward science/scientists after participating in inquiry-based activities?
3) What are teachers’ views on the advantages/disadvantages of teaching science as inquiry to their diverse learners, including ELL students?

**Methods**

**Participants.** A total of 30 students from an urban elementary school entering the eighth grade were recruited for this study. Of the students who participated, 51.4% were males, and 48.6% were females. 27.0% were Hispanic, 24.3% were White, 13.5% were African American, 24.3% were Asian, and 10.8% were unknown ethnicity. In addition, 54.1% said English was their first language, while 8.1% responded Spanish, 5.4% responded Korean, and 32.4% indicated that a language other than English, Spanish, or Korean was their first language. When asked how long they had been in the United States, 54.1% said they had been in the United States for 10 or more years (U.S.-born), 18.1% said 7–9 years, 18.1% said 4–6 years, 2.7% said 0–3 years, and 7.0% left the question blank. In the group, 18 out of 30 students were identified as ELL students (i.e., beginning to intermediate English proficiency level) based on their results on the language screener test, which assesses their English proficiency in the four language domains of Listening, Speaking, Reading, and Writing. In the study, we also used the participants’ descriptive data (i.e., their native language, the length of time living in the US, and past experiences with or access to English) as a reference for planning the presentation of science concepts for the Green Earth program.

**Green Earth Curriculum.** The two science teachers involved in this study taught during the Green Earth program, a five-week science inquiry program for seventh-grade students, developed by the science education faculty at the researcher’s university. Green Earth lessons focus on core ideas in four disciplinary areas (physical sciences, life sciences, earth and space
EFFECTS OF SCIENCE AND ENGINEERING PRACTICES ON ACHIEVEMENT

sciences, and engineering) and on crosscutting concepts (Energy, Cause and effect, and System) that address scientific problems related to environmental issues.

The Green Earth curriculum, which uses real-world inquiry projects, was created based on the Next Generation of Science Standards that utilize the eight science and engineering practices (i.e., asking questions and defining problems; developing and using models; planning and carrying out investigation; analyzing and interpreting data using math and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; obtaining, evaluating, and communicating information). Each lesson took three class periods (120 minutes) to complete. Participating teachers also developed a graphic organizer with targeted science concepts, which is proven to be effective for all learners prior to their science and engineering practices (Kaldenberg, Therrien, Watt, Gorsh, & Taylor, 2011).

Professional development with teachers. The participating teachers attended workshops (PowerPoint slides, online resources, journal articles, and emails) and face-to-face meetings to learn strategies for the scientific inquiry framework (Crain & Bass, 2009; NRC 2012). The content of the workshops emphasized the new science standards (i.e., Eight Science and Engineering Practices) and teaching within a 5E (engage, explore, explain, elaborate, and evaluate) instructional model for the class periods during which the Green Earth lessons and data collection would occur. A leading teacher experienced in the previous research worked as a liaison to facilitate questions and discussions among participating teachers and the university faculty member, who was the principal investigator of this research in terms of lesson planning, testing instruments, and experimental designs.

The Science Exploration Sheet (SES). The Science exploration sheet (SES), developed by Green Earth teachers, consists of ten open questions covering major scientific concepts
related to UV light/human health issues. The questions were aligned with the eight science and engineering practices. Sample SES items and corresponding practices are presented in Table 1.

Table 1

*Sample Questions in the Science Exploration Sheet (SES) that are tied with eight Science and Engineering Practices and the 5E Instructional Model*

<table>
<thead>
<tr>
<th>A Set of Eight Science and Engineering Practices in NGSS</th>
<th>Procedures/Questions in the Science Exploration Sheet (SES)</th>
<th>5E Instructional Model</th>
</tr>
</thead>
</table>
| 1. Asking questions (for science) and defining problems (for engineering) | 1. What question do you want to explore?  
2. You can use an “If ..., then ...” statement if you wish.  
Or you can use “I predict that…”  
Or you can use “I hypothesize that…” | Engagement |
| 2. Developing and using models | 3. List the materials you will need.  
4. How will you find the answer to your question? | Exploration |
| 3. Planning and carrying out investigations | 5. List step by step how you will do your exploration (you can write as many steps as you like)  
After you follow your chosen steps, write down what you observe. | Explanation |
| 4. Analyzing and interpreting data | 6. Draw a graph to support your results.  
Remember, the x-axis is the independent variable and the y-axis is the dependent variable. | |
| 5. Using mathematics and computational thinking | 7. Label the level of color change using the intensity scales of 3, 2, 1, and 0? | Elaboration |
| 6. Constructing explanations (for science) and designing solutions (for engineering) | 8. What are the best ways to protect ourselves from the sun? | |
| 7. Engaging in argument from evidence | 9. Why is it important to protect ourselves from UV rays? | |
| 8. Obtaining, evaluating, and communicating information | 10. Pair up and present your entire procedure/findings to the class using a poster board | Evaluation |
The Attitudes toward Science Test (ATST). Students were administered the ATST for 40 minutes on the first day of the Green Earth program at a local elementary school in the large Midwest area and given the same ATST again for 40 minutes immediately after they completed the Green Earth program.

Table 2

Attitudes Toward Science Test (ATST) Questions

<table>
<thead>
<tr>
<th>Statements</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I would like to work in the field of science and/or technology.</td>
<td>.545</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Science plays a great role in improving our standard of living.</td>
<td></td>
<td>.494</td>
<td></td>
</tr>
<tr>
<td>3 I feel good about myself when learning or working with science.</td>
<td></td>
<td></td>
<td>.735</td>
</tr>
<tr>
<td>4 I am good at science.</td>
<td></td>
<td></td>
<td>.598</td>
</tr>
<tr>
<td>5 When I hear the word <strong>science</strong>, I have a <strong>dislike</strong> feeling.</td>
<td></td>
<td></td>
<td>.851</td>
</tr>
<tr>
<td>6 Science helps me work with others to find answers.</td>
<td></td>
<td>.667</td>
<td></td>
</tr>
<tr>
<td>7 Scientific knowledge is useful to keep our national economy</td>
<td></td>
<td></td>
<td>.816</td>
</tr>
<tr>
<td>competitive in today's world.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Science is difficult for me.</td>
<td></td>
<td></td>
<td>.849</td>
</tr>
<tr>
<td>9 Currently accepted scientific knowledge can be modified or changed in</td>
<td></td>
<td></td>
<td>.615</td>
</tr>
<tr>
<td>the future.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Educational guess (personal experience) plays a role in scientific</td>
<td></td>
<td></td>
<td>.934</td>
</tr>
<tr>
<td>investigation.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Scientific investigation follows the scientific method.</td>
<td></td>
<td></td>
<td>.570</td>
</tr>
<tr>
<td>12 I am interested in many scientific ideas that are not taught at school.</td>
<td></td>
<td></td>
<td>.791</td>
</tr>
<tr>
<td>13 Science is interesting to me, and I enjoy it.</td>
<td></td>
<td></td>
<td>.911</td>
</tr>
<tr>
<td>14 African Americans, Asians, and other minorities are just as welcome in</td>
<td></td>
<td></td>
<td>.717</td>
</tr>
<tr>
<td>the scientific community as White people are.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Computers, GPS, DVDs, Solar Panels, airplanes, and hybrid cars are</td>
<td></td>
<td></td>
<td>.880</td>
</tr>
<tr>
<td>related to science and/or engineering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability=0.875</td>
<td>0.856</td>
<td>0.728</td>
<td>0.767</td>
</tr>
</tbody>
</table>

Factor 1: Interest in Science (Q1, Q3, Q5, Q8, Q12, and Q13)
Factor 2: Understanding about science/scientist (Q6, Q9, Q11, Q14, and Q15)
Factor 3: Relevance to real life (Q2, Q4, Q7, and Q10)
The ATST was revised from findings of the previous research (Kim, 2011), and more questions were added on the nature of science (e.g., scientific method). A total of 15 questions (alpha=.854) ranked on a 5-point Likert-type scale (2 = Absolutely yes, 1 = Yes, 0 = I am not sure, -1 = No, -2 = Absolutely not). Sample questions (see Table 2) were the following: Q3: I feel good about myself when learning or working with science; Q9: Currently accepted scientific knowledge can be modified or changed in the future.

Results

The Science Exploration Sheet (SES). 92% of students were able to define a question (hypothesis), plan and carry out scientific investigations using their own model, and explain their investigations/conclusions (i.e., how to protect skin from the sun/UV light) using a graph that included color intensity scale (0: no color change, 1: pale purple, 2: medium purple, 3: dark purple). For example, student A conducted an experiment testing a group of UV beads with sunscreen SPF 30 against a second group of UV beads with sunscreen SPF 15. This student’s observations indicated that the beads with SPF 30 sunscreen were not affected (turned to pale purple) by the UV light as much as the beads with SPF 15 (turned to medium purple) sunscreen. The student concluded that “There were fewer affected beads with SPF 30 than SPF 15.” This student also was able to relate the beads’ color change to his own skin damaging when outside. He was able to consider how to prevent his skin/body from being damaged by the sun (UV light) and used that information to come up with what number SPF lotion (SPF 30 or SPF 15) to use on the beads to keep them from changing to purple.

As another example, student B conducted an experiment testing a group of UV beads with yellow-colored cloth against a second group of UV beads tested with black-colored cloth. The student initially predicted that the beads covered with a light-colored cloth would not be affected by the UV light at all (perfect UV protection), and the darker-colored cloth would pretty much absorb the UV light (no UV protection). After the observation, he modified his prediction
and explained that the beads with black cloth turned to light purple, while the beads with yellow cloth turned to strong purple. The student concluded that “Dark colored cloth will protect our skin/body better than light colored cloth.”

In another example, student C hypothesized that “black sunglasses will make the UV beads have no color change, and brown glasses will make the UV beads turn pale/medium purple color.” His observation is shown below as a graph (Figure 1) with the color intensity scale ranging from 0 to 3. He was able to analyze, compare, and explain his collected data using a graph that shows different types of sunglasses (i.e., black vs brown) and their UV protection levels (i.e., color intensity scale). He confidently reported that black sunglasses with beads had the most protection (color intensity scale 0-perfect protection) from UV rays compared to brown sunglasses with beads (color intensity scale 2-medium protection) and beads without sunglasses (color intensity scale 3-no protection).

Figure 1. Student C’s Observation/Interpretation on Different Sunglasses (no sunglasses, brown sunglasses, and black sunglasses) with UV Protection Levels.

<table>
<thead>
<tr>
<th>Bead Color Intensity Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-dark (strong/intense) purple</td>
</tr>
<tr>
<td>2-medium purple</td>
</tr>
<tr>
<td>1-very pale: light purple-only slight change of color</td>
</tr>
<tr>
<td>0-no color change (still white in color)</td>
</tr>
</tbody>
</table>
The Attitudes Toward Science Test (ATST). Overall, participating students changed their views slightly of science/scientists/science-related careers after the intervention. However, the results of the $t$-test showed there was no statistical significance for the intervention between the pre- and post-ATST ($t = -0.593$, $p<.05$). By group, ELL participants had a mean change of -1.44 after the intervention, while Non-ELL participants had a mean change of 0.67 after the intervention. Regardless of the survey mean changes, there were no statistical significance for both group participants for the intervention between the pre- and post-ATST ($p<.05$). The ATST loaded three factors. These three factors included an interest in science (Q1, Q3, Q5, Q8, Q12, and Q13), the nature of science (Q6, Q9, Q11, Q14, and Q15), and science relevance to real life (Q2, Q4, Q7, and Q10). The mean difference between the pre- and post-ATST for these three factors was not statistically significant at $p < .05$.

Teacher reflections on inquiry instruction for diverse learners. The participating teachers indicated that inquiry-based learning using the science and engineering practices is more beneficial for both non-ELL and ELL students because the students are more productive and are able to design/develop science experiments on their own. For example, teacher A commented, “Students felt like they were scientists and they enjoyed experimenting on their own. Inquiry approach can open up opportunities for working with others, sharing ideas, and most importantly students teaching students.”

Teachers also addressed inquiry teaching strategies for their ELL students. Both teachers felt that inquiry-based learning is effective for ELL students. Teacher A said, “The ELL students demonstrated they too understand science concepts and even thinking of questions to test.” For example, teacher A said “student S (a newcomer) benefited from speaking more and using better science vocabulary when using the inquiry method. Since a question (i.e., hypothesis) was not
given to him, he was forced to communicate his idea to his partner(s) using the inquiry method when talking with his group.” According to students’ responses on the question 4 (Q4: How will you find the answer to your question?) in the science exploration sheet (SES), student M benefited from the inquiry method since the student was expected to choose a material to test and question to answer. When given the material category choices she was to test, she thought of HOW to test the black and brown sunglasses. She was able to write her own question about what and how to test. This query also benefited her confidence as a learner in science since she made choices of which materials to use in the experiment and what question she would try to answer through experiment process.

Student G benefited from the inquiry method because using it forced him to be very specific when speaking/writing about his question during the science and engineering practices (Table 1). Many times he tended to hurry his work and not be specific, but since the designated experiment had many materials and specific vocabulary, he was forced to do independent thinking. For example, he used vocabulary (e.g., more or less UV protection, human health, ozone effect, & effect and cause of the sun light) successfully and was able to sound more like a native speaker using more specific vocabulary during the speaking/writing portion of experiment engagement.

Teacher B said “inquiry-approach has an advantage for ELL students because it teaches them to think outside the box, use their prior knowledge, and guides them to think critically, which can be hard for an English learner under traditional science classes using step by step procedures. Through the Inquiry Approach, ELL students learn more questioning skills because they are expected to think of various possibilities, they expand their vocabulary through background building of concepts, make connections to what they know, and introducing them to
new vocabulary in new contexts. Furthermore, with guided writing/speaking support, ELL students learn sentence/grammar structures while using science vocabulary and communicating science concepts. Science is often a hands-on practice, and through the inquiry approach, students can gain confidence by choosing materials and developing critical thinking skills by asking questions. They can begin to learn the way everyone in their class learns, which boosts their academic confidence.” Teacher B also mentioned how hard or easy it was to guide them to write their own prediction/hypothesis using an independent variable (e.g., SPF 50/30/15 Lotion, black/brown sunglasses, & yellow/black colored cloth). Some students did have a hard time writing a prediction using variables (independent and dependent variables). Teachers then went back to discuss the meaning of variables and their specifics and then modeled how to write a prediction using each variable, so students had a clearer idea of what to write and how the variables could be used in the experiment. Teachers also created sentence starters for their ELL students. An example is explaining how to control variables (number of sprays) and identifying all the independent (materials to test; SPF lotion/Cloth/Sunglasses) and dependent variables (color change).

Example Sentence: I predict that 5 sprays of SPF 50 will keep the beads white color, 5 sprays of SPF 30 will change the beads to pale purple, and the control with no spray (no SPF lotion) will change the beads to dark purple (no UV protection).

Both teachers agreed that one disadvantage of inquiry-based learning is that it takes longer to prepare and develop lessons compared to non-inquiry lessons, which are very straightforward and much simpler regarding specific teaching procedures and material selections.

Discussion and Conclusions

Science Achievement Using Inquiry Practices. The Green Earth program significantly increased seventh graders' content knowledge of selected science concepts for UV/human health through science inquiry practices. This result is consistent with previous research (Bulunuz,
EFFECTS OF SCIENCE AND ENGINEERING PRACTICES ON ACHIEVEMENT

Jarrett, & Martin, 2012), which found that students can understand well on selected science concepts if they are actively engaged in learning the subject via an inquiry-based method.

Meyer and Crawford (2011) suggested in their research that inquiry-based instruction with culturally relevant topics may better support ELLs in science learning. Therefore, the Green Earth Program utilized a big idea (i.e., human health) that embraces environmental science concepts (sunlight, Ozone effect, and harmful UV) that are culturally relevant for all leaners with different cultural backgrounds. Indeed, 92% of students were able to carry out their own investigations based on their developed models, interpret data from evidence, and draw conclusions using mathematical data (graphing) regardless of their gender, ethnicity, or English proficiency, as shown in previous research (Cuevas, Deaktor, & Lee, 2005). Windschitl, Thompson, and Braaten (2008) determined that the scientific method (TSM) is not exactly how real scientists approach science. According to these authors, real science that scientists are doing is more explanatory than that yielded by TSM. In this study we implemented their suggestions by incorporating the 5E instructional model to engage, explore, explain, elaborate, and evaluate so as to complement rich argumentation, and the basic cause-and-effect relationship. During the program, teachers used heavy modeling and thinking aloud strategies for ELL students to make sure they had a solid prediction/hypothesis using each variable. Then students would have a better idea of what to write and how the variables were used in the experiment. During the inquiry practices students were taught that the purpose of science experiments is to explain and understand the relationships that underlie cause and effect, not simply test hypotheses and variables with no prior analysis and thought. The graphing from their observations (Figure1) on the science exploration sheet really helped them better interpret data they collected and draw better conclusions about their initial question using their own vocabulary.
The NGSS language goals for ELL are almost identical to the content goals for non-ELL students because the science and engineering practices combine language practice with crosscutting (cycle, cause and effect, energy and matter, pattern, sustainability, system) concepts (Quinn, Lee, & Valdés, 2012, 2013). However, Miller, Lauffer, and Messina (2014) found in their study that ELL students were not engaging in a scientific discussion like the NGSS demands. Instead the students were just agreeing with the previous groups. In this study, not only ELL but also non-ELL students were unable to actively discuss human health issues and UV light/ozone issues at the beginning of the program, which was mainly taught as lectures.

However, during the inquiry project, the participating teachers guided the students to support their evidence and independently reason with visuals, which were mostly drawings of their experimental plan/design and graphs tied to their data analysis and interpretations. This procedure got, both ELL and non-ELL students more involved in discussing the evidence and the outcome. The entire class was very active in explaining their initial planning and data interpretations with their visuals and their own vocabulary. This outcome meant that the Green Earth instructional approach was successful in facilitating both ELL and non-ELL students to practice languages and understanding targeted science concepts (e.g., energy and matter, cause and effect) from core ideas (e.g., environmental & human health issues) in both their speaking and writing efforts within the NGSS framework.

**Attitudes Toward Science.** The increased science achievement of the participating students using inquiry practices did not significantly impact their attitudes toward science/scientists. Students often rely on finding an answer during reading/reading in science, social studies, etc., so giving them an opportunity to create an investigation or procedure can be challenging, although a more valuable experience. The Green Earth program used a guided open-
inquiry approach (Banchi & Bell, 2008) for both ELL and non-ELL students. They started defining the problem to plan and carry out investigations by selecting their own materials, although the teachers did provide a sentence starter (e.g., “If… then…”, “I predict that…”) for them to create a hypothesis. The teachers did not pass out any structured step-by-step procedures for their students to follow; instead, students had to figure out and write their own plans using their own vocabulary in the science exploration sheet (Table 1). Participating teachers commented that some students did not prefer inquiry because they did not like to figure out/think about how to create something. This correlated with the findings of Zion and Mendelovici (2012) who addressed the challenges and limitations when moving from structured to open inquiry. These authors state that there are always certain students who just don’t want to do the work, so this method can be hard to encourage them to do the science and have the experiment become a reality for them.

The participating teachers agreed that ELL students should begin to learn the way everyone else in their class learns, which will boost their confidence academically. This aspect is well addressed in the NGSS. However the inquiry method can be also overwhelming in terms of ‘motivating’ some ELL students especially who had been in the United States less than 4 years (i.e., 2.7% of the students) even though their science achievement turned out to be as good as the non-ELL students. Some students were afraid to do something wrong, so they had trouble starting their own experiments. These factors could affect the ATST in less positive ways after the inquiry intervention.

However, the teachers also found that inquiry-based learning has an advantage for ELL students because it teaches them to think outside the box and use their prior knowledge. It also guides them to think critically, which is hard for an English learner under traditional science
classes which often require them to fill out simple answers/vocabulary. Improving the students’ attitudes toward science (including greater confidence in learning about science) will take more time than simply improving science achievement and content knowledge for diverse learners (Bulunuz, Jarrett, & Martin 2012; Kim, 2011; Stoddart, Bravo, & Solis, 2011).

The Green Earth program did not explicitly introduce the STEM issues. Instead, the program embedded the nature of science and scientists implicitly by undertaking unique inquiry projects in the classroom. Kier and el. (2014) found that the nationwide STEM Career Awareness Project helped eighth-grade students become more aware of careers in science, technology, engineering, and mathematics. The project discussed the use of videos in the classroom to enhance students’ ideas about scientists and scientific diversity. Explicitly embedding this type of STEM career project idea into the Green Earth program might indeed impact students’ attitudes toward science and scientists very significantly.

Now inquiry is more prominently emphasized as a set of eight science and engineering practices in the NGSS. How then do teachers/educators make science classroom environments more effective at facilitating both science understanding and language learning for diverse students, including ELLs? The Green Earth approach, which uses inquiry practices along with visual evidences/modeling and rich argumentation within the 5E instructional model, helped both ELLs and non-ELLs in learning targeted science concepts (energy, human health, ozone effect, and UV rays) with language development. The NGSS demands the same expectations of academic performance and language development for both non-ELLs and ELLs utilizing the eight engineering practices that focus on guided/open-inquiry practices. However, we witnessed that some of the students, including ELLs, showed less favor of this approach and consequently resulted in lower level of attitudes about the nature of science and scientists in the ATST.
Structured inquiry (Bell, 2008), which uses scaffolded explicit instruction, might help those students increase their interest in science and their confidence level for doing science with a longer period before moving to student–initiated, guided, open inquiry. Finally, the Green Earth approach can be an exemplary model for educators who need and want greater familiarity with the science and engineering practices that immerse diverse students in science content through direct observation, hands-on investigation, and discourse using various visual representations/models of information.

Acknowledgement

This study was supported by the NEIU’s Summer Research Award. I also thank you to a leading teacher, Ms. Malovey who assisted this research.
References


need to know. Stanford, CA: Stanford University, Understanding Language Initiative at Stanford University (ell.stanford.edu).


